Spitzer Space Telescope - General Observer Proposal #3126

A Complete IRAC Map of M31

Principal Investigator: Pauline Barmby
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Technical Contact: Steven Willner, Center for Astrophysics

Co-Investigators:
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David Thilker, Johns Hopkins University

Science Category: local group galaxies
Observing Modes: IracMap
Hours Approved: 35.5

Abstract:
We propose a complete IRAC map of M31, the Andromeda Galaxy. The mid-infrared window opened by Spitzer will provide a new view of the stellar populations and dust content of this nearest large galaxy and Milky Way analog. The spatial distribution of the aromatic infrared band (AIB) emission will be compared to the UV flux distribution as revealed by GALEX, contributing to the solution of several puzzles raised by ISO observations. The AIB emission will also be compared to other indicators of star formation, such as Halpha, far-IR, and radio emission, at the highest spatial resolution possible for a large external galaxy. Populations of unusual objects such as extremely luminous stars, supernova remnants, and planetary nebulae, have already been well-studied in M31; IRAC observations will serve to characterize these populations in the mid-IR and complete their spectral energy distributions. This program complements existing GTO and Legacy observations, and will provide a rich target list for follow-up observations.

Spitzer Space Telescope - General Observer Proposal #50134

The Local Group Dwarf Spheroidals

Principal Investigator: Pauline Barmby
Institution: SAO

Technical Contact: Pauline Barmby, SAO

Co-Investigators:
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Karl Gordon, STScI
Tom Jarrett, SSC
Matthew Ashby, SAO

Science Category: local group galaxies
Observing Modes: IracMap MipsPhot MipsScan
Hours Approved: 30.0

Abstract:
We propose to complete the Spitzer survey of the Local Group. The galaxies not yet observed include most of the dwarf spheroidals, a galaxy type which, although numerous, has not been heavily studied by Spitzer so far. Imaging observations with IRAC and MIPS will yield a complete census of asymptotic giant branch stars, probing mass loss in galaxies with a range of metallicities, masses, and environments. Long-wavelength MIPS observations will detect any interstellar dust or constrain the gas-to-dust ratio. Completing the Spitzer observations of Local Group galaxies forms an important part of the Spitzer Legacy for future missions.

Spitzer Space Telescope - General Observer Proposal #30491

A Complete Picture of the Dust in the Small Magellanic Cloud: Following up Spitzer Imaging with Spectroscopic Observations

Principal Investigator: Alberto Bolatto
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Technical Contact: Alberto Bolatto, University of California at Berkeley

Co-Investigators:
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Frank Israel, University of Leiden
Francois Boulanger, Institute d'Astrophysique Spatiale
James Jackson, Boston University
Jacco van Loon, Keele University
Monica Rubio, Universidad Nacional de Chile
Adam Leroy, U.C. Berkeley
Ronak Shah, Boston University
Caroline Bot, IPAC

Science Category: local group galaxies
Observing Modes: IrsMap IrsStare
Hours Approved: 105.6

Abstract:
We request Spitzer Space Telescope time to obtain wide-field spectroscopic maps of several regions in the Small Magellanic Cloud. This survey is complementary to the imaging information obtained by the Spitzer survey of the SMC (S3MC), and it is designed to sample a variety of environments. We will use these data to unravel the life-cycle, distribution, abundance, and composition of PAHs and dust throughout the SMC, linking spectral variations to the measured IRAC/MIPS SEDs. IRS spectroscopy will allow us to relate variations in PAH and dust chemistry and excitation (such as size, structure, hydrogenation, and ionization state) to the physical conditions and astrophysical processes present in the mapped regions. This study will provide strong constraints on theoretical dust models, in addition to producing information on the abundance, life cycle, and evolution of PAHs and VSGs. Ultimately, this research will help constrain the properties of the ISM in primordial galaxies at high redshifts.This project takes advantage of the uniquely new ability of Spitzer, which is capable of obtaining sensitive spectral maps covering large areas with a modest investment of time.

Spitzer Space Telescope - General Observer Proposal #3316

The Small Magellanic Cloud: A Template for the Primitive Interstellar Medium

Principal Investigator: Alberto Bolatto
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Technical Contact: Alberto Bolatto, University of California at Berkeley

Co-Investigators:
Snezana Stanimirovic, University of California at Berkeley
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Aigen Li, University of Arizona
Ronak Shah, Boston University
Joshua Simon, University of California at Berkeley
Lister Staveley-Smith, Australia Telescope/CSIRO

Science Category: local group galaxies
Observing Modes: IracMap MipsScan
Hours Approved: 48.8

Abstract:
The Small Magellanic Cloud constitutes an excellent laboratory to study the properties of the dust in a low metallicity environment. We propose to obtain images of the entire SMC in all IRAC and MIPS wavebands, a feat only possible because of Spitzer's unparalleled sensitivity. With these observations we will quantify the distribution and properties of very small grains and PAHs throughout the SMC in relation to their environment. These data will allow us to constrain theoretical dust models, and provide information on the abundance, distribution, ionization state, composition, and evolution of PAHs and VSGs. MIPS observations will probe the distribution of small and large dust grains, and in combination with ground-based observations, will be used to provide an independent estimate of the amount of molecular gas in the SMC. Ultimately, this research will help constrain the properties of the ISM in primordial galaxies at high redshifts. The SMC images will be publicly released within 6 months of the last observations, for the benefit of the entire astronomical community and to allow other groups to perform follow-up observations.

Spitzer Space Telescope - General Observer Proposal #3680

Ejecta and Interstellar Dust in Magellanic Clouds Supernova Remnants

Principal Investigator: Kazimierz Borkowski
Institution: North Carolina State University

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Co-Investigators:
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Parviz Ghavamian, Johns Hopkins University
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John Raymond, Harvard University
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Ravi Sankrit, Johns Hopkins University
Chris Smith, National Optical Astronomy Observatory
Frank Winkler, Middlebury College

Science Category: local group galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 21.4

Abstract:
Stellar explosions govern the interstellar dust lifecycle. In the early Universe, supernovae (SN) injected the first heavy elements into the interstellar medium (ISM). A significant fraction of ejecta was dust. Dust is destroyed today in supernova remnant's (SNR) blast waves. Our current understanding of both formation of dust in SNe and destruction of dust in blast waves is poorly understood. We propose to observe a complete sample of SNRs in Magellanic Clouds (MCs) with the Spitzer Space Telescope (SST) in order to dramatically advance our knowledge of these processes. Heavy-element ejecta have been detected in more than one third of all SNRs in MCs, mostly in X-rays. Dust within these ejecta is collisionally heated by electrons and ions, and reradiates the absorbed energy in the far-IR. We propose deep MIPS and IRAC imaging of all MC SNRs with heavy-element ejecta in order to detect and study ejecta dust. We will determine dust temperature, dust mass, and its spatial distribution within ejecta. We will also detect dust in the ISM swept by SNR blast waves. This dust is destroyed by sputtering in hot X-ray emitting plasmas. We will learn about dust destruction by measuring the dust/gas mass ratio behind blast waves through a combined IR-X-ray analysis. Sputtering preferentially destroys small dust grains, modifying the grain size distribution. This strongly affects thermal dust emission in the IRAC bands which is produced by small grains. We will learn about the destruction of small grains by observing spatial variations of IRAC band ratios behind blast waves. An unbiased survey of all SNRs in MCs is necessary for understanding of dust destruction. We propose 24 micron MIPS imaging of all MC SNRs, and 70 micron MIPS imaging of X-ray bright SNRs. The proposed MIPS and IRAC imaging of MC SNRs will provide us with unique information about ejecta dust in a large sample of SNRs and about destruction of the ISM dust.

Spitzer Space Telescope - Archive Research Proposal #40568

Star Clusters in M31: Stellar Populations and Mass Loss

Principal Investigator: Jean Brodie
Institution: University of California, Santa Cruz

Technical Contact: Jean Brodie, University of California, Santa Cruz

Co-Investigators:
Jay Strader, University of California, Santa Cruz
Jacco van Loon, Keele University

Science Category: local group galaxies
Dollars Approved: 48294.0

Abstract:
We propose an imaging study of massive star clusters in M31 using archival Spitzer imaging with IRAC and MIPS. We have two distinct goals: (1) Estimate cluster ages, metallicities, and reddenings through panchromatic FUV to mid-IR imaging, and (2) Assess the production rate and lifetime of dust in the intracluster medium (ICM) as a function of cluster properties. Our results will give important constraints on the star formation history of M31 and on mass loss in stellar clusters.

Spitzer Space Telescope - General Observer Proposal #20610

Molecular Gas In The Nearby Extremely Metal-Poor Dwarf Galaxy Leo A

Principal Investigator: John Cannon
Institution: Max Planck Institute for Astronomy

Technical Contact: John Cannon, Max Planck Institute for Astronomy

Co-Investigators:
Fabian Walter, Max Planck Institute for Astronomy
Evan Skillman, University of Minnesota

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 6.6

Abstract:
Knowledge of the nature of molecular gas at sub-solar metallicities is essential for understanding the process of star formation both in the local and the high-redshift universe. CO is usually used to trace the molecular phase, but there have been no extragalactic detections of CO in environments more metal poor than the SMC. With detailed studies of nearby metal-deficient systems, we can discern trends between molecular gas properties and ambient metallicity that may be generalized to more distant systems. In this project we propose IRS spectral mapping observations of carefully-selected star formation regions in the nearby extremely metal-poor (less than 5% solar abundance) dwarf galaxy Leo A, concentrating on the S(0) H2 pure rotational line at 28 microns. The unprecedented sensitivity of Spitzer will allow variations in molecular gas content to be studied as a function of HI column density, stellar population, HI line width, H Alpha luminosity, and dust content. These data will directly probe the molecular phase, overcoming the limitations of tracer species that may be environmentally-dependent. These observations are designed to provide the first detections of molecular gas in extremely metal-poor environments, thus giving new insights into the low-metallicity ISM. These observations will allow a concise investigation of the H2 content of low-metallicity galaxies in a modest number of telescope hours, and the results will be applicable to a wide range of models of star formation at low metallicities.

Spitzer Space Telescope - Archive Research Proposal #30836

Star Formation in the Large Magellanic Cloud

Principal Investigator: You-Hua Chu
Institution: University of Illinois at Urbana-Champaign

Technical Contact: You-Hua Chu, University of Illinois at Urbana-Champaign

Co-Investigators:
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Lee Hartmann, University of Michigan
Nuria Calvet, University of Michigan
Wolfgang Brandner, Max Planck Institute
Chris Smith, CTIO
Sean Points, CTIO
John Dickel, University of New Mexico

Science Category: local group galaxies
Dollars Approved: 100000.0

Abstract:
Star formation is fundamental to the evolution of galaxies. It can be simply described on global scales, but shows remarkable variation on local scales. Theoretical models describe numerous paths to star formation, from global gravitational instability to local formation dynamically triggered by cloudlet compression in superbubbles, compression by H II region expansion, and gas accumulation in the borders of supergiant shells. For a better understanding of star formation, one must empirically relate the initial level of gravitational instability, and any triggering mechanisms, to the final result. The Large Magellanic Cloud (LMC) is the optimal site for such a study, as it is close enough to resolve protostars, yet not subject to the line-of-sight confusion of the Galaxy. Our Cycle 1 IRAC/MIPS observations of seven LMC HII complexes revealed a wide range of triggered star formation phenomena. The Spitzer survey of the LMC (SAGE), carried out in Cycle 2, reveals massive protostars throughout the entire LMC galaxy, allowing studies of global star formation. We propose to use the archival data from the Spitzer survey, and multi- wavelength surveys of stars and ISM in the LMC, to study star formation. We will examine both the interstellar conditions that lead to star formation, and the mass functions and clustering properties of protostars that are formed. For the former we will evaluate the gravitational potential from the stellar and gas surface densities; search for expanding shells that may be triggers; and examine the physical conditions in star formation sites. For the latter we will create a census of protostar candidates and their spatial distribution. Combined, these will allow us to determine the causes of star formation and how these affect the mass function and clustering properties of the stars formed.

Spitzer Space Telescope - General Observer Proposal #3565

Massive Star Forming Regions in the Large Magellanic Cloud

Principal Investigator: You-Hua Chu
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Technical Contact: Robert Gruendl, UIUC

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Rosa Williams, University of Illinois at Urbana-Champaign
Geoff Clayton, Louisiana State University
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Bryan Dunne, University of Illinois at Urbana-Champaign

Science Category: local group galaxies
Observing Modes: IracMap MipsScan
Hours Approved: 21.5

Abstract:
Massive stars inject energy into the ISM through UV radiation, fast stellar winds, and supernova blasts. This stellar energy feedback ionizes the ambient gas, sweeps it into shell structures, and fills the shell interior with hot, shock-heated gas. The interplay between massive star formation and stellar energy feedback plays an important role in the structure and evolution of the ISM in a galaxy. The Large Magellanic Cloud (LMC) provides an ideal site to study the stellar energy feedback process in star forming regions because individual massive stars can be resolved, classified, and inventoried and the associated interstellar structures can be studied both globally and in detail. We have been using the large sample of star forming regions in the LMC to carry out a multi-wavelength investigation of the structure of the ISM and the effects of stellar energy feedback. We find that the stellar energy input in superbubbles far exceeds the observed thermal and kinetic energies of the associated interstellar gas. We request IRAC and MIPS observations of a large sample of HII regions in the LMC in order to assess the stellar energy feedback at the earliest evolutionary stage and the role played by dust in the energy budget. These regions are selected to cover a wide range of evolutionary stages, structural complexity, and X-ray surface brightness. Specifically, we will (1) search for massive young stars and proto-stars, (2) examine how star formation proceeds spatially and temporally, (3) study the stellar energy feedback at the earliest evolutionary stages, (4) determine the distribution and temperature of dust in varied stellar UV radiation and interstellar X-ray radiation fields, and (5) assess the importance of dust on the thermal evolution of the ISM.

Spitzer Space Telescope - General Observer Proposal #3649

The Optical/Infrared Dust Properties of Early-Type Galaxies

Principal Investigator: Patrick Cote
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Eric Peng, Rutgers, the State University of New Jersey
John Blakeslee, Johns Hopkins University
Michael West, University of Hawaii, Hilo
Mei Simona, Institut d'Astrophysique Spatiale

Science Category: local group galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 24.5

Abstract:
We propose to obtain IRAC and MIPS images for 15 early-type galaxies in the Virgo Cluster. Combining the data with existing Spitzer GTO/Legacy observations for seven additional galaxies will give a magnitude-limited sample of 21 early-type galaxies in Virgo. All 21 galaxies are part of our deep, high-resolution (0.1 arcsec), multi-band HST/ACS imaging survey of early-type galaxies; high S/N ground-based optical spectra are also in hand for each galaxy. The combination of ground-based spectroscopy, optical imaging from HST and infrared imaging from Spitzer will provide the most complete dataset ever assembled for the study of dust in a large and unbiased sample of early-type galaxies. In particular: (1) the Spitzer/MIPS images will provide the definitive study of the incidence of dust in these galaxies, and the measurement of dust masses down to 250 solar masses, a hundred-fold improvement compared to IRAS; (2) The multi-band IRAC and MIPS data will allow us to determine the contribution of stars and dust to the observed flux, leading to an unambiguous determination of the dust temperature compared to previous studies; (3) The dust mass determined from MIPS observations will be compared to the mass required to account for the extinction seen in our optical HST/ACS images. The high resolution of Spitzer/MIPS will allow us to spatially resolve the dust emission if this follows the stellar density, with obvious implications regarding the origin of dust in early-type galaxies; (4) the total gravitational mass derived from our optical ground-based spectra will be used to determine the empirical ratio of dust to gravitating mass. The unprecedented depth, sensitivity, and spatial resolution of the Spitzer data, the unrivaled clarity of the HST images, and the complete kinematical coverage of the ground-based spectra will enable the most detailed view yet of dust in early-type environments.

Spitzer Space Telescope - General Observer Proposal #40149

The Continuing Infrared Evolution of SN1987A

Principal Investigator: Eli Dwek
Institution: NASA Goddard Space Flight Center

Technical Contact: Eli Dwek, NASA Goddard Space Flight Center

Co-Investigators:
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David Burrows, Pennsylvania State University
Peter Challis, Harvard-Smithsonian CfA
John Danziger, Osservatorio Astronomico de Trieste
James De Buizer, Gemini Observatory
Robert Gehrz, University of Minnesota
Robert Kirshner, Harvard-Smithsonian CfA
Richard McCray, University of Colorado
Sangwook Park, Pennsylvania State University
Elisha Polomski, University of Minnesota
Charles Woodward, University of Minnesota

Science Category: Local Group Galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot MipsSed
Hours Approved: 19.5

Abstract:
We will use the SPITZER to continue the ongoing monitoring of SN1987A, the youngest supernova remnant that is undergoing noticable evolutionary changes during the lifetime of the Great Observatories. At infrared wavelengths SN1987A provides a unique complimentary view of the interaction of the SN blast wave with the equatorial ring (ER). Dust in theÊ ERÊ is being swept up by the expanding shock and collisionally heated by the X-ray emitting gas observed with CHANDRA, giving rise to IR emission that reveals the composition and amount of dust that formed in the outflow of the presupernova star. The IR observations also provide a unique tool for studying physical processes - the collisional heating and destruction of dust -Ê in dusty X-ray emitting plasmas. Parts of the blast wave has penetrated the denser regions of the ER, creating the "hotspots" observed with HUBBLE. IR line emission from these regions provide important information on the physical conditions and theÊelemental and dust composition in these cooling shocks. Additionally, the ejecta of the SN explosion contains dust that was observed to have formed about 530 days after the explosion. Its imminent interaction with the ring will heat up this dust, which will be observable with SPITZER. In addition to providing useful information on SN1987A and its environment, the proposed observations will address key global issues regarding the origin and evolution of dust in the universe: how much dust is formed in SN ejecta and in quiescent stellar outflows, and how efficiently grains are destroyed by interstellar shock waves.

Spitzer Space Telescope - General Observer Proposal #30067

THE INFRARED EVOLUTION OF SN1987A

Principal Investigator: Eli Dwek
Institution: NASA Goddard Space Flight Center

Technical Contact: Eli Dwek, NASA Goddard Space Flight Center

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James De Buizer, Gemini Observatory
Robert Gehrz, University of Minnesota
Robert Kirshner, Harvard-Smithsonian CfA
Richard McCray, University of Colorado
Sangwook Park, Pennsylvania State University
Elisha Polomski, University of Minnesota
Charles Woodward, University of Minnesota

Science Category: local group galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot MipsSed
Hours Approved: 19.5

Abstract:
We will use the SPITZER to continue the ongoing monitoring of SN1987A, the youngest supernova remnant that is undergoing noticable evolutionary changes during the lifetime of the Great Observatories. At infrared wavelengths SN1987A provides a unique complimentary view of the interaction of the SN blast wave with the equatorial ring (ER). Dust in the ER is being swept up by the expanding shock and collisionally heated by the X-ray emitting gas observed with CHANDRA, giving rise to IR emission that reveals the composition and amount of dust that formed in the outflow of the presupernova star. The IR observations also provide a unique tool for studying physical processes - the collisional heating and destruction of dust in dusty X-ray emitting plasmas. Parts of the blast wave has penetrated the denser regions of the ER, creating the "hotspots" observed with HUBBLE. IR line emission from these regions provide important information on the physical conditions and the elemental and dust composition in these cooling shocks. Additionally, the ejecta of the SN explosion contains dust that was observed to have formed about 530 days after the explosion. Its imminent interaction with the ring will heat up this dust, which will be observable with SPITZER. In addition to providing useful information on SN1987A and its environment, the proposed observations will address key global issues regarding the origin and evolution of dust in the universe: how much dust is formed in SN ejecta and in quiescent stellar outflows, and how efficiently grains are destroyed by interstellar shock waves.

Spitzer Space Telescope - General Observer Proposal #50444

THE CONTINUING INFRARED EVOLUTION OF SN1987A

Principal Investigator: Eli Dwek
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John Danziger, Osservatorio Astronomico de Trieste
James De Buizer, Gemini Observatory
Robert Gehrz, University of Minnesota
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Richard McCray, University of Colorado
Sangwook Park, Pennsylvania State University
Elisha Polomski, University of Minnesota
Charles Woodward, University of Minnesota

Science Category: local group galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot MipsSed
Hours Approved: 10.4

Abstract:
We will use the SPITZER to continue the ongoing monitoring of SN1987A, the youngest supernova remnant that is undergoing noticable evolutionary changes during the lifetime of the Great Observatories. At infrared wavelengths SN1987A provides a unique complimentary view of the interaction of the SN blast wave with the equatorial ring (ER). Dust in the ER is being swept up by the expanding shock and collisionally heated by the X-ray emitting gas observed with CHANDRA, giving rise to IR emission that reveals the composition and amount of dust that formed in the outflow of the presupernova star. The IR observations also provide a unique tool for studying physical processes - the collisional heating and destruction of dust - in dusty X-ray emitting plasmas. Parts of the blast wave has penetrated the denser regions of the ER, creating the "hotspots" observed with HUBBLE. IR line emission from these regions provide important information on the physical conditions and the elemental and dust composition in these cooling shocks. Additionally, the ejecta of the SN explosion contains dust that was observed to have formed about 530 days after the explosion. Its imminent interaction with the ring will heat up this dust, which will be observable with SPITZER. In addition to providing useful information on SN1987A and its environment, the proposed observations will address key global issues regarding the origin and evolution of dust in the universe: how much dust is formed in SN ejecta and in quiescent stellar outflows, and how efficiently grains are destroyed by interstellar shock waves.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #125

Magellanic Clouds Survey

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Joseph Hora, Harvard/CfA

Science Category: local group galaxies
Observing Modes: IracMap
Hours Approved: 0.6

Abstract:
Understanding star formation in a low-metallicity dwarf environment is fundamental to our understanding of the origin and evolution of galaxies is the early Universe. The Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC) are the nearest available laboratories to study star formation. This short program will obtain data that will enable us to prepare for a larger survey of the Clouds. The unique sensitivity and speed of IRAC will result in a survey that has up to 1000 times more sensitivity and 11 times better angular resolution than the most recent infrared surveys. This tremendous improvement in point source sensitivity and resolution will allow us to study the location and characteristics of 1-3 solar mass young stellar objects in the Clouds on ~0.5 pc scales. A large area survey is essential to the success of source classification and to the proper identification of young stellar objects. Central themes include: How does star formation vary with metallicity and environment across the clouds? Is there evidence for sequential, triggered star formation? Is star formation occurring in dense HI clumps with no obvious molecular counterparts?

Spitzer Space Telescope - Guaranteed Time Observer Proposal #3

Brown Dwarf Galaxy Haloes

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Science Category: local group galaxies
Observing Modes: IracMap
Hours Approved: 32.4

Abstract:
The form of matter in galaxy haloes inferred from dynamical studies (i.e., rotation curves) remains unknown. We propose to image four bright local edge-on spiral galaxies with IRAC to detect these haloes and (if possible) characterize the distribution of halo mass. IRAC observations will be at least an order of magnitude more sensitive than previous attempts to measure flux from galaxy haloes. Combining images from all four IRAC bands also provides a potential means of discriminating among possible constituents of the dark matter.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40032

Mysterious PAHs in M31

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Pauline Barmby, Smithsonian Astrophysical Observatory

Co-Investigators:
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Matthew Ashby, SAO
Karl Gordon, University of Arizona
Els Peeters, University of Western Ontario/SETI Inst.
Nick Devereux, Embry-Riddle Aeronautical University
David Thilker, Johns Hopkins University

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 13.0

Abstract:
Spitzer/IRS observations are the ideal tool to investigate puzzling ISO results on the spectra of PAHs in M31. The SINGS Legacy project has convincingly demonstrated that the 6-8um PAH bands dominate the mid-IR spectrum of star-forming galaxies, carrying a significant fraction of the total infrared luminosity. But ISOCAM spectro-imaging observations of M31 showed that the nucleus and bulge of this galaxy had very odd PAH spectra, bright at 11.3um and 12.7 microns but lacking the usual 6.2, 7.7 and 8.6 micron bands. The IRAC images clearly show that there is non-stellar emission in the 8 micron band in both the bulge and nucleus, as well as in the star-forming ring where the ISO spectra were more "normal". It has been suggested that the unusual ISO spectra are due to neutral (as opposed to the usual ionized) PAHs in regions with weak UV fields, possibly due to the presence of an AGN. We propose to map 11 regions in M31 with IRS spectral maps covering the wavelength range 5-20 microns (SL+LL2). The regions to be mapped include the nucleus, two regions observed by ISOCAM, and 9 other regions chosen for a range of dust temperatures, UV intensities and metallicities. We will measure the variation in relative strength of the PAH bands and its dependence on environment. M31 offers a unique laboratory for mapping PAH variations within a well-studied galaxy, furthering our understanding of these astrophysically important bands.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50474

Mysterious Ionized Nuclear Spirals in M31 and M81

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Center for Astrophysics

Co-Investigators:
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Pauline Barmby, University of Western Ontario
Nick Devereux, Embry-Riddle Aeronautical University
Howard Smith, Harvard-Smithsonian Center for Astrophysics

Science Category: local group galaxies
Observing Modes: IrsMap IrsPeakupImage
Hours Approved: 9.0

Abstract:
Despite decades of study, M31 and M81 remain enigmatic galaxies. Both harbor large (~ 1kpc), and luminous, H-alpha emission line spirals, the origin and excitation of which remains poorly understood. None of the usual sources of ionization, such as massive stars for example, can account for the observed H-alpha line emission. Evidently, there is some unconventional source of ionization present in the central region of M31 and M81 that could be present in other galaxies and other active galactic nuclei. However ubiquitous, this phenomenon can only be studied in very nearby galaxies like M31 and M81 where we can acquire observations with high angular resolution and sensitivity. We propose to use the Infrared Array Spectrometer aboard the Spitzer Space Telescope to obtain mid-infrared spectroscopic observations of the emission line spirals in M31 and M81. Specifically, we propose to sample the spatial distribution of [NeII] and [NeIII] line emission, as these lines will enable us to determine the spatial extent and the spectral shape of the ionizing radiation field that is responsible for exciting the emission line gas. The observations will allow us to distinguish between viable candidates for the ionization as diverse as hot, billion year old post AGB stars, mechanical shocks and hot x-ray gas.

Spitzer Space Telescope - Legacy General Observer Proposal #40245

SAGE-SMC: Surveying the Agents of Galaxy Evolution in the Tidally-Disrupted, Low-Metallicity Small Magellanic Cloud

Principal Investigator: Karl Gordon
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Co-Investigators:
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Alberto Bolatto (SF, ISM), U. of California-Berkeley
Jean-Philippe Bernard (ISM, SF), Centre d'Etude Spatiale des Rayonnements
Marta Sewilo (SF), U. of Wisconsin, Madison
Brian Babler (IRAC), U. of Wisconsin-Madison
Miwa Block (MIPS), U. of Arizona
Caroline Bot (ISM, SF), Caltech/IPAC
Steve Bracker (IRAC, SF), Univ. of Wisconsin-Madison
Lynn Carlson (SF), Johns Hopkins
Ed Churchwell (SF, IRAC), U. of Wisconsin-Madison
Geoffrey Clayton (ISM, ES), Louisiana State University
Martin Cohen (ISM, ES, Cal), UC Berkeley/RAL
Charles Engelbracht (ISM, SF, MIPS), U. of Arizona
Yasuo Fukui (ISM, SF), Nagoya University
Varoujan Gorjian (SF), JPL/Caltech
Sacha Hony (ISM, SF), CEA Saclay
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Adam Leroy (ISM, SF), MPIA
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Suzanne Madden (ISM, SF), CEA Saclay
Ciska Markwick-Kemper (ES), U. of Manchester
Marilyn Meade (IRAC), U. of Wisconsin-Madison
Karl Misselt (ISM, SF, MIPS), U. of Arizona
Akira Mizuno (ISM, SF), Nagoya University
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Joana Oliveira (SF), U. of Keele
Knut Olsen (ES), CTIO/NOAO
Toshikazu Onishi (SF, ISM), Nagoya University
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Thomas Robitaille (SF), University of St Andrew
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Shuji Sato (SF), Nagoya University
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Linda Smith (ISM, SF, ES), STScI/ESA
Sundar Srinivasan (ES), Johns Hopkins/STScI
Xander Tielens (ISM, SF, ES), NASA Ames
Uma Vijh (ISM, SF, ES, archive), STScI
Schuyler Van Dyk (ES, ISM), IPAC/Caltech
Jacco Van Loon (ISM, SF, ES), U. of Keele
Kevin Volk (ES), Gemini
Dennis Zaritsky (SF), U. of Arizona

Science Category: local group galaxies
Observing Modes: IracMap MipsScan
Hours Approved: 285.0

Abstract:
The observable properties of galaxy evolution are largely driven by the life-cycle of baryonic matter: stars precipitate out of a complex, multi-phase interstellar medium; and eventually, evolved stellar populations return enriched material back to the ISM via stellar winds or supernova explosions. As demonstrated by the SAGE-LMC survey, comprehensive Spitzer imaging of a nearby galaxy provides an incredibly rich view of this baryonic lifecycle, allowing for an unprecedented understanding of the physical processes which drive galaxy evolution. This proposal will extend the SAGE analysis to the whole SMC (Bar, Wing, and high-density portion of the Magellanic Bridge), a galaxy whose properties are uniquely similar to those of star-forming galaxies at high redshift. Specifically, the SMC's metallicity is below the critical threshold (1/3-1/4 Z_sun) where interstellar medium properties are observed to change dramatically (sharp reduction in the PAH dust mass fraction, reduced dust-to-gas ratio, and extreme ultraviolet extinction curve variations). In addition, the SMC has been profoundly influenced by past interactions with the LMC and Milky Way, allowing us to study the impact of periodic interactions on the structure of the ISM and the physical processes of star formation. We will gain crucial insight into the ISM and star formation in a known tidal debris structure (Bridge portion of SMC), which has a metallicity 4 times lower than the rest of the SMC. When combined with observations of the Milky Way (GLIMPSE, MIPSGAL) and the LMC (SAGE-LMC), our survey of the SMC (SAGE-SMC) will provide a complete and detailed picture of the life-cycle of baryons in galactic environments spanning orders of magnitude in metallicity, and wide ranges in star formation history. This understanding will equip us to properly interpret the infrared properties of more distant galaxies, both in the local (e.g., SINGS) and high-redshift (e.g., GOODS and SWIRE) universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50816

A complete Survey of the SDSS metal-poor BCDs

Principal Investigator: Lei Hao
Institution: Cornell University

Technical Contact: Lei Hao, Cornell University

Co-Investigators:
Vianney Lebouteiller, Cornell University
Yanling Wu, Cornell University
Jim Houck, Cornell University

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 33.3

Abstract:
Extremely low-metallicity galaxies represent key objects to understand the chemical evolution of galaxies throughout the ages of the Universe. Spitzer observed so far an incomplete sample for which the metallicity distribution may not be representative of the actual situation in the Universe. We selected a complete sample of very metal-poor galaxies ($leq 1/10 Zodot$) from the SDSS DR5 survey. This sample will allow doubling the present sample of Spitzer observations of BCDs with comparable metallicities. The main goal of the proposal is to view the sample as a whole, and study the variation and distributions of their infrared properties. We will explore the effect of metallicity on the variation of these properties, particularly examine the possibility of a metallicity threshold for the formation of polycyclic aromatic hydrocarbons. We are also interested in the general properties and variations in the SED of these BCDs. The wealthy information from the SDSS survey will be implemented to the sample to understand the influence of the large-scale environment on the star-formation properties inferred from their infrared observations. The resulted dataset we can obtain will constitute a long-lasting resource for studies of metal-deficient galaxies. The whole observations are divided into one GO and one GTO proposals. The GTO proposal is focused on obtaining the IRS spectra of the sample, while the GO one is focused on the photometry of the sample. Thus they are each complete in its own.

Spitzer Space Telescope - Directors Discretionary Time Proposal #489

MIPS Imaging of M31

Principal Investigator: Joannah Hinz
Institution: University of Arizona

Technical Contact: Karl Gordon, STScI

Co-Investigators:
Karl Gordon, STScI
George Rieke, University of Arizona

Science Category: local group galaxies
Observing Modes: MipsScan
Hours Approved: 13.5

Abstract:
Spitzer will provide a unique and lasting legacy on Local Group galaxies due to its high surface brightness sensitivity and exquisite resolution. This legacy is already in place for M33, the SMC, and the LMC, where multiple MIPS scans maps have been taken or are planned. M31, however, has been observed with only one pass, one which has a gap in coverage near the center of the galaxy at 70um. This current map is not of legacy quality. The gap and patterned artifacts associated with the direction of the scan prevent analysis of, for instance, the diffuse dust components at large distances from the galaxy center. The importance of doing M31 well cannot be overstated: it is the nearest galaxy most like our own and is the most analogous to objects studied at high redshift. Therefore, we propose to map M31 thoroughly and deeply with MIPS to create a high quality mosaic that will have complete coverage of the entire 1 x 5 degree HI disk, providing a lasting Spitzer legacy for the astronomical community for a variety of scientific topics.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #103

IRS Study of Planetary Nebulae in the SMC/LMC

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Jeronimo Bernard-Salas, Cornell University

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 11.3

Abstract:
We propose to observe a number of planetary nebulae in LMC and SMC. The subsolar metallicities in the Magellanic clouds may result in strong ionization fields and thus unique high-exitation lines in the PNEs, unlike those of their Galactic analogues. Several of the sources will be used as early release observations and for bootstrapping the wavelength calibration of IRS.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #200

Circumstellar Dust in the Magellanic Clouds

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Greg Sloan, Cornell University

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 14.8

Abstract:
This program will obtain low-resolution spectra of approximately 50 evolved stars in the Large and Small Magellanic Clouds known or suspected to exhibit a dust component on their infrared spectra. The goal is to obtain a representative sample of dust emission from evolved stars born in a metal-poor environment to (1) produce templates of dusty sources for use in interpreting the spectra of star-burst and blue compact dwarf galaxies obtained in the SBGAL_DEVOST and JRH_BCD program and (2) compare to similar samples of galactic sources obtained by ISO. Both objectives require a sample of as wide a variety of sources as possible, from both the LMC and SMC, including Miras (both short-period and long-period), irregular variables, MS stars, full S stars, carbon stars associated with both optically thin and thick shells, OH/IR stars, and supergiants. More evolved sources observed in other programs will supplement this list.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30145

IRS Follow-up of Sources in M33

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Thomas Roellig, NASA Ames Research Center

Co-Investigators:
Robert D. Gehrz, University of Minnesota
Thomas L. Roellig, NASA Ames Research Center
Charles Woodward, University of Minnesota
Elisha Polomski, University of Minnesota
Brent Buckalew, IPAC
Kristy McQuinn, University of Minnesota

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 8.2

Abstract:
We are currently engaged in a Guaranteed Time Observation (GTO) program (PID 5) to obtain MIPS and IRAC maps of M33 that will provide a global perspective on star formation, stellar evolution, and chemical evolution in the interstellar medium in a spiral galaxy. Combined with ground-based observations, these maps will provide a unified set of images that relate the locations of chemical enrichment, gas available to form stars, star formation, and evolved stars. We are proposing here to perform IRS spectroscopy using all of the IRS modules to follow-up on five embedded compact HII clusters which are located at various distances ranging up to 3.5 kpc from the center of M33. The low-resolution data will be particularly useful in identifying broad-band solid-state features, while the high-resolution module observations will be used to measure the strength of fine-structure emission lines, providing a wealth of information on the excitation levels and electron densities in the targets, without the complicating effects of extinction that hampers optical studies of these highly-enshrouded objects. Our proposed observations will allow important new insight into how star formation environments change across the face of the spiral galaxy M33.

Spitzer Space Telescope - General Observer Proposal #3591

The O-rich condensation sequence at low metallicity: Large Magellanic Cloud AGB and post-AGB stars

Principal Investigator: Francisca Kemper
Institution: University of California, Los Angeles

Technical Contact: Francisca Markwick-Kemper, UCLA

Co-Investigators:
Schuyler D. Van Dyk, IPAC/CalTech, Pasadena, CA
Ryszard Szczerba, NCAC, Torun, Poland
Angela K. Speck, University of Missouri, Columbia, MO
Margaret Meixner, STSci, Baltimore, MD
Toshiya Ueta, Royal Observatory, Belgium

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 7.6

Abstract:
The goal of this proposal is to study the formation and processing of dust around oxygen-rich evolved stars in the Large Magellanic Cloud (LMC). The condensation may depend heavily on the metallicity, although its effect is currently unknown. From current condensation theories it may be expected that: 1) the total condensed dust mass is lower, 2) there will be more simple oxides and less silicates, 3) the degree of crystallinity will be lower for the silicates. We propose to do IRS low resolution observations to study dust properties such as composition, grain size and shape and the dust mass distribution, to validate current condensation models. We have selected a sample of 67 oxygen-rich evolved stars in a large range of evolutionary states, ranging from red giants to planetary nebulae, in order to sample the entire dust condensation sequence. The dust in the LMC interstellar medium, as well as star forming regions in the LMC originates largely from oxygen-rich evolved stars, and therefore it is of crucial importance to know its properties. In addition, gaining an understanding of the dust condensation sequence at low metallicities will improve our understanding of dust formation in general, and will provide the ability to use grain properties and dust composition as an astronomer's tool to trace physical conditions.

Spitzer Space Telescope - Theoretical Research Proposal #50137

Simulating Star Formation in Space and Time

Principal Investigator: Mark Krumholz
Institution: University of California, Santa Cruz

Technical Contact: Mark Krumholz, University of California, Santa Cruz

Co-Investigators:
Mordecai-Mark Mac Low, American Museum of Natural History
Christopher McKee, University of California, Berkeley
Christopher Matzner, University of Toronto

Science Category: local group galaxies
Dollars Approved: 125000.0

Abstract:
Spitzer observations of nearby galaxies have produced considerable insight into the question of where and when star formation occurs. By combining Spitzer maps of galactic disks, which probe embedded regions of star formation at high spatial resolution, with large-scale surveys of atomic and molecular gas, we have for the first time been able to determine the spatial and temporal distribution of star formation and its relation to the distributions of gas and old stars. To date, no comprehensive theoretical model has been capable of reproducing these observations in detail. Simulations indicate that large-scale gravitational instability plays a key role in determining where atomic gas condenses to form giant molecular clouds (GMCs), but they are limited by their inability to resolve the internal dynamics of these objects. Because the conversion of GMC gas into stars is an extremely inefficient and comparatively slow process, most likely as a result of stellar feedback, it is not possible to reproduce the overall rate of star formation and its spread in space and time without understanding GMCs' internal behavior. We propose to remove this limitation by combining large-scale numerical simulations of galactic disks with detailed, physically well-motivated models for the behavior of GMCs on scales too small and involving physics too computationally complex to be included in galactic-scale simulations. We will extend and develop semi-analytic GMC evolution models including stellar feedback that are suitable for implementation as subgrid physics within galactic-scale simulations. Using simulations based on these models, we will predict observables such as the locations and ages of newly-formed star clusters and the distribution of 24 micron emission behind spiral arms. Comparing these predictions with data will provide a new means of testing theories of star formation, and will yield new insight into the physical mechanisms behind the complex patterns that Spitzer has revealed.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50282

Extreme Star-Formation in LMC-N157B

Principal Investigator: Vianney Lebouteiller
Institution: Cornell University

Technical Contact: Vianney Lebouteiller, Cornell University

Co-Investigators:
Jeronimo Bernard-Salas, Cornell University
Nicolas Peretto, University of Manchester
Duncan Farrah, Cornell University
David Whelan, University of Virginia
Jim Houck, Cornell University

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 8.5

Abstract:
We propose to investigate the unique and extreme environment of the nebula LMC-N157B in 30 Doradus. Protostellar regions are under the influence of stellar winds from nearby massive O6 stars, and of shocks from a supernova (SN) explosion. Our observations will allow characterizing the physical association produced by the impact of the SN shocks on the protostellar regions. Furthermore, we will be able to define the relative effect from stellar winds and SN shocks on the formation and evolution of the protostellar regions.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50318

Dust Properties in the Starburst Galaxy IC10

Principal Investigator: Vianney Lebouteiller
Institution: Cornell University

Technical Contact: Vianney Lebouteiller, Cornell University

Co-Investigators:
Henrik Spoon, Cornell University
Estelle Bayet, UCL
Olivier Berne, CESR, Toulouse
Jeronimo Bernard-Salas, Cornell University
David Whelan, University of Virginia
Jim Houck, Cornell University

Science Category: local group galaxies
Observing Modes: IrsMap IrsStare
Hours Approved: 9.1

Abstract:
We propose to investigate two key dust tracers (silicate dust and very small grains) across the closest starburst known IC10. By comparing the spatial distribution of silicate dust in the diffuse ISM with the visual extinction map, we will investigate the possible relation between silicate dust and large carbonaceous grains. Our observations will enable us to probe the silicate dust properties as a function of the local physical conditions, notably the hardness of the radiation field. In a second part, we intend to study the nature and evolution of PAHs and VSGs toward the many giant molecular clouds (GMCs) within IC10. We propose to address the formation process of very small grains within GMCs.

Spitzer Space Telescope - Archive Research Proposal #50156

The Mid-Infrared Cepheid Distance Scale: A Reconnaissance Program of Cepheids in the Local Group

Principal Investigator: Barry Madore
Institution: Carnegie Institution of Washington

Technical Contact: Barry Madore, Carnegie Institution of Washington

Co-Investigators:
Wendy Freedman, Carnegie Observatories
Violet Mager, Carnegie Observatories
Jane Rigby, Carnegie Observatories

Science Category: local group galaxies
Dollars Approved: 25000.0

Abstract:
We request archival funding to search for serendipitous IRAC detections of known Cepheids in Local Group galaxies. This archival proposal is a parallel study in support of a Cycle 5 GO proposal (PI: Freedman) to re-calibrate the Cepheid distance scale from the ground up using new IRAC photometry of ten Galactic Cepheids having HST trigonometric parallaxes (Benedict et al. 2007), in combination with eighty LMC Cepheids (from Persson et al. 2004), to establish the slope and secure the zero point of the Cepheid Period-Luminosity Relation at 3.6 and 4.5 micron. Here we intend to characterize the mid-infrared detectability of Cepheids in Local Group galaxies, by examining upwards of 8,000 archival images containing cataloged Cepheids with known periods and predicted luminosities. The Cepheids in these images exhibit a wide range of background intensity, often have complex crowding, and have a wide range of apparent magnitudes. From this reconnaissance survey we will be able to directly assess the ability of Spitzer to obtain high signal-to-noise observations of Cepheids in individual Local Group galaxies, and we will select the least crowded and least confused of the serendipitously--obserserved Cepheids. We plan to target this sample in the Warm Mission, with the goal of putting the Local Group securely onto the mid-infrared Cepheid distance scale.

Spitzer Space Telescope - General Observer Proposal #20173

Detailed Study of the Dust in M31's Four Elliptical Companions

Principal Investigator: Francine Marleau
Institution: Spitzer Science Center, Caltech

Technical Contact: Francine Marleau, Spitzer Science Center, Caltech

Co-Investigators:
Alberto Noriega-Crespo, Spitzer Science Center, Caltech
Karl Gordon, Steward Observatory, University of Arizona
Karl Misselt, Steward Observatory, University of Arizona
George Rieke, Steward Observatory, University of Arizona
Phil Choi, Spitzer Science Center, Caltech
Gary Welch, Saint Mary's University
Marla Geha, Carnegie Observatories

Science Category: local group galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 14.4

Abstract:
We propose to carry out a multi-wavelength study of the four dwarf/compact elliptical galaxies, NGC 205, NGC 185, NGC 147 and M32, the well known satellites of M31. The distinct properties of these systems -- different gravitational interactions, star forming histories and interstellar medium (ISM) -- create a unique opportunity to learn about the evolution of the ISM in these galaxies and the processes that regulate its state. The proposed IRAC (3.6-8 micron) and MIPS (24, 70 and 160 micron) observations of NGC 185, NGC 147 and M32 will trace simultaneously the distribution of the dust and the old stellar population. For NGC 205, for which we have GTO MIPS observations, we will obtain new IRAC maps, 16 micron IRS peakup imaging and deeper MIPS photometric observations. These new observations will provide a complete census of the extended emission, and therefore, of the dust distribution in this galaxy. In the case of NGC 205 and NGC 185, where dust emission has already been detected, current (NGC 205) and proposed (NGC 185) observations will be supplemented by IRS spectroscopy (5.2 to 38 micron) of the dust clouds. These observations will enhance our knowledge of the infrared emission and dust properties in dwarf/compact elliptical systems and how they compare with those of the Galaxy and other elliptical galaxies.

Spitzer Space Telescope - Legacy General Observer Proposal #20203

Spitzer Survey of the Large Magellanic Cloud: Surveying the Agents of a Galaxy's Evolution (SAGE)

Principal Investigator: Margaret Meixner
Institution: Space Telescope Science Institute

Technical Contact: Margaret Meixner, Space Telescope Science Institute

Co-Investigators:
Karl Gordon (ISM, SF), University of Arizona
Edward Churchwell (SF), University of Wisconsin
Remy Indebetouw (SF), University of Virginia
Joseph Hora (ES,SF), CFA/Harvard
Robert Blum (ES), CTIO/NOAO
William Reach (ISM,SF), IPAC/Caltech
Jean-Philippe Bernard (ISM,SF), Centre d'Etude Spatiale des Rayonnements
Brian Babler (SF), University of Wisconsin
Francois Boulanger (ISM), IAS, Paris
Martin Cohen (ISM), UC Berkeley/RAL
Charles Engelbracht (ISM, SF), University of Arizona
Jay Frogel (ES,SF), AURA
Yasuo Fukui (SF), Nagoya University
Jay Gallagher (ISM, SF), University of Wisconsin
Varoujan Gorjian (SF), JPL/Caltech
Jason Harris (SF), University of Arizona
Stephen Jansen (SF), University of Wisconsin
Douglas Kelly (ES), University of Arizona
Ciska Kemper (ES), University of Virginia
Akiko Kawamura (SF), Nagoya University
William Latter (ES), IPAC/Caltech
Claus Leitherer (ES), STScI
Suzanne Madden (ISM, SF), CEA, Saclay
Marilyn Meade (SF), University of Wisconsin
Karl Misselt (ISM), University of Arizona
Akira Mizuno (SF), Nagoya University
Norikazu Mizuno (SF), Nagoya University
Jeremy Mould (ES), NOAO
Antonella Nota (ES, SF), ESA/STScI
Sally Oey (ISM, SF), University of Michigan
Knut Olsen (ES), CTIO/NOAO
Toshikazu Onishi (SF), Nagoya University
Roberta Paladini (ISM), Centre d'Etude Spatiale des Rayonnements
Nino Panagia (SF), ESA/STScI
Pablo Perez-Gonzalez (ISM), University of Arizona
Hiroshi Shibai (SF), Nagoya University
Sato Shuji (SF), Nagoya University
Linda Smith (ISM, SF), University of College, London
Lister Staveley-Smith (ISM), CSIRO
Xander Tielens (ES, ISM), Kapteyn Institute
Toshiya Ueta (ES), NASA/Ames
Schuyler Van Dyk (ES), IPAC/Caltech
Kevin Volk (ES), Gemini
Michael Werner (ES), JPL/NASA
Barbara Whitney (SF), Space Science Institute
Dennis Zaritsky (SF), University of Arizona

Science Category: local group galaxies
Observing Modes: IracMap MipsScan
Hours Approved: 511.0

Abstract:
The recycling of matter between the interstellar medium (ISM) and stars drives the evolution of a galaxy's visible matter. To understand this recycling, we propose to study the physical processes of the ISM, the formation of new stars and the injection of mass by evolved stars and their relationships on the galaxy-wide scale of the Large Magellanic Cloud (LMC). Due to its proximity,

favorable viewing angle, multi-wavelength information, and measured tidal interactions with the Milky Way (MW) and Small Magellanic Cloud (SMC), the LMC is uniquely suited for surveying the agents of a galaxy's evolution (SAGE), the ISM and stars. Our uniform and unbiased survey of the LMC (7x7 degrees) in all IRAC and MIPS bands will have much better wavelength coverage, up to ~1000 times better point source sensitivity and ~11 times better angular resolution than previous IR surveys. Full and uniform coverage of the LMC is necessary to study the galaxy as a system, to develop a template for more distant galaxies and to create an archival data set (rights waived) that promises a lasting legacy to match current LMC surveys at other wavelengths. SAGE will reveal over 6 million sources including ~150,000 evolved stars, ~50,000 young stellar objects and the diffuse ISM with column densities >1.2e21 H/cm2. In contrast to the MW and SMC, the diffuse IR emission in the LMC can be unambiguously associated with individual gas/dust clouds, thereby permitting unique studies of dust processes in the ISM. SAGE's complete census of newly formed stars with masses >1-3 Msun will reveal whether tidally-triggered star formation events in the LMC are sustained or short-lived. SAGE's complete census of evolved stars with mass loss rates >1e-8 Msun/yr will quantitatively measure the rate at which evolved stars inject mass into the ISM. SAGE will be the crucial link between Spitzer's survey of individual IR sources in the MW (GLIMPSE) and its surveys of galaxies (e.g., SINGS) and a stepping stone to the deep surveys (e.g., GOODS & SWIRE).

Spitzer Space Telescope - General Observer Proposal #3578

Infrared Extinction in the Magellanic Clouds

Principal Investigator: Karl Misselt
Institution: University of Arizona

Technical Contact: Karl Misselt, University of Arizona

Co-Investigators:
Karl Gordon, University of Arizona
Geoff Clayton, Louisiana State University
JD Smith, University of Arizona
Kate Su, University of Arizona

Science Category: local group galaxies
Observing Modes: IracMap IrsStare
Hours Approved: 20.7

Abstract:
We propose to examine the infrared extinction curve in the Magellanic Clouds. As our nearest galactic neighbors, the Clouds provide an ideal laboratory for the study of dust properites in environments very different from the Galaxy. We will use IRAC imaging in conjunction with IRS spectra for selected targets to explore the shape of the infrared extinction curve as well as the nature of the dust grains in both the Large and Small Magellanic Clouds. All of our targets have extensive data in the vacuum ultraviolet as well as optical and hence correlations of the IR properties of the dust (shape of the extinction curve from IRAC + IRS, mineralogy from IRS) will provide previously unavailable insight into the nature of grains in diverse environments. In addition, the IRAC images will provide information on the surrounding environment and its effect on grain properties. With the IRS spectra covering the stong aborption feature of silicate dust at 9.7 micron, we will be able to address recent evidence that silicon is undepleted into a solid state in the SMC. Previous studies of the UV extinction in extragalactic environments indicate that dust grains and their attendant extinction of starlight vary significantly with environment. In particular, the dust in the Magellanic Clouds, especially the SMC, appears similar to that found in starburst and high redshift galaxies. Hence, understanding how grain properties and hence their attenuation of starlight varies in the Clouds will provide valuable tools in interpreting data from the distant universe.

Spitzer Space Telescope - Archive Research Proposal #50029

Extragalactic Cepheids from Spitzer Archival Data

Principal Investigator: Chow Choong Ngeow
Institution: University of Illinois, Urbana-Champaign

Technical Contact: Chow Choong Ngeow, UIUC

Co-Investigators:
Shashi Kanbur, SUNY at Oswego
Lucas Macri, NOAO

Science Category: local group galaxies
Dollars Approved: 25000.0

Abstract:
We have recently derived the Cepheid Period-Luminosity (PL) relations in the IRAC bands using archival Spitzer data from the SAGE project. These PL relations can be used in future distance scale studies with the James Webb Space Telescope, which will mainly operate in the near and mid infrared. We propose to test the suitability of the LMC IRAC band PL relations for extragalactic work by applying them to extragalactic Cepheids present in archival Spitzer observations of three nearby galaxies: WLM, IC 1613 and M33. We request a funding of $25,000 to carry out this proposal.

Spitzer Space Telescope - General Observer Proposal #20080

Infrared Spectroscopy of SN 1987A

Principal Investigator: Elisha Polomski
Institution: University of Minnesota

Technical Contact: Elisha Polomski, University of Minnesota

Co-Investigators:
Diane Wooden, NASA/Ames Research Center
Charles Woodward, University of Minnesota
Robert Gehrz, University of Minnesota
Ben Sugerman, Space Telescope Science Institute

Science Category: local group galaxies
Observing Modes: IrsMap IrsStare
Hours Approved: 4.5

Abstract:
We propose to conduct deep spectroscopic observations of SN 1987A with the IRS instrument on the Spitzer Space Telescope. Supernova 1987A in the Large Magellanic Cloud was the brightest and nearest supernova in almost 400 years and has been intensely scrutinized with both ground and space-based observatories (for a review see Arnett et al. 1989; Sugerman et al. 2005). Since its outburst the remnant has faded significantly and no infrared spectroscopy (with the exception of our Spitzer GTO observations), and only limited IR photometry has been possible since day 2000 (Bouchet et al. 2004; Wooden et al. 1993; Dwek et al. 1992). We will focus our study on determining the dust mass and mineralogy as well as the physical state and composition of the circumstellar material and the ejecta. These observations will provide insight into the abundances of heavy elements in Type II SN ejecta and the relative importance of SN for the production of dust. The spectral evolution of the SN 1987A was studied until 1990, when it became too faint for all IR instrumentation. Our observations will be an important contribution to nearly 20 years of temporal monitoring of this object.

Spitzer Space Telescope - General Observer Proposal #3400

A Local Group Inventory of Simple Stellar Populations

Principal Investigator: Michael Rich
Institution: University of California - Los Angeles

Technical Contact: David Reitzel, University of California, Los Angeles

Co-Investigators:
Flavio Fusi Pecci, INAF - Osservatorio Astronomico Bologna
Livia Origlia, INAF - Osservatorio Astronomico Bologna
Luciana Federici, INAF - Osservatorio Astronomico Bologna
David B. Reitzel, UCLA
Soo-Chang Rey, Caltech
Carla Cacciari, INAF - Osservatorio Astronomico Bologna

Science Category: local group galaxies
Observing Modes: IracMap
Hours Approved: 32.2

Abstract:
Globular clusters, as aggregates of coeval stars with the same chemical abundance, are the best examples of Simple Stellar Populations and ideal templates for studying the evolution of stellar populations and for a correct interpretation of integrated colors (spectral energy distributions) of distant galaxies, with a crucial impact on cosmology. These templates, however, need to be calibrated over the widest possible wavelength range, from the far UV to the mid-IR, in order to take properly into account the contribution of all stellar components, including the coolest ones that were so far poorly known for lack of adequate observations. We propose to use Spitzer/IRAC imaging to characterize a sample of Local Group globular clusters defined to span a wide range in age and abundance. These clusters are meant to provide a grid of templates for the above purposes. Globular clusters in the LMC and SMC, chosen to span a wide range in age, will be resolved into stars. In the Fornax dwarf spheroidal galaxy, clusters are found with [Fe/H] = -2 yet with widely varying horizontal branch morphology (e.g. mass loss history). We propose also to image a set of globular clusters in M31, selected to span a wide range in abundance and different environmental conditions across the body of the galaxy. In addition to these populations, we propose to image the bulges of M31 and M32, which have been resolved into stars in the near-IR. While not strictly simple stellar populations, the bulges may give insight into similarities and differences between galaxy and globular cluster populations, and will provide an important test and verification in the application of stellar population synthesis models using the new and complete grid of templates we are proposing to assemble.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30203

Extended Dust in M31: MIPS Imaging to the HI Edge

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Karl Gordon, The University of Arizona

Co-Investigators:
Karl Gordon, Univ. of Arizona
Charles Engelbracht, Univ. of Arizona
Joannah Hinz, Univ. of Arizona
Karl Misselt, Univ. of Arizona
Chris Willmer, Univ. of Arizona
David Thilker, Johns Hopkins Univ.
Robert Braun, ASTRON, Netherlends

Science Category: local group galaxies
Observing Modes: MipsScan
Hours Approved: 14.3

Abstract:
We are proposing to extend the existing MIPS/GTO map of M31 from 1x3 degrees to approximately 1x5 degrees. The existing MIPS map covers the optical disk of M31 and clearly shows extended infrared emission to the edge of the current map along the major axis. HI observations of M31 also show that the HI disk extends well beyond the optical disk of M31, and the extended emission detected by MIPS supports an extended gas *and* dust disk of M31. The MIPS observation proposed here will complete the MIPS mapping of M31 out to the HI edge. Such observations will reveal the spatial distribution of cold dust in the extended HI disk. The spatial correlation of the MIPS emission with existing HI and GALEX ultraviolet images of M31 will probe the origin of the extended dust disk. Is it due to local star formation, fountains from inner disk star formation, interactions, or primordial infall? The answer(s) to these questions will provide insight on galaxy evolution and similar observations of more distant galaxies with MIPS.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40591

Dissecting the IR SED of a Galaxy: Spectroscopy of Regions in M33

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Karl Gordon, University of Arizona

Co-Investigators:
Karl Gordon, U. of Arizona
Karl Misselt, U. of Arizona
Charles Engelbracht, U. of Arizona
Pauline Barmby, Harvard/CFA

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 18.5

Abstract:
We propose to dissect the mid-IR SED of the Local Group galaxy M33 using IRS spectra to learn the physical properties of the different regions that contribute to the total mid-IR flux of M33. M33 is an ideal galaxy to study the relative contributions of different sources to the total flux in the disks of galaxies as it is the closest late type spiral. The IRS spectra will provide diagnostics of the excitation conditions in both the bright HII regions and the fainter diffuse regions. Although compact sources dominate our visual impression of galaxies, the diffuse regions make up over 50% of the total flux of M33 from 8 to 160 micron. A similar portion is likely to hold for other spirals: these relatively unstudied regions therefore make an major contribution to the SED and total IR power from spiral galaxies. For example, these diffuse regions also dominate the IR color-color space of M33 that was used to pick the diffuse targets for this proposal. Since the total IR power and SED colors are the most widely used parameters to characterize the integrated IR emission of galaxies, understanding of the behavior of the diffuse regions is an essential step toward improving our understanding of IR galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #99

Giant Extragalactic H II Regions in M31

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Karl Gordon, The University of Arizona

Science Category: local group galaxies
Observing Modes: MipsScan
Hours Approved: 17.1

Abstract:
This program is aimed at investigating the H II regions in M31. These regions will be used as analoges of starbursts and to probe the evolution of dust grain properties as a function of star formation activity. This program will acquire 24, 70, & 160 micron photometric spectral energy distributions on a large number of H II regions in M31. When combined with existing ultraviolet, optical, and near-IR images of M31, the data will be used to the star formation process and the properties of dust associated with H II regions.

Spitzer Space Telescope - General Observer Proposal #20057

Galactic Chemical Evolution & the Hot Star-H II Region Connection in M33

Principal Investigator: Robert Rubin
Institution: NASA Ames Research Center

Technical Contact: Robert Rubin, NASA Ames Research Center

Co-Investigators:
Janet Simpson, NASA Ames Research Center
Adi Pauldrach, University Munich
Sean Colgan, NASA Ames Research Center
Reginald Dufour, Rice University
Edwin Erickson, NASA Ames Research Center
Michael Haas, NASA Ames Research Center

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 23.9

Abstract:
H II regions play a crucial role in the measurement of current interstellar abundances while also serving as laboratories for atomic physics. They provide fundamental data about heavy element abundances that serve to constrain models of galactic chemical evolution. We propose to use Spitzer/IRS to measure the Ne/H and S/H abundances in H II regions in the nearby spiral galaxy M33. By observing a substantially face-on galaxy with a significant abundance gradient, we will cover a full range of galactocentric radii (R_G) & abundances, and avoid the extinction problems that plague optical/near IR Milky Way studies, particularly in the inner Galaxy. An important advantage compared with prior optical studies is that the IR lines have a weak and similar electron temperature (Te) dependence while optical lines vary exponentially with Te. We plan to observe 5 emission lines: S IV 10.5, Ne II 12.8, Ne III 15.6, S III 18.7, & H7-6 12.4 micron cospatially with IRS/SH. By virtue of being able to measure lines from all the major ionic states of Ne and S in H II regions, together with an H line, in the SAME spectrum, there is a unique opportunity to obtain reliable Ne/H & S/H ratios and determine how they vary with R_G. Our prior measurements of the Galactic Ne/O ratio using far-IR lines, showed the observed Ne++/O++ ratio significantly exceeds model predictions. This has been referred to as the "Ne III problem". The nebular models rely on stellar atmosphere models to provide the ionizing spectral energy distribution (SED) for hot stars. The SED used is the largest source of uncertainty when comparing theory and observations to determine nebular abundances in general and galactochemical gradients. We will use novel diagnostic tools designed to investigate the Ne III problem via the proposed observations to validate the SED input to the nebular code. These observations will pave the way for similar Spitzer studies of other galaxies to yield the most detailed, reliable data by far of S/H and Ne/H abundance variations.

Spitzer Space Telescope - General Observer Proposal #40910

Galactic Chemical Evolution & the Hot Star - H II Region Connection in NGC6822

Principal Investigator: Robert Rubin
Institution: NASA Ames Research Center

Technical Contact: Robert Rubin, NASA Ames Research Center

Co-Investigators:
Sean Colgan, NASA Ames Research Center
Simpson Janet, NASA Ames Research Center
Adalbert Pauldrach, University Munich
Reginald Dufour, Rice University
Edwin Erickson, NASA Ames Research Center
Michael Haas, NASA Ames Research Center
Brent Buckalew, Caltech/IPAC

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 27.5

Abstract:
H II regions provide fundamental data about heavy element abundances that constrain galactic chemical evolution (GCE) models. We propose to use Spitzer/IRS to follow up on our Spitzer observations of M83 and M33 H II regions. We will measure S IV 10.5, Ne II 12.8, Ne III 15.6, S III 18.7, & H7-6 12.4 micron cospatially with IRS/SH. By measuring all the major ionic states of Ne and S in H II regions with an H line, there is a unique opportunity to estimate S3+/S++, Ne++/Ne+, Ne/H, S/H, & Ne/S ratios and test if they vary with galactocentric radius (R_G). The high Ne/S ratios we derived for M83 are likely upper limits due to our estimate of the S abundance not accounting for S+ or dust. The M33 H II regions have much lower metallicity and higher ionization, leading to a truer total S abundance & a Ne/S close to the Orion Nebula value 14. The H II regions in the nearby, dwarf irregular galaxy NGC6822 are both low metallicity (O/H ~3.5x lower than Solar) and high ionization, allowing a reliable derivation of gas-phase Ne/S. The solar Ne abundance is very controversial, with much evidence pointing to a higher Ne value than the current Ne/S~5. NGC6822 observations will test how robust and universal the ratio of ~14 is. Such a finding will place important constraints upon GCE models. Our derivation of ionic abundances from Spitzer data depends on nebular models, which rely on the spectral energy distribution (SED) which comes from stellar atmosphere models. From our M83 and M33 data, we derive <Ne++>/<S++> & <Ne++>/<S3+> vs. <S3+>/<S++> ratios for the various H II regions and compare with theoretical loci, which show a factor >10 spread in y at a given x. The data points best follow the trend of the loci using the supergiant SEDs of Pauldrach, who will compute a set of atmosphere models with metallicity similar to that of NGC6822. Data for a third galaxy with a very different history and gas content will further validate whether or not any SED set preferentially fits the nebular observations.

Spitzer Space Telescope - General Observer Proposal #50088

A Population of Dusty B Stars in the SMC: The First Extragalactic Debris Disks?

Principal Investigator: Joshua Simon
Institution: California Institute of Technology

Technical Contact: Joshua Simon, California Institute of Technology

Co-Investigators:
Alberto Bolatto, University of Maryland
Jacco van Loon, Keele University
Joana Oliveira, Keele University
Luke Keller, Ithaca College
Greg Sloan, Cornell University
Karin Sandstrom, UC Berkeley

Science Category: local group galaxies
Observing Modes: IrsStare IrsPeakupImage
Hours Approved: 32.7

Abstract:
Using data from the Spitzer Survey of the SMC, we have discovered a population of 120 B stars with large 24 micron excesses. Optical spectroscopy and the IRAC SEDs demonstrate that they are not ordinary YSOs or Be stars. We suggest instead that these objects may be debris disks around massive main sequence stars. Confirmation of this hypothesis would provide one of the only ways to study the process of planet formation in a low-metallicity external galaxy. We propose Spitzer IRS spectroscopy to measure the long-wavelength SED of the dust emission and blue peak-up imaging to better constrain the size of the emitting region around each star. From the mid-infrared SEDs, we will determine the dust temperature, thereby placing strong constraints on its location and relationship to the B stars. If the B stars do indeed host debris disks, they provide perhaps the only plausible method for constraining planet formation in an external galaxy for the foreseeable future.

Spitzer Space Telescope - General Observer Proposal #50804

Leo T: Probing Star Formation and Dust in the Most Metal-Poor Galaxy Known

Principal Investigator: Joshua Simon
Institution: California Institute of Technology

Technical Contact: Joshua Simon, California Institute of Technology

Co-Investigators:
Alberto Bolatto, Maryland
Marla Geha, Yale

Science Category: local group galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 8.5

Abstract:
We propose IRAC and MIPS imaging of Leo T, the most metal-poor galaxy ever discovered. This new denizen of the Local Group is located just 420 kpc from the Milky Way and has a metallicity of less than 1/100 Zsun. However, it also contains significant amounts of cold gas, as well as a population of young massive stars. We will use very deep IRAC imaging of this unique system to search for YSOs, with techniques that we have perfected in the Small Magellanic Cloud. We will be sensitive to protostars with masses down to 4 Msun. We will also create a deep 160 um map of Leo T to constrain the dust associated with the cold gas, with the sensitivity to detect dust masses of as little as 10 Msun. Because of the combination of its unprecedently low metallicity and nearby location, Leo T is by far the best target for studying star formation and the dust content of the ISM at extremely low metallicities. With a small investment of Spitzer time, these observations offer the possibility of a very large scientific payoff: learning about stars similar to the theoretical Population III, but in the local universe.

Spitzer Space Telescope - General Observer Proposal #20425

Dust at Low Metallicity: MIPS Observations of Local Group Dwarfs

Principal Investigator: Evan Skillman
Institution: University of Minnesota

Technical Contact: Evan Skillman, University of Minnesota

Co-Investigators:
John Cannon, Max Planck Institute for Astronomy
Robert Gehrz, University of Minnesota
Dale Jackson, University of Minnesota
Henry Lee, University of Minnesota
Elisha Polomski, University of Minnesota
Soo-Chang Rey, Yonsei University, Korea
Fabian Walter, Max Planck Institue for Astronomy
Charles Woodward, University of Minnesota
Ted Wyder, Califonia Institute of Technology

Science Category: local group galaxies
Observing Modes: MipsScan
Hours Approved: 16.4

Abstract:
Characterizing the ISM and the star formation process at low metallicity is vital to our understanding of galaxy formation and evolution. Nearby dwarf galaxies represent our best opportunity to obtain observational constraints on our theoretical models of the low metallicity environment. Prior to Spitzer, even the closest dwarf galaxies were practically invisible at mid- and far-infrared wavelengths due to their intrinsically low surface brightnesses. However, the unprecedented sensitivity of MIPS on Spitzer allows us to make high resolution observations of the nearest low metallicity dwarf star forming galaxies for the first time. We will map the dust distributions, fluxes, and temperatures in these galaxies and, in combination with a nearly ideal set of ancillary observations, study the dependence of the physical properties of the ISM as a function of metallicity. We will also determine the metallicity dependence of three independent measurements of the star formation rate. The proposed modest number of requested observing hours will allow important strides forward in our understanding of the nature of the ISM and star formation at very low metallicities.

Spitzer Space Telescope - General Observer Proposal #40457

Spatially Resolved PAH Emission in Nearby Low-Metallicity Galaxies

Principal Investigator: Evan Skillman
Institution: University of Minnesota

Technical Contact: Evan Skillman, University of Minnesota

Co-Investigators:
Dale Jackson, University of Minnesota
John Cannon, Wesleyan University
Robert Gehrz, University of Minnesota

Science Category: local group galaxies
Observing Modes: IrsMap IrsStare MipsScan
Hours Approved: 18.5

Abstract:
Significant progress has recently been made in measuring the mid-IR luminosity of galaxies over an impressive range of parameter space. An empirical trend of decreasing mid-IR luminosity with decreasing metallicity has now been well established. Further, a 'transition metallicity' has been identified where a drastic shift occurs in the relative mid-infrared contributions from hot dust continuum and polycyclic aromatic hydrocarbons (PAHs). However, we have not yet pinpointed the physical processes responsible for this shift. We know that the strength of mid-IR emission is dependent on a galaxy's underlying dust and PAH content, as well as the ability of these components to be individually stimulated into emission, destroyed, and regrown through different physical processes in the ISM. However, the conditions regulating these processes remain highly unconstrained. To place strict constraints on the conditions regulating both hot dust and PAH emission we propose Spitzer/IRS spectral mapping of three nearby star-forming irregular galaxies. We will measure the relative strengths of hot dust and PAH emission with resolution on unprecidented spatial scales (70 pc). Our sample of metal-poor targets are the closest systems in which we can investigate the empirical transition where PAHs go from dominating the mid-IR flux to being completely absent, providing the conditions required to understand the physical processes responsible for this transition. In combination with a comprehensive set of ancillary data, we will compare our spectral maps with highly resolved stellar population data to precisely quantify the effects that radiation field strength and hardness and history of supernova activity have on dust and PAHs.

Spitzer Space Telescope - General Observer Proposal #40524

The AGB Star Census of Local Group Irregular Galaxies

Principal Investigator: Evan Skillman
Institution: University of Minnesota

Technical Contact: Evan Skillman, University of Minnesota

Co-Investigators:
Dale Jackson, University of Minnesota
Robert Gehrz, University of Minnesota

Science Category: local group galaxies
Observing Modes: IracMap
Hours Approved: 2.2

Abstract:
Studies of the resolved stellar populations of nearby galaxies provide very strong constraints on their evolutionary histories. Because these are the most secure of all galaxy evolution studies, they represent a calibration of high-redshift investigations where the stellar populations are not resolvable. This work has typically been done at optical wavelengths, and therefore, is biased against very red and highly extincted objects. For example, AGB stars, which are important tracers of the intermediate age evolution of galaxies and are also important contributors to their chemical evolution, are incompletely sampled in typical optical studies, due to extinguishing material expelled by winds late in their evolution. Prior to Spitzer, infrared observations of low surface brightness galaxies were virtually impossible, but our Spitzer/IRAC pilot program imaging Local Group dwarf irregular galaxies has demonstrated that infrared studies of the resolved stellar populations in these galaxies are now available. These observations, in combination with ground based and HST optical imaging, confirm that optical studies do present a highly biased view of the stellar populations in nearby galaxies. These observations also provide the first direct measurement of AGB mass-loss in environments very different from the Milky Way, placing strict constraints on the role metal abundance plays on the physics governing the late stages of stellar evolution. Here we propose to extend our pilot study to a much broader range of parameter space, completing our IRAC investigation of the evolved stellar populations in Local Group star forming dwarf galaxies.

Spitzer Space Telescope - General Observer Proposal #50141

Connecting the Dots: IRS 16 Micron Imaging of AGB Stars and ISM Dust in Low Metallicity Local Group Dwarf Galaxies

Principal Investigator: Evan Skillman
Institution: University of Minnesota

Technical Contact: Martha Boyer, University of Minnesota

Co-Investigators:
Martha L. Boyer, University of Minnesota
John M. Cannon, Macalester College
Jacco Th. van Loon, Keele University
Robert D. Gehrz, University of Minnesota

Science Category: local group galaxies
Observing Modes: IrsPeakupImage
Hours Approved: 21.4

Abstract:
Through a combination of GO and GTO programs, we have obtained IRAC and MIPS imaging of 15 gas-rich Local Group dwarf galaxies. These data have allowed us to produce a complete census of asymptotic giant branch (AGB) stars in these galaxies and to measure the strength and spatial distribution of polycyclic aromatic hydrocarbon (PAH)s, warm dust, and cold dust emission. We have also identified the most extreme mass-losing AGB stars in the same 15 galaxies. The IRAC and MIPS data sets are complementary to each other, but the factor of three gap in wavelength between 8 and 24 microns leaves considerable uncertainty in the AGB and ISM spectral energy distributions (SEDs). We propose to complete the SEDs with IRS peak-up imaging at 16 microns, a wavelength that is crucial for understanding the PAH and small grain contribution to ISM dust and for determining the characteristics of AGB circumstellar dust and AGB mass-loss rates. Since the galaxies in our sample span over 1 dex in metallicity, the proposed observations will enable us to better study both AGB mass loss and PAH and small grain emission as a function of metallicity at very low metal abundance. Because the low metallicity environments of these dwarf galaxies are similar to those of galaxies at high redshift, these observations will help us to better interpret observations of high redshift star formation and dust production. Similar observations are not currently possible with any facility other than Spitzer and will not be possible with any planned future infrared missions, making Spitzer cycle-5 the final opportunity to fill this gap in our knowledge. These observations will be the only complete near- to far-infrared observations of resolved dwarf galaxies for considerable time into the future, and the resulting database will leave a valuable Spitzer legacy.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50240

The SMC as a probe of dust in the early Universe (GTO)

Principal Investigator: Greg Sloan
Institution: Cornell University

Technical Contact: Greg Sloan, Cornell University

Co-Investigators:
Jeronimo Bernard-Salas, Cornell Univ.
Robert Blum, NOAO
Alberto Bolatto, Univ. of Maryland
Caroline Bot, Caltech
Martin Cohen, Univ. of California at Berkeley
Karl Gordon, STScI
Joseph Hora, Harvard-Smithsonian CfA
Remy Indebetouw, Univ. of Virginia
Luke Keller, Ithaca College
Kathleen Kraemer, Air Force Research Laboratory
Eric Lagadec, Manchester Univ.
Vianney Lebouteiller, Cornell Univ.
Aigen Li, Univ. of Missouri
Sue Madden, CEA/Saclay
Massimo Marengo, Harvard-Smithsonian CfA
Mikako Matsuura, NAO of Japan
Franciska Markwick-Kemper, Manchester Univ.
Margaret Meixner, STScI
Joana Oliveira, Univ. of Keele
Karin Sandstrom, Univ. of California at Berkeley
Marta Sewilo, STScI
Josh Simon, Caltech
Angela Speck, Univ. of Missouri
Alexander Tielens, NASA Ames Research Center
Schuyler van Dyk, SSC/Caltech
Jacco van Loon, Univ. of Keele
Kevin Volk, Gemini Observatory
Peter Wood, Australian National Univ.
Albert Zijlstra, Manchester Univ.
James Houck, Cornell Univ.

Science Category: local group galaxies
Observing Modes: IrsMap IrsStare MipsSed
Hours Approved: 62.0

Abstract:
We propose a comprehensive spectroscopic survey of the Small Magellanic Cloud (SMC), using the IRS and MIPS-SED. The SMC has a metallicity similar to high-redshift galaxies, and its proximity makes it a spatially resolved proxy for star-forming galaxies in the distant, early Universe. The sensitivity of the Spitzer Space Telescope allows us to to observe dust in nearly every stage of its life cycle in the SMC so that we can study how the interactions of dust and its host galaxy differ from more metal-rich systems like the Galaxy and the LMC. Our proposed observations concentrate on important classes underrepresented in the archive of SMC spectra such as young stellar objects, compact H II regions, objects in transition to and from the asymptotic giant branch, and supergiants. These observations, in combination with those already in the archive, will give us a complete picture of the dust in a metal-poor star-forming galaxy similar to those in the early Universe. We request 116 hours, 62 as IRS GTO time and 54 as GO time.

Spitzer Space Telescope - General Observer Proposal #20443

Magellanic Cloud Planetary Nebulae: probing the effects of metallicity on dust formation, mass-loss, and evolution.

Principal Investigator: Letizia Stanghellini
Institution: National Optical Astronomical Observatory

Technical Contact: Letizia Stanghellini, NOAO

Co-Investigators:
Pedro Garcia-Lario, ESA/VILSPA
Eva Villaver, STScI
Jose Vicente Perea, ESA/VILSPA
Richard A. Shaw, NOAO
Arturo Manchado, IAC

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 14.8

Abstract:
Planetary nebulae (PNe) in the Magellanic Clouds (LMC, SMC) offer a unique opportunity to study both the population and evolution of low- and intermediate-mass stars in an environment which is free of the distance scale bias that hinder Galactic PN studies. At the same time, LMC and SMC PNe cover a wide metallicity baseline. Their progenitors might have metallicity from nearly equal to less than a tenth of Galactic PN progenitors. Such properties make the Magellanic Cloud PNe the ideal probes to study the effects of progenitor metallicity in the cosmic recycling. The emission shown by PNe in the 5-40 micron range is characterized by the presence of a combination of solid state features (from the dust grains) and nebular emission lines over-imposed on a strong dust continuum. We propose to acquire low resolution IRS spectroscopy of a selected sample of LMC and SMC PNe whose morphology, size, central star brightness, and chemical composition are known. We propose to: i) determine the dominant chemistry (C-rich vs. O-rich) of the PN dust through the study of the solid state features, with the ultimate goal of evaluating the dust formation efficiency versus metallicity; ii) establish connections between chemistry, morphology, and evolutionary stage of the PNe; iii) test the current models of stellar evolution at various initial metallicities, comparing predicted composition of the dredged-up material and observed composition in the PNe as a function of the mass of the progenitor star; iv) recover the AGB mass loss history from the analysis of the overall spectral energy distribution; v) determine the contribution of the infrared to the total PN luminosity.

Spitzer Space Telescope - Legacy General Observer Proposal #40159

SAGE-Spectroscopy: The life cycle of dust and gas in the Large Magellanic Cloud

Principal Investigator: Alexander Tielens
Institution: NASA Ames Research Center

Technical Contact: Ciska Markwick-Kemper, U. of Manchester

Co-Investigators:
Jean-Philippe Bernard, CESR, Toulouse
Robert Blum, NOAO
Martin Cohen, UC-Berkeley
Catharinus Dijkstra, unaff.
Karl Gordon, U. Arizona
Varoujan Gorjian, NASA-JPL
Jason Harris, U. Arizona
Sacha Hony, CEA, Saclay
Joseph Hora, CfA-Harvard
Remy Indebetouw, U. Virginia
Eric Lagadec, U. of Manchester
Jarron Leisenring, U. of Virginia
Suzanne Madden, CEA,Saclay
Massimo Marengo, CfA-Harvard
Mikako Matsuura, NAO, Japan
Margaret Meixner, STScI
Knut Olsen, NOAO
Roberta Paladini, IPAC/Caltech
Deborah Paradis, CESR, Toulouse
William T. Reach, IPAC/Caltech
Douglas Rubin, CEA, Saclay
Marta Sewilo, STScI
Greg Sloan, Cornell
Angela Speck, U. Missouri
Sundar Srinivasan, Johns Hopkins U.
Schuyler Van Dyk, Spitzer Science Center
Jacco van Loon, U. of Keele
Uma Vijh, STSci and U. of Toledo
Kevin Volk, Gemini Observatory
Barbara Whitney, Space Science Institute
Albert Zijlstra, U. of Manchester

Science Category: local group galaxies
Observing Modes: IrsMap IrsStare MipsSed
Hours Approved: 224.4

Abstract:
Cycling of matter between the ISM and stars drives the evolution of a galaxy's visible matter and its emission characteristics. To understand this recycling, the SAGE legacy project has surveyed the Large Magellanic Cloud with IRAC and MIPS to study the physical processes of the ISM, the formation of new stars and the injection of mass by evolved stars and their relationships on the galaxy-wide scale. Due to its proximity, favorable viewing angle, and multi-wavelength information, the LMC is uniquely suited to survey the agents of a galaxy's evolution, the ISM and stars. We propose to leverage the SAGE legacy program to conduct a comprehensive IRS and MIPS-SED spectroscopy program of dust with the goal to determine the composition, origin, evolution, and observational characteristics of interstellar dust and its role in the LMC. Analysis of the spectra will yield composition and abundance of the dust compounds in different LMC objects, including AGB stars, post-AGB, young stellar objects, HII regions and the general diffuse ISM and provide a quantitative picture of the dust lifecyle. Besides dust features, the spectra will also contain molecular and atomic emission and absorption lines, providing the diagnostics to determine physical parameters such as temperature, density and radiation field - all important to the formation and processing of dust, and understanding the life cycle of matter. The proposed spectroscopic survey will provide critical underpinning for the SAGE survey by linking observed IRAC and MIPS colors of LMC objects to the infrared spectral type of the object. We will to the maximum

extent utilize the LMC spectroscopy available in the Spitzer archive. A subset of the IRS point sources from this proposal will also be surveyed in MIPS SED. Legacy data products that will be made available to the public include all reduced single point spectra and data cubes, feature maps, a spectral catalog, and a fully classified SAGE point source catalog.

Spitzer Space Telescope - General Observer Proposal #20608

The Dust Condensation Sequence at Low Metallicity: AGB Stars in NGC 6822

Principal Investigator: Schuyler Van Dyk
Institution: Spitzer Science Center

Technical Contact: Schuyler Van Dyk, Spitzer Science Center

Co-Investigators:
Franciska Kemper, U. Virginia
Toshiya Ueta, NASA Ames
Margaret Meixner, STScI
Angela Speck, U. Missouri
Ryszard Szczerba, NCAC, Torun
Els Peeters, NASA Ames

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 32.0

Abstract:
We will study the formation and processing of dust around carbon- and oxygen-rich evolved stars in the Local Group dwarf galaxy NGC 6822. Dust condensation may depend heavily on the metallicity, although the effect is currently unknown. From current condensation theories it may be expected that: 1) the total condensed dust mass is lower, 2) there will be more simple oxides and less silicates, 3) the degree of crystallinity will be lower for the silicates. We propose to conduct IRS low-resolution observations to study dust properties, such as composition, grain size and shape and the dust mass distribution, to validate current condensation models. We have selected a sample of 20 asymptotic giant branch stars, based on a bandmerge of recent deep near-infrared and extractions from Spitzer SINGS IRAC mid-infrared images of the galaxy. To our knowledge, this will be the first time such evolved stars have been observed spectroscopically in NGC 6822. We will compare the results here to those for stars in the Galaxy and the Magellanic Clouds. Building an understanding of the dust condensation sequence at low metallicities will improve our understanding of dust formation in general, and will provide the ability to use grain properties and dust composition as a tool to trace physical conditions in nearby galaxies.

Spitzer Space Telescope - General Observer Proposal #3280

Stellar-Nebular Feedback in Galaxian Starbursts: IR Spectral Imaging of HII Regions in M33

Principal Investigator: William Waller
Institution: Tufts University

Technical Contact: William Waller, Tufts University

Co-Investigators:
Robert Gehrz, University of Minnesota
Roberta Humphreys, University of Minnesota
Bernhard Brandl, Cornell University
Paul Hodge, University of Washington
Francois Boulanger, Institut d'Astrophysique Spatiale
Elisha Polomski, University of Minnesota
Steven Willner, Harvard-Smithsonian Center for Astrophysics
Donald Garnett, University of Arizona
Other_GTO#5 Gehrz_team_members, University of Minnesota
Myung Gyoon Lee, Seoul National University
Eric Murphy, Yale University

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 10.7

Abstract:
We propose a spectrophotometric investigation of starburst activity in the Local Group galaxy, Messier 33. By observing 7 selected giant HII regions that span a decade in metallicity, we will test the generic relationships between the ionizing stellar populations (previously observed with HST), the photo-dissociation regions (PDRs), and their associated dust content. We are especially interested in determining whether the observed variations in the stellar IMFs correlate with variations in the PDRs. We will use the IRS to obtain fully-sampled spectral maps of the 7 selected HII regions at 5.2 ==> 14.5 microns. The resulting datacubes will contain abundant spatial and spectral information on the molecular and dust content in the PDRs. This research program -- in close coordination with complementary GTO programs #5 and #63 -- will provide important benchmarks for interpreting starburst activity on many scales and over many epochs.

Spitzer Space Telescope - General Observer Proposal #30383

IRS Mapping of Three LMC Supernova Remnants and Their Surroundings

Principal Investigator: Rosa Williams
Institution: University of Illinois at Urbana-Champaign

Technical Contact: Rosa Williams, UIUC

Co-Investigators:
You-Hua Chu, University of Illinois at Urbana-Champaign
Robert Gruendl, University of Illinois at Urbana-Champaign
Gary Ferland, University of Kentucky

Science Category: local group galaxies
Observing Modes: IrsMap
Hours Approved: 32.2

Abstract:
Supernova SNRs (SNRs) play a significant role in dust production in the interstellar medium (ISM). Dust, in turn, is an important factor in cooling the hot plasma in SNRs. To investigate dust properties in SNRs, we used IRAC and MIPS images of 6 SNRs in the Large Magellanic Cloud (LMC), and found them to be line-dominated, with little evidence for continuum emission. This is surprising, as we expect significant continuum emission from hot dust. Its absence would raise questions about previous studies with dust properties inferred from broad-band IR emission, and would also raise the issue of whether dust is actually destroyed or persists in cold clumps. We propose to spectrally map 3 of these LMC SNRs and their surroundings. The small angular size of LMC SNRs allows complete coverage of each SNR (not possible for Galactic SNRs). Each of our selected SNRs is in a different environment: N49 interacts with a molecular cloud; N63A is embedded in an HII region; and N11L is on the edge of an HII complex. We will use the background-subtracted, spatially-mapped spectra to: (a) search for continuum emission from hot dust, (b) quantify the flux contribution from line emission to place upper limits on continuum flux, (c) compare emission from the SNR to its environment, (d) establish upper limits for PAH bands, (e) use diagnostic lines to infer physical properties in SNR regions, and (f) model dust and line emission from SNRs for comparison with these spectra. The results will show whether continuum emission is significant in any region of each SNR, and if so, how that emission is distributed spatially over the SNR. If we cannot detect continuum emission in the SNRs, our examination of the surroundings will allow us to establish whether dust is present in the environment, and perhaps destroyed in the SNRs. Or, if we can detect and quantify continuum contributions in these SNRs, we will be able to use dust models to describe such features as the mass, grain distribution, and temperatures of dust.

Spitzer Space Telescope - Directors Discretionary Time Proposal #263

IRS DDT Spectra of LMC 2005

Principal Investigator: Charles Woodward
Institution: Univ. Minnesota

Technical Contact: Charles Woodward, Univ. Minnesota

Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 1.5

Abstract:
Infrared (IR) observations of galactic classical novae (CN) have established their importance for understanding the formation of astrophysical grains, and as contributors to abundance anomalies in the interstellar medium (ISM) on local scales. Studies of abundances in nova ejecta also provide information about nucleosynthesis in the white dwarf (WD) progenitor and in the thermonuclear runaway (TNR) during a nova explosion. However, the infrared study of novae in external galaxies, such as the Magellanic Clouds (MC), is an observational challenge. We propose to obtain DDT IRS observations of the newly discovered (2005 Nov. 26.164 UT, V = 12.6) LMC nova (Liller, IAUC 8635). This opportunity affords the first investigation of an extragalactic nova with Spitzer in a system with lower metallicity. The IRS 5 to 40 micron wavelength regime contains forbidden lines from heavy elements that are useful for excitation and abundance studies. Continuum emission and broad features at these wavelengths provide information about dust. The determination of the elemental abundances from a CN is of extreme importance in understanding the evolution of the nova explosion and chemical evolution of the ISM. Our proposed Spitzer (+IRS) DDT observations of nova LMC 2005, combined with complementary ground-based and spacecraft data (Swift) will enable determination of abundances in the ejecta in a Magellanic Cloud nova (lower metallicty system). Such determinations are rare for extragalactic events.

Spitzer Space Telescope - General Observer Proposal #30333

Dust Production in Local Group Dwarf Galaxies

Principal Investigator: Albert Zijlstra
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Technical Contact: Greg Sloan, Cornell University

Co-Investigators:
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Science Category: local group galaxies
Observing Modes: IrsStare
Hours Approved: 33.2

Abstract:
The superwind phase on the Asymptotic Giant Branch is a crucial ingredient of stellar and galactic evolution. The superwind ejecta are responsible for much of the interstellar hydrogen of evolved galaxies, and are a dominant contributor to the dust input into the ISM. The superwind determines the final mass of stellar remnants, and therefore affects, e.g., the type-I supernova rate. The characteristics of the superwind are still very poorly known, especially at non-solar metallicities. Spitzer has contributed a large and invaluable dataset on Magellanic Cloud stars, measuring dust, molecular bands and allowing accurate mass-loss measurements. We now propose to extend the (age, metallicity) parameter range by observing a number of other Milky Way satellites. The carbon stars in these galaxies trace an older population than the Magellanic Clouds, and extend to much lower metallicities. They are therefore crucial to allow us to extrapolate the Magellanic Cloud measurements to metal-poor environments. We propose to acquire low-resolution spectra of stars in the Sagittarius dwarf galaxy, Carina, Sculptor and Fornax. The selected stars range in metallicity from -0.55 to -2.0, and in age from 5-8 Gyr. Two low-metallicity planetary nebulae in these galaxies are also included. We will study the dust continuum, dust minerals (SiC, MgS) and gas-phase molecular bands (especially acetylene). Mass loss rates will be determined using our dust models, and we will measure the fractional abundances of amorphous carbon dust and SiC grains. Only Spitzer can provide these crucial measurements of extra-galactic AGB stars. The result will be our first knowledge of mass loss efficiency, dust formation, and dust abundances, at low to very low metallicities. These data are necessary to obtain reliable models of mass loss and of stellar evolution.

Spitzer Space Telescope - General Observer Proposal #50534

Dust Production in Type II SNe

Principal Investigator: Jennifer Andrews
Institution: Louisiana State University

Technical Contact: Jennifer Andrews, Louisiana State University

Co-Investigators:
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Margaret Meixner, STScI
Mike Barlow, University College London
Barbara Ercolano, Harvard Smithstonian Center for Astrophysics

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 4.8

Abstract:
Recent detection of large amounts of dust in high redshift galaxies has led to an increased interest in the importance of Type II supernovae (SNe) as dust producers. The dust in high-z galaxies must come from young, massive stars, so Type II SNe are one of the few possible sources. We propose to observe three very bright Type II SNe (SN 2007it, 2007oc and 2007od) in nearby galaxies. The ages of these SNe mean that they will be perfectly timed to be in their dust formation phases during Cycle 5. Three observational signatures of this dust formation can be seen, a decrease in the continuum brightness in the visible, a developing infrared excess, and asymmetric, blue-shifted emission-line profiles. We are already planning photometric and spectroscopic observations of these SNe with Gemini and SMARTS, but observations of the IR emission are needed to confirm that dust formation has occurred. These three indicators usually appear around 300-600 days after the SN explosion, when the brightness of the SN has diminished considerably. Fortunately, these three SNe are all unusually bright, allowing us a rare opportunity to follow them through and beyond their dust formation phases. With Spitzer, we will be able to carefully study the IR emission, and together with the Gemini and SMARTS data, we may be able to double the number of Type II SNe known to have shown all three dust formation signatures. This increased sample size will help answer what fraction of Type II SNe produce dust, how much dust they produce, and what conditions of the SNe ejecta affect the dust formation. These estimates will put strong constraints on the formation of dust seen in young, high redshift galaxies.

Spitzer Space Telescope - General Observer Proposal #40142

Resolving the cooling in the powerful H2 emitting shock in Stephan's Quintet

Principal Investigator: Philip Appleton
Institution: California Institute of Technology

Technical Contact: Philip Appleton, California Institute of Technology

Co-Investigators:
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Guillaume Pineau des Forets, Institut d'Astrophysique-Paris

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap IrsPeakupImage IrsStare MipsPhot
Hours Approved: 32.5

Abstract:
Recent Spitzer observations have discovered a potentially important new class of galaxy system in which a significant fraction of the bolometric luminosity from the system arises in the Mid-IR emission lines of molecular hydrogen. This emission is thought to arise in large-scale shocks. We propose to study the nearest and best-studied example of this effect which arises in a group-wide shock wave in Stephan's Quintet. The shock-wave, which extends for over 1 arcminute throughout the intragroup medium, is believed to be the result of a ~1000 km/s collision between an infalling galaxy and the group. Previous limited Spitzer IRS observations by our team showed extremely strong, unusually broad emission lines of the H2 and almost nothing else. The discovery of such powerful emission from a high-velocity shock was unexpected because of the fragile nature of the H2 molecule, and yet numerous examples are being discovered at higher redshift in other group and cluster environments. We propose to critically test new models of the process which might give rise to powerful H2 emission in the cooling layer behind a shock. By taking advantage of the large angular size of the giant X-ray shock we can map both the H2 excitation temperature and dust SEDs over the shocked region. Our proposed observations will help us isolate the most important model parameters that are needed to explain the extreme luminosities being emitted during the cooling of H2. Such models are necessary if we are to make progress understanding these ultra-powerful H2-emitting galaxies at higher redshift.

Spitzer Space Telescope - General Observer Proposal #3333

Supernovae and the Origin of Dust in Galaxies

Principal Investigator: Michael Barlow
Institution: University College London

Technical Contact: Michael Barlow, University College London

Co-Investigators:
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Ben Sugerman, Space Telescope Science Institute
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Douglas Welch, McMaster University
Michael Wolff, Space Science Institute, University of Colorado
Albert Zijlstra, UMIST, Manchester

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 9.3

Abstract:
We propose to use IRAC and MIPS to carry out a sensitive mid-IR survey for thermal dust emission from 30 nearby extragalactic supernovae (SNe) discovered between April 1999 and January 2004. The goal is to find evidence for dust formation and spectral evolution in the SN ejecta and to determine the masses of dust that have been formed, in order to quantify for the first time the contribution by SNe to the dust cycle of galaxies. Our estimates for the mid-IR brightnesses of our targets are conservatively based upon SN 1987A, which formed modest amounts of dust and whose emission peaked in the mid-IR. For each target we will use an IRAC AOR of 1574s, yielding 600s per pixel in all four bands, together with a MIPS 24-micron AOR of 2639s, yielding an exposure time per pixel of 2*1088s. The IRAC and MIPS observations will yield comparable image fov's of 5x5 arcmin. The IRAC observations are capable of detecting SN1987A-type events between 3.6 and 8.0 microns to distances of up to 25 Mpc, while the MIPS observations could detect SN 1987A at 24 microns out to distances of 15 Mpc. The 30 SNe that have been selected have distances of less than 25 Mpc and consist of 23 massive-star SNe (16 Type II, 7 Type Ib/c) and 7 low-mass Type Ia SNe. The 28 IRAC and MIPS fields needed to cover the 30 SNe require a total of 32.8 hours of observing time. Our team comprises experienced IR observers, together with experts on supernovae, dust grain characteristics, and mass loss from evolved stars, The team members have extensive accumulated experience in the analysis of thermal IR spectra to derive the properties and masses of emitting dust and have available to them several state-of-the-art dust radiative transfer codes, including ones developed by members of the team. We have an approved high-priority 2004/5 8-m Gemini programme, to obtain high angular resolution mid-IR imaging of recent SNe, which will enhance and complement the current proposal.

Spitzer Space Telescope - General Observer Proposal #30720

The Red Halos of Blue Compact Galaxies - Constraining the Dust Content.

Principal Investigator: Nils Bergvall
Institution: Uppsala Astronomical Observatory

Technical Contact: Nils Bergvall, Uppsala Astronomical Observatory

Co-Investigators:
Thomas Marquart, Uppsala Astronomical Observatory
Erik Zackrisson, Uppsala Astronomical Observatory
Göran Östlin, Stockholm Observatory
Matthew Hayes, Stockholm Observatory
Eija Laurikainen, Astronomy, Dept. of Physical Sciences, University
Genoveva Micheva, Uppsala Astronomical Observatory
Kjell Olofsson, Uppsala Astronomical Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 8.2

Abstract:
The halos of BCGs play a crucial role in the understanding of the star formation history of BCGs and provide unique information about the starburst host. We intend to investigate the outer regions of a sample of luminous Blue Compact Galaxies (BCGs) that show a red color excess in our previous deep optical and near-IR data. These colours have been compared to spectral evolutionary models and found to be inconsistent with an expected old metal poor stellar population. Possible models for the excess include reddening by a dusty circumgalactic shell. We propose to use Spitzer to test this option in a search for cold dust at 70 and 160 micron in 5 BCGs. For comparison we will also observe 7 starburst host galaxy and postburst candidates for which we recently obtained deep optical/near-IR photometry. In addition, we propose to use IRAC to search for excess emission from hot circumstellar dust from late type stars in halos of two of the BCGs.

Spitzer Space Telescope - General Observer Proposal #40132

Dust in the Extremely Metal Poor Galaxy IZw18

Principal Investigator: Alberto Bolatto
Institution: University of California, Berkeley

Technical Contact: Alberto Bolatto, University of California, Berkeley

Co-Investigators:
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Fabian Walter, Max Planck Institute for Astronomy - Heidelberg
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Karin Sandstrom, U.C. Berkeley

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 8.0

Abstract:
IZw18, with one of the lowest nebular metallicities measured to date (12+log(O/H)=7.2), is perhaps the most important link between primitive galaxies in the local universe and distant primeval sources. It is also the touchstone of any theory relating galaxy properties to metallicity. Existing archival MIPS observations were unsuccessful at detecting IZw18 at 160 um, but detected it at 70 um. We propose to obtain multiepoch deep MIPS observations at these wavelengths, designed to provide an order of magnitude better sensitivity than currently available. With a very modest investment of time, we will be able to measure the dust mass of this galaxy and determine its dust-to-gas ratio. If these observations resolve the extended atomic envelope of IZw18 we will be able to constrain the molecular gas content of this galaxy, and study the relationship between molecular gas and star formation at the lowest metallicities, providing valuable insights into star formation in the primitive universe.

Spitzer Space Telescope - General Observer Proposal #3605

Molecular Gas in IR-Bright Galaxies: Masses and Physical Conditions

Principal Investigator: Charles Bradford
Institution: Jet Propulsion Laboratory, California Institute of

Technical Contact: Charles Bradford, JPL

Co-Investigators:
Colin Borys, California Institute of Technology
John-David Smith, Steward Observatory, University of Arizona
Thomas Phillips, California Institute of Technology

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 15.7

Abstract:
We propose a program of mid-infrared and submillimeter spectroscopy of molecular gas probes in a sample of 24 IR-bright galaxies. We will combine Spitzer observations of the pure rotational transitions of molecular hydrogen with observations of optically-thin CO isotopes only possible with sensitive receivers at the Caltech Submillimeter Observatory (CSO). The two measurements are complementary, and the combination with existing datasets will allow estimates of total molecular gas mass and the run of temperature with mass in its warm components. The results will test theories of gas heating and cooling and star formation in massive dusty galaxies, and guide extrapolations to the more distant ULIGs and the high-redshift submillimeter galaxy popluation. Our sample is carefully selected from the much larger Submillimeter Local Galaxy Sample (SLUGS), and benefits from ongoing spectral and continuum observations which will benefit our analysis.

Spitzer Space Telescope - General Observer Proposal #50114

Infrared-Bright Interacting Galaxies: From Molecular Gas to Stars to Black Holes

Principal Investigator: Charles Bradford
Institution: Jet Propulsion Laboratory, California Institute of

Technical Contact: Eric Murphy, Yale University

Co-Investigators:
Eric Murphy, IPAC
Charles (Darren) Dowell, JPL
J.D. Smith, Arizona / U. Toledo

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap IrsStare
Hours Approved: 38.0

Abstract:
We propose to map the mid?IR spectral features in 5 nearby IR?bright interacting galaxy pairs. Galaxy?galaxy interactions are known to be associated with large IR luminosities and massive molecular gas reservoirs. With ISO and Spitzer demonstrating that the sources producing the cosmic far?IR background (FIRB) are similar to our local LIRGS but at redshifts 0.5?2, it is becoming clear that interactions are a prime driver of galaxy evolution, and may have triggered the bulk of the star formation and AGN activity in the history of the Universe. The details of the process, however, remain poorly understood. In many cases, energy release is triggered several kpc from either galactic nucleus, where giant molecular clouds of the two galaxies impinge. Other evidence suggests that interactions funnel gas to the nuclei to feed black holes and/or trigger nuclear star formation. To study the processes at work in local analogues of the FIRB sources, we propose a spatially-resolved study in a sample of LIRG-class, IR-bright, interacting systems. We combine mid-IR imaging spectroscopy with ground-based 350-micron imaging and mm-wave spectroscopy to probe all components of the dust and interstellar gas. These long-wavelength tools are critical because the traditional optical/near?IR probes are not reliable given the huge extinction in these systems. Our low?res imaging data will provide maps of the PAH & silicate features as well as the molecular hydrogen & nebular fine?structure transitions. These probes will reveal the sites of energy production, probe the conditions of embedded starbursts, and assess the role of active nuclei. Mid-IR molecular hydrogen measurements combined with comprehensive millimeter-wave spectroscopy will provide a complete census of all phases of the molecular gas. Finally the 350-micron images of a larger sample, including sources previously-observed with Spitzer, will provide a complete spatially-resolved SED of the interacting systems, guiding the interpretation of the mid-IR datasets.

Spitzer Space Telescope - General Observer Proposal #3535

The Ages and Mass Loss Rates of Elliptical Galaxies

Principal Investigator: Joel Bregman
Institution: Univerisity of Michigan

Technical Contact: Joel Bregman, Univerisity of Michigan

Co-Investigators:
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Pasquali Temi, NASA-Ames Research Center

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 12.8

Abstract:
The ages of elliptical galaxies are traditionally determined through absorption line indices where investigators must contend with the age-metallicity degeneracy and contamination by a few young stars. These studies result in a wide range of mean ages, 2-18 Gyr, suggesting that many ellipticals are relatively young, which has implications for models of elliptical galaxy formation and evolution. An independent and possibly more powerful age diagnostic for these galaxies is the collective mass loss rate of the stars, since it decreases as age^-1.35. We can to determine the collective stellar mass loss rate in a galaxy by measuring the silicate emission feature near 10um, which is produced during stellar outflow in AGB stars. We detected this feature in a few early-type galaxies with ISO, but with the IRS, we propose to measure the silicate emission accurately and as a function of radius for a sample of 31 galaxies with the best available optical absorption line ages.

Spitzer Space Telescope - General Observer Proposal #40714

The Intrinsic Luminosity of Ultraluminous X-Ray Sources

Principal Investigator: Joel Bregman
Institution: University of Michigan

Technical Contact: Joel Bregman, University of Michigan

Co-Investigators:
Jon Miller, University of Michigan
Jimmy Irwin, University of Michigan

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 4.9

Abstract:
Ultraluminous X-ray sources are non-nuclear sources in normal disk galaxies that are second only to AGNs in point-source luminosity. These enigmatic objects are either stellar mass black holes that are super-Eddington emitters, or sub-Eddington emission from 1E3-1E4 Msolar black holes. The key to this debate is whether the X-ray luminosity is indeed super-Eddington for a 10 Msolar black hole, or if it beamed and intrinsically much lower. X-ray spectral studies show that much of the soft X-ray emission is absorbed by gas and dust, which will be reemitted isotropically in the far-infrared. The ratio of the absorbed X-ray luminosity to the FIR luminosity is a direct measure of the anisotropy of the X-ray emission, and leads to a determination of the intrinsic luminosity of the ULX. A weak detection for one nearby ULX from existing data suggests that the X-ray emission is beamed and here we propose a much more sensitive IRAC and MIPS study of this ULX in Holmberg IX as well as another nearby high luminosity ULX in NGC 1313. These data will determine whether ULXs are sub-Eddington or super-Eddington emitters.

Spitzer Space Telescope - General Observer Proposal #40810

Young or Old Elliptical Galaxies? A Conflict of Age-Dating Methods

Principal Investigator: Joel Bregman
Institution: University of Michigan

Technical Contact: Joel Bregman, University of Michigan

Co-Investigators:
Jesse Bregman, NASA-Ames Research Center
Pasquale Temi, SETI

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 7.7

Abstract:
We developed a stellar population age diagnostic from mid-IR spectra, because as a population ages, the 10um silicate excess from stellar mass loss decreases relative to the shorter wavelength continuum. Our IRS program showed that all 29 nearby ellipticals are old systems (10 Gyr), but our ages are in conflict with the optical absorption line age determinations, which show a sizeable fraction of these same galaxies to have ages of only 2-6 Gyr. Either result has important implications for galaxy formation scenarios. However, one of these age-dating schemes is seriously flawed, so here we test the mid-IR method to determine if it is capable of correctly identifying an early-type galaxy with a known young stellar component. We propose to observe a handful of the nearest E+A galaxies, systems that had a major starburst during the past Gyr, but with no current star formation. Not only will this provide a critical test of our age-dating scheme, it will be the first mid-IR spectra of this important class of galaxies.

Spitzer Space Telescope - General Observer Proposal #50728

Hidden Star Formation in Elliptical Galaxies?

Principal Investigator: Jesse Bregman
Institution: NASA Ames Research Center

Technical Contact: Jesse Bregman, NASA Ames Research Center

Co-Investigators:
Joel Bregman, University of Michigan

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 13.1

Abstract:
In our Spitzer Cycle-1 study of normal early-type galaxies, we obtained low resolution 5-21 um spectra that showed an old population with low mass stars shedding gas as they evolve. Surprisingly, about a third of these galaxies also showed forbidden line emission from NeIII (15.55 um) sometimes accompanied by NeII (12.81 um) and/or SIII (18.7 um) lines (we did not observe using LL1, so did not have a chance to observe the SIII 33.5 um line). We see two likely possible origins for the emission lines. The first scenario is that there is no recent star formation, and all the heating comes from old stars (i.e., the cores of planetary nebulae and post-AGB stars), while in the second scenario, there has been recent star formation and the ionizing radiation from these stars is producing the observed line emission. In the first case, we expect the gas density to be approx. 30-100 cm-3, while in the second case, the density could be approx. 100x higher. Since the ratio of the SIII lines is sensitive to the density in the range expected for these two cases, we propose to use the IRS high resolution modes to measure the density in these galaxies, providing a discriminator between these two possibilities. We will also obtain a good measure of the hardness of the ionizing radiation by measuring the ratio of NeIII/NeII. These data will lead to one of two results for normal ellipticals: it will determine the duty cycle of star formation and the star formation rate; or it will place a limit on the frequency of even low level star formation activity.

Spitzer Space Telescope - General Observer Proposal #3419

Breaking the Age-Metallicity degeneracy in local early-type galaxies: clues about the formation and evolution of spheroids.

Principal Investigator: Alessandro Bressan
Institution: INAF Padova Astronomical Observatory

Technical Contact: Pasquale Panuzzo, INAF Padova Astronomical Observatory

Co-Investigators:
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Laura Silva, INAF Astronomical Observatory of Trieste, Italy
Luigi Danese, SISSA, Italy

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 23.0

Abstract:
We propose to obtain Spitzer IRS (SL1, SL2 and LL2) high signal to noise (S/N~40) observations in the spectral region from 5.2 to 21.3 micron, of a sample of early-type galaxies in Virgo cluster and in the field. We present a new method that, fully exploiting the spatial resolution and sensitivity of Spitzer Space Telescope, seeks for the signatures of younger and/or more metal rich stellar populations, through the presence of the 9.7 micron silicate feature of their Asymptotic Giant Branch (AGB) stars. By combining such mid-infrared observations with optical observations, we are able to break the "age-metallicity" degeneracy that affects any estimate of age and metallicity in such galaxies. The 9.7 micron feature has been already detected by ISO in a few early type galaxies -we show the case of NGC1399-, though without the required spatial resolution and high signal to noise. We propose to apply this method to early type galaxies populating two different environments: the Virgo cluster and the local field. Spitzer Space Telescope will allow, for the first time, a ranking of these galaxies in age and metallicity unbiased by the effect of "age-metallicity" degeneracy, and thus will cast light on the processes of formation of spheroids in these two markedly different environments.

Spitzer Space Telescope - Archive Research Proposal #40773

Mapping Molecular Hydrogen Excitation and Mass in Nearby Galaxies from the SINGS Archive

Principal Investigator: Gregory Brunner
Institution: Rice University

Technical Contact: Gregory Brunner, Rice University

Co-Investigators:
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Kartik Sheth, Spitzer Science Center
Stuart Vogel, University of Maryland
Mark Wolfire, University of Maryland

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 96765.0

Abstract:
Molecular hydrogen (H2) is inherently connected with the evolution of a galaxy through a variety of processes. In galaxies, H2 traces star formation in nuclear regions, near the ends of bars in barred spirals, and along spiral arms where star formation is triggered by the passage of a spiral density wave. The SINGS legacy program has used the Spitzer Infrared Spectrograph (IRS) long-low module (LL; 14 - 38 microns) in spectral mapping mode to map large strips across 65 galaxies ranging in Hubble type, star-formation rate, and nuclear activity. We propose to use the SINGS LL data cubes to map the spatial distribution of warm (T = 100 - 300 K) H2, traced by the H2 S(0) (28.2 micron) and H2 S(1) (17.0 micron) lines, in 18 SINGS galaxies that have also been observed in CO (J = 1 - 0) emission through the Berkeley-Illinois-Maryland Array Survey of Nearby Galaxies (BIMA SONG). We have developed unique software that creates spatially resolved maps of extremely faint and blended spectral lines from Spitzer IRS LL data cubes. Using our software, we propose to map H2 S(0) and H2 S(1) emission across each galaxy and use these two lines to model variations in the H2 excitation and mass across each galaxy. We will distinguish the H2 excitation mechanism as a function of position across each galaxy by comparing the H2 maps to CO emission (from SONG) and maps of mid-infrared spectral diagnostics such as the [O IV](25.89 micron) line (a shock diagnostic) and the [S III](18.71 micron)-to-[S III](33.48 micron) line ratio (an HII region electron density diagnostic). We will also compare H2 spatial variations to UV and optical imagery (U, B, V, R, and H(alpha)) for additional insight into the H2 excitation mechanisms and to correlate H2 properties with the ages, masses, and star formation rates of stellar clusters and associations across the sample of SINGS galaxies.

Spitzer Space Telescope - General Observer Proposal #3410

Impact of Young Star Clusters in Nearby Galaxies on the Local Interstellar Medium as a Function of Age Using IRS Spectra

Principal Investigator: Brent Buckalew
Institution: California Institute of Technology

Technical Contact: Brent Buckalew, California Institute of Technology

Co-Investigators:
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Mark Wolfire, University of Maryland

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 5.1

Abstract:
We propose IRS-Stare short-low first order, long-low second order, and long-low first order spectra of 16 individual young star clusters in 5 nearby galaxies to study the local impact that these clusters have on their interstellar medium (ISM) in terms of dust/PAH destruction or creation. Massive stars in these young (0-10 Myr) star clusters drive a galaxy's evolution and determine the state of its ISM. From the proposed spectra, we will determine: 1) when dust produced by supernovae is prevalent in a cluster?s evolution, 2) how the dust/PAH mid-infrared properties evolve over 3-10 Myr, and 3) if hot dust is responsible for H-K color excesses observed in young star clusters. Our Spitzer results will aid in the interpretation of dust found in low-metallicity high-redshift galaxies by providing a timescale for dust infusion into the ISM and will provide an evolutionary sequence of young star clusters based on their mid-IR spectra.

Spitzer Space Telescope - General Observer Proposal #20356

The Nearby and Extremely Metal-Poor Galaxy CGCG 269-049

Principal Investigator: David Burstein
Institution: Arizona State University

Technical Contact: David Burstein, Arizona State University

Co-Investigators:
Michael Corbin, Arizona State University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 8.8

Abstract:
We propose to obtain IRAC and MIPS imaging and an IRS spectral map of the nearby (~ 2 - 3 Mpc) extremely metal-poor (12 + log(O/H) = 7.43) blue dwarf galaxy CGCG 269-049. This object offers an unprecendented opportunity to study an extremely metal-poor galaxy at high spatial resolution, as it has a major axis of approximately 40". Spitzer data will establish whether this object contains a large amount of dust indicative of past episodes of star formation, which will in turn indicate whether or not it is forming its first generation of stars. The proposed observations will also establish whether, like some other blue dwarf galaxies, CGCG 269-049 contains dust-obscured super star clusters that are redistributing its flux to the mid-infrared. The IRS spectral map will reveal any spatial variation in the properties of the galaxy's dust, such as temperature, grain size, and the presence of PAHs. This will in turn aid in the interpretation of the mid-IR spectra of more compact blue dwarf galaxies, whose spectra represent their spatially-integrated emission.

Spitzer Space Telescope - General Observer Proposal #20289

Dust and Star Formation in Extreme Outer Disks: The Case of M83 (NGC5236)

Principal Investigator: Daniela Calzetti
Institution: Space Telescope Science Institute

Technical Contact: Daniela Calzetti, Space Telescope Science Institute

Co-Investigators:
Michael Regan, Space Telescope Science Institute
Luciana Bianchi, Johns Hopkins University, Dept of Phys & Astronomy
Gerhardt Meurer, Johns Hopkins University, Dept. of Phys. & Astrono
David Thilker, Johns Hopkins University, Dept. of Phys. & Astrono

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 2.6

Abstract:
The recent discovery by GALEX of extensive UV emission in the extreme outskirts of local star-forming galaxies may challenge our current understanding of star formation, of the modality for polluting the intergalactic medium, and of the long-term impact of interactions. Further, the nature outer disk UV light is not settled yet, as UV photons from the galaxy disk scattered by dust in the outskirts may contribute to the observed radiation. Spitzer, with its wavelength windows sensitive to both the low mass stars and the dust emission, has a unique capability to address some of these fundamental questions. We propose IRAC mapping of 2 regions in the extreme outer disk (>2 R_{opt}) of the nearby star-forming spiral M83 to: (1) investigate whether a fraction of the UV light in those regions is due to dust scattering, and, via models, obtain a census of the UV photons from the galaxy that are scattered and absorbed outside the optically-bright disk; (2) derive masses and star formation rates for the UV-bright knots associated with stellar populations, to obtain a census of the current to past star formation and compare the observed mass distribution with that of disk clusters; (3) constrain the presence and mass of star formation older than ~100-300 Myr, which may provide a link to the past interaction of M83 with its companion. M83 is a prototype testbed for such study because of its relative proximity, high star formation rate, presence of an H-alpha edge, and large number of detected outer disk UV-bright knots. With a modest committment of time, Spitzer will provide the first milestone for unraveling the properties of the boundaries between galaxies and the intergalactic medium.

Spitzer Space Telescope - General Observer Proposal #30753

Dust and Star Formation in the Extreme Outer Disks of Spiral Galaxies

Principal Investigator: Daniela Calzetti
Institution: Space Telescope Science Institute

Technical Contact: Daniela Calzetti, Space Telescope Science Institute

Co-Investigators:
Luciana Bianchi, Dept. of Physics and Astronomy, The Johns Hopkins
Rupali Chandar, Dept. of Physics and Astronomy, The Johns Hopkins
Robert Kennicutt, Institute of Astronomy, Cambridge University
Gerhardt Meurer, Dept. of Physics and Astronomy, The Johns Hopkins
Michael Regan, Space Telescope Science Institute
David Thilker, Dept. of Physics and Astronomy, The Johns Hopkins

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 6.7

Abstract:
The discovery by GALEX of extended UV emission in the extreme outskirts of local star-forming galaxies challenges our current understanding of star formation, of the modality for polluting the intergalactic medium, and of the long-term impact of interactions. The nature of the outer disk UV light is unclear with possible origins including in-situ star formation as well as dust-scattered photons originating in the galaxy disk. Spitzer, with its wavelength windows sensitive to both the low mass stars and the dust emission, has a unique capability to address some of these fundamental questions. Building on the success of our Cycle 2 pilot program on the UV-emitting outer regions of M83, we propose IRAC imaging of regions in the extreme outer disks (> 1.5 R_{opt}) of five nearby star-forming spirals. The five galaxies are a subsample of all the galaxies with extended UV emission discovered by GALEX, selected to cover the full range of UV morphologies and properties, including arm-interarm contrast and extended emission in the presence/absence of H-alpha edges. With this varied sample we plan to: (1) investigate whether a fraction of the UV light in those regions is due to dust scattering, and obtain a census of the UV leakage from galaxy disks; (2) derive masses for the UV--emitting knots associated with star formation and compare this mass range with those of disk clusters; (3) investigate variations in the properties of those extreme regions as a function of the parent galaxy's characteristics. With a modest committment of time, Spitzer will provide a milestone for unraveling the properties of these regions at the boundary between galaxies and the intergalactic medium.

Spitzer Space Telescope - General Observer Proposal #30562

A Spitzer-MIPS Study of Extraplanar Dust in Spiral Galaxies

Principal Investigator: J. Christopher Howk
Institution: University of Notre Dame

Technical Contact: J. Christopher Howk, University of Notre Dame

Co-Investigators:
Nicolas Lehner, University of Notre Dame

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsScan
Hours Approved: 33.3

Abstract:
The gaseous thick disks of spiral galaxies are thought to be created and supported by energetic feedback from massive stars. High resolution optical continuum images of edge-on spirals have revealed an extensive web of hundreds of dense, dusty clouds in the disk-halo interface of such galaxies. These clouds, seen in ground-based and Hubble Space Telescope (HST) images, are found at heights 0.4 < z < 1.5 kpc from the midplanes of half of all spirals in the nearby universe, and their presence in the thick disks of galaxies is likely the result of stellar feedback processes operating in the thin disks of these systems. Each of these clouds has >10^5 to 10^6 solar masses of gas. Given their large masses, these clouds may house regions of thick disk star formation in galaxies, as evidenced by the presence of extraplanar H II regions in several systems. H I and other tracers are known to extend to much larger heights, z~10 kpc and beyond, but optical searches are not sensitive to dust associated with gas above z>1.5 kpc. We propose to obtain deep Spitzer-MIPS maps of three edge-on spiral galaxies in the nearby universe - NGC 4013, NGC 4631, and NGC 5775 - to study the distribution of dust in the thick disks of these systems. We will use the proposed observations to: (1) determine the total vertical extent of dust in these galaxies, including cold dust that may exist at very large distances; (2) determine if the mixture of PAHs, very small grains, and classical large grains changes as a function of height, as predicted by models for creating thick gaseous disks in galaxies; and (3) determine the average gas-to-dust ratio of the thick interstellar disks by comparison with H I observations. We will use supplemental images acquired with the WIYN 3.5-m telescope and WFPC2 and ACS imagers on HST to better understand the nature of extraplanar dust and gas in galaxies.

Spitzer Space Telescope - General Observer Proposal #30444

IRS Assessment of Star Formation and Galactic Evolution in Ellipticals with resolved Cold ISM

Principal Investigator: Jacqueline Davidson
Institution: USRA

Technical Contact: Jesse Bregman, NASA Ames Research Center

Co-Investigators:
Lerothodi Leeuw, Rhodes University, South Africa
Jesse Bregman, NASA Ames Research Center

Science Category: Nearby Galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 11.7

Abstract:
We propose to use Spitzer-IRS to measure the mid-IR spectral features of polycyclic aromatic hydrocarbons (PAHs) and silicates from a sample of nearby, elliptical galaxies. This sample of galaxies covers a range of merger tracers or ages, and more importantly is a sample where recent observations have resolved cold gas and dust emission. The emission from the cold ISM in these ellipticals is more compact than their stellar distributions, and may imply star-formation activity in these compact regions fueled by gas and dust externally accreted and decoupled from the stellar components. Our primary aim with these Spitzer observations is to obtain PAH and silicate, long-slit spectra that can be used as an independent measure of the level and period of star-formation activity and its spatial distribution within these galaxies. The secondary aim is to use the IRS intensity and spatial data in comparison with the resolved cold gas and dust images to gain more information about the nature and evolution of the dust in the sparse ISM in these galaxies. The results will help assess the possibility that these are elliptical galaxies with cold gas and dust and (subsequent) star formation.

Spitzer Space Telescope - Directors Discretionary Time Proposal #234

The Supermassive Black Hole in Arp102B

Principal Investigator: Harlan Devore
Institution: Cape Fear High School

Technical Contact: Ranga-Ram Chary, Spitzer Science Center

Co-Investigators:
Lauren Chapple, Traverse City East Junior High School
Howard Chun, Cranston High School
Doris Daou, Spitzer Science Center

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 0.5

Abstract:
Arp102B is a radio-loud, Seyfert 1 galaxy located in the constellation Hercules with a B-band magnitude of 15.2 mag. It has a redshift z = 0.024, giving it a recessional velocity of 7250 km/s and a distance of about 99.1Mpc. At its core is a low luminosity AGN with a black hole estimated to be ~108 solar masses. Although there have been many radio, X-ray, UV, optical, and ground-based IR studies of the Arp102B nucleus, they have not converged to produce a single, unified model for the nucleus. For example, Chen and Halpern (1989) used a geometrically thin, optically thick accretion disk model to fit double-peaked Balmer lines in the spectrum of Arp102B. Sulentic (1998) suggested that a bicone model would better fit the Fe K alpha lines in the x-ray spectrum. Korista summarizes the current state of our understanding as follows: "Despite significant progress, some fundamental issues relating to the geometry of the broad line emitting gas remain unsolved. We do not know whether in general the broad line region is composed of discrete clouds, winds, disks, or bloated stellar atmospheres or a combination of these." (Strateva et al., 2003). We believe that quality spectral data covering the IR spectrum may be the key to resolving these differences and could lead to a unified model for this type of AGN. Therefore, we propose to use Spitzer's IRS instrument to obtain LH, SH, SL1 and SL2 spectral data of Arp102's supermassive blackhole. With this data, we can measure the mass of the black hole, analyze the geometry, composition, and physical properties of the dust structure surrounding the black hole and reach conclusions about the energy production mechanism(s) in the nucleus.

Spitzer Space Telescope - Archive Research Proposal #20379

The Evolution of the 24 Micron Luminosity Function from Large Wide-field Spectroscopic Samples of Spitzer Galaxies

Principal Investigator: Daniel Eisenstein
Institution: University of Arizona

Technical Contact: Daniel Eisenstein, University of Arizona

Co-Investigators:
Casey Papovich, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 74722.0

Abstract:
We propose for archival funding to use existing deep, wide-area Spitzer imaging to study the evolution in the low-redshift 24 micron luminosity function. Our group has obtained the world's largest sample of wide-field spectroscopy in Spitzer fields through an ambitious survey with the Hectospec multi-fiber spectrograph on the MMT. We have measured 1200 redshifts for 24 micron-selected galaxies in the 4 sq. degree Spitzer First-Look Survey (FLS) field and 9000 galaxies in the 9 sq. degree NOAO deep-wide Bootes field (including 1000 24 micron-selected sources). The focus of this proposal is to study the local IR luminosity function and its evolution to moderate redshifts using this large spectroscopic data set combined with roughly 2000 SDSS spectra in fields of the SWIRE Legacy survey. We will also use the spectroscopic dataset to study the 24 micron emission as a function of the optical rest-frame color and optical luminosity. As a data product from this proposal, we will provide the full spectroscopic catalog of redshifts for Spitzer-selected sources in the FLS field through the SSC (as well as electronic versions of peer-review journals) in time to support the Spitzer CP-3, greatly increasing the archival value of the Spitzer data before the end of the Spitzer mission.

Spitzer Space Telescope - General Observer Proposal #50234

MIPS Spectral Energy Distribution Observations of M82

Principal Investigator: Chad Engelbracht
Institution: The University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Co-Investigators:
Lee Armus, Spitzer Science Center
Caroline Bot, California Institute of Technology
Daniela Calzetti, University of Massachusetts
Daniel Dale, University of Wyoming
Bruce Draine, Princeton University
George Helou, Spitzer Science Center
Robert Kennicutt, University of Cambridge

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsSed
Hours Approved: 1.6

Abstract:
We propose to obtain new MIPS Spectral Energy Distribution (SED) observations towards the nucleus of the starburst galaxy M82. M82 is a dwarf galaxy in the M81 group hosting a strong burst of star formation in its center. It is also the closest IR-bright starburst to our own Galaxy, and its proximity enables the detailed investigation of the dust emission even with MIPS-SED. We will join our data with existing IRS and other datasets to provide the most comprehensive investigation of the dust emission in this starburst, and its relation to the stellar populations that heat it. M82 is the template IR-bright starburst and a benchmark for distant galaxies studies. We will obtain a small mapping observation that is designed like the existing mapping observations made by the Spitzer Infrared Nearby Galaxies Survey (SINGS). Our proposed mapping observation requires only 1.6 hours of time. The galaxy M82 is nearby and very bright, but is the only galaxy in SINGS for which no nuclear map was obtained. Using the data we propose to obtain, we will generate a product similar to the other SED observations in SINGS, which we will make available to the SINGS team and to the community through the Spitzer Science Center.

Spitzer Space Telescope - General Observer Proposal #3513

Glitters of warm H2 in cold diffuse molecular gas

Principal Investigator: Edith Falgarone
Institution: Ecole Normale Superieure

Technical Contact: Edith Falgarone, Ecole Normale Superieure

Co-Investigators:
Francois Boulanger, IAS, Universite Paris-Sud
Laurent Verstraete, IAS, Universite Paris-Sud
Guillaume Pineau des Forets, IAS, Universite Paris-Sud
Francoise Combes, LERMA/Observatoire de Paris
Cecile Gry, ISO Data Center, ESA Vilspa
Georges Helou, SSC, Caltech
Chaz Beichman, JPL, Pasadena
Edwin Valentijn, SRON, Groningen
Rene Laureijs, ESTEC, Noordwijk

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 17.7

Abstract:
Cold molecular hydrogen, a possibly dominant gas fraction in galaxies, does not radiate due to the symmetry and small moment of inertia of the molecule. The only tracers of cold H2, the rotational lines of CO and dust thermal emission operate only in metal-rich environments. By detecting the lowest rotational lines of H2 at unexpected levels in cold diffuse medium, ISO-SWS has challenged the traditional view of the interstellar medium (ISM) by possibly revealing the transient existence of tiny fractions of gas, disseminated within the cold ISM, and warm enough to excite the H2 lines. The heating source of H2 there is the intermittent dissipation of supersonic turbulence, pervading the entire ISM. These glitters of H2 line emission may become the unique tracers of cold H2 in low metallicity environments. Given the fundamental importance of probing large hidden masses of gas in galaxies, for their implication on galaxy dynamics, star formation thresholds in metal-poor environments, and the hypothesis of H2 as baryonic dark matter in galaxies, the present SST/IRS proposal is dedicated to further search and characterization of this still elusive emission. The proposed observations consist of 27 small maps (55 by 45 arcsec) of the S(0), S(1) and S(2) H2 lines at high spectral resolution in the Milky Way and in external galaxies with massive HI disks extending far beyond their optical radius, for which the HI rotation curve cannot be accounted for by the stellar and visible gas components. The goals of the proposal are to strenghten the existence of the warm H2 pockets disseminated in the cold diffuse medium, further characterize the warm H2 emission as new tracer of hitherto undetected amounts of cold H2 by observations of nearby low metallicity environments, investigate the spatial distribution of unseen cold H2 in the external parts of galaxies, and, as a more exploratory facet, probe the presence of large amounts of baryonic dark matter in galaxies in the form of cold molecular hydrogen.

Spitzer Space Telescope - General Observer Proposal #40535

Glitters of warm H2 in cold diffuse molecular gas

Principal Investigator: Edith Falgarone
Institution: Ecole Normale Superieure

Technical Contact: Edith Falgarone, Ecole Normale Superieure

Co-Investigators:
Francois Boulanger, IAS Orsay
Francoise Combes, LERMA Paris
Guillaume Pineau des Forets, IAS Orsay
Laurent Verstraete, IAS Orsay

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 7.1

Abstract:
Cold molecular hydrogen, a dominant gas fraction in galaxies, does not radiate due to the symmetry of the molecule. The only tracers of cold H2, the rotational lines of CO and dust thermal emission operate only in metal-rich environments. By detecting the lowest rotational lines of H2 at unexpected levels in the cold diffuse medium of the Galaxy, ISO-SWS has challenged the traditional view of the interstellar medium (ISM) by possibly revealing the existence of tiny gas fractions within the cold ISM, warm enough to excite H2 lines. The heating source of H2 there is the intermittent dissipation of supersonic turbulence, pervading the entire ISM. These glitters of H2 line emission may become the unique tracers of cold H2 in low metallicity environments. Given the fundamental importance of probing large hidden masses of gas in galaxies, for their implication on galaxy dynamics, star formation thresholds in metal-poor environments, and the hypothesis of H2 as baryonic dark matter in galaxies, the present SST/IRS proposal is dedicated to further search of this still elusive emission. The proposed observations consist in several IRS LL pointings along the major axis of two external galaxies with massive HI disks extending far beyond their optical radius, and for which the HI rotation curve cannot be accounted for by the stellar and visible gas components. These spectra also observed in the direction of the galaxy nuclei, are meant to allow the separation between the H2 emission with stellar-type excitation from that originating in gas heated by turbulence dissipation. The goal of the proposal is to strenghten the existence of pockets of warm H2 disseminated in the cold diffuse medium of galaxies. These glitters of warm H2 would be a new tracer of hitherto undetected amounts of cold H2 in low metallicity environments, and, as a more exploratory facet, might probe the presence of large amounts of baryonic dark matter in galaxies in the form of cold molecular hydrogen.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #215

IRAC Imaging of NGC4013

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Co-Investigators:
Matt Ashby, SAO
Judy Pipher, Univ. of Rochester

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 0.8

Abstract:
The proposed IRAC observations will characterize the disk properties of NGC 4013 in the infrared with unprecedented detail -- disk scale lengths and scale heights in all four IRAC bands, the location and strength of star formation within the disk, and the putative warp. The IRAC data will be particularly sensitive to the expected strong PAH emission. The resulting mosaiced image will make a striking contrast with existing visible wavelength images (e.g., HST NICMOS and WFPC2) that show a strong band of dust attenuation along the center of the disk; IRAC will reveal the underlying stellar emission.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #25

Luminosity Function in Local Clusters

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Peter Eisenhardt, JPL

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 19.2

Abstract:
We will obtain spectral energy distributions of large numbers of galaxies across the SIRTF wavelength range by mapping four local galaxy clusters with IRAC and MIPS. The four clusters: Coma, Hercules, A1367, and A2199, span a wide range of X-ray luminosity, cooling flow rates, and late vs. early type galaxy morphologies. Coma and A2199 will be mapped by MIPS under a MIPS GTO program. The maps will cover 30 by 30 arcmin, roughly one Mpc at these cluster distances, and one square degree in the case of Coma. The IRAC 3.6um map will reach to about L*+5, probing well into the dwarf galaxy regime. Dust emitting at 7.7um and in the far IR will also be revealed. Finally, a map reaching several magnitudes deeper will be obtained with IRAC over 10 x 10 arcmin regions centered on the peak of the cluster x-ray emission, to determine whether the cooling flows in these clusters are producing low mass stars or brown dwarfs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30134

IRAC Observations of a Statistically Complete Sample of Star-Forming Dwarf Galaxies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jessica Rosenberg, Harvard-CfA

Co-Investigators:
Jessica Rosenberg, Harvard-Smithsonian Center for Astrophysics
Matthew Ashby, Harvard-Smithsonian Center for Astrophysics
John Salzer, Wesleyan University
Steve Willner, Harvard-Smithsonian Center for Astrophysics
Jiasheng Huang, Harvard-Smithsonian Center for Astrophysics
Caryl Gronwall, Pennsylvania State University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 9.8

Abstract:
We propose to carry the first large, statistically complete study of star-forming dwarf galaxies at 3.0, 4.5, 5.8, and 8.0 um with Spitzer. Contrary to our expectations, our small, preliminary study of 15 objects in the Bootes field has shown that these objects contain significant amounts of dust emission in the mid-infrared. These observations, in combination with the low line-of-sight absorption and the low luminosities of these galaxies indicate that their properties are significantly different from those observed in spiral galaxies. A larger, statistically complete sample of dwarf star-forming galaxies will allow us to probe the full range of dust/mid-infrared properties found in the dwarf star-forming galaxies in order to evaluate the cosmic scatter in these populations. We will also use this sample to: (1) compare 8 um star-formation rate estimates with those determined from [O II] and H-alpha, (2) determine the contribution of dwarf galaxies to the star-formation rate density in the local universe, (3) determine the luminosity- metallicity relation and other measurements of the stellar and dust properties in these galaxies, and (4) determine the mid-infrared spectral energy distributions of these local systems which can be used as a template for comparisons with high-redshift, low metallicity, star-forming systems.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30318

Life Cycle of Dust in Elliptical Galaxies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Michael Pahre, Smithsonian Astrophysical Observatory

Co-Investigators:
Michael Pahre, SAO
Tod Lauer, NOAO
Sandra Faber, UCSC
Christine Jones, SAO
William Forman, SAO

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 32.0

Abstract:
The old concept of ISM-free elliptical galaxies was discarded when roughly half of early-type galaxies were detected at 60 um by IRAS. Nonetheless, little is known to date on the nature of the warm ISM in this class of galaxies, since "normal" elliptical galaxies were not often observed in space missions since IRAS. Questions such as: Where is the dust? How does its temperature vary within a galaxy and among galaxies? How is the presence of dust related to AGN activity? And, especially, what are the probable origins, reservoirs, and life cycles of the dust in elliptical galaxies? Early Spitzer observations have found tantalizing examples where the dust is organized into features (arms, rings, disks) reminiscent of disks of spiral galaxies, which could have profound implications for understanding the origin of the Hubble morphological sequence. We propose to obtain moderately deep imaging with Spitzer from 3.6 to 160um of a sample of galaxies that is well studied optically (with HST imaging) in order to address these questions. The outcome of the project will be a broad picture of the origin and fate of the dust and its properties (mass, temperature, size distribution, PAH content) as a function of location within the galaxies. These data will also make a large and lasting contribution to the legacy of archival data from the Great Observatories on the global properties of nearby, normal galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30725

A Search for Infrared Light in a Dark HI Galaxy in the Virgo Cluster

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Zhong Wang, Smithsonian Astrophysical Observatory

Co-Investigators:
Zhong Wang, Harvard-Smithsonian Center for Astrophysics
Stephanie Bush, CfA
Pauline Barmby, CfA
Jessica Rosenburg, CfA
Douglas McElroy, SSC
Robert Minchin, Cardiff University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 6.0

Abstract:
We propose an exploratory investigation on the nature of a potentially ‘‘hidden’’ galaxy in the Virgo cluster, revealed in a recent deep HI survey by Davies et al. (2004). This rotating HI disk is found at Virgo’s systemic velocity, with an implied mass-to-light ratio of 500 or more given the upper limit put on by deep optical surveys, and well below the surface brightness predicted assuming a fiducial Tully-Fisher relationship. These make it arguably one of the most unusual objects in the local universe. While it is possible that this is the tidal-disrupted remains of a past galaxy-galaxy interaction, we believe dust associated with it must have played an important role --- otherwise tidal forces alone should not inhibit the conversion from gas to stars to such an extent. If some stars do form in the neutral gas, then one can expect an unambiguous detection of dust emission with the Spitzer instruments. Even without hard UV photons from star forming regions, we should still be able to measure scattered emission from diffuse interstellar radiation field, assuming that the minimal dust-to-gas ratio still applies in this case. The higher spatial resolution of IRAC and MIPS compared to the HI maps should allow a much better assessment of the object with such massive HI concentration in this seemingly empty region on the outskirt of Virgo. A non-detection would be even more challenging in that we may be confronting a new type of object which is truly dark.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40175

IRAC Imaging of the Unique, Face-on Spiral Galaxy NGC 309

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
David Block, University of Witwatersrand, South Africa
Matthew Ashby, Harvard-Smithsonian Astrophysical Observatory
Debra Elmegreen, Vassar College
Bruce Elmegreen, IBM Watson Research Center
Ken Freeman, The Australian National University
Steven Willner, Harvard-Smithsonian Astrophysical Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 0.6

Abstract:
The late type galaxy NGC 309 is one of the largest and most luminous spiral galaxies known. At a redshift distance of 83 Mpc (H=70 km/s/Mpc; Spergel et al. 2003), the absolute blue magnitude is -22.52 and the diameter is ~ 70 kpc (1 arcsec = 0.40 kpc). NGC 309 belongs to the multiple arm class 9 of Elmegreen & Elmegreen (1984). Combined with an almost face-on orientation, NGC 309 offers unique prospects for addressing important issues associated with spiral structure and star formation, including radically different morphology in optical compared with infrared wavelengths, star formation and PAH distribution. We propose to investigate the color gradients across the arms of NGC 309, and to study the distribution of macromolecules and PAHS in regimes along spiral arms where the associated shock front strengths rank amongst the highest ever encountered in a spiral galaxy. NGC 309 also provides an excellent test for the origin of exponential disks. For this giant galaxy, the outer parts should be dynamically young. At the outer radius of 35 kpc, the orbit time for 250 km/s rotation speed is only 0.88 Gyr; there have not been many rotations in the outer domains. We wish to explore whether the exponential disk continues smoothly at large radii, and whether the exponential scale length is different along different directions (asymmetric). If the exponential disk takes time to settle down, then with only a few rotations in the outer parts, it could have a different scale length in different directions, as it has not yet stabilized. On the other hand, if we find that there is a smooth, uniform exponential disk in all directions (even in the outer parts), the implication would be that the exponential disk forms at birth. Our modest program includes just one AOR, to carry out IRAC imaging of NGC 309 in all four IRAC bands.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40301

Dissecting the Star Formation Within Late-Type Galaxies

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Michael Pahre, Smithsonian Astrophysical Observatory

Co-Investigators:
Michael Pahre, Smithsonian Astrophysical Observatory
Rogier Windhorst, Arizona State University
Rolf Jansen, Arizona State University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 10.6

Abstract:
The past decade has brought the discovery and characterization of star-forming galaxies in the distant universe, detected through signatures of their rest-frame UV emission. One question about these galaxies is whether the UV continuum is a complete and unbiased picture of the star formation activity. Late-type galaxies are the best local analog candidates to the star formation occuring in galaxies in the distant universe. While samples reaching ~1000 galaxies at high redshift have been constructed, local samples are comparatively small. Early Spitzer observations have generated several large, general surveys the IR properties of nearby galaxies, but these survey inadequately sample the wide range of UV/Halpha/IR properties of late-type galaxies, so it is difficult to assess any trends---or to identify which kinds of local galaxies are the best analogs to the distant ones. In fact, late-type galaxies show so little self-similarity, that large samples of them are needed to span the full, multi-dimensional parameter space of those galaxy properties. We propose to fill-in this gap by obtaining IRAC and MIPS 3-24um images of a large sample of late-type galaxies (T>7) that all have UV (and many have Halpha) imaging already publicly-available in the HST archive. The result will be a wide and varied sample spanning many magnitudes of galaxy luminosity, star formation rate, stellar ages, metallicities, and merger activity. We will trace out the star formation activity in a variety of environments, and combine this with high-resolution HST imaging in order to dissect the processes occuring within those regions. The loss of HST's STIS, CTE degradation of WFPC-2, and uncertainity over WFC-3 all mean that our proposed sample is the complete list of galaxies with high spatial resolution UV images from HST. Our proposal will generate a generally useful Great Observatories dataset on star formation in late-type galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40349

Star Formation in Early-type Spirals

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Zhong Wang, Smithsonian Astrophysical Observatory

Co-Investigators:
Stephanie Bush, Harvard University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 12.0

Abstract:
Recent studies of nearby early-type (Sa-Sab) spiral galaxies have revealed a significant fraction (~30%) which are actively forming stars. It has been suggested that past close encounters or minor mergers may be inducing activities in these systems, which would otherwise remain quiescent and passively evolve. We propose to perform IRAC and MIPS observations to measure the distribution and luminosity function of the star-forming regions in a selected sample of these galaxies. The data, when combined with ground-based narrow-band imaging and broad-band SED studies, can provide a definitive explanation to how star formation is affected by interactions, and address to what extent these can be considered as an essential part of galactic evolution.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50128

The Spitzer/IRAC Star Formation Reference Survey

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
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Sukanya Chakrabarti, Havard-Smithsonian CfA
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Jia-Sheng Huang, Harvard-Smithsonian CfA
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Kai Noeske, Harvard-Smithsonian CfA
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Jason Surace, Spitzer Science Center
Zhong Wang, Harvard-Smithsonian CfA
Barbara Whitney, Space Science Institute
Steven Willner, Harvard-Smithsonian CfA
Hong Wu, National Astronomical Obs., Beijing, China
Andreas Zezas, University of Crete, Crete, Greece

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 39.2

Abstract:
We propose a statistically robust study of 380 nearby, bright star-forming galaxies of all types to better understand the nature of star formation. The goal of this IRAC reference survey will be to measure total star formation rates via 8.0 micron PAH emission, with an emphasis on quantitative comparisons of multiple global star formation indicators including ultraviolet emission, H-alpha, and radio continuum measurements. The sample is selected to be fully representative of the entire ranges of infrared luminosity, dust temperature, and stellar mass exhibited by star-forming galaxies in the local universe: the sample galaxies exhibit all existing combinations of these properties with the minimum overall number, selected in a manner that allows results to be applied to the entire local galaxy population. Here we propose four-band Spitzer/IRAC photometry for the 275 out of 380 objects which lack suitable observations in the Spitzer archive. All sample galaxies already have extensive complementary data available including global ugrizJHK photometry plus radio continuum intensities. Most also have GALEX imaging; in addition we have already begun a ground-based campaign to acquire global H-alpha imaging for the complete sample. We are submitting this IRAC proposal in the context of a larger campaign that includes a GTO proposal to complete the MIPS 24 micron imaging, and a GO proposal to acquire the IRS low-resolution spectroscopy. Although these companion proposals will significantly increase the scientific return of our survey program, the success of this proposal is not contingent in any way on any other Spitzer proposal. Our international team is dedicated, experienced, and has adequate manpower and institutional resources, with expertise in all the relevant disciplines to ensure the success of this undertaking. PI Fazio believes this proposal to be the most important element of his extragalactic GTO program, and requests that it be assigned first priority.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50132

The Spitzer/MIPS Star Formation Reference Survey

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
Matthew L. N. Ashby, Harvard-Smithsonian CfA
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Sukanya Chakrabarti, Havard-Smithsonian CfA
Eduardo Gonzalez-Alfonso, Univ. Alcala, Alcala, Spain
Jia-Sheng Huang, Harvard-Smithsonian CfA
Suzanne Madden, CEA, Saclay, France
Kai Noeske, Harvard-Smithsonian CfA
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Thomas Robitaille, St. Andrews Univ., St. Andrews, UK
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Eckhard Sturm, MPIE, Garching, Germany
Jason Surace, Spitzer Science Center
Zhong Wang, Harvard-Smithsonian CfA
Barbara Whitney, Space Science Institute
Steven Willner, Harvard-Smithsonian CfA
Hong Wu, National Astronomical Obs., Beijing, China
Andreas Zezas, University of Crete, Crete, Greece

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 45.9

Abstract:
We propose a statistically robust study of 380 nearby, bright star-forming galaxies of all types to better understand the nature of star formation. The goal of this MIPS reference survey will be to better understand global star formation via mid-IR continuum emission, with an emphasis on quantitative comparisons of multiple global star formation indicators including ultraviolet emission, H-alpha, and radio continuum measurements. The sample is selected to be fully representative of the entire ranges of infrared luminosity, dust temperature, and stellar mass exhibited by star-forming galaxies in the local universe: the sample galaxies exhibit all existing combinations of these properties with the minimum overall number, selected in a manner that allows results to be applied to the entire local galaxy population. Here we propose Spitzer/MIPS 24 micron photometry for the 267 out of 380 objects which lack suitable observations in the Spitzer archive. All sample galaxies already have extensive complementary data available including global ugrizJHK photometry plus radio continuum intensities. Most also have GALEX imaging; in addition we have already begun a ground-based campaign to acquire global H-alpha imaging for the complete sample. We are submitting this proposal in the context of a larger campaign that includes a GTO proposal to complete the four-band IRAC micron imaging, and a GO proposal to acquire the IRS low-resolution spectroscopy. Although these companion proposals will significantly increase the scientific return of our survey program, the success of this proposal is not contingent in any way on any other Spitzer proposal. Our international team is dedicated, experienced, and has adequate manpower and institutional resources, with expertise in all the relevant disciplines to ensure the success of this undertaking.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50539

A Multi-wavelength Study of Nearby Galaxies Based on Molecular Line Surveys: MIPS Observations

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Zhong Wang, Harvard-SAO

Co-Investigators:
Erik Rosolowsky, CfA
Howard Smith, CfA
Thomas J. Cox, CfA
Michael Pahre, CfA
Eric Keto, CfA
Stephanie Bush, CfA

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 4.0

Abstract:
Dense molecular gas, warm dust, and hot ionized gas are different components of the multi-step transformation of cold gas into stars and star clusters. While empirical laws on star formation in galaxies have been established based on global measurements of these components, substantial galaxy-to-galaxy variations still exist and remain unexplained. To understand the mechanisms that induce and regulate star formation and thus galaxy evolution, we need to study processes on the local scales of typical star forming regions and giant molecular clouds. In a set of pilot studies, we analyzed the Spitzer and Galex data of nearby giant spirals M31, M33 and M99, and compared with the new interferometric CO maps of matching angular resolution. We found evidence that variations in local condition, environmental effects, and viewing geometry may explain much of the large scatter in the empirical relationships. Based on the success of this initial investigation, we have collected high- resolution CO images of 63 late-type galaxies from several large surveys, and we are working on obtaining a complete set of Spitzer and Galex data for these galaxies. A companion Spitzer archival research program will re-examine the existing observations along with CO, HI, UV and optical data, focusing on correlations in spatially resolved, individual star-forming regions. Here we propose MIPS imaging of the 11 galaxies in our CO sample that have not already been observed by Spitzer. A GO proposal will request IRAC time for these galaxies, which are a significant addition to our study because they substantially increase the fraction of gas-rich late types in the full sample. Insight from this program will be applicable to not only nearby system, but also high red-shift galaxies for which only integrated quantities are measurable.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #520

Neon and Sulfur Abundances in M33

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Center for Astrophysics

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 7.4

Abstract:
This program contains three separate small projects: 1. The first galaxy ever discovered at 350 microns (Khan 2005) has several IRAC sources near it based on the IRAC GTO Shallow Survey. This imaging is for an improved SED and to look for possible companions. 2. As a follow up of our ISO and ground based investigations of M33, we will obtain new, high signal/noise measurements of neon and sulfur fine structure lines with the IRS to determine much more accurately how the Ne/H and S/H gradients behave compared with O/H and to determine which explanation for the discrepancies in abundance gradients is most likely. 3. Three 24-micron-selected sources in the HDFN are too faint for redshifts to be measured via visible spectroscopy. IRS spectra may give redshifts from dust features.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #69

A Mid-IR Hubble Atlas of Galaxies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Michael Pahre, Smithsonian Astrophysical Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 76.2

Abstract:
The unprecendented spatial resolution and sensitivity of SIRTF at mid- and far-IR wavelengths will allow detailed images of the distribution of and relative importance of non-thermal nuclear emission, stars, gas, dust, and star formation activity for nearby, bright galaxies. This observing program targets a representative sample of 101 galaxies in the local universe for IRAC and MIPS photometry from 3.6 to 160 um, and IRS step-and-stare spectroscopy to cover the 7.7 um PAH feature. The goals of the project are: to resolve spatially various components of the mid- and far-IR galaxy emission as a function of galaxy type and luminosity; to calibrate UV, Halpha, and far-IR estimators of the unobscured star formation rate; to determine the stellar masses using the shortest wavelength data; to create a nearby galaxy sample suitable for comparison with higher redshifts; and to construct a mid-IR "Hubble Atlas."

Spitzer Space Telescope - General Observer Proposal #30496

Star Formation In The Centers Of Galaxies Due To Secular Evolution

Principal Investigator: David Fisher
Institution: University of Texas at Austin

Technical Contact: David Fisher, University of Texas at Austin

Co-Investigators:
Niv Drory, University of Texas at Austin
John Kormendy, University of Texas at Austin

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 15.3

Abstract:
The two fundamental channels for disk galaxy evolution are environmentally driven hierarchical clustering (galaxy mergers) and internally driven secular evolution. Ellipticals and "classical bulges" are believed to form by mergers. "Pseudobulges" are observed to be more disk-like than classical bulges: they are flatter, they rotate very rapidly, and they have embedded bars, spiral structure, and ongoing star formation. They are the likely products of slow ("secular") rearrangement of disks by bars and oval distortions. Note that pseudobulges can form only if it has been a long time since the last major merger. This qualitative picture is well supported by observations. But, what is the relative importance of mergers and secular evolution in building bulges -- quantitatively? We propose to measure star formation rates in classical bulges and pseudobulges using the far-infrared fluxes observed with MIPS. Additionally, we use mid-infared IRAC imaging to resolve star-forming substructure within these bulges. To measure star formation rates we use published warm dust SED calibrations (Dale and Helou 2002; Wu et al 2005) as well as any that are still under development. Our purpose is to measure pseudobulge growth rates in Sa, Sb, and Sbc galaxies, and to tie together star formation rates with other indicators of secular evolution. Estimating pseudobulge growth time is the necessary next step in determing the relative importance of major mergers and secular evolution in bulge formation. A key to our strategy is the choice of galaxy sample. We propose to observe matched triples of the nearest giant galaxies that have strong, weak, and no obvious driving agents for internal evolution; i.e. galaxies that are barred, globally oval, and unbarred, respectively. Our sample will provide a valuable augmentation of archive data, completing observations of triples where necessary. The result is to increase the return of previous investments for a wider variety of science applications.

Spitzer Space Telescope - Archive Research Proposal #20423

A Chandra-Spitzer Study of Low Luminosity AGN in a Sample of Nearby Normal Early-type Galaxies

Principal Investigator: William Forman
Institution: Smithsonian Astrophysical Observatory

Technical Contact: William Forman, Smithsonian Astrophysical Observatory

Co-Investigators:
Christine Jones, Smithsonian Astrophysical Observatory
Michael Pahre, Smithsonian Astrophysical Observatory
Eugene Churazov, Max Planck Institute for Astrophysics

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 47530.0

Abstract:
The high angular resolution and sensitivity of the Spitzer instruments enable us to undertake a study of low luminosity AGN and warm dust in a sample of 103 "normal" elliptical and lenticular galaxies for which we have measured the X-ray luminosity of the AGN and the extent and mass of the hot X-ray gas with Chandra observations. With the Spitzer and Chandra observations, supplemented by radio fluxes and optical spectroscopy, we will determine the contribution of IR and X-ray emission to the bolometric luminosity of low luminosity AGN as a function of luminosity and test if the spectral energy distribution is consistent with that predicted by RIAF models. We will use the IRAC and MIPS colors to characterize and help classify the low luminosity AGN. We will determine if the luminosity of the AGN is affected by either the presence of cool IR emitting material or the cooling rate of the hot gas. We will compare the rate at which cooling gas forms new stars with the amount of recent star formation estimated from Spitzer images. We also will map the distribution of warm dust and compare that with the mass and distribution of hot gas to study the coexistence of hot gas and dust in galaxy cores. In addition to this archival proposal to analyze the 45 early-type galaxies, we also have proposed Spitzer IRAC and MIPS observations of 58 galaxies (C. Jones - PI) to complete the Chandra-Spitzer sample of 103 early type galaxies.

Spitzer Space Telescope - General Observer Proposal #50550

Dust Evolution in Low-Metallicity Environments: Bridging the Gap Between Local Universe and Primordial Galaxies

Principal Investigator: Frederic Galliano
Institution: University of Maryland, College Park

Technical Contact: Frederic Galliano, University of Maryland, College Park

Co-Investigators:
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Luigi Spinoglio, IFSI Frascatti, Italy
Mattia Vaccari, University of Padova
Christine Wilson, McMaster University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 23.1

Abstract:
The local galaxy Science Advisory Group (SAG 2) in the Herschel/SPIRE consortium, has constructed a Guaranteed Time Key Program using the PACS and SPIRE insruments to obtain 60 to 550 micron photometry of a statistically significant sample of 51 dwarf galaxies in our local universe chosen to cover an impressivly broad range of physical conditions. Here we propose the necessary complementary IRAC, MIPS and IRS Spitzer observations which together with the Herschel GT database will provide a rich database to the community to perform the dust and gas analyses in unprecedented detail in low metallicity galaxies ranging between 1/50 to 1 solar metallicity. Due to their chemical youth, and to the extreme conditions they experience, low metallicity environments constitute a keystone to understand dust evolution. The primary goal of this combined Herschel and Spitzer project is to study in details the physical processes at play within the ISM of these galaxies. We will take advantage of the powerful combination of Spitzer, Herschel and ancillary data to decompose the SED into the emission coming from the main phases of the ISM. Such a decomposition will provide reliable estimate of the abundances of the principal dust species, as a fonction of metallicity and physical conditions. These results will be exploited to compare the various evolutionary processes affecting the dust content of galaxies. All these outstanding scientific advances will be the true legacy value that this project brings to the community.

Spitzer Space Telescope - Archive Research Proposal #20394

Multi-variate Optical to Infrared Luminosity Functions of SWIRE Galaxies with Measured Redshifts

Principal Investigator: Jonathan Gardner
Institution: NASA's GSFC

Technical Contact: Jonathan Gardner, NASA's GSFC

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 61800.0

Abstract:
Multi-variate optical to infrared luminosity functions of nearby galaxies will reveal the complex interplay between starlight, dust, and overall luminosity within the galaxy population. We propose to measure the ugriz-3-4-6-8-24 luminosity function of galaxies detected by the SWIRE survey with redshifts measured by Sloan and 2dF surveys. We will use principal component analysis to remove correlations from the resulting 10-dimensional histogram, reducing it to the most relevant 2 to 3 dimensions. The luminosity function of the principal components will show the dependence of optical to infrared colors upon luminosity, measuring a brightness-dustiness relation. We will also calculate more traditional measures of luminosity functions in the IRAC and MIPS bands.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #5

M33 Mapping and Spectroscopy

Principal Investigator: Robert Gehrz
Institution: University of Minnesota

Technical Contact: Steven Willner, Center for Astrophysics

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap IrsStare MipsScan
Hours Approved: 54.9

Abstract:
SIRTF maps of M33 will provide a global perspective on both star formation and stellar evolution in a spiral galaxy. Combined with ground-based observations, MIPS and IRAC maps will provide a unified set of maps that relates the locations of chemical enrichment, gas available to form stars, star formation, and existing stars. Repetition of the maps during the SIRTF mission will detect many types of variable stars, including the luminous, massive stars that inject processed material into the interstellar medium. The project includes followup IRS spectroscopy of sources found in the maps.

Spitzer Space Telescope - General Observer Proposal #3319

Mid-Infrared H2 Lines in Edge-On Galaxies

Principal Investigator: Stephen Gottesman
Institution: University of Florida

Technical Contact: Stephen Gottesman, University of Florida

Co-Investigators:
Catherine Garland, University of Hawaii
Seppo Laine, Spitzer Science Center, Caltech

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 3.8

Abstract:
One of the biggest mysteries with disk galaxies is the apparently large invisible mass of material at large galactocentric distances, known as the dark or missing mass. It is possible that there is a large reservoir of molecular gas that has remained undetected in the absence of vigorous star formation in the outer disks. We propose to use the InfraRed Spectrograph on the Spitzer Space Telescope to look for the 17 and 28 micron pure rotational lines of molecular hydrogen in two edge-on spiral galaxies. Earlier observations of the edge-on galaxy NGC 891 with ISO suggest that molecular, not atomic, hydrogen may dominate the mass out to large radii. By observing the two lowest quadrupole transitions of molecular hydrogen at various positions along the galaxy disks we can set limits on the mass and physical conditions (temperature and density) of the gas. This will help us to understand the interstellar medium in the Milky Way and provide a template for interpreting high redshift observations of molecular gas and star formation.

Spitzer Space Telescope - General Observer Proposal #50510

A Spitzer/MIPS survey of the Shapley Supercluster core - Obscured star-formation in the most dynamically active region at z<0.1

Principal Investigator: Christopher Haines
Institution: University of Birmingham

Technical Contact: Christopher Haines, University of Birmingham

Co-Investigators:
Graham Smith, University of Birmingham
Somak Raychaudhury, University of Birmingham
Russell Smith, Durham University
Gianni Busarello, INAF - Osservatorio Astronomico di Capodimonte
Adriana Gargiulo, INAF - Osservatorio Astronomico di Capodimonte
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Paola Merluzzi, INAF - Osservatorio Astronomico di Capodimonte
Eelco van Kampen, University of Innsbruck

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsScan
Hours Approved: 13.8

Abstract:
We propose to conduct a wide-field (~2 square degrees) 24/70um Spitzer/MIPS survey of obscured star-formation within the Shapley supercluster, the richest and the most dynamically active region in the local universe (z<0.1). Specifically we are targeting the region covered by the Shapley Optical Survey (SOS) which contains three rich Abell clusters and two poor clusters embedded in a filamentary structure and where there are multiple ongoing cluster mergers. The Spitzer data will complement extensive multi-wavelength observations in hand, including panoramic imaging in UV, optical, NIR, X-ray and radio, and high-S/N optical spectroscopy, and will be fundamental to our main science goals of understanding the level and nature of star-formation in local clusters. In particular the unprecedented sensitivity of MIPS to obscured star-formation will allow us to target the dwarf galaxy population which usually encounter the cluster environment while still gas-rich, and which make up the vast majority of starburst galaxies in cluster environments, as they are transformed in-situ by processes such as ram-pressure stripping and galaxy harassment. The MIPS data in conjunction with our existing datasets will enable us to: (i) determine how much of the star-formation within clusters is triggered by interactions with the cluster environment (mergers, fly-bys, ram-pressure from ICM) as opposed to that produced by normal infalling spiral galaxies whose star-formation has not yet been quenched by the cluster environment; and (ii) by correlating the global MIR-based SFRs with the level of substructure within the clusters, investigate in detail how obscured star-formation relates to the hierarchical assemby of structures. All of this can be acheived with a modest 13.8 hours. The Shapley supercluster is a uniquely dense and active environment in the local universe, and so the MIPS dataset will have an enduring legacy value for comparing obscured star-formation across the full range of environments.

Spitzer Space Telescope - General Observer Proposal #30773

Mid-Infrared Spectroscopy of the Brightest Type 2 AGN in the SDSS

Principal Investigator: Timothy Heckman
Institution: Johns Hopkins University

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
Lee Armus, Spitzer Science Center
Lucimara Martins, Space Telescope Science Institute
Christy Tremonti, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 13.6

Abstract:
We propose to use the IRS on Spitzer to observe a complete and well-defined sample of the 20 brightest Type 2 (obscured) Active Galactic Nuclei (AGN) in the Sloan Digital Sky Survey (SDSS). They are selected from a sample of over 100,000 SDSS AGN on the basis of the flux in the [OIII]5007 emission-line. The full SDSS sample has been used to study the properties of local AGN and their host galaxies with unmatched statistical precision. The results imply that there is on-going co-evolution of black holes and galaxy bulges in the present universe (albeit at lower mass scales than in the past). Given the sensitivity of optical observations to even modest amounts of dust extinction, it is imperative to determine whether mid-IR and optical observations of these objects are consistent. The general goal of the proposal is to produce a set of high-quality mid-IR spectra for a complete sample of the brightest SDSS Type 2 AGN. The specific goals are: 1) To compare measurements of the AGN luminosity derived from the high-ionization mid-IR emission-lines to those derived from similar optical emission-lines. 2) To compare estimates of the relative energetic significance of black hole accretion and star formation in AGN host galaxies derived from optical data to those derived from mid-IR spectroscopy. These two goals address the following two questions: 1) How well can the luminosity of Type 2 SDSS AGN be estimated from optical spectra alone? 2) Can the coupled growth of black holes and galaxy bulges in the low-z universe be adequately quantified from optical data alone? Using the IRS to observe a complete sub-set of the 100,000 Type 2 SDSS AGN is essential to understand the degree to which the SDSS data provide a fair picture of the low-redshift AGN phenomenon. These data will beautifully complement existing IRS surveys of IR-selected AGN.

Spitzer Space Telescope - General Observer Proposal #20120

A Search for PAH Emission in Extremely Low Luminosity Galaxies

Principal Investigator: David Hogg
Institution: New York University

Technical Contact: David Hogg, New York University

Co-Investigators:
Morad Masjedi, New York University
Michael R. Blanton, New York University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsStare
Hours Approved: 17.1

Abstract:
Low-luminosity galaxies are deficient in PAH emission; it is not known why. Whether the deficiency is a metallicity effect, some property of radiation fields, or a consequence of dust geometry or dust properties, the question requires observations of low-luminosity galaxies that span the space of physical properties. We propose IRAC imaging and IRS SL spectroscopy of a uniformly selected sample of 29 extremely low luminosity (M_r > -15 mag) galaxies selected from the Sloan Digital Sky Survey. Comparison of Spitzer observations of different low-luminosity galaxies and comparison of low-luminosity and high-luminosity galaxies from the SINGS Legacy Program (particularly their outskirts) ought to break the current degeneracy of possible explanations for the PAH deficiency. Our sample of low-luminosity galaxies has been selected completely independently of environment, making it a unique sample for the study of galaxy formation and evolution; the data taken for this project will have great legacy value. We are also obtaining HST imaging, H-alpha rotation curves, and HI measurements for this sample, allowing myriad studies of the physics of galaxy evolution. We waive all proprietary period on these Spitzer observations and all of the other data we have for this sample.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30669

The Spitzer/IRS View of Blue Compact Dwarf Galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Yanling Wu, Cornell University

Co-Investigators:
Yanling Wu, Cornell University
Vassilis Charmandaris, Cornell University
Lei Hao, Cornell University

Science Category: Nearby Galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 12.4

Abstract:
Galaxy formation is one of the critical issues in extragalactic astronomy. WMAP has shown that the hierarchical or "bottoms up" scenario is the most likely mode of galaxy formation in the early Universe. Unfortunately, current instruments are not capable of directly observing the "building blocks" in the epoch of galaxy formation, z >~ 8. However, there are numerous low metallicity, Z ~ Z_solar/40, blue compact dwarf galaxies, BCDs, that may mimic the development of galaxies in the early Universe. Infrared studies of these local BCDs can trace the evolution of star formation and the subsequent enrichment of the ISM and the formation of dust grains. Through the infrared we can identify the grain types, their abundances and their interactions with the ISM. It is well documented that there is too little gas in BCDs to sustain the observed star bursts for more than a fraction of the Hubble time. Either more gas is accreted or the star bursts are episodic or both. There is growing evidence that the episodes star formation are triggered by interactions or merging of the host galaxy and an HI cloud or another dwarf galaxy. In either event the mass of the host galaxy grows. In this proposal we plan to use Spitzer/IRS to observe both the formation and properties of dust in very low metallicity BCDs and infrared properties of BCDs that show indications of interacting or merging with another nearby dwarf or HI cloud. This observation, if successful, will unvail stunning secretes in the Universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #197

Mid-IR Imaging & Spectroscopy of Starburst Rings

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: James Higdon, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 10.2

Abstract:
Ring galaxies are spectacular examples of galaxy transformation through gravitational interactions. They are created by the passage of a companion galaxy through the disk of a spiral along the rotation axis. This interaction reorganizes the spiral's disk, concentrating >90% of ISM into an expanding orbit-crowded ring. The enhanced gas density promotes the growth of very massive cloud complexes during the ring's ~400 Myr lifetime, which results in a coherent propagating starburst. Some rings, most notably the Cartwheel & AM0644-741, are host to "Super Starburst Clusters", which may be analogs of young globular clusters. At the same time, star formation interior to the rings is extinguished. These systems are ideal for studies as diverse as the global regulation/triggering of massive star formation and starburst populations. My collaborators and I are concentrating on the Cartwheel & AM0644-741, combining optical imaging & spectroscopy, HI and radio continuum interferometry, and (for AM0644-741) CO single dish mapping. They are physically the largest, the most gas rich, and with the highest SFRs (~20 M0/yr). The Cartwheel's metallicity is similar to the SMC, while AM0644-741's is close to solar. Both show strong & systematic changes in local SFR/area around the rings, arising from variations in orbit crowding. We wish to use SIRTF to obtain deep Mid/Far-IR images and Mid-IR spectra of starburst clusters in both of these dramatic systems: IRS Long/Short-High Spectroscopy: We will obtain high resolution Mid-IR spectra of two starburst clusters in each ring. IRAC 4.5 & 8um mapping: Deep 8um images will show emission from the strong PAH feature at 7.7um, after subtracting a similar map at 4.5um. MIPS 70um imaging: Both galaxies are unresolved by IRAS. MIPS 70um maps will have sufficient resolution (20") for us to distinguish FIR emission from the nucleus, disk, and rings.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30172

Spectral Engery Distribution of low metallicity Blue Compact Dwarf Galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: James R. Houck, Cornell University

Co-Investigators:
Yanling Wu, Cornell University
Vassils Charmandaris, University of Crete
Lei Hao, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsPeakupImage MipsPhot
Hours Approved: 12.7

Abstract:
We propose to use IRAC and MIPS 70 micron band, together with SDSS and Palomar spectra, to obtain the spectral energy distribution (SED) of a sample of blue compact dwarf galaxies (BCD), which may be local laboratories for the study of star formation in the early universe. Unlike normal starburst galaxies, which have strong PAH bands, low-ionization emission lines and a continuum peaking near 80 micron, the third-metal poor BCD, SBS0335-052E, shows no evidence of PAH emission and a very flat mid-IR continuum peaking ~30 micron. Is this dramatical difference common among typical BCDs and starburst galaxies? What is the underlying physics? If the spectra of BCDs do peak at a much shorter wavelength, it would be very important for us to have mid-IR flux densities shortward of 30 micron in order to better constrain the SEDs. The new IRAC and MIPS data, together with 16 and 22 micron flux densitities obtained from our GTO program and available optical spectra, will allow us to better understand the SEDs of these BCDs. Faint as they are, the unprecedented sensitivity of Spitzer Space Telescope will provides us a unique tool to complete this study and an insight into the galaxy evolution in the most primodial-like environment.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40335

Dust and Gas in Extremely Low-Metallicity Blue Compact Dwarf Galaxies

Principal Investigator: James Houck
Institution: Cornell University

Technical Contact: Leslie Hunt, INAF - Istituto di Radioastronomia/Firenze

Co-Investigators:
Yanling Wu, Astronomy Department, Cornell University
Jeronimo Bernard-Salas, Astronomy Department, Cornell University
Bernhard Brandl, Leiden Observatory, Leiden University
Vassilis Charmandaris, University of Crete
Lei Hao, Astronomy Department, Cornell University
Vianney Lebouteiller, Astronomy Department, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 21.0

Abstract:
The power of Spitzer/IRS to penetrate dust and measure its emission has already changed how we view star-formation processes in metal-poor environments. Despite theoretical expectations, it appears that dust in metal-poor star-forming regions dominates the spectral energy distribution and can heavily obscure the optical light. Previous IRS GTO observations of blue compact dwarf galaxies (BCDs) have begun the data set needed to understand how dust affects star formation in low-metallicity environments and how dust grains themselves are created in metal-poor starbursts. Exploratory IRS GTO observations have been made of 61 BCDs, most only in peakup imaging mode, and of 26 observed spectroscopically, only 11 had adequate data for analysis. The current proposal will observe 7 extremely metal-poor BCDs which are sufficiently bright in the IR for full coverage with adequate S/N in all IRS modules. The new observations will be combined with those already in the Spitzer/IRS archive to achieve a comprehensive BCD sample with oxygen abundances ranging from 2% to 40% solar, and with several objects with good S/N in each metallicity bin. This will provide a greatly improved assessment of how star-formation properties of BCDs depend on metal abundance. We request 21.0 hrs in IRS AORs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50635

Jim's Last Look at SBS0335-052

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Yanling Wu, Cornell University

Co-Investigators:
Vassilis Charmandaris, University of Crete
Vianney Lebouteiller, Cornell University
Jeronimo Bernard-Salas, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 10.3

Abstract:
We propose to reobserve SBS0335-052 with the IRS Short High module (10 to 20 micron and R ~ 500) with the paramount objective of detecting the Hua (12.37 micron) line flux. In previous observations we have detected lines of and [SIV] 10.51, [NeIII] 15.55, [SIII] 18.71, [OIV] 25.89, [SIII] 33.48, and [SiII] 34.82 micron. There is also a hint of Hua 12.37 and/or H2 (S2) 12.28 with SNR ~ 2. With the ionic lines and a clear detection of Hua we will have a self contained data set of lines for determining the abundances of the above elements. Our earlier spectrum also shows a weak 14um PAH complex. Our proposal is to use an integration time of 10 times longer as compared to the previous observations. The expected SNR improvement will be at least a factor of 3. With this new data set we will recompute the abundances for the above ions. The increased SNR will provide a far better spectrum to identify the 14um PAH complex and a first view of the 17 um complex as well. Achieving the expected SNR will give the deepest view of this enigmatic BCD until JWST is flying.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #85

Dust and Gas in BCDs

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: James R. Houck, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 42.6

Abstract:
The objective is to learn about the formation of stars under conditions which are similar the those under which the first generation of stars formed. The regions of study are blue compact dwarf galaxies. These are low mass regions which are undergoing their first, or more likely second, episode of star formation. Typical metallicities range from 1/5 to 1/50 solar. The latter value is typical of the metallicity following the first round of star formation. The scientific questions which will be addressed include: What is the iozionation state of the gas as assessed primarily by the NeII, NeIII and NeV, and the SIII and SIV lines. Why are the PAH feature often absent in the ISO spectra of BCDs. Are the star formation regions matter bound, as suggested by the presence of NeIII, but not NeII. Why is NeIII sometimes seen to be very extended. What is the MIR SED of BCDs, as measured by low resolution spectra. What are the implications for determining the redshift of medium redshift of ULIRGs using the PAH features if the PAH feature disappear at high z,and therefore low Z. What are the implications for the infrared background radiation. What is the extinction curve for dust formed under thse low metallicity conditions. The data to answer these, and other related questions, will require both high and low resolution spectra. Most objects will be imaged by the peak-up prior to taking the spectra. Objects with known MIR fluxes will be observed directly without the preceeding images. If the "success rate" with imaging is very high we will consider eliminating the reimages.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #97

Molecular hydrogen content in nearby spirals

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Vassilis Charmandaris, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 2.0

Abstract:
It is believed that the ratio of molecular to atomic hydrogen remains constant as a function of radius in late type spirals. The reason why the former is not detected is that current methods of estimating the molecular gas mass are based on indirect CO measurements which are metallicity depended. If the H2 to HI ratio is constant then molecular gas could potentially constitute a considerable fraction of the dark matter of a galaxy. We wish to examine this hypothesis by directly mapping the molecular hydrogen profile, using the mid-IR H2 lines, in one edge-on and one face-on spiral galaxy.

Spitzer Space Telescope - General Observer Proposal #3454

A Spitzer Study of Extraplanar Dust in Spiral Galaxies

Principal Investigator: J. Christopher Howk
Institution: UC San Diego

Technical Contact: J. Christopher Howk, University of Notre Dame

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 9.2

Abstract:
High-resolution optical continuum images of edge-on spirals have revealed an extensive web of hundreds of dense, dusty clouds in the disk-halo interface of these galaxies. These clouds, seen in gound-based and Hubble Space Telescope (HST) images, are found at heights 0.4 < z < 2.0 kpc from the midplanes of ~1/2 of all spirals in the nearby universe, and their presence in the thick disks of galaxies is likely the result of stellar feedback processes operating in the thin disks of these systems. With masses >10^5 to 10^6 solar masses, these clouds may house regions of thick disk star formation in galaxies, as evidenced by the presence of extraplanar H II regions in several systems. We propose to obtain Spitzer-IRAC maps of four edge-on spiral galaxies in the nearby universe to study the distribution of dusty interstellar clouds and stars in the thick disks of these systems. With the planned GTO observations of several other galaxies, our proposed observations will complete a survey of all edge-on systems within 30 Mpc known to contain extraplanar dust. We will use these images to: (1) Determine the total vertical extent of small grains in galaxies, including a determination of the scale height of PAHs within these systems; (2) Search for massive star formation hidden from optical view in the dense thick disk clouds; and (3) Determine the scale heights and lengths of stellar light in these galaxies to determine the extent to which the thick disk dust affects such determinations in the optical. We will use supplemental images acquired with the WIYN 3.5-m telescope and WFPC2 imager on board the Hubble Space Telescope to better understand the nature of extraplanar dust and gas in galaxies.

Spitzer Space Telescope - General Observer Proposal #2310

Molecular Clouds and Star Formation in Dwarf Irregular Galaxies

Principal Investigator: Deidre Hunter
Institution: Lowell Observatory

Technical Contact: Deidre Hunter, Lowell Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 5.0

Abstract:
Molecular gas is an important component of the interstellar medium of galaxies and plays a crucial role in star formation. Dwarf irregular (dIm) galaxies often have intense stellar radiation fields due to the young, massive star populations, low dust-to-gas ratios, and long path-lengths for photons. Therefore, significant portions of the molecular gas in these galaxies could be warm. We propose to explore this component of the ISM of a sample of dIm galaxies through direct observations of H_2 in the S(0) and S(1) rotation lines. We are targeting four representative HI/CO complexes in four representative dIm galaxies that have been the target of our studies of the cold molecular content. The four galaxies cover a range in galactic properties, including HI distribution, metallicity, and total mass, and the four HI/CO complexes within these galaxies cover a range in properties of HI complexes, particulary relationship to Halpha and embedded star formation. Thus, we can determine the molecular content of HI/CO complexes under a variety of galactic and local environments in Im galaxies. We will use this to estimate the molecular content of other galaxies in our large star-forming survey from HI and infrared maps.

Spitzer Space Telescope - General Observer Proposal #30653

Stellar Feedback on Circumcluster Gas and Dust in 30 Doradus, the Nearest Super-Star Cluster.

Principal Investigator: Remy Indebetouw
Institution: University of Virginia

Technical Contact: Remy Indebetouw, University of Virginia

Co-Investigators:
Brian Babler, U Wisconsin
Francois Boulanger, IAS, Paris, France
Chad Engelbracht, U Arizona
Frederic Galliano, NASA Goddard
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Suzanne Madden, CEA Saclay
Marilyn Meade, U Wisconsin
Margaret Meixner, StSci
JD Smith, U Arizona
Linda Smith, UCL
Xander Tielens, NASA ames
Uma Vijh, StSci
Mike Werner, JPL
Mark Wolfire, U Maryland

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap MipsSed
Hours Approved: 81.2

Abstract:
Massive stars dominate the evolution of their host galaxies by energetic feedback into the interstellar medium. Therefore, if we wish to understand galaxy evolution, we must understand how massive star clusters process local gas and dust (radiatively and mechanically), and how strong stellar winds interact with the HII region. In particular, the most energetic form of star formation in the universe occurs in super star clusters, which are an increasingly dominant mode of star formation as one looks further back in time. The only super star cluster near enough to be studied in detail with Spitzer (or any other existing telescope) is 30 Doradus in the Large Magellanic Cloud. 30 Doradus is also the ideal massive cluster to study because it has a very well characterized stellar population, is extremely massive, and has subsolar metallicity. We propose a complete spectral map of the 30 Doradus region with the IRS low-resolution modules (5-38um) and MIPS/SED mode (55-95um). Analysis of the fine-structure lines and aromatic features, using sophisticated modeling tools already developed by our team, will allow a complete self-consistent understanding of how this super-star cluster is affecting its circumcluster gas and dust. Understanding the infrared emitting species (dust, PAHs, ionized gas) with this unprecedented level of detail is a necessary step to quantitatively connect the spectra of distant unresolved galaxies to the star formation in those galaxies. This detailed analysis relies on simultaneous mapping of multiple diagnostic line ratios and dust features, and thus can only be accomplished with Spitzer/IRS (many of the diagnostic lines are not observable through the atmosphere). Furthermore, conditions in 30 Dor are known to vary dramatically on small scales, so a spatially and spectrally complete data cube will be the only way to link the physical conditions of the gas, radiation, and dust.

Spitzer Space Telescope - General Observer Proposal #50173

The Circinus Galaxy Revealed

Principal Investigator: Thomas Jarrett
Institution: Spitzer Science Center

Technical Contact: Thomas Jarrett, Spitzer Science Center

Co-Investigators:
Baerbel Koribalski, ATNF/CSIRO
Lister Staveley-Smith, University of Western Australia

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 11.8

Abstract:
We propose to map the large-scale disk of the optically highly obscured Circinus Galaxy, which remains the only major galaxy in the Local Volume (D < 10 Mpc) whose stellar and ISM components have not been fully explored. And yet Circinus is a most remarkable galaxy. Its close proximity offers a unique opportunity to study in detail star formation processes that are known to be dominant during the z=2-3 galaxy formation era. At a distance of about 3 Mpc, it is the closest known spiral galaxy with a Seyfert 2 nucleus and star-forming circumnuclear ring. While its location behind the Milky Way prevents detailed visual observations of the large-scale disk, we know from radio data that its neutral hydrogen gas envelope is gigantic -- about 100 kpc in diameter. With Spitzer the Galactic Plane can be 'stripped away' and Circinus revealed as never seen before, making it the premier laboratory for the study of the starburst-AGN connection. High-resolution mid-infrared imaging of the Circinus galaxy with Spitzer IRAC and MIPS will allow us to measure the size and structure of the stellar disk, the variations in the gas-to-dust ratio, and the radio-infrared correlation.

Spitzer Space Telescope - General Observer Proposal #50362

NGC 6946: A Laboratory for Studying the Diversity of SNR Evolution

Principal Investigator: Thomas Jarrett
Institution: Spitzer Science Center

Technical Contact: Thomas Jarrett, Spitzer Science Center

Co-Investigators:
Jeonghee Rho, SSC
William Reach, IPAC/Caltech
David Hollenbach, ARC
Brent Buckalew, ERAU
Jonathan Keohane, Hampden-Sydney College
Thomas Pannuti, Morehead State University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 29.9

Abstract:
We propose Spitzer IRS spectral mapping of a sample of fifteen supernova remnants (SNRS) in the nearby, face-on spiral galaxy NGC6946. Selected from deep NIR imaging of the shock-sensitive emission lines [FeII] 1.644um and H2 2.121um, the SNRs are predominately located in the spiral arms where core-collapse SNe trace the ongoing massive star formation. The SNR sample represents a set of evolutionary 'snapshots', following the earliest stages of a remnants life, t ~ few years, through the adiabatic expansion phase and into the radiative 'snow-plow' phase, t ~ 10^5 years. We will use our 'snapshot' sample to study how the interaction between SNe and their birth clouds evolve from the earliest stages to the relatively mature phase in which the remnant settles back into the ISM. With our IRS spectral maps keyed to the location of shocked-gas based on [FeII] 1.644um emission, we will detect and measure the most important shock diagnostic lines, density and temperature sensitive ionic lines, and the major PAH broad emission bands. In combination with an extensive body of ancillary xray-to-radio data and models, our Spitzer data will allow us to: 1) investigate the properties of the ISM within and surrounding SNRs, comparing across a diverse range in SNR age, gas density, radiation field and metallicity conditions, 2) test different shock and photoionization models that are optimized for fast shocks, slow shocks, radiation field, grain destruction, dust to gas coupling, and metal enrichment; (3) infer the supernova rate of NGC6946, which can be compared with other starburst galaxies and with the Milky Way, and (4) study the ULX 'hypernova' candidate "MF16" and its birth environment, comparing the strength and broadening of the H2 lines relative to the sample SNRs and HII regions.

Spitzer Space Telescope - Directors Discretionary Time Proposal #482

IRS-LL Observation of the WISE Calibrator NGC 6552

Principal Investigator: Thomas Jarrett
Institution: IPAC/Caltech

Technical Contact: Thomas Jarrett, IPAC/Caltech

Co-Investigators:
Martin Cohen, UC Berkeley
Peter Eisenhardt, JPL
Amy Mainzer, JPL

Science Category: nearby galaxies
Observing Modes: IrsStare
Hours Approved: 0.5

Abstract:
The Wide-field Infrared Survey Explorer (WISE) will survey the entire sky at 3/4/12/23 micron bands down to depths of 0.1/0.2/0.7/3 mJy (5 sigma). The WISE science team requests Spitzer DDT to measure the 15-35 micron spectrum of the WISE flux calibrator NGC 6552. The purpose is to spectrally match the WISE 23 micron measurement with the MIPS 24 micron measurement that has already been acquired in a previous set of observations. With IRS LL observations providing the necessary mid-infrared spectral information of NGC 6552, it will then be possible to construct an absolute flux calibration scale for the longest wavelength measurements of WISE.

Spitzer Space Telescope - General Observer Proposal #30483

Environmental Effects on PAHs and VSGs in X-ray-bright Dusty Elliptical Galaxies

Principal Investigator: Hidehiro Kaneda
Institution: Japan Aerospace Exploration Agency

Technical Contact: Hidehiro Kaneda, Japan Aerospace Exploration Agency

Co-Investigators:
Takashi Onaka, University of Tokyo
Yoko Okada, University of Tokyo
Yuka Tajiri, University of Tokyo
Itsuki Sakon, University of Tokyo
Tetsu Kitayama, Toho University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 12.5

Abstract:
Elliptical galaxies provide dust with a unique environment, i.e. old stellar radiation fields without active star formation and interstellar media (ISM) mostly dominated by hot plasma. Small particles such as polycyclic aromatic hydrocarbons (PAHs) and very small grains (VSGs) are expected to be easily destroyed through sputtering by plasma ions. However, in our GO1 program, we have detected PAH emission features and prominent VSG mid-IR excess from X-ray-bright dusty elliptical galaxies. The observed IRS/SL spectra are quite unusual; the usually strong features at 6.2, 7.7, and 8.6 micron are very faint in contrast to prominent features at 11.3 and/or 12.7 micron. A naive interpretation is that the dominant emitters are neutral PAHs. We propose IRS/SL&LL observations of 18 nearby elliptical galaxies with properties similar to the GO1 galaxies, which include IRS/LL observations of the GO1 galaxies; we did not observe them with the IRS/LL. The IRS spectra are ideal to study the environmental effects on PAHs and VSGs; the IRS/SL is well matched to study overall properties of PAHs, while the IRS/LL is crucial to discuss the ionization state of PAHs and the properties of VSGs. Detection of aforementioned unusual PAH features as well as the 16-18 micron plateaus would lay strong constraints on the ionization state of the PAHs and thus their origins. If the results really support the dominance of neutral PAHs, we may have to relinquish a commonly-believed picture that dust and plasma are well mixed in the interstellar space. Then how are the dust spatially separated from the plasma? Detection of prominent mid-IR excess would reasonably explain efficient interaction of the dust with the plasma. Then, how do we sustain the hot plasma against the effective radiative cooling via a dust channel? Observational results with the large sample would give a great impact on the understanding of the dust and plasma physics and the evolutionary history of the ISM of the elliptical galaxies.

Spitzer Space Telescope - General Observer Proposal #3619

Observations of X-ray-bright Dusty Elliptical Galaxies

Principal Investigator: Hidehiro Kaneda
Institution: Japan Aerospace Exploration Agency

Technical Contact: Hidehiro Kaneda, Japan Aerospace Exploration Agency

Co-Investigators:
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Tetsu Kitayama, Toho University
Hidenori Takahashi, University of Tokyo
Hirohisa Nagata, National Astronomical Observatory of Japan
Yoshitomo Maeda, Japan Aerospace Exploration Agency
Motohide Kokubun, University of Tokyo
Shigeo Yamauchi, Iwate University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare MipsPhot
Hours Approved: 13.6

Abstract:
We propose to observe 5 nearby elliptical galaxies with a large amount of dust and hot plasma, i.e. IR-bright and X-ray-bright ellipticals. We also observe 2 IR-bright but X-ray-faint ellipticals. The object of this proposal is to challenge problems on the origin and the fate of excessive contents of the dust in the X-ray-bright ellipticals where the dust is expected to be easily destroyed through sputtering by plasma ions. How can such a large amount of the dust survive? Does the dust really interact with the plasma? Spatially-resolved imaging are crucial for our study; the MIPS has a great advantage over ISO and IRAS on the imaging capability. We create color maps with the MIPS 3 bands and compare them with X-ray images to search for the evidence on the collisional heating of the dust by the plasma electrons. If the dust and the plasma really coexist and affect each other, some correlation between the X-ray brightness and the dust temperature distribution as well as the mid-IR excess should be observed in our sample. The Spitzer capabilities would enable us for the first time to obtain direct evidence on the interaction between the dust and the plasma in the elliptical galaxies, if any. Such evidence would strongly supports external process scenario, such as accretion during galaxy interaction, for the dust origin to replenish the galaxies against the sputtering destruction. On the other hand, if we find no evidence at all, we have to think about special mechanism to separate the dust from the plasma so that the dust can escape the bombardments by the plasma electrons and ions. In either case, the X-ray-faint ellipticals in our sample would play an important role since a large fraction of the dust is really unaffected by the plasma and thus can survive in these galaxies. The IRS spectra provide us information on the dust properties, such as presence (or not) of PAH and silicate features, and might be helpful to discuss whether the remaining dust is of the internal origin or not.

Spitzer Space Telescope - General Observer Proposal #50369

Spatially-resolved study of PAHs and VSGs in elliptical galaxies

Principal Investigator: Hidehiro Kaneda
Institution: Japan Aerospace Exploration Agency

Technical Contact: Hidehiro Kaneda, Japan Aerospace Exploration Agency

Co-Investigators:
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Tetsu Kitayama, Toho University
Itsuki Sakon, University of Tokyo
Yoko Okada, ISAS/JAXA
Toyoaki Suzuki, ISAS/JAXA

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 18.5

Abstract:
To perform spatiall-resolved study of very small grains (VSGs) and PAHs in elliptical galaxies, we propose to observe the three elliptical galaxies, NGC4589, NGC4125, and IC3370, in a deep spectral mapping of central 1'x1' area with the IRS; the targets are carefully selected from our AKARI sample of nearby elliptical galaxies. With Spitzer, we have found that a considerable amount of PAHs as well as VSGs are present in nearby dusty elliptical galaxies, emitting very unusual features: usually strong features at 6.2, 7.7, and 8.6 micron are very faint in contrast to prominent features at 11.3 and 17 micron, which might be explained by a dominance of neutral PAHs over ionized ones due to very soft radiation fields from evolved stars. The Spitzer results have also exhibited the presence of warm molecular and ionized gases, which is apparently inconsistent with the dominance of neutral PAHs irradiated by soft radiation field. What are the supplying sources of the dust in elliptical galaxies? How are they related with the warm molecular and ionized gases? How can such small dust particles as PAHs and VSGs survive sputtering destruction in the hot plasma of the elliptical galaxies? The three elliptical galaxies have prominent PAH emissions at 11.3 and 17 micron as well as relatively strong mid-IR excess emission at wavelengths longer than 25 micron; however we have no spatial information. Our earlier IRS observations were performed in a staring mode by one pointing at the center of each galaxy. Spatial information is indispensable to disentangle various competing components and pursue follow-on studies of the above Spitzer discoveries. For example, if the distributions of the dust are more extended than the stellar distribution and smaller grains are abundant in outer regions, it will support that the dust is of external origin. The spatially-resolved IRS data can elucidate the origin and history of the dust, providing key information about the evolution of the elliptical galaxies.

Spitzer Space Telescope - General Observer Proposal #30406

Understanding the Blue-Sequence E/S0 Population: Fading Remnants and Future Spirals

Principal Investigator: Sheila Kannappan
Institution: University of Texas at Austin

Technical Contact: Sheila Kannappan, University of Texas at Austin

Co-Investigators:
Andrew Baker, Rutgers University
Shardha Jogee, University of Texas at Austin
Seppo Laine, Spitzer Science Center, CalTech
Rolf Jansen, Arizona State University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 18.8

Abstract:
Recent work has identified an intriguing population of field S0 and disky E galaxies that reside on the "blue sequence" in color-stellar mass parameter space --- i.e., the locus of spiral galaxies. While some must be young merger remnants destined to fade onto the red sequence, many appear to be settled products of long-ago mergers that have since rebuilt disks, as indicated by an unusually high frequency of extended counterrotating stellar disks and polar rings. Many also show signs of recent central star formation fueled by gas inflow, which may reflect disky "pseudobulge" growth involving bars and/or satellite interactions. Such galaxies could represent a long-sought missing link in the hierarchical picture of galaxy formation: disk regrowth in post-merger systems, potentially transforming E/S0s back into spirals. To examine possible disk and bulge growth in this population, we propose a MIPS 24-micron + IRAC 4-band imaging survey of 18 blue-sequence E/S0s and 13 red-sequence E/S0s, with the red-sequence systems serving as a control sample and enabling a search for dust-reddened examples of the same evolutionary processes seen in the blue-sequence systems. First, we will use stellar population analysis and dynamical/structural characteristics to identify disk-building systems, fading merger remnants, and disky or classical bulges. Second, we will measure the quantity and spatial distribution of current and recent star formation in both disks and bulges, to test whether (a) the two components grow in a time-coordinated way, (b) the amount of star formation is sufficient to transform galaxy morphology, and (c) the disk-building systems will grow to obey the scaling relations between disk/bulge radius, mass, and velocity dispersion observed for spirals. Spitzer is essential for this program because starbursts and dust clearly compromise optical/near-IR analyses of stellar populations and star formation in blue-sequence E/S0s and possible red-sequence analogues.

Spitzer Space Telescope - General Observer Proposal #50819

Shocked Molecular Gas in Virgo Spirals Being Stripped

Principal Investigator: Jeffrey Kenney
Institution: Yale University

Technical Contact: Jeffrey Kenney, Yale University

Co-Investigators:
George Helou, IPAC/SSC
Eric Murphy, SSC
O. Ivy Wong, Yale University
Anne Abramson, Yale University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 17.7

Abstract:
We propose IRS spectroscopy in 4 Virgo cluster spiral galaxies with evidence for strong ongoing ram pressure to search for evidence for shock-heating in the ISM. The galaxies we have selected are those galaxies in Virgo with clear evidence for strong ongoing ram pressure, from a wealth of radio continuum, optical, infrared, and HI data. For shock diagnostics we will use both the H$_2$/PAH ratios and the ortho-to-para ratios of H$_2$. We will explore correlations between the H$_2$/PAH ratio and the local radio deficit parameter, which is a likely tracer of the strength of current ram pressure, to see whether the degree of shock excitation of the molecular gas depends on the strength of ram pressure. Shock excitation throughout the ISM may explain the enhanced global radio-to-FIR ratios in these galaxies, and would teach us how ram pressure energizes the ISM that is not stripped.

Spitzer Space Telescope - Legacy General Observer Proposal #159

SINGS: The Spitzer Infrared Nearby Galaxies Survey -- Physics of the Star-Forming ISM and Galaxy Evolution

Principal Investigator: Robert Kennicutt
Institution: University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Co-Investigators:
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Daniela Calzetti, STScI
Daniel Dale, Caltech
Bruce Draine, Princeton University
Chad Engelbracht, University of Arizona
Karl Gordon, University of Arizona
George Helou, Caltech
David Hollenbach, NASA/Ames Research Center
Claus Leitherer, STScI
Sangeeta Malhotra, Johns Hopkins University
Michael Regan, STScI
George Rieke, University of Arizona
Marcia Rieke, University of Arizona
Michele Thornley, Bucknell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap MipsScan MipsSed
Hours Approved: 512.0

Abstract:
We propose a comprehensive Legacy survey to characterize the infrared emission across the entire range of galaxy properties and star formation environments, including regions that until now have been inaccessible at infrared wavelengths. SINGS will provide: 1) New insights into the physical processes connecting star formation to the ISM properties of galaxies; 2) A vital foundation of data, diagnostic tools, and astrophysical inputs for understanding SIRTF observations of the distant universe and ultraluminous and active galaxies; and 3) An archive that integrates visible/UV and IR/submillimeter studies into a coherent self-consistent whole, and enables many follow-up investigations of star formation and the ISM. SINGS will characterize the large-scale infrared properties of galaxies and their principal infrared-emitting components through SIRTF imaging and low-resolution spectroscopy of 75 nearby galaxies ($d < 30$ Mpc), and targeted high- resolution spectroscopy of their centers and a representative set of extranuclear IR-emitting regions in the galaxies. These data will be combined with an extensive library of ground- and space-based data at other wavelengths.

Spitzer Space Telescope - Legacy General Observer Proposal #40204

The Local Volume Legacy Survey

Principal Investigator: Robert Kennicutt
Institution: University of Cambridge and University of Arizona

Technical Contact: Charles Engelbracht, University of Arizona

Co-Investigators:
Ayesha Begum, University of Cambridge
Daniela Calzetti, University of Massachusetts
Julianne Dalcanton, University of Washington
Danny Dale, University of Wyoming
Charles Engelbracht, University of Arizona
Jose Funes, Vatican Observatory
Amando Gil de Paz, University of Madrid
Karl Gordon, University of Arizona
Benjamin Johnson, Columbia University
Janice Lee, NOAO/Carnegie
Shoko Sakai, UCLA
Evan Skillman, University of Minnesota
Liese van Zee, Indiana University
Fabian Walter, MPIA
Daniel Weisz, University of Minnesota
Benjamin Williams, University of Washington
Yanling Wu, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 280.5

Abstract:
The Local Volume Legacy (LVL) is an IRAC and MIPS survey of a volume-complete sample of 258 galaxies within the 11 Mpc local volume. Its broad goal is to provide critical insight into two of the primary processes that shape the growth of galaxies: star formation and its interaction with the interstellar medium. This goal will be accomplished by investigating the spatially-resolved star formation, dust, and red stellar populations of local galaxies which span the full diversity of luminosities, surface brightnesses, metallicities, dust properties, and star formation properties. The survey will also provide an infrared and multi-wavelength census of the Galactic neighborhood, exploiting the highest spatial resolution and absolute depth achievable with Spitzer. LVL is unique in that it extends current Spitzer observations of galaxies to an unbiased, fully representative, and statistically robust sample of nearby galaxies. The tiered survey includes: (1) all known galaxies inside a sub-volume bounded by 3.5 Mpc (HST ANGST Treasury survey), and (2) an unbiased sample of S-Irr galaxies within the larger, and more representative, 11 Mpc sphere (GALEX 11HUGS survey). Our strategy provides volume-complete coverage of galaxies over the entire luminosity function, with the minimum sample needed to fully characterize the local galaxy population. The Spitzer observations will leverage a rich suite of multi-wavelength ancillary data from the ANGST and 11HUGS surveys, including H-alpha and GALEX UV imaging, stellar population mapping with HST, HI mapping with the VLA and GMRT, and broad-band optical imaging and spectroscopy, to enhance the scientific return and provide an enduring core dataset on the Galactic neighborhood for the scientific community at large.

Spitzer Space Telescope - General Observer Proposal #50407

Mapping Warm H2 in M51: Impacts of Global Galactic Dynamics on Molecular Clouds and Their Formation

Principal Investigator: Jin Koda
Institution: California Institute of Technology

Technical Contact: Jin Koda, California Institute of Technology

Co-Investigators:
Nick Scoville, Caltech
Adwin Boogert, Caltech/IPAC
Caroline Bot, Caltech

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 32.3

Abstract:
We propose to investigate ISM evolution and turbulence driven by large-scale galactic dynamics, using the high spectral-resolution IRS (SH&LH) mapping of a large region (3.6x3.6kpc2) in M51. We will use three H2 lines, i.e. S(0), S(1), and S(2), as signposts of warm gas, local shocks, and turbulence. We will investigate their distributions in global galactic structures and dynamics. The proposed region covers two successive spiral arms and an interarm region in between; and therefore, we can trace the variations of ISM properties continuously along gas flows from one arm to the other. Our high-fidelity CO(J=1-0) map from the CARMA key science project complements this Spitzer project. We will correlate the ISM properties derived from Spitzer (e.g. temperature, surface density, and warm/cold gas fraction), with global and local gas dynamics and distribution traced with CARMA. From the variations of S(0), S(1), and S(2) line ratios over global scale, we will investigate the impacts of global galactic dynamics on interstellar turbulence, and on the formation and lifetime of molecular clouds.

Spitzer Space Telescope - General Observer Proposal #30914

Spitzer Study of the Hidden Galaxy HIZOAJ0836-43

Principal Investigator: Ren'ee Kraan-Korteweg
Institution: University of Cape Town

Technical Contact: Ren'ee Kraan-Korteweg, University of Cape Town

Co-Investigators:
Patrick Woudt, Cape Town Univ.
Thomas Jarrett, Caltech
Lister Staveley-Smith, CSIRO/ATNF
Baerbel Koribalski, CSIRO/ATNF
Jennifer Donley, University of Arizona
Tony Fairall, Univ. of Cape Town
Anja Schroder, Univ. of Leicester
Phil Appleton, SSC/Caltech
Patricia Henning, Univ. of New Mexico
Ken Wakamatsu, Gifu Univ.
Taka Nagayama, Kyoto University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap IrsStare MipsScan
Hours Approved: 12.1

Abstract:
We aim to study the extremely massive spiral galaxy HIZOAJ0836-43 (Vh = 10689 km/s) with the Spitzer Space Telescope. This optically obscured galaxy was detected in a systematic HI survey of the southern Zone of Avoidance. Its intriguing properties -- enormous HI and dynamical mass, despite a NIR morphology suggestive of S0 or Sa type, and an active central starforming bulge indicative of starburst activity or even an AGN -- have led to many questions about its nature and origin (Kraan-Korteweg et al. 2005; Staveley-Smith et al. 2005; Donley et al. 2006). High-resolution Spitzer IRAC & MIPS images of HIZOAJ0836-43 are essential to reveal the stellar and dust content of its disk, the extent of the disk and its morphology, while IRS spectroscopy is needed to investigate the nature of the nucleus and test for the presence of an AGN. We also wish to study the environment of HIZOAJ0836-43 which appears to lie in a high-density filament associated with the Shapley cluster and understand how such a supermassive galaxy could have formed by today within the current hierarchical galaxy formation models.

Spitzer Space Telescope - Directors Discretionary Time Proposal #276

A new class of transients

Principal Investigator: Shrinivas Kulkarni
Institution: Caltech

Technical Contact: Arne Rau, Caltech

Co-Investigators:
A. Rau, Caltech
E. Ofek, Caltech
L. Yan, SSC

Science Category: Nearby Galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsPeakupImage
Hours Approved: 9.3

Abstract:
The two most common astronomical explosions are novae and supernovae. It has long been noted that there is a curious dearth of explosive events with brightness in between these two classes. We have uncovered and followed up such an event located in the outskirts of the nearby lenticular galaxy Messier 85. This object, hereafter M85 OT 2006-1, peaked at an absolute R-band magnitude of -13 and released ~10E47 erg over the first two month. The optical light curve showed steady emission for about 100 days together with a shift of the peak frequency from optical to near-IR. This resembles two other mysterious transients, the enigmatic M31-RV in M31 as well as V838 Mon in the Milky Way. However, M85 OT 2006-1 is even more challenging to understand given that it is more luminous by an order of magnitude. One possibility for their origin is the merger of a star with a companion, either another star or brown dwarf. Based on the evolution of V838 Mon, the spectrum of M85 OT 2006-1 can be expected to shift further to the thermal infrared. Here we propose to use IRAC for deep imaging from 3.6 to 8 microns in order to monitor the IR evolution of the source and diagnose the mass and geometry of the ejecta.

Spitzer Space Telescope - General Observer Proposal #20801

Resolving the Controversy about the Anomalous Arms in NGC 4258

Principal Investigator: Seppo Laine
Institution: Caltech

Technical Contact: Seppo Laine, Caltech

Co-Investigators:
Christos Siopis, University of Michigan

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 0.9

Abstract:
NGC 4258 is an exceptional nearby spiral galaxy with anomalous kpc-scale radio continuum and ionized hydrogen arms. These arms have been interpreted as jet features by most investigators, but an alternative explanation as a bar-induced feature has also been presented. Understanding the unique radio continuum morphology is important. To do that, the question of the origin of the anomalous structure must be first settled. We propose IRAC observations of the PAH emission near 8 microns in this galaxy. These observations have the potential of settling the origin of the anomalous feature in NGC 4258. A bar-induced origin would predict single ridges of emission along the leading edges of the bar. On the other hand, a jet would bore through the ISM and create a channel and the emission would have two ridges. Thus the extinction-free morphology of the PAH emission would reveal the origin of the anomalous feature. We will also get 4.5 micron images that would reveal the exact location of any oval distortion of bar in the galaxy. PAH emission is expected to be excited since there is lots of ionized hydrogen emission along the anomalous feature. Short (1 hour) observations are requested. The results will be compared to another barred galaxy with a possible kpc-scale anomalous radio continuum feature, NGC 7479. Observations for that galaxy will be obtained in a GTO program and we will take them from the archive when they become available in the summer of 2005.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40079

Dense and diffuse H2 in star-forming galaxies

Principal Investigator: Vianney Lebouteiller
Institution: Cornell University

Technical Contact: Vianney Lebouteiller, Cornell University

Co-Investigators:
Daniel Devost, Cornell University
Jeronimo Bernard-Salas, Cornell University
Yanling Wu, Cornell University
Jim Houck, Cornell University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 5.2

Abstract:
Molecular material is thought to be a necessary ingredient for star-formation. The study of the molecular content in star-forming galaxies gives valuable insights into galaxy evolution: where, when, and how do galaxies start to form molecules? What impact does it have on the star formation history? Preliminary results on the dense and diffuse H2 content in a small sample of objects observed with IRS and FUSE indicate that the lack of H2 detection could probe genuinely young systems, with one or few star-formation episodes. Moreover, it seems that the paucity of dense H2 in some objects can be explained by extremely hard radiation. We propose to investigate further and answer these questions by doubling the existing cross-sample of objects observed with the IRS and FUSE.

Spitzer Space Telescope - Theoretical Research Proposal #20436

Modeling the Dust Infrared Emission from Nearby Galaxies

Principal Investigator: Aigen Li
Institution: University of Missouri-Columbia

Technical Contact: Aigen Li, University of Missouri-Columbia

Co-Investigators:
Bruce Draine, Princeton University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 80000.0

Abstract:
Based on the silicate-graphite-PAHs interstellar grain model, we propose to model the dust IR emission from nearby galaxies obtained by Spitzer on a pixel-by-pixel basis. The dust, consisting of a mixture of silicate grains and carbonaceous grains (graphite and PAHs) and spanning a wide range of sizes from a few angstroms to a few micrometers, is heated by starlight with a range of intensities in each pixel. By fitting the IRAC, MIPS photometry and IRS spectroscopy of each pixel, we will be able (1) to determine the spatial distribution of dust, the spatial distribution of starlight intensity, and the regional variation of the PAH abundance and properties within a galaxy, (2) to see how the dust mass and the abundance and properties of the PAHs vary from galaxy to galaxy, and (3) to relate the dust mass and the PAH abundance and properties with environmental conditions and galaxy type. We will calculate the temperature probability distribution functions for small grains (neutral PAHs and charged PAHs; silicate and graphite grains smaller than 250 Angstrom), as well as the steady temperatures of large graphite and silicate grains, for a wide range of sizes, exposed to starlight of a wide range of intensities and of a wide range of spectral shapes. We will build a ‘‘library’’ of temperature probability distribution functions and model IR emission spectra for each grain species of each grain size, heated by each starlight intensity of each starlight spectrum. This ‘‘library’’ will be made available to the astronomical community on WWW at http://www.astro.princeton.edu/~draine/dust/dust.html. This ‘‘library’’ will be very useful for interpreting the IR emission data (particularly the PAH emission features) obtained by Spitzer for both Galactic and extragalactic objects.

Spitzer Space Telescope - Archive Research Proposal #40070

GALEX-Spitzer study of resolved galaxies

Principal Investigator: Barry Madore
Institution: Carnegie Institution of Washington

Technical Contact: Barry Madore, Carnegie Institution of Washington

Co-Investigators:
Samuel Boissier, Laboratoire d'Astrophysique de Marseille
Alessandro Boselli, Laboratoire d'Astrophysique de Marseille
Veronique Buat, Laboratoire d'Astrophysique de Marseille
Denis Burgarella, Laboratoire d'Astrophysique de Marseille
Timothy Heckman, Johns Hopkins University
Mark Seibert, Carnegie Observatories
Armando Gil de Paz, Universidad Complutense de Madrid
Pablo Perez Gonzalez, Universidad Complutense de Madrid
Daniel Dale, University of Wyoming

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 139102.0

Abstract:
The aim of this proposal is to extract, cross-compare and study the intersection of nearby galaxies observed with GALEX with those currently contained in the Spitzer archive. We have already determined that the sample for which Spitzer data are available is representative of the entire GALEX Atlas of Nearby Galaxies, which covers the range of the observed properties of the field galaxy population as judged by optical and FIR luminosities and colors. The combined sample is already a factor of 4 larger that the number of objects of SINGS. This is now enough to allow statistical studies on sub-sets even when down-selecting to a specific group of galaxies (e.g., chosen according to sub-type, colors, luminosities, environment, etc.). A wide range of scientific issues can be addressed with the UV+far-infrared spatially resolved data. Our prime scientific objective will be the study of the properties of dust attenuation in all star formation regimes (from normal to starburst galaxies), on a local basis (in individual regions, and along profiles). The obtained products will be made available to the community, as is already the GALEX Atlas of nearby galaxies.

Spitzer Space Telescope - Archive Research Proposal #50100

The Dust - AGN Connection in Early-Type Galaxies

Principal Investigator: Paul Martini
Institution: Ohio State University

Technical Contact: Paul Martini, Ohio State University

Co-Investigators:
Thaisa Storchi-Bergmann, UFRGS
Ramiro Simoes Lopes, UFRGS

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 100000.0

Abstract:
While many efforts over the years have searched for evidence of the fueling mechanism(s) of Active Galactic Nuclei, we recently identified the first substantial difference between the hosts of AGN and inactive galaxies: all AGN in early-type galaxies show evidence for circumnuclear dust, while dust is only present in a minority (about 25%) of inactive, early-type galaxies. These observations suggest that circumnuclear dust, within hundreds of parsecs of the centers of these galaxies, is a necessary condition for fueling the central, supermassive black hole, and that the AGN may affect the observed dust morphology or its absence. However, this analysis was based on HST observations that were primarily sensitive to clumpy dust on small scales, rather than the diffusely distributed dust identified in many infrared studies of elliptical galaxies. As over 90% of our sample (60 galaxies) have archival Spitzer IRAC and MIPS observations, we propose to search for diffuse dust between our well-matched sample of AGN and inactive galaxies and determine if these pronounced differences also hold for diffuse dust. We will also use these infrared observations to estimate the total attentuation by dust and place constraints on the total dust mass in ellipticals, which can be used to infer the dust survival time against sputtering.

Spitzer Space Telescope - General Observer Proposal #50102

Secular Evolution at the End of the Hubble Sequence

Principal Investigator: Paul Martini
Institution: Ohio State University

Technical Contact: Paul Martini, Ohio State University

Co-Investigators:
Tosten Boeker, ESA
Eva Schinnerer, MPIA-Heidelberg
Ute Lisenfeld, Universidad Granada

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 2.8

Abstract:
The bulgeless disk galaxies at the end of the Hubble Sequence evolve at a glacial pace relative to their more violent, earlier-type cousins. The causes of their internal, or secular evolution are important because secular evolution represents the future fate of all galaxies in our accelerating Universe and is a key ingredient to understanding galaxy evolution in lower-density environments at present. The rate of secular evolution is largely determined by the stability of the cold ISM against collapse, star formation, and the buildup of a central bulge. Key diagnostics of the ISM's stability are the presence of compact molecular clouds and narrow dust lanes. Surprisingly, edge-on, bulgeless disk galaxies with circular velocities below 120 km/s do not appear to contain such dust lanes. We propose to obtain IRAC images of a well-selected sample of extremely late-type disk galaxies to measure the intensity and concentration of PAH emission to determine if they possess the molecular gas necessary to drive secular evolution and early evidence for pseudobulge growth. Our sample has been carefully constructed to include disk galaxies above and below the critical circular velocity of 120 km/s where the dust properties of edge-on disks change so remarkably. These data, when combined with our HST ACS images of the dust attenuation, VLA HI observations, and IRAM CO data, will provide a complete picture of the ISM in the bulgeless disk galaxies at the end of the Hubble Sequence.

Spitzer Space Telescope - Theoretical Research Proposal #40229

Evolution of Dust in Elliptical Galaxies

Principal Investigator: William Mathews
Institution: University of California, Santa Cruz

Technical Contact: William Mathews, University of California, Santa Cruz

Co-Investigators:
Fabrizio Brighenti, University of Bologna
Pasquale Temi, Nasa Ames Research Center & SETI Institute

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 79447.0

Abstract:
We request funding to develop a theoretical understanding of the complex and fascinating life cycle of interstellar dust in elliptical galaxies. Our recent Spitzer observations show that many otherwise normal elliptical galaxies have unexpected extended regions of cold dust with masses exceeding that of dust produced by a normally evolving local old stellar population. The dust lifetime is only ten million years in the hot interstellar gas. In one galaxy excess dust is observed in a highly asymmetric, plume-like extension out to five kiloparsecs from the center and coincident with warm gas that emits optical line emission. Since the excess dust is highly transient, it must be internally produced (not by mergers) on a frequent duty cycle of about ten million years. Evidently, the extended dust in these normal ellipticals originates in small dusty nuclear disks a few hundred parsecs in size which are commonly observed and contain enough dust to account for the extended dust we observe. We request funding to study the kinematic and thermal evolution of dust lost by normally evolving stars, and to demonstrate in detail how dust from stars in galactic cores collects into small disks. With gasdynamical computations we will show how disks form in rotating elliptical galaxies and investigate their properties. Then we will disrupt the disks with intermittent energy associated with the active galactic nucleus (central black hole) and compute how heated dusty gas is transported out into the hot gas in buoyant plumes. Preliminary calculations show that dust eventually cools the buoyant gas, explaining the presence of extended plumes of warm gas that emits optical emission lines. The astronomical implications of this unexpected excess dust we observed with Spitzer -- and now wish to study in more detail -- are far-reaching and provide new information about energetic processes in galactic cores.

Spitzer Space Telescope - General Observer Proposal #20432

The Interstellar Medium of Low Surface Brightness Disk Galaxies

Principal Investigator: Lynn Matthews
Institution: Harvard-Smithsonian Center for Astrophysics

Technical Contact: Lynn Matthews, Harvard-CfA

Co-Investigators:
Kenneth Wood, St. Andrews University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 9.2

Abstract:
Low surface brightness (LSB) spiral galaxies are one of the most common classes of disk galaxy in the local universe, yet little is known about the detailed structure and composition of their interstellar medium (ISM). This has implications for our understanding of star formation in a wide range of low-density, low-metallicity galactic environments. We propose IRAC and MIPS imaging of a sample of three edge-on, LSB spirals, two of which have been recently detected in CO. Our study will explore how the distributions of warm and cold dust are correlated with other ISM and star formation tracers, including HI, H alpha, CO, and dark clouds seen in optical images. Additional goals include searching for a radially or vertically extended component of cold dust in LSB spirals that may trace an underlying dark baryonic component, and obtaining robust measurements of the stellar mass of LSB disks. With the aid of 3-D Monte Carlo radiative transfer models, we will use our data to assess the structure and energy balance of the ISM of LSB spirals and to constrain the nature of their past and present star formation.

Spitzer Space Telescope - General Observer Proposal #50111

The Spitzer Tully-Fisher Relation

Principal Investigator: Stacy McGaugh
Institution: University of Maryland, College Park

Technical Contact: Stacy McGaugh, University of Maryland, College Park

Co-Investigators:
Jim Schombert, University of Oregon
Erwin de Blok, University of Capetown

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap
Hours Approved: 7.7

Abstract:
We propose to investigate the Tully-Fisher (TF) relation in the Spitzer IRAC bands. The slope of the TF relation, which is the most fundamental relationship reflecting galaxy formation scenarios, increases from B to K band passes, and the scatter around the relation decreases over the same range. We seek to determine if this trend continues, or if it saturates at a value set by an intrinsic relation between mass and rotation velocity. Indeed, this intrinsic "baryonic" Tully-Fisher relation provides the one of the most direct test of galaxy formation scenarios. Our target sample possesses extensive supporting data, including BVJK photometry (at a minimum; other bands and Halpha are often available) and high quality extended HI velocity fields. It is selected to cover the widest possible range in circular velocity, from 20 to 320 km/s. This large dynamic range is essential to constraining the slope of the TF relation, complementing and considerably extending the range of galaxies represented in the Spitzer archive. We will use these data to measure the impact of extinction and star formation on the intrinsic TF relation, and to test the efficacy of competing estimators of the stellar mass. This will produce an empirical calibration of the Spitzer Tully-Fisher relation and insight into its physical significance.

Spitzer Space Telescope - Archive Research Proposal #50243

Star Formation and the Tully-Fisher Relation

Principal Investigator: Stacy McGaugh
Institution: University of Maryland, College Park

Technical Contact: Stacy McGaugh, University of Maryland, College Park

Co-Investigators:
Jim Schombert, University of Oregon
Erwin de Blok, University of Capetown

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 25000.0

Abstract:
We propose to investigate the Tully-Fisher (TF) relation in archival Spitzer data. The slope of the TF relation, which is the most fundamental relationship reflecting galaxy formation scenarios, increases from B to K band passes, and the scatter around the relation decreases over the same range. We seek to determine if this trend continues, or if it saturates at a value set by an intrinsic relation between mass and rotation velocity. Indeed, this intrinsic "baryonic" Tully-Fisher relation provides the one of the most direct test of galaxy formation scenarios. Our target sample possesses extensive supporting data, including BVJK photometry (at a minimum; other bands and Halpha are often available) and high quality extended HI velocity fields. We will use these data to measure the impact of extinction and star formation on the intrinsic TF relation, and to test the efficacy of competing estimators of the stellar mass. This will produce an empirical calibration of the Spitzer Tully-Fisher relation and insight into its physical significance.

Spitzer Space Telescope - General Observer Proposal #50332

Starbursts: Emitters or Absorbers?

Principal Investigator: Sally Oey
Institution: University of Michigan

Technical Contact: Jane Rigby, University of Arizona

Co-Investigators:
Jane Rigby, Carnegie Observatories

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 11.9

Abstract:
Recent results show that starbursts have comparatively less diffuse, warm ionized medium than other star-forming galaxies. This intriguing effect may be caused by either the escape of ionizing radiation from starburst galaxies, or by comparatively higher absorption of the photons by dust. The former scenario has vital consequences for understanding the ionization and evolution of the cosmic web, the intergalactic environment of starbursts, the reionization of the universe, and the energy budget of star-forming galaxies. We propose Spitzer MIPS observations, which will be used together with optical and UV archive data from GALEX, to evaluate the full SED and emission morphology of the galaxies. We will then do radiative transfer modeling to understand and determine the energy budget and fate of the Lyman continuum photons. Our sample comprises 13 starburst galaxies with known low fractions of warm ionized medium and a control sample of 10 ordinary star-forming galaxies. Thirteen galaxies have archive observations; we propose for the remaining ten.

Spitzer Space Telescope - General Observer Proposal #20469

The Properties of Dust in Population II: Spitzer Survey of the Carina Dwarf

Principal Investigator: Knut Olsen
Institution: National Optical Astronomy Observatory

Technical Contact: Knut Olsen, National Optical Astronomy Observatory

Co-Investigators:
Robert Blum, NOAO
Jeremy Mould, NOAO
Michael Werner, JPL
Jay Frogel, AURA/The Ohio State University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 38.1

Abstract:
We propose to use Spitzer to identify the primary sources of stellar mass loss in the Carina dwarf spheroidal galaxy. Carina is unique among resolved stellar populations in that the bulk of its stars are only a few billion years old, yet they have an extreme Population II chemical composition. The spectral energy distributions we derive will characterize, for the first time, the nature and content of dust formed by metal-poor stars as old as the universe was at z~1. As such, our survey will provide a critical component to models that aim to predict the spectra of galaxies at an early epoch. Carina's unique mix of stellar populations also makes it an important testbed for galactic chemical evolution models. Our data will connect the chain of Carina's chemical evolution, as expressed by stellar abundances, with the current output of metals ejected by its asymptotic giant branch stars in the form of dust.

Spitzer Space Telescope - Theoretical Research Proposal #20040

Global Modeling of Spur Formation in Spiral Galaxies

Principal Investigator: Eve Ostriker
Institution: University of Maryland

Technical Contact: Eve Ostriker, University of Maryland

Co-Investigators:
Stuart Vogel, University of Maryland
Misty Lavigne, University of Maryland
Rahul Shetty, University of Maryland

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Dollars Approved: 73552.0

Abstract:
Spitzer 8 micron Legacy images of M51 and other SINGS galaxies show, in addition to the classic ''beads on a string'' associated with localized star formation, striking intermediate-scale filamentary structures. These features consist of many trailing ''spurs'' extending from the main arms well into the interarm regions. Cospatial ''spur-like'' dust lanes are also evident in HST optical images of M51 and other disk galaxies -- including barred and flocculent types -- suggesting that a similar dynamical process drives their development in many systems. We believe that these spurs are created by the magneto-Jeans instability (MJI), and that nonlinear evolution of the MJI leads to fragmentation into GMCs, and subsequently arm and interarm HII regions. In previous MHD simulations using a simplified local model, the PI demonstrated the formation of gaseous spurs and bound clouds with masses and spacings similar to observations. We propose to extend these models into the global domain, which will allow for realistic effects including curvature of spiral arms, spatial variation of the background surface density, and gradients in the background flow velocity relative to the spiral pattern. In addition to modeling tuned for specific galaxies, we also plan to perform a larger survey to explore the parameter dependence of structural and dynamical development. Since much of the arm and interarm 8 micron emission is produced by PAHs in dusty clumps and filaments, and star formation may be driven by the corresponding gas enhancements, understanding how the ISM is concentrated into these structures may be key to interpretation of many existing and future Spitzer data sets.

Spitzer Space Telescope - General Observer Proposal #30254

A panchromatic study of extragalactic HII regions

Principal Investigator: Els Peeters
Institution: NASA Ames Research Center

Technical Contact: Els Peeters, SETI Institute

Co-Investigators:
Alexander Tielens, NASA Ames Research Center
Jeronimo Bernard-Salas, Cornell University
Louis Allamandola, NASA Ames Research Center

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 24.4

Abstract:
Star formation rates (SFR) are considered the key to understanding galaxy formation and evolution. All wavelength regions have been exploited to determine the SFR by studying massive star forming regions at all redshifts. Indeed, traditionally, SFR in galaxies are determined based upon H alpha, FIR and the UV. In recent years, MIR tracers of star formation activity of galaxies have been explored but their quantitative use is still under debate. Here, we propose to obtain Spitzer-IRS SL-LL observations of a sample of well-characterized HII regions in two galaxies, M33 and M83. These HII regions span a wide range in galactocentric radii and hence metallicity. These metallicities have been determined through an earlier, unrelated investigation (PID 3412 & 20057; PI Rubin). The proposed observations are complementary to existing auxiliary data and are in fact the missing link for a panchromatic view of individual extragalactic HII regions. This proposal will provide, for the first time, a quantitative estimate of the effects on the MIR characteristics of extagalactic HII regions of parameters such as the metallicity, the hardness of the stellar radiation field (NeIII/NeII and/or SIV/SIII ratios), density (NeIII and/or SIII line ratios), stellar luminosity (radio, H alpha) can be systematically investigated. Hence, the proposed observations form the basis for a systematic study of PAH and dust properties, their dependency on the physical conditions of the environment and their usefulness as a quantitative tracer for star formation. As a result, this study will influence the interpretation of star forming regions on small and large scales and distances out to the era of vigorous star formation activity.

Spitzer Space Telescope - Directors Discretionary Time Proposal #487

An IRS Spectrum of the Luminous Transient in NGC 300

Principal Investigator: Jose Prieto
Institution: Ohio State University

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Co-Investigators:
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Science Category: nearby galaxies
Observing Modes: IrsStare
Hours Approved: 1.0

Abstract:
We propose obtaining an IRS spectrum of the luminous transient discovered in the nearby galaxy NGC 300 on May 16, 2008. This transient shares remarkably similar properties with SN~2008S discovered earlier this year in NGC 6946: they have peak absolute magnitudes approx. -14, intermediate between bright novae and low-luminosity core-collapse supernovae, and optical spectra dominated by relatively broad Balmer lines in emission, similar to some type IIn supernovae and LBV outbursts. Most surprisingly, both transients had progenitors identified in Spitzer pre-explosion archival images as ~10 Msun stars enshrouded in their own optically-thick circumstellar dust. These transients, along with the luminous transient discovered in the Virgo galaxy M85 in 2006, are most likely part of a new class of stellar explosions/eruptions of dusty-massive stars unveiled by Spitzer observations. A low-resolution IRS spectrum will help us characterize the composition of its circumstellar dust and the nature of the explosion.

Spitzer Space Telescope - General Observer Proposal #20695

Intergalactic HII Regions: Probing a Non-Standard Mode of Star Formation

Principal Investigator: Mary Putman
Institution: University of Michigan

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Co-Investigators:
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M.S. Oey, University of Michigan
Rob Kennicutt, University of Arizona
Gerhardt Meurer, JHU

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 7.5

Abstract:
We propose to image intergalactic HII regions with both IRAC and MIPS in all their bands, contributing to our understanding of star formation in extreme low density environments with no obvious external trigger. These HII regions represent star formation proceeding in an entirely different mode from the standard Schmidt law understanding. With MIPS, we plan to measure cold dust emission in the vicinity of these recently discovered objects and compare these measurements to regions with similar HI column densities that have not formed stars. The comparison will test the hypothesis that stars only begin forming in low density gas that is dust-rich. With IRAC, we will measure the warm dust emission near the intergalactic HII regions, as traced by PAH emission. IRAC observations will also identify any associated older stellar populations and assess the relationship of intergalactic HII regions to satellite galaxies.

Spitzer Space Telescope - General Observer Proposal #30256

Tracing the eventful life of field early-type galaxies with the silicate emission feature of evolved stars

Principal Investigator: Roberto Rampazzo
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Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 48.4

Abstract:
Early-type galaxies (ETGs) are considered the fossil evidence of the process of galaxy evolution. Recent optical studies suggest that, on the average, field ETGs are younger than their cluster counterparts. This is likely to be a consequence of accreation/merging episodes that leave their signature in a younger stellar population. However, any accurate estimate of the star formation history based solely on optical data is affected by the age-metallicity degeneracy, which seriously detracts from previous findings. We have devised a new method which overcomes this problem by comparing optical data with MIR spectra based on the 10 micron silicate emission due to dusty circumstellar envelopes around evolved stars. The method, already applied to a sample of Virgo cluster galaxies, fully exploits Spitzer's IRS spectral capabilities (Bressan et al. 2006). We propose to extend this method to a sample representative of possibly rejuvanated ETGs in the field for which we already have high S/N optical spectra. The analysis of IRS data coupled with our optical spectra will permit us to measure the age and metallicity unambiguously for our sample. Furthermore, the combined use of the proposed sample and the successful IRS observation of bright Virgo cluster galaxies will allow us to explore the ETGs evolution across a factor of 40 in local galaxy density. This will quantify the role of the environment in determining the ETGs star formation history.

Spitzer Space Telescope - General Observer Proposal #20380

The Ionization of the Diffuse Ionized Gas Halo of NGC 891

Principal Investigator: Richard Rand
Institution: University of New Mexico

Technical Contact: Richard Rand, University of New Mexico

Co-Investigators:
Robert Benjamin, University of Wisconsin Whitewater
Kenneth Wood, University of St. Andrews

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 18.1

Abstract:
The ionization of Diffuse Ionized Gas (DIG) layers in galaxies remains a critical but unsolved problem for our understanding of galaxy energetics. Work using optical emission lines has indicated that photo-ionization by massive stars in the disk dominates the energy input, but no pure photo-ionization model can reproduce all the observed line ratios, leading to the possibility that non-ionizing heat sources and/or secondary ionization sources may be important for the energetics. However, the optical diagnostics present three main problems: sensitivity to extinction, gas temperature, and (for some crucial lines) weak emission. The MIR diagnostic ratio [Ne III]/[Ne II] provides a measurable, extinction-free diagnostic of the hardness of the ionizing spectrum with little temperature sensitivity. Thus this ratio will provide an excellent test of whether photo-ionization alone can maintain the DIG, or whether a second source of ionization is required. We therefore propose to use the SH module on the Spitzer IRS to observe two fields in the lower halo (z=1 kpc) and one field in the disk of the well studied edge-on NGC 891 to determine how this ratio changes with distance from the thin disk of ionizing sources. We will compare our results with predictions from our own 2-d and 3-d simulations of the ionization structure, where such inputs as the ionizing spectrum, spectral hardening by propagation through intervening gas, and additional heat sources can be modeled.

Spitzer Space Telescope - General Observer Proposal #40284

Spitzer Spectroscopy of Gaseous Halos of Nearby Edge-on Galaxies

Principal Investigator: Richard Rand
Institution: University of New Mexico

Technical Contact: Richard Rand, University of New Mexico

Co-Investigators:
Robert Benjamin, University of Wisconsin-Whitewater
Kenneth Wood, University of St. Andrews

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 39.6

Abstract:
The majority of ionized gas in galaxies is in a diffuse phase - the so-called Diffuse Ionized Gas (DIG) - and its maintenance represents a significant power requirement for galaxies. In the past fifteen years, it has been found that DIG layers in spirals are suprisingly thick, and the way in which galaxies maintain these thick ionized layers is not well understood. Diagnostic optical emission line ratios suggest that the dominant ionizing source is photo-ionization by the thin disk of massive stars, but there is evidence that additional sources of ionization in these DIG "halos" is required. The degree to which such sources are necessary, the nature of the sources, and environment-dependent variations all rely on unambiguous ionization diagnostics. Unfortunately, the optical ratios suffer from complications due to gas temperature, abundance and extinction effects. Spitzer offers access to the [Ne III]/[Ne II] ratio - a diagnostic free of all these complications. A successful pilot IRS study of NGC 891 by us showed the feasibility of detecting these lines in faint gaseous halos and already revealed severe difficulties for pure photo-ionization models. However, this study featured only two positions in the halo of a single spiral. Here we propose to extend this study to observe positions in the halos of three nearby edge-on spiral galaxies, where the optical ratios indicate a variety of ionization requirements, allowing more general conclusions to be drawn about the maintenance of DIG layers, as well as the interpretation of the optical ratios. We will compare results with our own state-of-the-art photo-ionization and shock-ionization models. Our pilot study also featured the first spectroscopic detections of PAHs in an external galaxy halo, and the proposed observations will extend our knowledge of the PAH population in halo environments.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30244

IRS Spectra of M101 HII Regions in the Aromatic Feature Transition Region

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Karl Gordon, The University of Arizona

Co-Investigators:
Karl Gordon, Univ. of Arizona
Charles Engelbracht, Univ. of Arizona
Karl Misselt, Univ. of Arizona
JD Smith, Univ. of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 8.0

Abstract:
We are proposing to obtain IRS spectroscopy of 6 HII regions in M101 in the metallitcity range [12+log(O/H)] from 7.9 to 8.4. Previous IRS spectroscopy of M101 HII regions and starburst galaxies has shown that this metallitcity range is crucial in understanding the physics of changes in the ratio of the feature strengths seen in the ubiquitous Aromatic Emission Features (AFEs, also commonly called the PAH features). Due to its large size and strong metallicity gradient, the HII regions in M101 provide a unique opportunity to study the properties of massive star formation as a function of metallicity and radiation field hardness. The observations proposed here will allow for new, sensitive probes of the AEFs in this crucial metallicity range and put constraints on the carrier of these features, improving our ability to predict the IR SEDs of star forming regions.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30310

Cold Dust Halos in Nearby Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Joannah Hinz, University of Arizona

Co-Investigators:
Joannah Hinz, University of Arizona
Charles Engelbracht, University of Arizona
Karl Gordon, University of Arizona
Christopher Willmer, University of Arizona
Karl Misselt, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsScan
Hours Approved: 36.9

Abstract:
We propose to obtain deep MIPS images of a small sample of nearby spiral galaxies and star-bursting dwarf galaxies to measure their spectral energy distributions (SEDs), determine the frequency with which significant amounts of cold (T=15-20K) dust appear in galaxies, assess the spatial distribution, mass, and temperature for this cold dust, and explore the temperature and mass distributions across the galactic disks. We will test how each individual galactic component contributes to the heating and structure of the cold dust emission. The proposed observations will address crucial question in galaxy evolution and formation, including how galaxies typically form, retain, and accumulate reserves of cold dust and in what quantities, and, historically, how galactic dust has interacted with its surrounding environment. These will be combined with existing GTO data on nearby galaxies to analyze these properties over a wide range of morphological types. This is part of a coordinated study of cold dust in galaxies conducted by members of the MIPS GTO team.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30348

Dust Properties in Nearby Sub-mm Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: George Rieke, The University of Arizona

Co-Investigators:
Christopher Willmer, University of Arizona
Joannah Hinz, University of Arizona
Karl Gordon, University of Arizona
Chad Engelbracht, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 14.2

Abstract:
We propose MIPS and IRAC observations of 11 nearby galaxies for which cold dust has been detected at 850 microns with SCUBA. These galaxies have morphological types ranging from elliptical to late spirals, have quiescent star formation rates and dust masses dominated by cold dust. The combined sub-millimeter, far-and mid-infrared properties of these galaxies show they have no counterparts in the SINGS survey. The proposed sample will be used to address several questions: What are the properties of cold dust such as extent, emissivity, temperature and mass ? How do these cold dust properties correlate with galaxy morphology, stellar populations and star formation rates ? Does the cold dust contain imprints from past and present interactions of galaxies ? By probing a parameter space not covered by SINGS, the proposed sample of galaxies will also expand the number of local templates to which observations of distant galaxies can be compared.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30577

IRS Spectral Mapping of a Representative Sample of Local Luminous Infrared Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Almudena Alonso-Herrero, CSIC

Co-Investigators:
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Tanio Diaz-Santos, DAMIR, Instituto de Estructura de la Materia, CSIC
Luis Colina, DAMIR, Instituto de Estructura de la Materia, CSIC
Chad Engelbracht, Steward Observatory, University of Arizona
Marcia Rieke, Steward Observatory, University of Arizona
Pablo Perez-Gonzalez, Steward Observatory, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap IrsStare
Hours Approved: 35.9

Abstract:
We propose to measure the mid-infrared spectroscopic properties (using the IRS Spectral Mapping mode with the low and high spectral resolution modules) of a representative sample of local universe luminous infrared galaxies (LIRGs). Current Spitzer cosmological surveys at 24micron are revealing a population of high-z LIRGs that account for nearly 50% of the cosmic IR background at z~1 . The interpretation of these distant LIRGs depends on a deep understanding of local LIRGs. The sample of 12 local LIRGs has been selected to be representative of a volume-limited sample (distances of 35 to 76Mpc) for which HST/NICMOS continuum and Pa-alpha observations were obtained in Cycle 13. In addition, there are archival IRAC and MIPS observations for the sample. The regions to be mapped with the IRS (central 20-30arcsec) cover the majority of the mid-IR emitting area of these LIRGs, so the entire set of HST and Spitzer data can be converted into integrated properties. The goals of this proposal are: (1) To use the high spectral resolution modules to look for high excitation lines to reveal obscured AGN, and to determine the nature of the dominant energy source when both AGN and star formation are present, as observed in a large fraction of high-z LIRGs and ULIRGs (2) To calibrate the mid-IR star formation rate indicators, such as the 24micron luminosity, the [NeII]12.8micron emission line, and the aromatic emission features for LIRGs and compare them with the behavior of normal galaxies (3) to characterize the obscuration and to understand the properties of the star-forming regions of LIRGs, and compare them with less extreme cases such as starburst galaxies from SINGS (4) to construct local templates for high-z IR bright galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30732

Dust Properties in Low-Metallicity Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Co-Investigators:
Charles Engelbracht, Steward Observatory
Karl Gordon, Steward Observatory
Joannah Hinz, Steward Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 17.2

Abstract:
Star formation and galaxy evolution in low metallicity environments is a central issue in astronomy. The formation and evolution of the first stars and galaxies occurred in such environments. Learning about them can also reveal the dependencies on heavy element production that lead to the current conditions. To probe these issues, we will observe a sample of low-metallicity galaxies with all three Spitzer instruments. Our first goal is to understand the behavior of the interstellar dust as the availability of heavy elements decreases, including the major changes in strength of the aromatic feature that we have documented in previous work. In addition to its intrinsic interest, this study will help interpret Spitzer measurements at high redshift, where the aromatic features (when they are still present) fall in the MIPS 24 micron band.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40192

Cold Dust in Isolated Dwarf Galaxies

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Joannah Hinz, University of Arizona

Co-Investigators:
Liese van Zee, Indiana University
Karl Gordon, University of Arizona
Charles Engelbracht, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsScan
Hours Approved: 24.2

Abstract:
We propose for 24.2 hrs of deep MIPS scan observations of five isolated, irregular dwarf galaxies to determine the distribution, mass, and extent of both the warm (T~60K) and cold (T~15K) dust components. Dwarfs are considered to be the building blocks of which all more luminous systems are formed, yet are the least studied with regards to dust and metal retention due to their faint nature in the infrared. Discovering if or where significant amounts of dust and, by proxy, metals, are located in dwarfs will place much needed constraints on chemical evolution models of these systems. Furthermore, the observations will address questions that are crucial for understanding galaxy evolution in more general terms, such as how galaxies typically form, retain, and/or accumulate dust and metals, and in what quantities and temperatures, how dust is heated by other galactic components, how dust emission is correlated with other cold extended material such as the H I emission, and how galactic dust typically interacts with its surrounding environment. Quiescent dwarfs simply must be observed deeply with Spitzer if we are to understand galaxy evolution with a view unbiased by optical luminosity.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40352

Deep MIPS Imaging of M101: Probing the Gas-to-Dust Ratio versus Metallicity Relationship in a Single Galaxy

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Karl Gordon, University of Arizona

Co-Investigators:
George Rieke, University of Arizona
Charles Engelbracht, University of Arizona
Fabian Walter, MPIA
Adam Leroy, MPIA
Karl Misselt, U. of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsScan
Hours Approved: 11.9

Abstract:
We are proposing for deep MIPS imaging of M101 to investigate the spatial variations of the gas-to-dust ratio in this galaxy. M101 is a unique galaxy in that it has a large well-measured metallicity gradient ranging from log[O/H]+12 values of 8.8 in the center to 7.4 at the edge. The metallicity gradient coupled with the M101's large apparent size (> 30 arcmin) makes it the best target for studying variations in the interstellar medium with metallicity. The existing observations provide good measurements to approximately 0.8R_o (where R_o = 14.43 arcmin). This is just above the metallicity of log[O/H]+12 = 8.2, where recent work has shown that the aromatic features begin to weaken and, possibly, the dust-to-gas ratio drops off the expected metallicity relationship. Obtaining deep MIPS images of M101 will enable clean measurements of the dust-to-gas ratio well below the 8.2 transition metallicity. Increasing the depth of the Spitzer images will allow us to determine if there is a true transition in the bulk dust properties at a metallicity around 8.2 or if the transition seen in the aromatics is just tracing a minor component of the ISM.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40410

Extraplanar Dust in Nearby Galaxies

Principal Investigator: George Rieke
Institution: Steward Observatory, U. Arizona

Technical Contact: Charles Engelbracht, Steward Observatory, U. Arizona

Co-Investigators:
Charles Engelbracht, Steward Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot MipsScan
Hours Approved: 4.5

Abstract:
The interstellar medium (ISM) of late-type galaxies is largely confined to a disk in the plane of the galaxy, but can be removed from that configuration by a variety of processes. Forces internal to the galaxy, like energetic star formation or an active nucleus can drive winds which push the ISM out of the plane or even eject it altogether, while external forces like gravitational interaction or ram-pressure stripping can compress the ISM, also possibly driving it out of the galaxy. The displacement of the ISM affects star formation activity and the chemical content, altering the subsequent evolution of the host galaxy or its neighbors. The gaseous component of the displaced ISM is the most readily detected, but displaced dust has also been detected in some galaxies. It is unknown, however, whether dust always accompanies the displaced gas. Whether dust is present in significant quantities in the ISM ejected from galaxies has profound implications for the host galaxy and for its environment: dust that stays in the plane of the galaxy will alter the chemical balance of the ISM, affecting subsequent star formation activity and the observational properties of the galaxy, while dust that enters the intergalactic medium will redden and attenuate light from more distant galaxies and possibly also fall onto neighboring galaxies, affecting their subsequent evolution as well. The distribution and composition of ejected dust provides clues to the expulsion mechanism (e.g., is the dust found only in a nuclear wind, and is it chemically similar to the dust in the nucleus?) and thus insight into the processes that affect the ISM. The Spitzer 8 micron and 24 micron bands are ideal for measuring extraplanar dust, and we propose to survey a sample of nearby galaxies to look for this dust. The images will show the dust distribution and provide statistics on the frequency of dust emission from extraplanar gas, while the ratio will constrain the composition and provide insight into the expulsion mechanism.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40479

IRS Spectral Mapping of local Luminous Infrared Galaxies

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: George Rieke, University of Arizona

Co-Investigators:
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Tanio Diaz-Santos, DAMIR, Instituto de Estructura de la Materia, CSIC
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Chad Engelbracht, Steward Observatory, University of Arizona
Marcia Rieke, Steward Observatory, University of Arizona
Pablo Perez-Gonzalez, Steward Observatory, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap IrsStare
Hours Approved: 14.6

Abstract:
We propose to measure the mid-infrared spectroscopic properties (using the IRS Spectral Mapping mode with the low and high spectral resolution modules) of four local luminous infrared galaxies (LIRGs). Current Spitzer cosmological surveys at 24micron are revealing a population of high-z LIRGs that account for nearly 50% of the cosmic IR background at z~1 . The interpretation of these distant LIRGs depends on a deep understanding of local LIRGs. These LIRGs have been selected to have strong nuclear emission (in two due to the presence of an AGN) as well as extended (over a few tens of arcsec) star formation. These four LIRGs together with our sample of 11 LIRG obseved in Cycle-3 are representative of a volume-limited sample (distances of 35 to 76Mpc). We obtained HST/NICMOS continuum and Pa-alpha observations in Cycle 13, and there are archival IRAC and MIPS observations for the sample. The regions to be mapped with the IRS (central 20-30arcsec) cover the majority of the mid-IR emitting area of these LIRGs, so the entire set of HST and Spitzer data can be converted into integrated properties. The goals of this proposal in conjunction with our Cycle-3 observations are: (1) To use the high spectral resolution modules to look for high excitation lines to reveal obscured AGN, and to determine the nature of the dominant energy source when both AGN and star formation are present, as observed in a large fraction of high-z LIRGs and ULIRGs (2) To calibrate the mid-IR star formation rate indicators, such as the 24micron luminosity; the [NeII]12.8micron emission line, and the aromatic emission features for LIRGs and compare them with the behavior of normal galaxies (3) To characterize the obscuration and to understand the properties of the star-forming regions of LIRGs, and compare them with less extreme cases such as starburst galaxies from SINGS (4) To construct local templates for high-z IR bright galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50155

The MIPS SED of SHOC 391

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsSed
Hours Approved: 0.9

Abstract:
We propose to measure the star forming galaxy SHOC 391 using the MIPS Spectral Energy Distribution (SED) mode. SHOC 391 is one of only three star forming galaxies known to have an SED peak in the mid infrared (MIR) rather than the far infrared (FIR). This behavior may result from an early stage in starburst evolution where very hot stars are still embedded in optically thick (in the near infrared) dust clouds. Measurements of the FIR behavior can expand on this hypothesis. The precise position of that peak and the strength of the FIR emission lines is best measured using the MIPS SED mode. We have measured one of these galaxies (Haro 11) in this mode, while another (SBS 0335-052) is far too faint. Thus, SHOC 391 is the only known star-forming galaxy with a short-wavelength infrared peak which has not been yet still can be measured using Spitzer's MIPS SED mode.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50158

The Dust Content of the Lowest Metallicity Star Forming Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Co-Investigators:
Joannah Hinz, Steward Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 16.4

Abstract:
We propose to measure dust masses for the lowest metallicity star forming galaxies known in the local universe. There are 15 galaxies with 12 + log(O/H) at or below 7.8 that have been detected at 70 microns, only three of which have significant detections at 160 microns in the shallow observations currently in the Spitzer archive. Without both 70 and 160 micron measurements, we are unable to compute dust temperatures and hence masses for the most metal poor star-forming galaxies. Star-forming galaxies with metallicities this low are likely undergoing their first significant episode of star formation, providing us local analogs of the galaxies forming in the early universe. Recent studies indicate that the dust properties at very low metallicity are significantly different from those in galaxies with metallicities larger than ~1/4 solar. Spitzer's new enhanced photometry mode at 160 microns provides us an opportunity to obtain the first detections of these galaxies beyond 70 microns, providing a critical anchor at the low-metallicity end of dust properties in nearby star-forming galaxies. 11 of the galaxies in our sample are amenable to detection at 160 microns - 3 have been detected in shallow observations and 1 (I Zw 18 - Bolatto et al.) will be observed soon. We propose to observe the other 7.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50213

Molecular Hydrogen Shocks As Tracers of Galaxy Evolution

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Suresh Sivanandam, University of Arizona

Co-Investigators:
Suresh Sivanandam, University of Arizona
Marcia Rieke, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap
Hours Approved: 22.1

Abstract:
We propose to search for shocked molecular hydrogen emission in 4 infalling cluster galaxies with strong evidence for ram-pressure stripping to understand how galaxies are transformed in the cluster environment. With IRS, Appleton et al. (2006) have observed strong molecular hydrogen emission emanating from Stefan's Quintet which can only be interpreted as a galactic scale shock created from the collision of galaxies with the intragroup medium. Spitzer spectroscopy offers a direct and quantitative way to observe interactions between the intragroup/intracluster medium and the galactic interstellar medium unlike other techniques that only observe after-effects of gas-stripping events. We will use IRS spectral mapping, following the methodology of Appleton et al., of the four likeliest nearby candidates for ICM/ISM interactions. These candidates have a variety of telltale signs that they are undergoing some form of interaction with the ICM, such as bow-shock like star-forming regions, H-alpha and X-ray tails, extraplanar HII regions, etc. We also propose to acquire ancillary deep IRAC data to improve the spatial resolution of our IRS data as 4.5-micron IRAC data are sensitive to molecular hydrogen emission. Combined with 8-micron imaging we can distinguish between molecular hydrogen emission produced in shocks and in photodissociation regions found in star-forming regions. We will also study the star-forming properties of these galaxies and how they relate to galactic scale shocks.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #60

Dust in Giant Extragalactic H II Regions in M101

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Karl Gordon, The University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap MipsScan MipsSed
Hours Approved: 16.3

Abstract:
This program is aimed at investigating the evolution of dust grain properties as a function of star formation activity. This program is aimed at acquiring 4-200 micron photometric spectral energy distributions on a large number (~500) of H II regions in M101. All of M101 (35’ x 35’) will be imaged with MIPS and IRAC resulting in images of the galaxy at 7 wavelengths from 4 to 160 microns. In addition, a smaller sample (~10) of the brighter H II regions will be observed with MIPS SED mode and IRS in both low and high resolution modes. This sample was defined to include H II regions in M101 which span a range of metallicities (7.9-9.1), luminosities, and dust contents. The low resolution spectroscopy will be used to determine the PAH emission spectrum and continuum level. The high resolution IRS spectroscopy will give various emission lines which act as diagnostics of the gas and stars present. When combined with existing ultraviolet images of M101, the resulting data will be used to probe the properties of dust associated with H II regions. This will be done using their ultraviolet attenuations and PAH emission spectra.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #62

Dust in Low Surface Brightness Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: George Rieke, The University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsStare MipsPhot MipsSed
Hours Approved: 15.3

Abstract:
Low surface brightness galaxies may represent a significant componentof the baryonic matter in the Universe. However, these galaxies appearto have followed a very different star formation history fromhigh surface brightness galaxies. IRAS was able to detect a coupleof these galaxies as was ISO, but enough data to characterizethe dust temperature and spatial distribution were not acquired.This project uses MIPS photometry mode to detect the dust ina sample of LSB galaxies chosen to have low cirrus and sufficientlylarge angular diameters for resolution by MIPS.

Spitzer Space Telescope - Directors Discretionary Time Proposal #240

Intergalactic Star Formation in Tidal Dwarf Galaxies of M81

Principal Investigator: Theresa Roelofsen
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Timothy Spuck, Oil City Area Sr. High School
Doris Daou, Spitzer Science Center
Cynthia Weehler, Luther Burbank High School

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 0.4

Abstract:
We propose to extend the area of existing Spitzer M81 observations to include the coordinates of these recently discovered tidal dwarf galaxies (TDGs). This will allow us to compare stellar formation in young TDGs with the disc of M81 to determine if the process of star formation differs in debris tails. The close proximity of M81 (3.6 Mpc: Freedman et al, 2001) makes these particular TDGs an ideal target for the study of the formation of stars due to galactic interaction. If metallicity in this area is low it could be analogous to stellar formation in the early universe. This would then be a unique opportunity to study early universe stellar conditions in a region of low redshift. This proposal will compare stellar formation conditions in TDGs and galactic discs. We propose to use IRAC's capabilities to look for PAH emission, indicating the presence of dust in the debris tails. The mid-IR capabilities of MIPS will provide the thermal properties of this dust.

Spitzer Space Telescope - General Observer Proposal #50520

Using Spitzer to Probe Galaxy Evolution in the Young Cluster Abell 1367

Principal Investigator: Jessica Rosenberg
Institution: Harvard-Smithsonian Center for Astrophysics

Technical Contact: Jessica Rosenberg, Harvard-SAO

Co-Investigators:
Luca Cortese, Cardiff University
Karen O'Neil, NRAO Green Bank
Maarten Baes, Universiteit Gent
Robbie Auld, Cardiff University
Jon Davies, Cardiff University
Robert Minchin, Arecibo Observatory

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 15.2

Abstract:
The galaxy cluster environment alters the properties of galaxies. However, the mechanisms and timescales that govern these changes are not well understood. We propose to use Spitzer (IRAC + MIPS 24um) in combination with existing UV, H$alpha$, and 21cm data, to study both the mechanisms and timescales in the Abell 1367 cluster. The cluster is young so there is a large sample of galaxies that are currently being transformed from blue, gas-rich systems to red stellar dominated ones. The sample we will use for this work is unique -- we will study both galaxies selected at 21 cm and in the optical. The 21cm selected systems in Abell 1367 have been found to be distributed fairly uniformly throughout the cluster while the optically-selected galaxies are strongly centrally concentrated. This is the first time that HI-selected galaxies in a cluster are being studied alongside an optically selected sample and they should provide an important probe of the galaxies for which the cluster may just be starting to have an effect as well as for the ones that have already been strongly altered by its influence. Spitzer provides important information to this study because it can be used to measure activity in galaxies over a longer timescale than the H_alpha measurements. In addition, the Spitzer data complement the UV data by probing the dusty regions of the galaxies.

Spitzer Space Telescope - General Observer Proposal #3412

Galactic Chemical Evolution and the Hot Star, H II Region Connection

Principal Investigator: Robert Rubin
Institution: NASA Ames Research Center

Technical Contact: Robert Rubin, NASA Ames Research Center

Co-Investigators:
Janet Simpson, NASA Ames Research Center
Adi Pauldrach, University Munich
Sean Colgan, NASA Ames Research Center
Reginald Dufour, Rice University
Edwin Erickson, NASA Ames Research Center
Michael Haas, NASA Ames Research Center

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 21.0

Abstract:
H II regions play a crucial role in the measurement of current interstellar abundances in our Galaxy and others while also serving as laboratories for atomic physics. They provide fundamental data about heavy element abundances that serve to constrain models of galactic chemical evolution.We propose to use Spitzer/IRS to measure the Ne/H and S/H abundances in H II regions in two very different, ~face-on spiral galaxies M83 and M33. By observing face-on galaxies, we will cover a full range of galactocentric radii (R_G) and avoid the extinction problems that plague Milky Way studies of H II regions, particularly in the inner Galaxy. An important advantage compared with prior optical studies is that the IR lines have a weak and similar electron temperature (Te) dependence while optical lines vary exponentially with Te. We plan to observe 5 emission lines: S IV 10.5, Ne II 12.8, Ne III 15.6, S III 18.7, & H7-6 12.4 micron cospatially with IRS/SH. By virtue of being able to measure lines from all the major ionic states of Ne and S in H II regions, together with an H line, in the SAME spectrum, there is a unique opportunity to obtain reliable Ne/H & S/H ratios and determine how they vary with R_G. With our prior efforts to measure the Galactic Ne/O ratio using far-IR lines, we found that the observed Ne++/O++ ratio significantly exceeds model predictions. This has been referred to as the "Ne III problem". The nebular models rely on stellar atmosphere models to provide the ionizing spectral energy distribution (SED) for hot stars. The SED used is the largest source of uncertainty when comparing theory and observations to determine nebular abundances in general (and galactochemical gradients). We will use novel diagnostic tools designed to investigate the Ne III problem via the proposed observations to validate the SED input to the nebular code. Whether or not we solve the Ne III problem, we will produce the most detailed and reliable study by far of abundance variations for S/H and Ne/H in these galaxies.

Spitzer Space Telescope - General Observer Proposal #50339

Beyond the Bulge: A Spitzer Search for Buried AGN in Pure Disk Galaxies

Principal Investigator: Shobita Satyapal
Institution: George Mason University

Technical Contact: Shobita Satyapal, George Mason University

Co-Investigators:
Nick Abel, University of Cincinnati
Torsten Boeker, European Space Agency, Dep. RSSD
Rachel Dudik, George Mason University
Mario Gliozzi, George Mason University
Tim Heckman, John Hopkins University
Devin Vega, George Mason University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 14.5

Abstract:
The well-known correlation between the black hole mass and the stellar velocity dispersion in bulge-dominated galaxies has fueled numerous speculations that black hole growth and the build-up of galaxies go hand in hand and that perhaps the presence of a bulge is necessary for a black hole to grow. Indeed, prior to Spitzer, the vast majority of actively growing black holes(AGN) in the local Universe were found in galaxies with prominent bulges. However, these studies are based on optical spectroscopic studies, which can be severely limited in the study of bulgeless galaxies, where a putative AGN is likely to be both energetically weak and deeply embedded in the center of a dusty late-type spiral. Remarkably, we have discovered using the limited set of Spitzer observations currently available, that AGN in late-type optically normal galaxies do exist and that Spitzer high resolution spectroscopy is the only way to find them. However, most IR spectroscopic studies have targeted infrared luminous and ultraluminous galaxies which are virtually all disturbed interacting systems. Only a handful of IRS observations of extremely late-type purely isolated galaxies exist. To address this serious deficiency, we propose a systematic search for potentially weak and obscured AGN using high resolution IRS staring observations of a unique, statistically significant sample of definitively bulgeless and purely isolated galaxies. We will: 1) determine the fraction of AGN in bulgeless galaxies 2) compare this fraction to that found in early-type and interacting galaxies based on previous studies, 3) determine if the incidence of AGN activity, the AGN's luminosity, or black hole mass, is correlated with the implied dark matter or disk mass. No such IR study has ever been conducted, leaving a glaring hole in our understanding of one of the most fundamental questions in extragalactic astronomy today.

Spitzer Space Telescope - General Observer Proposal #20587

A Detailed Study of the Spiral Density Wave in M51: Tracing the Temporal Evolution of Star Formation

Principal Investigator: Eva Schinnerer
Institution: Max Planck Institute for Astronomy

Technical Contact: Eva Schinnerer, Max Planck Institute for Astronomy

Co-Investigators:
Kartik Sheth, Caltech
Stuart Vogel, University of Maryland
Lee Armus, Caltech
Rob Kennicutt, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 9.1

Abstract:
Spiral Density Waves (SDWs) are believed to trigger star formation in spiral arms in galactic disks. We have embarked on a (optical to radio) multi-wavelength project to study the effect of a SDW in a well-selected region in M51. We see evidence that a significant fraction of on-going star formation is missed by our current tracers. Thus we request IRS high resolution spectroscopy (SH and LH) to quantify via MIR (H2,fine-structure) lines the properties of deeply embedded young star forming regions and of the warm molecular gas. This unique study will significantly increase our understanding of the physical processes that transform molecular gas into stars by taking advantage of the spatially resolved time evolution: from young molecular clouds (traced by molecular line emission) via star forming regions (seen in the IRS lines and the radio continuum) to mature stellar clusters (seen via H recombination lines, HST colors).

Spitzer Space Telescope - General Observer Proposal #20138

The M51 MIR Spectral Cube: A "Rosetta Stone" for Galaxy Evolution

Principal Investigator: Kartik Sheth
Institution: California Institute of Technology

Technical Contact: Kartik Sheth, California Institute of Technology

Co-Investigators:
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Stuart Vogel, U. Maryland
Mark Wolfire, U. Maryland
Lee Armus, Caltech
Daniel Dale, U. Wyoming
J.D. Smith, U. Arizona
George Helou, Caltech

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap IrsPeakupImage
Hours Approved: 15.0

Abstract:
The SINGS legacy survey is collecting a remarkable dataset for a large sample of nearby galaxies. Due to time constraints, however, the spectral data are limited. Except for the nucleus and a few selected HII regions, no SINGS galaxy has a full 5--37 micron spectral coverage across a galactic disk. The LL strips across the disks cover 14--37 microns missing most of the PAH features and other important spectral diagnostics limiting the use of the broadband data. This leaves open important questions about the state of the interstellar medium and the radial and regional variations across the disk. We propose to study the complete mid-infrared spectrum at low resolution (SL+LL) across the disk of the well studied, face-on, grand design spiral M51. We also propose to exploit the new peak-up imaging mode to obtain a 16 micron map of M51 to trace the dust continuum and determine the true PAH strengths. We chose M51 not only because it has a wealth of ancillary data but also because we have recently acquired a complete single dish + interferometer CO mosaic and 4, 6 and 20 cm radio continuum maps. This rare combination of data is well suited for a detailed study of the ISM as the CO traces the molecular gas and the radio continuum traces (extinction-free) star formation. We will combine these data with the proposed mid-infrared spectral data to determine the variations in the dust continuum and PAH emission as a function of radius and environment, the change in the ISM density, radiation field and grain size, and the change in the fraction of warm molecular gas across the disk. With this study M51 will be the spectral template for interpreting the wealth of broadband infrared data on nearby galaxies, and for improving our understanding of the dust content and dust properties of high redshift galaxies that are derived from rest-frame mid-infrared emission studies.

Spitzer Space Telescope - General Observer Proposal #20518

The Physical Context of PAH Emission in Galaxies: Metallicity, Radiation, and Environment

Principal Investigator: JD Smith
Institution: University of Arizona

Technical Contact: JD Smith, University of Arizona

Co-Investigators:
Evan Skillman, Univ. of Minnesota
Bruce Draine, Princeton Univ.
Daniel Dale, Univ. of Wyoming
Don Garnett, Univ. of Arizona
Lee Armus, Spitzer Science Center, Caltech
Robert Kennicutt, Univ. of Arizona
Karl Gordon, Univ. of Arizona
Chad Engelbracht, Univ. of Arizona
Aigen Li, Univ. of Missouri-Columbia

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 47.9

Abstract:
The PAH emission bands between 3-20 microns are uniquely important for modeling high redshift sources in the deep infrared surveys currently being produced by Spitzer's imaging instruments. Although very little is known about the physical mechanisms of formation, excitation and destruction which govern the behavior of PAH molecules, an important correlation has been very recently uncovered in low-metallicity dwarf starbursts: PAH features seem to vanish at a threshold oxygen abundance near 1/5 solar. Given the many factors known to influence PAH emission, it is very likely that metallicity alone does not govern its strength or presence. Early hints from much smaller and shallower spectral mapping data in the center of nearby galaxies suggest strong variability in the PAH emission spectrum on sub-kpc scales. Our goal is to probe the global mechanisms which govern the appearance and behavior of PAH emission. We propose deep, spatially resolved, low-resolution spectral maps from 5 to 38 microns, arranged in radial strips (approximately 1 x 5-10 arcmin) in three nearby galaxies with steep, well-measured oxygen abundance gradients. These data, when combined with existing IRS spectroscopy of bright HII regions in the target sample, will allow us to probe in detail the strength and structure of PAH emission over a wide range of physical parameters in the ISM, including metallicity, radiation field intensity, and environment (e.g. arm/inter-arm). In addition, we will use the five accessible pure rotational molecular hydrogen lines to test PDR models as a function of metallicity, and track low luminosity HII regions with the available fine structure lines of sulfur and neon. The deep, wide coverage spectral mapping strips produced will be of significant general scientific value, and for the two targets in the SINGS Legacy sample, we will waive the proprietary period to maximize their utilization.

Spitzer Space Telescope - General Observer Proposal #30471

PAH Emission in Low-Luminosity AGN: Ghosts in the Machine

Principal Investigator: JD Smith
Institution: University of Arizona

Technical Contact: JD Smith, University of Arizona

Co-Investigators:
John Moustakas, University of Arizona
Lisa Kewley, University of Hawaii, Institue for Astronomy
Bruce Draine, Princeton University
Lee Armus, Spitzer Science Center
Danny Dale, University of Wyoming
Vassilis Charmandaris, University of Crete

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap IrsStare
Hours Approved: 39.0

Abstract:
Massive nuclear black holes are now recognized as a fundamental property of almost all local elliptical and spiral galaxies, and low-luminosity AGN play an important role in modifying the observational form of even predominantly star-forming galaxies. The PAH emission bands between 3-18 microns dominate the MIR emission of star-forming galaxies, contributing up to 20% of the total 3-1100 micron infrared luminosity in these features alone. PAHs are uniquely important for modeling high redshift sources in the deep infrared surveys currently being produced by Spitzer's imaging instruments, and are commonly used to probe ongoing star formation, locally, and at high redshift. Although it is commonly assumed that AGN destroy all PAH grains, very recent results from the SINGS survey have uncovered important clues into the power source of galaxies containing low-luminosity AGN, with indications that the gas environments in these nuclei lead to a distinctive and unusual PAH emission spectrum, with marked suppression of the short wavelength PAH bands. These results suggest that the AGN itself may be providing the UV photons necessary to excite this PAH emission. This could have a profound impact on the use of PAH bands as indicators of star-formation rate in systems hosting weak AGN. Or goal is to uncover the nature of PAH emission in galaxies hosting low-luminosity AGN. We propose deep, low-resolution IRS spectral mapping of a small sample of nearby LLAGN to test whether AGN can excite PAH emission, and assess the energetic importance and physical extent of such emission in galaxies with both weak AGN and extended star-formation. We will quantify the difference in the PAH emission spectrum seen in such sources, compared to normal galaxies, and use these results to investigate the predominant power source of low-luminosity AGN. We will also investigate the degree to which AGN-fueled PAH emission could contaminate star-formation rates derived from the absolute strength of the PAH bands.

Spitzer Space Telescope - General Observer Proposal #40757

After the Fall: Dust and PAHs in Post-Starburst Galaxies

Principal Investigator: JD Smith
Institution: Steward Observatory, U. Arizona

Technical Contact: JD Smith, Steward Observatory, U. Arizona

Co-Investigators:
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Yujin Yang, Steward Observatory
Bruce Draine, Princeton University
Danny Dale, University of Wyoming
Ann Zabludoff, Steward Observatory
Emeric Le Floc'h, University of Hawaii

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 27.9

Abstract:
Post-starbursts, a class of galaxies discovered in large redshift surveys, are believed to be in transition from strong merger-induced starbursts to truly quiescent systems. Their distinctive optical spectra enable very precise measurements of their stellar populations, which range in burst age from 0.1-1.5 Gyr. These rare galaxies may hold the key to unlocking a recently discovered mystery regarding the behavior of PAH emission in low-luminosity AGN, which has a fundamental impact on the reliability of PAHs as direct indicators of star formation. Post-starburst galaxies, with little ongoing star formation and well understood stellar populations, offer the perfect laboratory in which to test the response of PAHs to the reduced star formation activity often associated with AGN. In these systems, the violent feedback which quenches the star formation is thought to completely expel most of the dust and gas. Though very little is known about the dust properties of these galaxies, a small number of serendipitous Spitzer observations indicates that they have strong and uniform infrared excess over the expected photospheric emission. Our goal is to study the dust content of this unique class of galaxy. Drawing on over 1 million spectra from the SDSS DR5, we have selected 15 post-starburst galaxies at z~0.04 with expected IR fluxes readily accessible by Spitzer. We propose deep, low-resolution IRS spectra and full 3-160um imaging of this carefully selected sample. We will test the response of PAH emission to their young but aging stellar populations, and probe the ISM-clearing feedback scenarios thought to drive their evolution. We will put strong limits on the amount of embedded star-formation hidden from optical view, and track the conditions of any warm gas in the systems. And we will combine the sample with local studies of low-luminosity AGN to help investigate the degree to which AGN-fueled PAH emission could contaminate star-formation rates derived from the absolute strength of the PAH bands.

Spitzer Space Telescope - General Observer Proposal #40877

Warm H2 at the Edge of NGC 891: Determining the Excitation and Mass of the Most Common Molecule

Principal Investigator: Gordon Stacey
Institution: Cornell University

Technical Contact: Gordon Stacey, Cornell University

Co-Investigators:
Thomas Nikola, Cornell University
Vassilis Charmandaris, University of Crete
Francois Boulanger, Institut d'Astrophysique Spatiale, Université Pari
Sarah Higdon, Georgia Southern University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 16.4

Abstract:
We propose to obtain deep IRS spectra of the outer disk of the nearby edge on spiral galaxy NGC 891. Our primary goal is to investigate the physical state, mass, and heating processes in the molecular ISM through investigations of four pure rotational lines of H2. Pioneering work in the S(0) and S(1) lines with ISO indicate large quantities of warm (T ~ 120 K) molecular clouds along the disk of the galaxy ? fully half of the cold H2 component traced in CO. Furthermore, the ISO results suggest vast quantities of cool (T < 90 K) molecular gas at radii beyond 8 kpc ? 5 to 15 times the mass of the atomic gas, and perhaps enough to solve the missing mass problem within the disk of the galaxy! These are exciting results that need to be verified. The key element, however, is that the large masses depend on an assumed ortho to para H2 ratio, and uncertain gas excitation due to limited lines. For example, GTO time spectra in the S(1) and S(0) lines are consistent with the ISO results, but adding in the S(2) line leads to an interpretation invoking a small ortho to para ratio (~ 0.65), and larger gas temperatures, resulting in 1/10 the mass of warm molecular gas! Unfortunately, our spectra are not deep enough to detect the S(2) line in the outer galaxy, so we are unable to properly model the gas excitation there. This proposal is to go at least 5 times deeper in the most interesting regions of the outer galaxy to strongly detect the S(2) line. We also plan to scour the outer regions (R > 12 kpc) for cool molecular gas by deep integrations in the S(1) and S(0) lines. Finally, we plan a sparse map of most of the disk to detect the S(3) line using the Short-Lo spectrometer. The S(0), S(2), and S(1) and S(3) transitions constrain the excitation of para and ortho H2 respectively, and together yield the o/p ratio. The four lines will therefore solidly establish the mass of warm and cool molecular gas in NGC 891. Are there massive quantities of cool gas in the outer disks of galaxies?

Spitzer Space Telescope - General Observer Proposal #50380

The Molecular Gas Excitation and Mass in Edge-On Spiral Galaxies: Constraining the Physical Parameters

Principal Investigator: Gordon Stacey
Institution: Cornell University

Technical Contact: Gordon Stacey, Cornell University

Co-Investigators:
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Sarah Higdon, Georgia Southern University
Vassilis Charmandaris, University of Crete

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 33.5

Abstract:
We propose to accurately trace molecular gas excitation and mass along the plane of the two nearby nearby edge-on spiral galaxies, NGC 4905 and 5907 through deep IRS spectroscopy of four pure rotational lines (S(3), S(2), S(1), and S(0)) of H2. Our primary goal is to investigate the physical state, mass, and heating processes in the molecular ISM in these galaxies, and compare them with our on-going study of the edge-on galaxy NGC 891. Prior modeling of the S(1) and S(0) emission from NCG 891 suggests an enormous amount of cool (T< 90K) H2 (5 to 15 times the atomic mass) for this galaxy if the ortho to para H2 ratio is 3. However, these models are hampered by the degeneracy between gas excitation and the (assumed) o/p ratio. Including the S(3) and S(2) lines in the analysis breaks the degeneracy, enabling independent determination of gas excitation for the ortho and para species, and a measure of the o/p ratio. Using three lines (S(2), S(1), and S(0)) for NGC 891, we find gas excitation near 220 K, with an o/p ratio near unity, resulting in greatly reduced molecular gas mass. We were awarded time in Cycle 4 to verify this model through deeper integrations of the S(0), S(1), and S(2) lines, and observations of the S(3) line in NGC 891. {These observations have not yet been scheduled}. Here we propose to extend our study by mapping all four lines in the disks of galaxies with different gas contents than NGC 891: the early type Sb NGC 4565 and the late type Sc NGC 5907. We are particularly intrigued with the regions outside of the CO emitting disk where the gas is likely not heated in a PDR scenario but rather by modest velocity cloud-cloud collisions in the outer galaxy. The proposed observations address the heating source as the ortho and para ratio depends on the formation temperature: a larger ratio indicates a larger formation temperature. Did H2 form in a relatively warm far-UV bathed environment near stars, or in a cold environment devoid of young stars?

Spitzer Space Telescope - General Observer Proposal #20320

Supernovae and the Origin of Dust in Galaxies: Follow-Up Observations of SNe 1999bw, 2002hh, and 2004et.

Principal Investigator: Ben Sugerman
Institution: STScI

Technical Contact: Ben Sugerman, STScI

Co-Investigators:
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Janet Bowey, University College London
Geoffrey Clayton, Louisiana State University
Barbara Ercolano, University College London
Joanna Fabbri, University College London
Tim Gledhill, University of Hertfordshire
Karl Gordon, Steward Observatory, University of Arizona
Margaret Meixner, STScI
Nino Panagia, STScI
Alexander Tielens, University of Groningen
Michael Wolff, Space Science Institute, University of Colorado
Albert Zijlstra, UMIST, Manchester

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 6.4

Abstract:
The role that massive stars play in the dust content of the Universe is extremely uncertain. While these stars may create considerable amounts of circumstellar dust in their stellar winds, the actual amount formed, and how much of it survives the eventual impact with the star's supernova (SN) blast, are not well known. It has long been hypothesized that dust can condense within the ejecta of SNe, however there is a frustrating discrepancy between the amounts of dust found in the early Universe, predicted by nucleation theory, and inferred from SN observations. The main problem is that dust emission is best observed in the mid-IR, but before the launch of Spitzer, instruments lacked the necessary sensitivity. We are now carrying out a sensitive mid-IR survey for thermal dust emission from recent SNe to address the extent to which they produce dust, and whether they are a primary source of dust in the Universe. We propose a comprehensive set of follow-up IRAC, MIPS, and IRS observations for the first three SNe discovered by our project: 2002hh and 2004et in NGC 6946 (d=6 Mpc), and 1999bw in NGC 3198 (d=14.5 Mpc). SN 1999bw is enigmatic, as its IR excess is that predicted for a SN half its age. SN 2002hh has a mid-IR excess from circumstellar dust, but has yet to show any signs of dust condensation. SN 2004et is very young and IR luminous, allowing us to carefully monitor its IR evolution from the earliest times. The rapid evolution of mid-IR emission make our observations time-sensitive, and if follow-ups are not made, critical scientific opportunities may be permanently lost. We will use these and archival observations with radiative-transfer models to determine the mass, temperature, grain properties, and location of dust in each SN. These detailed results are crucial for quantifying the contribution of SNe to the dust content of galaxies. Furthermore, SNe within 6 Mpc are rare, so SNe 2002hh and 2004et may be among the best objects we will encounter during Spitzer's lifetime for this study.

Spitzer Space Telescope - General Observer Proposal #30494

Supernovae and the Origin of Dust in Galaxies: Follow-Up Observations of Six SNe

Principal Investigator: Ben Sugerman
Institution: STScI

Technical Contact: Ben Sugerman, STScI

Co-Investigators:
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Janet Bowey, University College London
Geoffrey Clayton, Louisiana State University
Barbara Ercolano, University College London
Joanna Fabbri, University College London
Tim Gledhill, University of Hertfordshire
Karl Gordon, Steward Observatory, University of Arizona
Ciska Markwick-Kemper, UVa
Margaret Meixner, STScI
Martin Meyer, STScI
Nino Panagia, STScI
Alexander Tielens, University of Groningen
Michael Wolff, Space Science Institute, University of Colorado
Albert Zijlstra, UMIST, Manchester

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsPeakupImage IrsStare MipsPhot
Hours Approved: 11.7

Abstract:
The role that massive stars play in the dust content of the Universe is extremely uncertain. It has long been hypothesized that dust can condense within the ejecta of supernovae (SNe), however there is a frustrating discrepancy between the amounts of dust found in the early Universe, predicted by nucleation theory, and inferred from SN observations. We are now carrying out a sensitive optical through mid-IR survey for thermal dust emission from recent SNe to address the extent to which they produce dust, and whether they are a primary source of dust in the Universe. We propose a comprehensive set of follow-up IRAC, MIPS, and IRS observations for six recent SNe within 10 Mpc: SNe 2002hh, 2003gd, 2004am, 2004dj, 2004et, and 2005cs. Of these, four have identified progenitors, all but one have already been observed with Spitzer, two are forming dust, and one shows evidence of emission from pre-existing circumstellar material. In short, these six SNe offer our best chance of comparing measurements of condensed dust masses to theoretical predictions and establishing the role of SNe in the formation of dust in the early Universe. In the mid-IR, SNe are known to evolve rapidly, on timescales of 100 days or less, making our observations time-sensitive, and if follow-ups are not made, critical scientific opportunities may be permanently lost. Our proposed observations, combined with ground-based and HST optical observations, provide the ideal dataset through which the condensation and evolution of dust can be monitored, allowing us to use advanced radiative-transfer models to determine the the dust masses, temperature, grain properties, and location with unparalleled accuracy. Not only will be directly test theories of dust formation within supernovae, but these detailed results are crucial for quantifying the contribution of SNe to the dust content of galaxies. Furthermore, SNe within 10 Mpc are rare, so these may be among the best objects we will encounter during Spitzer's lifetime for this study.

Spitzer Space Telescope - General Observer Proposal #30894

Spitzer's Unobscured View of the DiskMass Survey: Fundamental Calibration of Light to Mass and Star-Formation to Mass Surface-Density

Principal Investigator: Robert Swaters
Institution: University of Maryland

Technical Contact: Robert Swaters, University of Maryland

Co-Investigators:
Matthew Bershady, University of Wisconsin
Marc Verheijen, Kapteyn Institute
David Andersen, Herzberg Institute of Astrophysics
Kyle Westfall, University of Wisconsin

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 26.3

Abstract:
Central themes of Spitzer observations include the uncovery of obscured star formation, the reliable assessment of bolometric luminosity, and the determination of how star formation depends on the interstellar medium in galaxies. As important is Spitzer's ability to observe the rest-frame near-infrared out to high redshift, from which estimates of stellar mass can be inferred. However, the legacy of the Spitzer Space Telescope will remain on uncertain footing until we understand how light traces mass, and how star formation traces mass surface density. This fundamental calibration has not been established despite an enormous investment in Legacy, GO and GTO programs. We propose to obtain a modest 26.3h of Spitzer observations for our DiskMass survey of 41 nearby, nearly face-on galaxies. This sample is unique in having direct dynamical estimates for halo mass as well as the mass surface density of the spiral disks. This information is derived from velocity and velocity dispersion maps of both stars and gas, measured with custom-built intergral-field spectrographs, to which the sample was tailored. These data are supplemented by deep optical and NIR photometry and two-dimensional maps of optical spectroscopic line ratios of the warm gas. What is missing is the infrared surface photometry at 8, 24, and 70 microns, from which we can measure the cold and warm dust emission and determine extinction and bolometric star formation rate as a function of both dynamical and gas mass surface density. Our measurements are complementary to, and will utilize the more detailed Spitzer measurements of, e.g., the SINGS Legacy program. Our proposal requires a small investment of observing time to accomplish the critical task of calibrating stellar mass-to-light ratios and the relation of star formation to physical environment within galaxies. This fundamental task benefits every Spitzer program which purports to measure the buildup of stellar mass and/or to probe the physical processes which drive star-formation.

Spitzer Space Telescope - General Observer Proposal #50594

Star Formation in the Low Surface Brightness Galaxy UGC 3371

Principal Investigator: Robert Swaters
Institution: University of Maryland

Technical Contact: Robert Swaters, University of Maryland

Co-Investigators:
Matthew Bershady, University of Wisconsin, Madison
Marc Verheijen, Kapteyn Institute

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 2.7

Abstract:
A central Spitzer theme is understanding how star formation depends on local conditions within galaxies. Previous studies span a wide range in galaxies, including massively star-forming, interacting, normal, and local-group galaxies. Missing from this expansive range are low surface brightness galaxies (LSBs). We propose to fill this gap and increase the legacy value of the Spitzer archive by observing a disk galaxy deep into the LSB regime. These LSBs present an unsolved puzzle in our understanding of star formation: Why do LSBs, rich in gas, have such low star formation rates? It has been suggested LSBs have gas densities below a critical threshold, thus inhibiting star formation. However, this is largely based on low-resolution or globally averaged data, insensitive to the ubiquitous small-scale structures in the gas densities and kinematics of LSBs. To understand what physically drives star formation in LSBs, a high-resolution, two-dimensional approach is required. To this end, we propose to acquire deep 24 micron MIPS photometry of UGC~3371. This galaxy is well suited because its large size, modest inclination and regular circular motion permit a detailed and simultaneous study of morphology and kinematics. We have acquired a deep, high-resolution VLA-B map at 21 cm, yielding an unprecedented view of the HI distribution and kinematics on 300 pc scales in an LSB galaxy. Deep H$\\alpha$ integral-field spectroscopy, optical, NIR, and H$\\alpha$ imaging also are in hand. We will use the proposed Spitzer observations to determine the bolometric star-formation rates on 300 pc scales. Combining these data, we will determine how star-formation is modulated as a function of kinematic properties, gas densities, and local disk instabilities. The proposed Spitzer observations will provide a unique picture of star formation in the extreme LSB regime. This, in turn, will be invaluable for our understanding of star formation in other low density environments, such as the outskirts of normal galaxies.

Spitzer Space Telescope - General Observer Proposal #20171

The Origin and The Evolution of Dust in the Hot Interstellar gas of Elliptical Galaxies

Principal Investigator: Pasquale Temi
Institution: NASA Ames & SETI Institute

Technical Contact: Pasquale Temi, NASA Ames & SETI Institute

Co-Investigators:
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Joel N. Bregman, University of Michigan
Fabrizio Brighenti, University of California, Santa Cruz
Jesse D. Bregman, NASA Ames

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 19.8

Abstract:
Detection of elliptical galaxies at 60 and 100 microns with the IRAS satellite showed conclusively that these galaxies contain truly interstellar dust, which is mixed into hot interstellar gas at the virial temperature, typically 10e7 K. Dust grains in this harsh environment are progressively destroyed by collisions with thermal protons that dislodge atomic fragments from the grain surface (sputtering). However, as the dust grains are slowly reduced in size, they are heated both by UV stellar radiation from post-AGB stars and by inelastic collisions with thermal electrons and this energy is radiated in the far-IR. New dust grains are continuously injected into the interstellar gas by dusty stellar winds from red giant stars. Dusty stellar winds are verified by mid-IR observations of ellipticals where the emission follows a de Vaucouleurs stellar profile. The total far-IR emission from internally produced grains during their sputtering lifetime is roughly consistent with the far-IR luminosities observed so far, but large discrepancies between expectation and observation have recently become evident. For example, in one giant Virgo elliptical the far-IR emission observed with ISO is about 40 times larger than expected, while another similar Virgo elliptical was undetected. The detected galaxy may have recently received a contribution of new dust from a merger with a gas-rich galaxy, but the merger must have been very recent indeed since the dust destruction time is only about 10e8 years. We propose to observe a small number of nearby spatially-resolved and optically luminous elliptical galaxies with SPITZER in order to calibrate our theoretical models of dust creation, destruction and radiation. In addition we wish to evaluate the alternative hypothesis that mergers are an important source of interstellar dust. Almost nothing is currently known about the radial distribution of far-IR emission from ellipticals, but we expect SPITZER to change this soon.

Spitzer Space Telescope - General Observer Proposal #3139

The infrared spectral energy distribution of metal-deficient blue compact dwarf galaxies: local templates for primordial galaxies

Principal Investigator: Trinh Thuan
Institution: University of Virginia

Technical Contact: Trinh Thuan, University of Virginia

Co-Investigators:
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Yuri Izotov, Main Astronomical Observatory, Kiev, Ukraine
Marc Sauvage, Centre d'Etudes de Saclay, France
Stephanie Plante, Universite Laval, Quebec, Canada

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 39.1

Abstract:
ISO, COBE and SCUBA have shown convincingly that dusty star formation plays a key role in the early universe, although it is often assumed in primordial galaxy formation scenarios that dust is essentially absent. Such an assumption however has recently been challenged by the detection of dust emission in the second-most metal-poor star-forming galaxy known (2.5% solar), the blue compact dwarf (BCD) SBS 0335-052. Thus, to interpret the spectra of high-redshift galaxies, it is crucial to understand how and when this ubiquitous dust component is formed and how it affects the spectral energy distribution (SED) of galaxies by redistributing the UV-optical energy radiated by the young stars in the star-forming regions to MIR and FIR energy. Low-metallicity BCDs constitute the best local approximations to primordial galaxies because of their chemically unenriched interstellar medium. We propose to use IRAC, IRS and MIPS to study the SED from 5 to 160 microns of a sample of 23 metal-deficient BCDs chosen to span a wide metallicity range, from Z(Sun)/30 to Z(Sun)/4. These objects will be analyzed together with similar objects in the ROC, more than doubling our sample. We wish to study how the SEDs change as a function of various physical parameters such as metallicity, the hardness of the ionizing radiation, and the compactness of the starburst region. We will also be able to assess dust production mechanisms. Spitzer will provide an unique view of these nearby chemically unenriched star-forming laboratories, and an unprecedented opportunity to study in detail dust in very metal-deficient environments.

Spitzer Space Telescope - General Observer Proposal #50272

Extreme Star Formation in Low-Metallicity Dusty Compact Dwarf Galaxies

Principal Investigator: Trinh Thuan
Institution: University of Virginia

Technical Contact: Leslie Hunt, INAF - Istituto di Radioastronomia/Firenze

Co-Investigators:
Yuri Izotov, Main Astronomical Observatory, Kyiv, Ukraine

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 36.5

Abstract:
Dusty star formation plays a key role in the early universe. ISOCAM, MIPS and submillimeter surveys have found significant populations of dusty luminous galaxies which dominate the cosmic infrared background at z >= 1. Some of these galaxies host starbursts with high star formation rates (SFRs) in such compact regions that they approach the maximum starburst intensity limit. Similar extreme conditions can occur in star clusters within nearby starburst galaxies, but these clusters generally do not dominate the light. We propose here to study extreme SF in the local universe in systems where most of the SF occurs in massive star clusters, the light of which does dominate the galaxy light. These systems are 23 low-metallicity dusty compact dwarf galaxies (DCDs) selected from the Sloan Digital Sky Survey to have a high SFR/area, potentially near the starburst intensity limit, and significant warm dust emission, a good indicator of extreme SF in massive star clusters. These DCDs will allow us to study the physics of extreme SF with a sensitivity and spatial and spectral resolution that high-z starbursts do not allow. We wish to use IRAC, IRS and MIPS to investigate how the spectral energy distributions of the DCDs, the dust properties, and the SFR/area change as a function of various physical parameters such as metallicity, the hardness of the ionizing radiation, and the compactness of the starburst region. Combining our proposed DCD observations with other data will allow us to quantify the amount of dust-enshrouded SF over a wide range of metallicities and dust properties and derive true SFRs, which are crucial for deriving the SFR as a function of cosmic epoch.

Spitzer Space Telescope - General Observer Proposal #20607

Mapping the Aromatic Emissions in the Nearby Spiral Galaxies IC 342 and Maffei 2

Principal Investigator: Jean Turner
Institution: UCLA

Technical Contact: Jean Turner, UCLA

Co-Investigators:
David Meier, UIUC
Lucian Crosthwaite, Northrop Grumman
Robert Hurt, IPAC/Caltech

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap IrsMap
Hours Approved: 7.6

Abstract:
We propose to map the nearby spiral galaxies IC 342 and Maffei 2 with IRAC, and their nuclear regions with IRS, to map out the spatial distribution of mid-infrared aromatic emission features for comparison with molecular line and HI maps. Our principal component analysis of the molecular line emission has revealed a complicated chemistry in the nucleus, dominated in some parts by shocks and in others by radiation fields. With IRAC maps we can extend the principal component analysis to mid-IR features. With IRS we can study the lines in the nucleus in greater detail but still with sufficient resolution to distinguish the regions of different chemistries. We also propose to do a large scale mapping of the disks of both galaxies with IRAC for comparison with our total neutral gas density maps from HI and CO.

Spitzer Space Telescope - General Observer Proposal #50361

MIPS Mapping of IC 342 and Maffei 2

Principal Investigator: Jean Turner
Institution: UCLA

Technical Contact: Jean Turner, UCLA

Co-Investigators:
David Meier, NRAO
Lucian Crosthwaite, Northrop Grumman

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot MipsScan
Hours Approved: 17.9

Abstract:
We propose to map the 24 and 70 micron emission in the disks of the nearby spiral galaxies, IC342 and Maffei 2. These galaxies are among the closest large spirals, actively forming stars, and each showing evidence of recent interaction. MIPS scanning mode is the ideal way to map the star formation, particularly young, obscured star formation, in the outer disks of these close and spatially large galaxies.

Spitzer Space Telescope - General Observer Proposal #50067

Testing the Nature of Ultraluminous X-ray Sources with Spitzer and Determining their Impact on their Immediate Environment

Principal Investigator: Kimberly Weaver
Institution: NASA GSFC

Technical Contact: Kimberly Weaver, NASA GSFC

Co-Investigators:
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Edward Colbert, JHU Applied Physics Lab
Tim Roberts, Durham University
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Ann Hornschemeier, NASA Goddard Space Flight Center
Leigh Jenkins, ORAU and NASA Goddard Space Flight Center
Martin Ward, Durham University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsMap
Hours Approved: 13.1

Abstract:
Based on our discovery that ultraluminous X-ray sources (ULX sources) in galaxies can impact their surroundings and thus produce key diagnostic IR spectral signatures, we propose IRS mapping observations of six ULX sources with Spitzer. These are chosen from established X-ray catalogs and have optical evidence for extended nebula or 'bubbles' or are located in regions near star formation. With these data, we will map key mid-IR diagnostic emission lines, such as [O IV] to measure the impact of a hard X/UV ionizing source. One of the only constraints on the emission geometry of ULX sources is set by observations of the ionization mechanism of the nebula with symmetric geometry that surround many of them. These nebula are very anamalous, being larger and more luminous than normal SNR and showing higher ionization than HII regions, and are likely photoionized by the ULX source. With our Spitzer observations, we will estimate the luminosity of the central object in the ionizing UV band in a geometry independent manner and test whether these sources are as luminous as the X-ray data would indicate, thus testing beaming models for the X-ray emission.

Spitzer Space Telescope - General Observer Proposal #50544

MIEOWS: The MIPS-IRAC Edge-on Wonder Survey

Principal Investigator: Tony Wong
Institution: University of Illinois, Urbana-Champaign

Technical Contact: Tony Wong, UIUC

Co-Investigators:
Richard Rand, University of New Mexico
Robert Benjamin, University of Wisconsin-Whitewater
Eric Murphy, Spitzer Science Center
J. Christopher Howk, University of Notre Dame

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 22.5

Abstract:
Many problems in galactic structure and evolution are uniquely addressed through the study of edge-on spirals. We request MIPS and IRAC imaging of nearby edge-ons, building on existing Spitzer observations to create a substantial, well-defined sample, limited only in K-band angular size. We describe three scientific applications enabled by such a sample that we will carry out by comparing with ancillary data. The first addresses the origin of gaseous halos, while the second tests the role of gravitational instabilities in star formation, and the third focuses on how cosmic rays diffuse into the halo. These are examples of the kind of work that such a sample can leverage, and we expect that it will serve as an important Spitzer legacy by providing a database for further comparative studies. Essential to this research on edge-ons is the use of MIPS 24um images as a high resolution, extinction-free star formation tracer, and IRAC imagery as tracers of the stellar and PAH distribution. The project exploits the unique capabilities of Spitzer which will not be available again in the near future.

Spitzer Space Telescope - General Observer Proposal #20780

Molecular Gas and Star Formation in Early-Type Galaxies

Principal Investigator: Lisa Young
Institution: New Mexico Tech

Technical Contact: Lisa Young, New Mexico Tech

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 21.3

Abstract:
Some early-type galaxies are now known to contain significant amounts of molecular gas. There is also a broad spectrum of evidence, from the UV through the radio, that some star formation may be occuring in these cold-gas-rich early type galaxies. But until now it has not been possible to make accurate estimates of the star formation rates in early type galaxies; one of the major problems has been very low angular resolution in the FIR data. The present proposal requests time for MIPS imaging of seven CO-rich early type galaxies. High resolution FIR images will be the key to estimating their star formation rates, testing the radio/FIR correlation, and gaining a new perspective on the star formation process in an unusual environment. The seven galaxies requested here will be supplemented with additional targets which have already been allocated time for MIPS imaging.

Spitzer Space Telescope - General Observer Proposal #20321

Exploring the Nature of Dust in the Extreme Outer Disks of Spiral Galaxies

Principal Investigator: Dennis Zaritsky
Institution: University of Arizona

Technical Contact: Dennis Zaritsky, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 8.5

Abstract:
Observations have demonstrated that dust (and star formation) exist in spiral galaxies well beyond the edge of the optical disk. This extended disk region may eventually play an important role in our understanding of how material infalls into galaxies, how star formation is regulated in low-density regions, how the initial chemical enrichment of galaxies proceeds, and how angular momentum is distributed in the baryonic component of galaxies. In the proposed study, MIPS 24 and 70 micron photometry of the outer regions of five galaxies will be used to formulate a high spatial resolution understanding of this material (including the density and temperature structure). This program builds on the successful detection of dust knots at 70 microns in the extended disk of NGC 6946 from a Cycle 1 exploratory study.

Spitzer Space Telescope - General Observer Proposal #3393

Exploring the Nature of Dust in the Outer Disks of Galaxies

Principal Investigator: Dennis Zaritsky
Institution: University of Arizona

Technical Contact: Dennis Zaritsky, University of Arizona

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: MipsPhot
Hours Approved: 8.9

Abstract:
We propose an exploratory study of the extended disks (r > R_25) of spiral galaxies. Observations suggest that dust (and star formation) exist in spiral galaxies well beyond the edge of the optical disk. This extended disk region may eventually play an important role in our understanding of how material infalls onto galaxies, how star formation is regulated in low-density regions, how the initial chemical enrichment of galaxies proceeds, and how angular momentum is distributed in the baryonic component of galaxies. In the proposed study, MIPS 70 and 160 micron photometry of the outer regions of two galaxies will be used to formulate an understanding of this material at high spatial resolution (including the density and temperature structure). If successful, this program will lay the groundwork for the study of a new disk component of spiral galaxies.

Spitzer Space Telescope - General Observer Proposal #20268

The Formation of Dust Lanes in Nearby, Edge-on Disk Galaxies

Principal Investigator: Roelof de Jong
Institution: Space Telescope Science Institute

Technical Contact: Roelof de Jong, Space Telescope Science Institute

Co-Investigators:
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Michael Regan, STScI
Simone Bianchi, Arcetri
Eric Bell, MPIA
Anil Seth, University of Washington

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsScan
Hours Approved: 21.3

Abstract:
We propose a comprehensive study of dust emission and absorption in a large sample of nearby, edge-on disk galaxies. We have recently discovered a sudden change in dust lane properties using ground-based and HST observations; all galaxies with rotation speeds in access of 120km/s show dust lanes, but none are seen in the slower rotators. Because dust and molecular gas are tightly coupled, this suggest a sudden transition in the state of the multi-phase ISM. We could be seeing a change in the amount of dust in galaxies, or galaxies could become dynamically unstable at 120km/s, forming spiral arms and compressing the ISM in thin lanes. Dust extinction studies are sensitive only to dust in front of the stars, and Spitzer observations are essential to fully quantify vertical dust distributions in edge-on galaxies. Here we propose to obtain four channel IRAC imaging of 15 nearby, well resolved edge-on galaxies and three channel MIPS scan images of 5 edge-on galaxies with large enough scale heights to be resolved at 70 micron. With these observations we can: - determine the cold dusty ISM distribution from the PAH emission in the 8 micron IRAC images; - measure hot and cold dust scale sizes from the MIPS observations, and; - establish the stellar light distribution from the IRAC 3.6 and 4.5 micron images, which in conjunction with our existing HST imaging will allow us to accurately quantify extinction structure on arcsec scales. Our targets cover a range in rotation velocity and other galaxy properties, and in combination with our radiative transfer models, we will fully quantify the change in dusty ISM properties across the 120km/s transition.

Spitzer Space Telescope - General Observer Proposal #20658

Molecular hydrogen in normal spiral galaxies

Principal Investigator: Paul van der Werf
Institution: Leiden Observatory

Technical Contact: Paul van der Werf, Leiden Observatory

Co-Investigators:
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John Cannon, University of Minnesota
Marco Spaans, Kapteyn Astronomical Institute
Padelis Papadopoulos, ETH Zurich Switzerland
Frank Israel, Leiden Observatory
Fabian Walter, MPIA Heidelberg Germany

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IrsStare
Hours Approved: 11.8

Abstract:
We propose an investigation of the molecular hydrogen component of normal spiral galaxies using the S(0) line at 28 microns. ISO observations have shown that the S(0) line probes moderately warm (about 100K) molecular gas which can contain significant mass, in particular in the outer regions of galaxies. In addition, it was found that even small quantities of warm gas can significantly affect the CO-H2 mass conversion factor. With the unprecendented sensitivity of IRS on SST we can now study in detail the warm H2 component, its mass, scale length, and temperature structure, as a function of environmental parameters such as position in a galaxy (arm or interarm location), galactocentric radius, and local metallicity and radiation field. We propose to use IRS to take deep spectra of the H2 S(0) line at intervals of 30 arcseconds over (a) the inner disk of the Local Group spiral galaxy M33 (30 positions in total) where we will have excellent spatial resolution across spirals arms and (b) the northern half of the normal quiescent gas-rich edge-on Sc galaxy NGC5907 (17 positions in total), where we will probe from the nucleus all the way to the end of the HI disk. In both of these galaxies we have excellent matching CO, HI and [CII] 158 micron data available, which are important for the interpretation of the results. While the S(0) line will not probe the cold bulk H2, we will pick up warm H2, also in regions where CO is dissociated. This is expected to occur in cloud envelopes and in regions of low metallicity, such as in the outer disks of galaxies. Recent star formation in the extreme outer disks shows that H2 must be there, yet CO is no detected. ISO observations have also shown that that the disk scale-length in the S(0) line is much larger than that of CO. The IRS observations will go more than 10 times deeper than ISO, and will allow us to pick up even small column densities of warm H2, giving us a much better understanding of the molecular hydrogen component of normal spiral galaxies.

Spitzer Space Telescope - General Observer Proposal #50630

The Interstellar Medium, Star Formation, Active and Inactive Nuclei of the Nearby Early-Type Galaxy Sample SAURON

Principal Investigator: Guido van der Wolk
Institution: Kapteyn Astronomical Institute

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Co-Investigators:
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Johan Knapen, Instituto de Astrofisica de Canarias
Peter Barthel, Kapteyn Astronomical Institute
Martin Bureau, Oxford University

Science Category: nearby galaxies (z<0.05, v_sys<15,000 km/s)
Observing Modes: IracMap MipsPhot
Hours Approved: 10.0

Abstract:
The determination of the star formation history of galaxies and the origin of the ISM fuel is one of the main unsolved issues in the study of the formation and evolution of galaxies. By now it appears that supermassive black holes play a major role in regulating the amount of gas, and thus the star formation in their host system. To understand these processes, it is important to simultaneously trace the i) properties of the interstellar medium, ii) the star formation rate, and iii) the nuclear activity. Our representative set of nearby elliptical, lenticular and early-type spiral galaxies, the SAURON sample, is ideal for such a study. For all 72 galaxies in this sample, we have measured the kinematics of the stars and ionized gas, as well as the stellar populations, via integral field spectroscopy. These data are crucial for understanding the mass distribution within a system, as well as kinematic substructures such as disks and decoupled cores, which likely play a significant role in driving star formation. We therefore propose to complement this sample with Spitzer IRAC and MIPS images, in order to quantitatively study the amount of star formation and dust in these systems. With the combination of Spitzer imaging and SAURON integral field data, we will be able to study the origin of the ISM in these early-type systems, and the affect of stellar and gas kinematics on star formation. Furthermore, using the multi-wavelength dataset (GALEX, CO, HI) we have accumulated for this sample, we will be able to isolate the contribution from the AGN and connect activity to other processes within the system in order to study the fueling of AGN. The data proposed here will therefore create a unique set of data that will provide much insight into the forces that drive galaxy evolution.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40137

IRS Spectroscopy and MIPS Mapping of the Intracluster Medium in the Bullet Cluster 1E0657-56

Principal Investigator: Philip Appleton
Institution: California Institute of Technology

Technical Contact: Philip Appleton, California Institute of Technology

Co-Investigators:
James Houck, Cornell University
Lee Armus, SSC-Caltech
Patrick Ogle, SSC-Caltech

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsMap IrsStare MipsPhot
Hours Approved: 6.0

Abstract:
We propose deep IRS and MIPS observations of the powerful X-ray cluster 1E0657-56 to map the distribution and properties of a likely cool intra-cluster medium associated with the Bullet-like collision of a dark-matter/galaxy sub-clump with the main cluster. Observations of 1E0657-56 (at z = 0.3) have been interpreted as conclusive evidence that dark-matter associated with the sub-clump interacts much more weakly with the cluster than the baryonic material in the clump. Weak-lensing tomography shows the dark-matter (and associated galaxies) lie ahead of a dissipative bow-shock structure seen in the X-ray-emitting gas mapped recently by Chandra. Our proposal will test this hypothesis further by studying the thermally important shock-coolants (large dust grains and molecules) which we predict should be associated with the shocked X-ray gas lagging the clump, and which is best detected in the mid and far-IR. We exploit the large angular scale of the IRS low-res slits to perform deep observations of 1E0657-56 to search for powerful emission from dust and molecular gas which we expect to be important in such shocks spread over several tens of arcsecs: the scale of the X-ray shock and filaments seen by Chandra. The recent discovery of ultra-powerful (L > 6 x 1042 ergs/s) H2 emission in the cluster Zwicky 3146 at a similar redshift to 1E0657-56 provides strong support for the feasibility of this project. Our MIPS imaging of the entire cluster will also test the idea that the dark matter/gaseous separation might affect the process of accretion onto the most massive cluster galaxies: a process that seems common in dynamically relaxed systems.

Spitzer Space Telescope - General Observer Proposal #3644

Far Infrared Study of SN Ia Host Galaxies

Principal Investigator: Lajos Balazs
Institution: Konkoly Observatory

Technical Contact: Lajos Balazs, Konkoly Obs.

Co-Investigators:
Peter Meszaros, Pennsylvania State University
Peter Abraham, Konkoly Observatory
Attila Moor, Konkoly Observatory
Csaba Kiss, Max-Planck-Institut fur Astronomie

Science Category: intermediate-z galaxies 0.05<z<0.5
Observing Modes: MipsPhot
Hours Approved: 29.2

Abstract:
We propose to observe with Spitzer 50 SN Ia host galaxies of z > 0.1 from the list of Tonry et al. (2003) and 10 more ones which were cross-identified with IRAS galaxies. We propose to get MIPS photometry from all targets at 24, 70 and 160 micron. The sample of the SN Ia hosts gives a unique opportunity to study the star formation activity and dust property as a function of the redshift. Although, the Ia type supernovae are not directly related to the star formation the anomalous dust properties have to be taken into account at their photometry. The SN Ia sample is biased towards objects of law extinction where the bulk of the dust is only in the background. However, the direction of the observer's line of sight is fully random and in a considerable fraction of cases the influence of the intrinsic dust extinction could be quite significant. The result might serve a useful input information for studying the proper conditions for optical afterglows of gamma ray bursts (GRB). There is a so far not fully understood dichotomy of the GRBs having or not optical after glow. A possible interpretation appears to be the absorption of the optical radiation in the interstellar dust. The suspected progenitors of these GRBs are the very massive stars strongly related to dense giant interstellar dust clouds. Normally, the observed GRBs are at higher z than the known Ia type SNs. However, the FIR results obtained for the SN Ia hosts might deliver a useful input information for planning FIR observations of GRB hosts. The observing time calculated for MIPS photomery amounts to 29.2 hours.

Spitzer Space Telescope - General Observer Proposal #50245

Evolution of IR-luminous SED from 0.1 < z < 0.6

Principal Investigator: Benjamin Bertincourt
Institution: Institut d'Astrophysique Spatiale

Technical Contact: Benjamin Bertincourt, Institut d'Astrophysique Spatiale

Co-Investigators:
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Francois Boulanger, IAS, France

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: MipsPhot
Hours Approved: 17.1

Abstract:
Luminous Infrared Galaxies (LIRGs) are primary contributors to the energy production at redshift ~1. They are responsible for the dramatic increase of the star formation density from z=0 to z=1. Establishing proper spectral energy distribution for this class of sources to characterize the physics of the high star formation activity is one of the challenge of the coming decade. We have obtained IRS low resolution spectra of a sample of 40 LIRGs at 0.1<z<0.6. The sample shows on average a strong evolution of PAH ratios and continuum emission with redshift. However, the interpretation of the evolution is hampered by the lack of precise determination of IR luminosity and dust temperature. We thus request for deep MIPS 70 and 160 photometric data. With these new data we will be able to place our measured mid-IR continuum, PAH strengths, and dust temperature in a coherent physical model of SED (similar as in Dopita et al. 2005).

Spitzer Space Telescope - General Observer Proposal #40784

Cluster Environmental Effects on Galaxy Evolution at z=0.2 (Abell 963 vs. Abell 2192)

Principal Investigator: Aeree Chung
Institution: National Radio Astronomy Observatory (NRAO)

Technical Contact: Aeree Chung, NRAO

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B. M. Poggianti, INAF - Padova Astronomical Observatory
D. Schiminovich, Columbia University

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IracMap MipsScan
Hours Approved: 30.4

Abstract:
We propose Spitzer IRAC and MIPS observations for two carefully selected clusters at z=0.2. This is the lowest redshift where the Butcher Oemler effect has been seen and the highest redshift where HI imaging is feasible with current instrumentation. Abell 963 is a rich and X-ray luminous cluster with an unusually high fraction of blue galaxies while Abell 2192 is less massive and has more substructure. To address the question of how galaxies get affected by the surroundings, we will investigate star formation and gas properties of galaxies in those two clusters as a function of environment. Using the Spitzer data, we will study star-forming or AGN activities, star formation histories, and dust contents. We are building up a multiwavelength database on the two clusters. Specifically, we have been allocated 2000 hrs of WSRT time to image the clusters in HI and 250 hrs of FCRAO time to determine the CO content of the cluster galaxies. We are also obtaining optical imaging and spectroscopy data. This unique dataset will allow us to relate star formation rates and histories directly to the gas content and stellar populations for the first time at this redshift. In addition, we will probe not only galaxies in the two clusters but also fore/background systems, using the huge velocity coverages of the HI and CO observations. In order to trace galaxies with normal star formation rates (1-2 Msun/yr) with S/N>5 in all four IRAC bands and 24/70 microns, we request 3.4 hours of IRAC and 11.8 hours of MIPS observation time on each cluster, yielding 30.4 hours of the integration time in total.

Spitzer Space Telescope - General Observer Proposal #30202

Revealing the Nature of one of the most H2-bright ULIRGs

Principal Investigator: Helmut Dannerbauer
Institution: MPIA

Technical Contact: Helmut Dannerbauer, MPIA

Co-Investigators:
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Dieter Lutz, MPE
Reinhard Genzel, MPE
Eckhard Sturm, MPE
Alan F. M. Moorwood, ESO
Helene Roussel, MPIA

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 1.3

Abstract:
We propose observations with all three instruments on-board Spitzer of one of the most H2-bright galaxies known so far, the local ULIRG IRASF23578-5307 at z~0.125. The H2-brightness of this ULIRG, relative to bright lines tracing HII-regions, was discovered through near-infrared follow-up spectroscopic observations of a sample of ULIRGs previously observed by ISO. We note that the NIR H2-emission in IRASF23578-5307 is even stronger than in the well known H2-bright object NGC 6240 which was observed by Spitzer (Armus et al. 2005). Due to the wealth of diagnostic tools in the mid-infrared, the proposed IRS spectroscopic observations both in low and high resolution mode will give us deep insight into the nature of the strong NIR H2-emission lines seen. We aim at observing atomic fine structure lines, H2 molecular lines, PAHs and possible silicate absorption features. And thus we will apply standard MIR-diagnostic tools in order to reveal the nature of the unusual strong H2 emission detected in this ULIRG and determine if starburst or AGN activity is the dominant energy source. We will test the relevance of possible excitation mechanisms of H2 (fluorescence, PDR, shocks, Xray-heating). In addition, the IRAC 4-band and the MIPS 24 micron observations will provide us a solid calibration of the IRS-spectroscopy. MIPS observations at 70 and 160 micron will allow us to set constraints on the dust temperatures, the geometry and the dust mass. The extraordinary properties in the NIR and the tantalizing ISOPHOT-S spectrum, make it indispensable to obtain Spitzer observations of this peculiar object.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50666

A systematic IRS survey of the Spitzer 70 micron extragalactic population

Principal Investigator: Duncan Farrah
Institution: Cornell University

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
James Houck, Cornell
Carol Lonsdale, Virginia
Maria Polletta, IAP, Paris
Henrik Spoon, Cornell
Dan Weedman, Cornell

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 89.9

Abstract:
We propose a systematic IRS survey of a complete sample of 68 extragalactic sources with 70 micron fluxes brighter than 20mJy. Recent theoretical and observational results suggest that the Spitzer extragalactic 70 micron population is very important; results from source counts and SED modeling suggest that 70 micron sources at these fluxes are mainly obscured starbursts over 0<z<8 with small numbers of dusty AGN, but small-scale IRS programs targeting 70 micron selected sources suggest that this population is surprisingly heterogeneous, with a wide dispersion in mid-IR spectral shapes (from power laws to PAH dominated) and covering a very wide redshift range (0.1<z<2.0). The Spitzer 70 micron population may thus be a critical unknown in understanding the dramatic evolution of LIRGs over 0<z<2. To date however, there has been no thorough mid-IR spectroscopic followup of 70 micron selected samples. This represents a major gap in our knowledge, as Herschel-PACS will discover large numbers of 70 micron sources, and is one that can only be filled by Spitzer before cryogen exhaustion. Our program will constitute the first systematic IRS followup of the extragalactic 70 micron population.

Spitzer Space Telescope - General Observer Proposal #30605

X-ray selected star-forming galaxies: the mid-IR view

Principal Investigator: Antonis Georgakakis
Institution: Imperial College

Technical Contact: Antonis Georgakakis, Imperial College

Co-Investigators:
Ioannis Georgantopoulos, National Athens Observatory
Panayiotis Tzanavaris, Athens Observatory
Manolis Rovilos, Athens Observatory

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 6.9

Abstract:
A key development from recent Chandra and XMM-Newton surveys has been the compilation of the first non-local (z=0.01-1) X-ray selected sample of normal galaxy candidates, with X-ray emission dominated by star-formation rather than AGN activity. This has opened the way to explore, for the first time, the star-formation history of the Universe at X-rays, providing information that is complementary to that obtained from other wavebands. However, concern has been raised for possible contamination of the X-ray selected star-forming samples by heavily obscured or low-level AGN activity that remains unidentified at the optical and the X-ray wavelengths. Addressing this issue is clearly essential to establish the link between X-ray emission and star-formation activity. This proposal aims to address this point using the unprecedented sensitivity of Spitzer to obtain low resolution mid-IR spectroscopy for a unique low-z X-ray selected star-forming galaxy sample. These observations will be used to (i) identify hidden AGNs using the diagnostic power of mid-IR spectroscopy and (ii) provide a quantitative relation between star-formation and X-ray luminosity for an X-ray selected galaxy sample (as opposed to optically selected samples studied todate).

Spitzer Space Telescope - Legacy General Observer Proposal #40539

The 5 mJy Extragalactic Spectroscopic Survey

Principal Investigator: George Helou
Institution: California Institute of Technology

Technical Contact: George Helou, California Institute of Technology

Co-Investigators:
Daniel Dale, U Wyoming
Guilaine Lagache, IAS, U Paris-Sud, France
Lee Armus, SSC, Caltech
John-David Smith, U Arizona
Casey Papovich, U Arizona
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Dario Fadda, IPAC, Caltech
Bruce Draine, Princeton U
Ned Wright, UCLA
Francois Boulanger, IAS, U Paris-Sud, France
Marc Sauvage, CEA-Saclay, France
Nurur Rahman, IPAC, Caltech

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 200.0

Abstract:
We propose to obtain IRS spectrosocopy of a flux-limited sample of galaxies with 5<fnu(24)<100mJy, a prime discovery range for Spitzer, but one largely unexplored. With a modeled 10th to 90th percentile range of 1e10 L(sun) to 2e13 L(sun) and z=0.05 to z=0.75, this sample bridges the gap between the pre-Spitzer objects such as nearby spirals and ULIRGs, and the much fainter and more distant sources pursued in most IRS follow-up work to date. This quintessential Legacy Science program will generate a library of spectra that will remain unique for a very long time, and is critical for (1) a first direct accounting of the frequency of various types of spectra from normal star-forming to QSO-like, and of the fractional contributions to the power source in mixed systems, (2) an overview of the prevailing ISM physical conditions and their evolution over the past 2 to 5 Gyr, (3) the search for new classes of objects with a 99% likelihood of funding 1% classes, and (4) a high signal-to-noise library of spectra, essential for proper modeling of counts and backgrounds in the infrared. Our targets are bright sources, readily available from FLS, SWIRE, Bootes and other fields. The data are straightfoward to reduce into high quality science-ready spectra, and will have many applications besides the above, especially given the richness of ancillary data available for them, including 70 and 160micron photometry. The total request is for 275 hours, a modest investment in view of the returns in immediate science and in long-term benefits to future missions like WISE, Herschel and JWST.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #31

Evolution of Intermediate Redshift Clusters

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Terry Herter, Cornell University

Science Category: intermediate-z galaxies 0.05<z<0.5
Observing Modes: IracMap IrsStare MipsScan
Hours Approved: 16.4

Abstract:
Science Objectives - The goal of this project is to understand the increased fraction of low luminosity radio galaxies (LLRGs) with increasing cluster redshift. It will address the following questions (1) Are the LLRGs starburst galaxies (2) Does the L(FIR) - L(20-cm) relationship hold for these galaxies. That is, is this relationship valid for evolved galaxies or potentially a different population of galaxies (3) A side project will be to examine the FIR luminosity function of cluster galaxies for these clusters.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30121

IRS Spectra of Extreme IRAS Sources

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Daniel Weedman, National Science Foundation

Co-Investigators:
Daniel Weedman, Cornell University
Areg Mickaelian, Byurakan Observatory, Armenia
Lei Hao, Cornell University
Bernhard Brandl, Leiden University

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 13.6

Abstract:
The 28 optically-faintest targets (E mag > 18) from the IRAS FSC survey, chosen by identification with the FIRST radio survey, will be observed in the full low resolution modes of the Spitzer IRS in order to provide a comparison sample for high redshift objects which we discovered in previous GTO observations on the basis of extreme Inrared/optical ratios. The median IR/optical of this new sample is 40, whereas the same ratio is ~10 in the classical ULIRGS Markarian 231 and Arp 220, implying that the new sample is much more obscured than typical ULIRGS. Median IRAS 25u flux density is 140 mJy, so IRS exposures are short, requiring only 16 minutes per source. Results will provide a relatively local comparison sample for measuring strength of silicate absorption and PAH emission features. This will enable determination of whether our high redshift samples are biassed toward AGN and whether we should always expect to find sufficiently strong features for redshift identification. To complete an unbiased flux-limited sample of infrared sources for comparison to the extreme sources, we will also observe ten sources brighter than 10 mJy at 24u in our Bootes survey field, to finish the total sample of 32 such sources.

Spitzer Space Telescope - General Observer Proposal #20128

PAH contribution to the infrared output energy at redshift 0.1 to 0.6

Principal Investigator: Guilaine Lagache
Institution: Institut d'Astrophysique Spatiale

Technical Contact: Guilaine Lagache, Institut d'Astrophysique Spatiale

Co-Investigators:
Herve Dole, Institut d'Astrophysique Spatiale
George Helou, California Institute of Technology
Emeric Le Floc'h, University of Arizona
Casey Papovich, University of Arizona
Jean-Loup Puget, Institut d'Astrophysique Spatiale
JD Smith, University of Arizona

Science Category: intermediate-z galaxies 0.05<z<0.5
Observing Modes: IrsStare
Hours Approved: 38.1

Abstract:
Locally 0.5% of galaxies with Log(L(V))>10 Lo have Spectral Energy Distribution (SED) typical of Luminous Infrared Galaxies (LIRGs). This changes dramatically at higher redshift: in deep surveys, ISO at 15 microns detect about 15% of the MB<-20 galaxies (LIRGs at median redshift of 0.65) and SPITZER at 24 microns detect about 30% of field galaxies (starbursts and LIRGs at median redshift of about 1, Ultra-LIRGs up to redshift 3). In the infrared, LIRGs become the dominant population contributing to the comoving energy density beyond z~0.5-0.6 and represent 70% of the star-forming activity at z~1. It is thus clear this population contributes an important part of the whole galaxy build-up in the Universe. The determination of the SEDs of these galaxies at cosmological distance remains an open question despite a lot of work in the last few years. First studies on the 24 microns SPITZER selected galaxies, together with interpretations of the deep number counts by empirical models, suggest that PAH features remain prominent in LIRGs/ultra-LIRGs up to z~2.5. Establishing proper SEDs is one of the challenges of the coming decade. The unique capabilities of the IRS provide unprecedent access to this difficult investigation. We propose to observe with the IRS low resolution spectroscopy mode 40 starburst LIRGs at 0.1<z<0.6 that are identified in the 24 microns FLS and BOOTES cosmological surveys and have also spectroscopic redshifts. We impose an upper luminosity cutoff (Log(L)<12 Lo) to probe only the dominant population contributing to the very strong evolution of the comoving infrared energy density up to z~1. This cutoff prevents us to go to higher redshift. Measuring the mid-IR SEDs up to z=0.6 in normal starbursting galaxies will allow, for the first time to (1) test the strength of PAHs in distant LIRGs and (2) combined with 70 and 160 microns detections, conduct detailed studies of SED variations with the physical LIRGs properties such as redshift, metallicity and environnement.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #83

Use of Massive Clusters as Cosmological Lenses/Evolution of Galaxies and Lensing in Clusters

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: George Rieke, The University of Arizona

Science Category: intermediate-z galaxies 0.05<z<0.5
Observing Modes: IracMap IrsStare MipsPhot MipsScan
Hours Approved: 144.2

Abstract:
Use of Massive Clusters as Cosmological LensesG. RiekeMassive galaxy clusters lens the part of the universe behind them D roughly speaking, the lensing action is strongest at twice the distance of the cluster. The effectiveness of the lensing is greatest for the most massive clusters. Although MIPS can observe to confusion limits at 24, 70, and 160mm, the advantage provided by lensing is that galaxies that normally would be below the confusion limit are amplified and can be detected individually. Hence, Massive clusters can be identified by their strong xray emission. This program concentrates on x-ray luminous clusters in the range 0.2 < z < 0.4, also selected to be in regions of very low infrared cirrus.Evolution of Galaxies and Lensing in ClustersKelly & G. RiekeWe have a number of goals for this survey. At low redshifts, we will scan map the clusters, measuring the brightnesses and colors of individual galaxies and checking to see if there is detectable emission from the intracluster medium. In addition, we will look at the properties of the cluster as a whole by determining the luminosity function and the total far-infrared flux, both globally and as a function of location in the cluster. At modest redshifts of 0.2-0.4 we will measure brightness distributions, fluxes for the brightest individual galaxies, and the brightnesses of the clusters as a whole. In this range, we will also use the data as a lensing cluster survey. Because of the very non-linear relation between redshift, z, and distance, the result is that clusters at z ~ 0.3 are effective at lensing from 1 < z < 2, approximately. Use of lensing can extend the MIPS deep surveys in depth by the lensing amplification factor, which typically is 3 to 5. At redshifts greater than 0.75, we will be studying the early history of the clusters. At all of these redshift ranges, we have used x-ray luminosity as a means to select massive clusters and hence we have a homogeneous sample ranging from nearby to z > 1.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40251

The Relation Between the IR Emission and Optical Colors of Galaxies

Principal Investigator: George Rieke
Institution: Steward Observatory, U. Arizona

Technical Contact: Casey Papovich, Steward Observatory, U. Arizona

Co-Investigators:
Casey Papovich, Steward Observatory
Emeric Le Floc'h, IfA, Hawaii
Delphine Marcillac, Steward Observatory
John-David Smith, Steward Observatory
Benjamin Weiner, Steward Observatory
Christopher Willmer, Steward Observatory
Peter Eisenhardt, JPL/Caltech

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 14.1

Abstract:
Great progress has been made in understanding the formation of galaxies with the recognition that the distribution of their rest-frame colors is bimodal. However, to date, how galaxies leave the star-forming blue cloud and migrate through the green valley to the red-sequence is unknown. We propose to study the mid-IR spectroscopic properties of sources with spectroscopic redshifts 0.2 < z < 0.6 and 24 micron flux densities S(24) > 2 mJy, spanning the full range of optical color and luminosity, from the blue cloud to the red sequence. The optical counterparts to MIPS 24 micron sources span a range of optical color, suggesting their is a strong dependency of galaxy colors on IR activity. Thus far our efforts to model the IR spectral energy distributions of galaxies have ignored galaxy color. The IRS spectroscopy is crucial for understanding the origin of the IR emission. We will use the IRS data, combined with existing IRAC 3-8 micron and MIPS 24-160 micron data, to (1) study the ionization state of the IR emission, (2) test for the existence of obscured AGN, (3) study how these correlate with the optical spectral properties and colors of the galaxies.

Spitzer Space Telescope - General Observer Proposal #50207

k+a galaxies and the starburst - AGN connection

Principal Investigator: Isaac Roseboom
Institution: University of Sussex

Technical Contact: Isaac Roseboom, University of Sussex

Co-Investigators:
Seb Oliver, University of Sussex
Matthew Thomson, University of Sussex
Nurur Rahman, University of Sussex
Duncan Farrah, Cornell University

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 14.3

Abstract:
k+a galaxies represent a short-lived post-starburst phase in which a galaxy goes from a period of high levels of star formation to quiescence in only a matter of a few Gyr. Of interest is the discovery that many k+a galaxies harbor AGN. Given that the quenching of star formation via AGN feedback is considered a vital component in models of galaxy formation at high-z, although as yet uncofirmed, observing low redshift analogues in the form of k+a galaxies should give us valuable insights into this process, if it exists. Here we propose to observe 12 nearby (z<0.2) galaxies which are known to be in a post-starburst phase from their optical spectra. The selection is grouped into three sub-classes which map out a range of times across the post-starburst phase. The aim is to identify what, if any, contribution AGN has to their mid-ir flux, and to then track the evolution of AGN activity with time. This should give constraints on the timescales and effeciency of AGN in quenching star formation.

Spitzer Space Telescope - General Observer Proposal #50460

Looking for shocked gas in a rare system of radio-jet triggered star-formation

Principal Investigator: Anna Sajina
Institution: Spitzer Science Center

Technical Contact: Anna Sajina, Spitzer Science Center

Co-Investigators:
Lin Yan, Spitzer Science Center
Mark Lacy, Spitzer Science Center

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsMap
Hours Approved: 8.2

Abstract:
Star-formation induced by radio jet-ISM interactions is a known phenomenon for high-z radio galaxies. However, it is extremely rare nearby, making its detailed study difficult. We present a unique case of a string of seven 24 micron sources 'hugging' the radio jet of a nearby (z=0.22) radio galaxy. The most likely explanation for this configuration is triggered star-formation via lateral shocks from the radio jet. We propose to obtain low-resolution IRS spectra of both the radio source host and the brightest of the 24 micron sources along the jet. Observations of molecular hydrogen, as well as fine structure lines such as [NeII] would allow us to study both the slow-moving molecular shocks and the fast-moving ionizing shocks. In addition, high-ionization lines would reveal the narrow-line region of the AGN, while PAH emission features would reveal the star-formation rate.

Spitzer Space Telescope - General Observer Proposal #30834

Gamma-Ray-Bursts Hosts: Digging out Low-Mass High-z Star-Forming Galaxies

Principal Investigator: Sandra Savaglio
Institution: Johns Hopkins Univeristy

Technical Contact: Sandra Savaglio, Johns Hopkins Univeristy

Co-Investigators:
Daniela Calzetti, STScI
Karl Glazebrook, Johns Hopkins University
Jochen Greiner, Max-Planck Institute
Damien Le Borgne, CEA/Saclay
Emeric Le Floc'h, University of Arizona
Ayb"ueke K"upc"u Yoldas, Max-Planck Institute

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 2.2

Abstract:
We propose IRAC and MIPS observations (4.5, 8 and 24 micron) of 6 gamma-ray burst (GRB) host galaxies at redshift 0.2<=z<=0.5. GRB hosts are generally low-luminosity metal poor galaxies. It is not clear whether they are also star-bursting, because measured star formation rates (SFRs) are very uncertain and because their total stellar mass has been poorly investigated. Using these and other existing Spitzer data (a total of 19 hosts at 0.0<z<1.1) we will obtain a robust estimate of the stellar mass and SFR for the sample, and establish whether GRB hosts are the equivalent at high redshift of local starburst galaxies. Small galaxies at z<1.1 are recognized as having a key role in the last 8 Gyrs of the history of the universe. This is also know as the 'downsizing' scenario. GRB hosts are unique probes to push to the limit our investigation of the downsizing scenario. The program can be execute with 2.2 hours of Spitzer time.

Spitzer Space Telescope - Legacy General Observer Proposal #30742

SSGSS: The Spitzer SDSS GALEX Spectroscopic Survey

Principal Investigator: David Schiminovich
Institution: Columbia University

Technical Contact: David Schiminovich, Columbia University

Co-Investigators:
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Tim Conrow, Caltech
Tim Heckman, Johns Hopkins University
Charles Hoopes, Johns Hopkins University
J. M. van der Hulst, Kapteyn Institute
Benjamin Johnson, Columbia University
Christopher Martin, Caltech
Lucimara Martins, STScI
Mark Seibert, Caltech
Marie Treyer, Caltech
Ted Wyder, Caltech

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 121.1

Abstract:
We propose the Spitzer SDSS GALEX Spectroscopic Survey (SSGSS), a Spitzer/IRS Legacy Program to obtain mid-IR spectra of a representative sample of 100 galaxies that have been observed at other wavelengths. These galaxies are selected from the SDSS main spectroscopic survey in the Lockman Hole field, and have been observed by GALEX in the UV and SWIRE in the IR. This survey provides a crucial link between mid-IR studies of nearby galaxies, such as those performed by ISO and SINGS, and on-going and future mid-IR studies of high redshift galaxies. We will use the SSGSS data to study the global properties of SDSS galaxies using atomic and molecular nebular diagnostics measured from IR to UV. SSGSS galaxies are selected to be uniformly distributed over two orders of magnitude in stellar mass, present to past-averaged star formation rate and IR luminosity. The addition of low and high resolution mid-IR spectroscopy will allow the measurement molecular band features, fine structure lines and the stellar and thermal dust continuum components. We will combine these measurements with UV, optical, and broadband IR indicators of star formation, AGN activity, and stellar populations. This will allow us to derive global physical properties and new diagnostics for the study of the physical state of the ISM and the star formation history of each galaxy.

Spitzer Space Telescope - Legacy General Observer Proposal #50568

S5: The Spitzer SDSS Statistical Spectroscopic Survey

Principal Investigator: David Schiminovich
Institution: Columbia University

Technical Contact: David Schiminovich, Columbia University

Co-Investigators:
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Elisabete da Cunha, IAP, France
Timothy Heckman, JHU
David Hogg, NYU
Benjamin Johnson, Cambridge University
Matt O'Dowd, Columbia University
Christopher Martin, Caltech
Marie Treyer, Caltech
Ronin Wu, NYU
Ted Wyder, Caltech

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsMap
Hours Approved: 45.0

Abstract:
We propose the Spitzer SDSS Statistical Spectroscopic Survey (S5), a unique and unprecedented legacy survey to obtain low and high resolution mid-infrared (MIR) IRS spectra of a large optically selected, statistical sample of 300 star-forming galaxies with available UV photometry, selected from the SDSS at redshifts 0.05<z<0.1. S5 will result in a powerful database of MIR spectra of homogeneously selected star-forming galaxies that will help answer key questions, develop new techniques and define the science goals for future large scale optical+IR galaxy evolution investigations, of immediate relevance as we enter the age of Herschel, WISE and JWST. Local star-forming galaxies selected from the vast SDSS sample will provide the perfect laboratory for combining and calibrating the optical and MIR diagnostics to be used in the next generation of low and high-z observations and theoretical models of star formation in galaxies. This program contains the Priority 2 observations.

Spitzer Space Telescope - Legacy General Observer Proposal #50569

S5: The Spitzer SDSS Statistical Spectroscopic Survey

Principal Investigator: David Schiminovich
Institution: Columbia University

Technical Contact: David Schiminovich, Columbia University

Co-Investigators:
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Elisabete da Cunha, IAP, France
Timothy Heckman, JHU
David Hogg, NYU
Benjamin Johnson, Cambridge University
Matt O'Dowd, Columbia University
Christopher Martin, Caltech
Marie Treyer, Caltech
Ronin Wu, NYU
Ted Wyder, Caltech

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes:
Hours Approved: 91.2

Abstract:
We propose the Spitzer SDSS Statistical Spectroscopic Survey (S5), a unique and unprecedented legacy survey to obtain low and high resolution mid-infrared (MIR) IRS spectra of a large optically selected, statistical sample of 300 star-forming galaxies with available UV photometry, selected from the SDSS at redshifts 0.05<z<0.1. S5 will result in a powerful database of MIR spectra of homogeneously selected star-forming galaxies that will help answer key questions, develop new techniques and define the science goals for future large scale optical+IR galaxy evolution investigations, of immediate relevance as we enter the age of Herschel, WISE and JWST. Local star-forming galaxies selected from the vast SDSS sample will provide the perfect laboratory for combining and calibrating the optical and MIR diagnostics to be used in the next generation of low and high-z observations and theoretical models of star formation in galaxies. This program contains the Priority 3 observations.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50038

High resolution spectroscopy of the luminous ULIRG IRAS F00183-7111

Principal Investigator: Henrick Spoon
Institution: Cornell University

Technical Contact: Henrick Spoon, Cornell University

Co-Investigators:
James Houck, Cornell University
Duncan Farrah, Cornell University

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IrsStare
Hours Approved: 7.5

Abstract:
IRAS F00183-7111 is one of the most luminous ULIRGs discovered by IRAS. Follow-up ISO spectroscopy revealed the central power sources to be deeply buried in thick layers of gas and dust. While rare at the time, Spitzer spectroscopy has since identified many ULIRGs to have very strongly obscured nuclei. And as is the case for most of them, the nature of the dominant central power source is hard to constrain, and evidence for both a powerful active galactic nucleus (AGN) and a massive starburst exist, with high margins of uncertainty. What sets apart IRAS F00183-7111 from other ULIRGs observed with Spitzer is its very unusual combination of 6.2 micron PAH equivalent width and depth of the 10 micron silicate feature. In the diagnostic diagram based on these two observables 95% of the ULIRGs are found on either of two 'forks' (or branches): one connecting starburst-dominated sources at the base of the fork with AGN-dominated sources at the tip; the other connecting starburst-dominated sources with deeply obscured central sources at its tips. IRAS F00183-7111 seems to be transitioning between the extreme ends of these tips, away from the deeply obscured branch to the AGN-dominated branch. Recently, we found evidence in support of such an evolutionary scenario, based on the discovery of a uniquely broad, very strong, blue-asymmetric emission line of [Ne II] in the Spitzer IRS spectrum. This emission traces optically obscured highly disturbed gas at the base of a nuclear outflow, possibly disrupting the obscuring medium and exposing the central AGN. We propose to reobserve IRAS F00183-7111 at 3-10 times higher S/N to find further spectroscopic evidence in support of this evolutionary scenario.

Spitzer Space Telescope - General Observer Proposal #20683

Life Before the Fall: Star Formation of Galaxies in Groups Prior to Cluster Assembly at z~0.37

Principal Investigator: Kim-Vy Tran
Institution: ETH Zurich

Technical Contact: Kim-Vy Tran, Leiden Observatory

Co-Investigators:
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John Moustakas, University of Arizona
Dennis Zaritsky, University of Arizona

Science Category: intermediate-z galaxies 0.05<z<0.5
Observing Modes: MipsScan
Hours Approved: 12.6

Abstract:
We propose to obtain a deep MIPS 24 micron map (18'x18') of a protocluster made of 4 distinct galaxy groups that are gravitationally bound to each other at z=0.37. The galaxy groups already have a total combined mass comparable to the Coma cluster, but they have at least 4 times as many emission line galaxies as Coma. The SG1120 complex thus provides an unprecedented opportunity for determining when and how star formation is quenched (or briefly enhanced) in the galaxies that will evolve into cluster members. MIPS is ideal for measuring the emission due to warm dust at mid-IR wavelengths. This sensitive tracer of integrated star formation enables us to identify weakly star-forming members (~1 solar mass/year) to very dusty, strongly star-forming ones, e.g. ultra-luminous infrared galaxies (ULIRGs) and the possible progenitors of post-starburst (E+A) members. Combining mid-IR with the deep, wide-field X-ray/optical/near-IR imaging and spectroscopy we already have in hand, we will trace how star formation varies as a function of environment and how quickly cluster galaxies build up their stellar masses.

Spitzer Space Telescope - General Observer Proposal #30150

Shear-Selected Galaxy Clusters: Stellar Mass Content and Star Formation History

Principal Investigator: David Wittman
Institution: UC Davis

Technical Contact: David Wittman, UC Davis

Co-Investigators:
Vera Margoniner, UC Davis

Science Category: intermediate-z galaxies (0.05<z<0.5)
Observing Modes: IracMap
Hours Approved: 16.0

Abstract:
We propose to obtain IRAC imaging as part of a multiwavelength campaign to characterize a unique sample of galaxy clusters: shear-selected clusters from the Deep Lens Survey (DLS). Shear selection is a new technique which uses weak gravitational lensing to detect the clusters based on their gravitational effects alone. Thus it is unbiased with respect to baryon content and star formation history, a key difference from X-ray and optical cluster selection. Understanding the biases in current traditionally selected samples is extremely important because mass, not emitted light, is the key cluster property for cosmology. The clustering of mass in different cosmologies and dark matter scenarios is well understood theoretically and quite tractable computationally, but the observed X-ray and optical emission result from complex gastrophysics which is not yet well modeled. Therefore a key question is whether a shear-selected cluster sample will reveal clusters with properties different from current X-ray and optically selected samples. The focus of this proposal is using IRAC data to derive the stellar mass content and star formation history of these clusters, to be compared with optically and X-ray selected clusters. As an added benefit, the infrared photometry will complement the existing data on these clusters (deep BVRz' optical imaging, mass maps, Chandra spectro-imaging, and spectroscopy) in many ways. For example, they will greatly improve the photometric redshifts, allowing for better identification of cluster members and more accurate lensing analyses.

Spitzer Space Telescope - General Observer Proposal #40430

Spitzer Observations of the Brightest Lensed LBGs

Principal Investigator: Sahar Allam
Institution: University of Wyoming

Technical Contact: Sahar Allam, University of Wyoming

Co-Investigators:
Andrew Baker, Rutgers University
Huan Lin, Fermilab
Dieter Lutz, MPE-Garching
Alice Shapley, Princeton University
J. Allyn Smith, APSU/Wyoming
Michael Strauss, Princeton University
Douglas Tucker, Fermilab

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 15.8

Abstract:
On rare occasions, the otherwise very faint Lyman break galaxies (LBGs) are magnified by gravitational lensing to provide exceptional targets for detailed spectroscopic and imaging studies. The primary objective of this proposal is to constrain the star formation histories and stellar masses of the two brightest such objects, estimate their bolometric dust luminosities, distinguish between starburst and AGN bolometric energetics, and compare the detailed rest-frame mid-IR spectra of dust emission and absorption with known low-redshift templates. In particular, the magnification of our targets enables a unique probe of the nature of dust and star formation at high redshift using IRS, which is simply not possible for typical unlensed UV-selected galaxies at similar redshifts. We propose Spitzer IRAC and MIP images and IRS low-resolution spectra of the two newly discovered brightest, lensed LBGs with, using only a modest amount of Spitzer time (24.6 hours).

Spitzer Space Telescope - General Observer Proposal #50086

Doubling the Sample of Bright Lensed LBGs Observed by Spitzer

Principal Investigator: Sahar Allam
Institution: University of Wyoming

Technical Contact: Sahar Allam, University of Wyoming

Co-Investigators:
Douglas Tucker, Fermilab
Huan Lin, Fermilab
Min-Su Shin, Princeton University
Michael Strauss, Princeton University
Andrew Baker, Rutgers University
Dieter Lutz, MPE
J. Allyn Smith, APSU
Alice Shapley, Princeton University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 114.5

Abstract:
Observations of galaxies at z=2-3 probe the epoch when star formation in galaxies peaked and the morphologies of galaxies were being set. UV-selected populations like the Lyman break galaxies (LBGs) have been extensively studied at short wavelengths, but in most cases are too faint to permit observations (particularly spectroscopy) in the mid-infrared. We propose new Spitzer observations of five recently discovered LBG-like objects whose apparent fluxes have been strongly boosted by gravitational lensing. By combining IRAC, MIPS, and (irreplaceable) IRS data with our extensive ancillary datasets, we will constrain our targets' star formation histories and stellar masses, bolometric dust luminosities, starburst/AGN bolometric energetics, and degree of similarity with various low-redshift templates. The proposed observations would more than double the number of lensed UV-selected galaxies at high redshift that Spitzer will have observed by the end of its cryogenic mission.

Spitzer Space Telescope - General Observer Proposal #30000

Gotcha! Using Swift GRBs to Pinpoint the Highest Redshift Galaxies

Principal Investigator: Edo Berger
Institution: Carnegie Observatories

Technical Contact: Edo Berger, Carnegie Observatories

Co-Investigators:
Lennox Cowie, U. Hawaii
Ranga-Ram Chary, Spitzer Science Center
Shirnivas Kulkarni, Caltech
Derek Fox, Pennsylvania State U.
Paul Price, U. Hawaii
Patrick McCarthy, Carnegie Institution of Washington
Brian Schmidt, Australian National University
Alicia Soderberg, Caltech
Bradley Cenko, Caltech
Michael Rauch, Carnegie Institution of Washington
Michael Gladders, Carnegie Institution of Washington
Amy Barger, U. Wisconson, Madison
Bruce Peterson, Australian National University
George Djorgovski, Caltech
Eran Ofek, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 20.4

Abstract:
While there is convincing evidence that the Universe was reionized between redshifts of 6.5 and 15, the role of galaxies in this process is still not understood. Several star-forming galaxies at z~6 have been identified in recent deep, narrow-field surveys, but the expensive observations along with cosmic variance and contamination make it difficult to assess their contribution to reionization, or to significantly increase the sample. It has now been demonstrated that gamma-ray bursts (GRBs) exist at z>6, and we have already obtained HST and Spitzer observations of the host galaxy of GRB050904 at z=6.295 using our Cycle 14 program. GRBs have the advantage of being an uncontaminated signpost for star-formation, and their afterglows are sufficiently bright even at z>6 to allow photometric selection (via the Ly-alpha drop out technique) with 2-5 meter telescopes. Spectroscopic confirmation, including detailed information on the host ISM, is also likely (as demonstrated in the case of GRB050904). Using our approved TOO programs at an extensive range of facilities (2-5m telescopes up to Keck/Magellan/Gemini), we can rapidly find afterglows at z>6 and easily distinguish them from dusty low redshift bursts. This approach is highly efficient compared to current techniques, especially at z>7. Our large allocation on Keck/Magellan/Gemini will also be used to obtain spectroscopy of the afterglows and host galaxies. Here we request to continue our program of imaging GRB-selected z>6 galaxies with NICMOS (z>6), and Spitzer/IRAC to characterize their properties (SFR, age, morphology, extinction), and begin to address their role in reionization. These observations are requested as >2 month TOOs, allowing flexibility of scheduling and at the same time taking a unique and timely advantage of the exquisite performance of three of NASA's premier missions.

Spitzer Space Telescope - General Observer Proposal #3621

Galaxy mass functions and star formation rates in redshift 1.5 clusters

Principal Investigator: Philip Best
Institution: Institute for Astronomy

Technical Contact: Philip Best, Institute for Astronomy

Co-Investigators:
Matt Lehnert, MPE-Garching
George Miley, Sterrewacht Leiden
Huub Rottgering, Sterrewacht Leiden

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 3.2

Abstract:
We propose to obtain deep 4.5, 8 and 24 micron images of the central regions of two galaxy clusters at redshifts 1.5 for which we already possess a wealth of complementary optical, near-IR and HST data. These are amongst the highest redshift clusters known, and so offer a unique opportunity to address some of the key issues relating to the formation and evolution of the most massive galaxies. The goals of our proposed observations are to: 1. Accurately determine the stellar masses of the cluster galaxies, and hence the galaxy mass function of the cluster. In this way we will investigate the mass assembly epoch of massive cluster galaxies, which in turn places tight constraints upon models of galaxy formation. 2. Provide improved estimates of the stellar population ages of the passive cluster galaxies, and hence investigate the epoch at which their stars were formed. 3. Investigate the current star formation activity of the clusters. Is star formation suppressed in dense environments even at these high redshifts? When did the morphology-density relation set in? Are the star formation rates enhanced in the infalling regions? 4. Compare all of these results to both samples of field galaxies (from the legacy surveys) at the same redshift, in order to determine the effect of the cluster environment. Also, compare the results with lower redshift cluster samples in order to track the evolution over cosmic epoch. The proposed observations offer the only route to obtaining a complete census of the galaxy content and galaxy properties of these distant clusters, and hence to answering some of the fundamental questions concerning the formation and evolution of massive galaxies in clusters.

Spitzer Space Telescope - Directors Discretionary Time Proposal #268

Star Formation in High Redshift Clusters with Spitzer

Principal Investigator: John Blackwell
Institution: Grainer Observatory, Phillips Exeter Academy

Technical Contact: Gregory Rudnick, NOAO

Co-Investigators:
Velvet Dowdy, Graves County High School
Rosa Hemphill, Oregon Espiscopal School
Ardis Herrold, Grosse Pointe North High School
Thomas Loughran, Saint Joseph's High School
Dwight Taylor, South Anchorage High School
Gregory Rudnick, NOAO
Rose Finn, Siena College
Vandana Desai, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 2.5

Abstract:
We propose to study the evolution of star formation in galaxy cluster environments by making measurements at epochs between 0.54 < z < 0.63. We will measure the integrated SFRs for three optically selected galaxy clusters from the ESO Distant Cluster Survey (EDisCS) using MIPS 24micron photometry. We will measure total past SFRs, i.e. stellar masses, from rest-frame near-infrared (near-IR) photometry obtained with IRAC. Two of the three galaxy clusters already have IRAC data. We propose taking new IRAC data for CL1232.5-1250 to complete the set. We have found that H_alpha-derived star-formation rates depend on both cluster mass and redshift (Finn et al. 2004, 2005a), demonstrating the necessity of sampling a large range in mass to disentangle evolutionary trends from trends in mass. Our three targeted clusters span the range in mass from near-group environment to the most massive cluster in the EDisCS sample. This mass range fills the gaps in existing studies, which are dominated by studies of field environments or of very massive clusters.

Spitzer Space Telescope - General Observer Proposal #20081

Mid-IR spectroscopy of high-redshift ultraluminous dusty galaxies

Principal Investigator: Andrew Blain
Institution: Caltech

Technical Contact: Andrew Blain, Caltech

Co-Investigators:
Scott Chapman, Caltech
Ian Smail, University of Durham
Lee Armus, Caltech/SSC
David Frayer, Caltech/SSC
David Alexander, University of Cambridge
Rob Ivison, UKATC
Harry Teplitz, Caltech/SSC

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 90.0

Abstract:
We propose deep IRS spectroscopy of a unique sample of 64 ultraluminous submillimeter-detected galaxies (SMGs) with known spectroscopic redshifts from 0.5 to 3.6. The median of their redshift distribution is z=2.4, spanning the peak epoch of massive galaxy formation activity and AGN fuelling. The SMG population certainly includes some of the most massive galaxies in the Universe. Much less common low-redshift galaxies with similar IR luminosities show a rich variety of mid-infrared(IR) gas and solid-phase spectroscopic features, revealing the physical conditions in the most active regions of these highly obscured systems, and especially the importance of AGN for powering their far-IR luminosity. The known redshifts and confirmed high luminosities will allow both the unambiguous interpretation of individual spectra, and a stacking analysis to reveal population-wide spectral features, as a function of color, magnitude and evolutionary state, as revealed by extensive multiwavelength data, including optical and near-IR imaging at HST resolution, and all a handful have archived or scheduled IRAC and MIPS imaging. IRS spectroscopy will contrast their mid-IR spectra with local analogs immune to the effects of dust extinction. For the subset of 21 targets with ultradeep X-ray data, we will be able to compare the relative power of X-ray and mid-IR diagnostics to reveal buried AGN activity. This ambitious IRS project will provide our first insight into the astrophysics of a large sample of ultraluminous galaxies spanning 80% of the lifetime of the Universe.

Spitzer Space Telescope - General Observer Proposal #3473

Deep infrared imaging around ultraluminous high-redshift galaxies

Principal Investigator: Andrew Blain
Institution: Caltech

Technical Contact: Andrew Blain, Caltech

Co-Investigators:
Scott Chapman, Caltech
Ian Smail, University of Durham
Lee Armus, Caltech/SSC
David Frayer, Caltech/SSC
David Alexander, University of Cambridge
Rob Ivison, UKATC

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 13.5

Abstract:
We have compiled a large sample of high-redshift submillimeter-selected galaxies with accurate positions and redshifts in seven well-studied fields around the sky. We propose to obtain fully-sampled MIPS and IRAC images of the regions surrounding these galaxies in three fields where no deep GTO observations are planned, to obtain accurate restframe near-/mid-/far-infrared(IR) luminosities and spectral energy distributions (SEDs) for this unique sample of very luminous distant galaxies. The observations will provide unprecedented information on the luminosities of evolved stellar populations in these galaxies, and seek mid-IR SED measurements that could discriminate between star formation and AGN activity during the most active epoch of galaxy formation in the distant Universe. These observations will allow us to test whether the tight correlation between the far-IR and radio emission seen in local star-forming galaxies holds at much earlier times, out to redshifts of order 3, by measuring accurate restframe SEDs for these dusty galaxies whose redshifts we know. In addition, these observations will provide constraints on the mid-IR properties of other, less active, galaxies in large scale structures we have identified around the submm sources where we have a rich redshift catalog.

Spitzer Space Telescope - Archive Research Proposal #30842

K-corrections in the mid- and far-infrared

Principal Investigator: Michael Blanton
Institution: New York University

Technical Contact: Michael Blanton, New York University

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 49838.0

Abstract:
Interpreting surveys of galaxies which span a range of redshifts requires being able to interpret broad-band observations of galaxies taken through different effective rest-frame bandpasses. All claims of evolution of the galaxy population rely on accurate K-corrections in order to do this. The PI has written widely used software (over 100 registered users and over 100 citations in the literature) for calculating K-corrections in the UV, optical and near-infrared, and proposes to extend this software to self-consistently include the mid and far-infrared. Large public Spitzer surveys like the First Look Survey and SWIRE overlap deep (to redshift unity) public redshift catalogs, and provide an excellent basis for developing these tools. This proposal outlines a plan for developing and testing an appropriate set of templates for fitting SEDs and calculating K-corrections. The tools (in addition to furthering the PI’s own work on galaxy evolution) will be publicly released.

Spitzer Space Telescope - Archive Research Proposal #50443

PRIMUS: stellar mass growth since z=1 with redshifts over 8 sq deg of SWIRE

Principal Investigator: Michael Blanton
Institution: New York University

Technical Contact: Michael Blanton, New York University

Co-Investigators:
John Moustakas, New York University
Daniel Eisenstein, University of Arizona
Alison Coil, University of Arizona
Richard Cool, University of Arizona
Adam Bolton, Institute for Astronomy, University of Hawaii
David Hogg, New York University

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 125000.0

Abstract:
We propose here for archival research funding to measure the build-up of stellar mass over the last eight billion years, using an unprecedentedly large sample. Measuring the increase of stellar mass in galaxies, and determining its dependence on galaxy type and environment, yields crucial information about the star-formation and merger history of galaxies. This history has been the subject of intense research over the past few years, but has been limited by both systematic effects and by the sizes of the available observational samples. Our PRIMUS survey contains over 200,000 spectroscopic redshifts, measured at 1 percent precision, out to redshift z=1, covering 8 square degrees of SWIRE and S-COSMOS imaging. Our sample is flux-limited at i=23 and includes all galaxy types, spanning the red and blue galaxy populations. We have created this sample using a special mode we have developed for the IMACS instrument on the Magellan 6.5m at Las Campanas Observatories: a low dispersion prism in combination with a multi-slit mask. This configuration allows redshift determination of 1 percent accuracy, while also allowing extreme multiplexing to obtain over 2,000 galaxy spectra simultaneously. With the SWIRE optical and infrared imaging in combination with our redshift determinations, we can recover much more accurate estimates of the stellar mass of each galaxy and construct a high signal-to-noise estimate of the stellar mass function over a range of redshifts. These measurements will dramatically improve our current understanding of the build-up of stellar mass, both by decreasing the statistical uncertainty due to sample variance with our massive sample, and by decreasing the systematic uncertainties in stellar masses by using the SWIRE and S-COSMOS imaging.

Spitzer Space Telescope - General Observer Proposal #30866

Measuring the Stellar Masses of Galaxies at z~7

Principal Investigator: Rychard Bouwens
Institution: UCO/Lick Observatory

Technical Contact: Rychard Bouwens, UCO/Lick Observatory

Co-Investigators:
Garth Illingworth, UCO/Lick Observtory
Ivo Labbe, Carnegie Observatories
Daniel Magee, UCO/Lick Observatory

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 34.0

Abstract:
The two UDF NICMOS parallels contain the deepest optical / near-IR images available at any point on the sky and provide us with a unique opportunity to study the high redshift universe. Over the second of these parallels, we find several strong z-dropout (z~7 galaxy) candidates, adding to the ~2-3 other secure candidates we have found from systematic searches through the HST archive. We propose to significantly increase the depth of the IRAC data available over this field and thus measure stellar masses for these z-dropout candidates. This may provide us with our best opportunity to model the stellar populations of objects at z~7, and therefore constrain star formation at z>7. In addition, by obtaining deep IRAC data over the ultradeep ACS+NICMOS imaging data already available, we would have a field second only to the HUDF in its value for studies of galaxies at z>5. This would allow for two other significant endeavors: (1) to set significant constraints of the redshift of three J-dropout (z~8-11) candidates found in this field and (2) to do stellar population modelling on z~5-6 galaxies faintward of what has even been possible in the HUDF.

Spitzer Space Telescope - General Observer Proposal #3406

Intermediate Aged Stars at Very High Redshifts: Constraining the Progeny of the Sources Responsible for Re-Ionization

Principal Investigator: Malcolm Bremer
Institution: Bristol University

Technical Contact: Malcolm Bremer, Bristol University

Co-Investigators:
Matthew Lehnert, MPE
Aprajita Verma, MPE
Laura Douglas, Bristol University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 13.0

Abstract:
We wish to image fields containing more than 20 spectroscopically confirmed z>5 galaxies in the 3.6, 4.5, 5.8 and 8.0 micron bands. When combined with our existing extremely deep optical data on the fields we can determine the complete observed SEDs of the sources to 4.5 microns, and possibly to 8 microns. Using these SEDs we can determine approximate star formation histories for these sources. If they are shown to have undergone bursts or extended periods of star formation to z>10, then this gives strong support for an extended or multiple reionization of the Universe. Non-detections will mean that these sources are undergoing their first burst of star formation at z<6,and cannot have contributed to any very early period of reionization.

Spitzer Space Telescope - General Observer Proposal #50310

Unveiling the Physics of the First Galaxies

Principal Investigator: Peter Capak
Institution: Spitzer Science Center

Technical Contact: Peter Capak, Spitzer Science Center

Co-Investigators:
Bahram Mobasher, University of California, Riverside
Nick Scoville, Caltech
Yoshi Tanaguchi, Ehime Univsersity
Mara Salvato, Caltech
Dave Sanders, University of Hawaii

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 46.0

Abstract:
We propose to observe 92 spectroscopically confirmed 4.5<z<6 galaxies with IRAC on Spitzer, providing an unprecedented census of massive galaxies and star formation in the epoch of early structure formation and reionization. These observations, combined with our existing data, will allow us to estimate the mass, age, dust content of these objects. This sample represents a ~10 fold increase in the number of objects at z>4.5 bright enough to study in detail (Eyles et al. 2007; Yan et al. 2005) and the proposed observations are a factor of 5 more efficient than blank field surveys for these bright objects due to their low surface density. Very little is known about galaxies in this redshift range because they are faint and relatively rare. Also, the region of the galaxy Spectral Energy Distribution (SED) containing mass and age information is redshifted to the near and mid infrared where it is more difficult to measure. The proposed IRAC observations provide some of the key pieces of information required to study these high redshift objects. This project complements the extremely deep observations of z>5 galaxies in GOODS and UDF by probing the bright end and knee of the luminosity function as well as probing a large enough volume to reduce the effects of cosmic variance.

Spitzer Space Telescope - General Observer Proposal #50126

IRS spectroscopy of a complete, unbiased sample of submm galaxies

Principal Investigator: Chris Carilli
Institution: National Radio Astronomy Observatory (NRAO)

Technical Contact: Chris Carilli, NRAO

Co-Investigators:
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Frank Bertoldi, Bonn University
Eva Schinnerer, Max-Planck Institute for Astronomy
Dave Sanders, University of Hawaii
Nick Scoville, Caltech
Herve Aussel, CNRS, Saclay
Manuel Aravena, Bonn University
James Aguirre, University of Colorado

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 51.5

Abstract:
We propose 51.5 hours of IRS spectroscopy of a complete, luminosity limited sample of 12 submm galaxies detected at high significance at 250 GHz (> 5sigma) in the Cosmos field. These observations will address two fundamental questions concerning the submm galaxies: (i) do starbursts dominate the energetics of these systems, and if so, how do the physical conditions compare to lower z, lower luminosity starbursts?, and (ii) is there a substantial (up to 30%) high redshift tail (z > 3.6) of hyper-luminous IR galaxies? Such a high redshift tail provides key leverage into models of massive galaxy formation in the early universe. A major legacy of Spitzer has been the demonstration that accurate redshifts for distant, luminous, dust-obscured star forming galaxies can be derived from the PAH features, in addition to the important physical diagnostics on dust heating and composition that come from such spectra. Observing the high S/N, unbiased Cosmos/MAMBO sample will complete this legacy, and test the theory that submm galaxies represent the formation of large elliptical galaxies in massive, dusty starbursts in dense environments at high redshift.

Spitzer Space Telescope - General Observer Proposal #20456

Balancing the Cosmic Energy Budget between AGN and Starbursts in the Great Observatories Origins Deep Survey

Principal Investigator: Ranga-Ram Chary
Institution: California Institute of Technology

Technical Contact: Ranga-Ram Chary, California Institute of Technology

Co-Investigators:
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David Alexander, Institute for Astronomy, University of Cambridge,
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Andrew Blain, Caltech
David Elbaz, CEA-Saclay, France
David Frayer, Spitzer Science Center, Caltech
Delphine Marcillac, CEA-Saclay, France
Alexandra Pope, University of British Columbia, Canada
Douglas Scott, University of British Columbia, Canada
Haojing Yan, Spitzer Science Center, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 89.0

Abstract:
We propose to undertake IRS spectroscopy of 22 cosmologically interesting sources in the GOODS/Hubble Deep Field-North with 24 micron fluxes above 0.3 mJy. 18 of our 22 targets have spectroscopic redshifts between 0.5<z<2.5; IRS offers the best chance to measure redshifts for the others. The HDF-N has uniquely deep and extensive data available, particularly the 2Msec Chandra observations which provide the best measures of X-ray hardness ratios and strongest non-detection limits for Compton-thick AGN and starbursts. The proposed spectroscopy, specifically measuring the 6.2 and 7.7 micron PAH line/continuum ratio, in conjunction with the X-ray properties will disentangle the contribution from star-formation and accretion activity to the energetics of the objects. By correlating the mid-infrared SB/AGN classifications for this IRS sample with their multiwavelength photometric properties, we will extrapolate our results to the multitude of fainter GOODS 24micron sources which dominate the far-infrared luminosity density of the Universe at high redshifts but which are too faint for IRS spectroscopy. This will yield the fraction of the comoving bolometric luminosity density at 0.5<z<2.5 arising from accretion and nucleosynthesis, one of the key goals of galaxy evolution studies.

Spitzer Space Telescope - General Observer Proposal #40599

Unveiling the Galaxy Counterparts of Damped Lyman-alpha Absorbers using GRB-DLAs

Principal Investigator: Ranga-Ram Chary
Institution: California Institute of Technology

Technical Contact: Ranga-Ram Chary, California Institute of Technology

Co-Investigators:
Edo Berger, Carnegie Institute of Washington
Andrew Blain, Caltech
George Djorgovski, Caltech
Shrinivas Kulkarni, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 77.4

Abstract:
Damped Lyman-alpha systems (DLAs) have primarily been detected along the line of sight to bright quasars (QSOs) through absorption line spectroscopy. They harbor the bulk of the neutral gas in the Universe between redshifts of 0<z<5 and are therefore thought to be the predecessors of star-forming galaxies. It is impossible to measure the stellar mass, star-formation rate and dust in QSO-DLAs at z>2 since the QSO overwhelms the light from the DLA by a factor of 10. The launch of Swift has enabled localization of the optical counterpart of gamma-ray bursts (GRBs) while they are still bright. Prompt, high resolution spectroscopy of these afterglows, which briefly outshine the brightest quasars, reveals a rich forest of absorption features providing an unprecedented window into the star-forming environments of distant galaxies. GRB hosts show higher metallicities, higher neutral gas column densities and depletion onto dust grains compared to QSO-DLAs. This can be attributed to the fact that QSO sight lines are more likely to cross the extended outer regions of intervening systems. GRBs on the other hand, due to their association with massive stars, provide an unbiased tracer of star-forming environments before the molecular cloud is destroyed by feedback. As a result, GRB hosts are the strongest candidates for bridging the evolutionary chasm between Lyman-break galaxies (LBGs) and QSO-DLAs. We propose Spitzer 3.6 and 24 micron imaging of the complete sample of 35 GRB host galaxies with well-characterized absorption line properties and spectroscopic redshifts in the range 2<z<5.6. We will accurately measure the stellar mass, assess the presence of dust which might be responsible for metal depletion and measure the dust-obscured star-formation rate in DLA systems. A comparison between the multiwavelength properties of GRB hosts and LBGs will help define the notion that GRBs can be used as a tracer of the co-moving star-formation rate density of the Universe out to the epoch of reionization.

Spitzer Space Telescope - Directors Discretionary Time Proposal #50647

Spitzer Spectroscopy to Distinguish z>5 Sources of Reionization from z~2 Luminous Infrared Galaxies

Principal Investigator: Ranga-Ram Chary
Institution: California Institute of Technology

Technical Contact: Ranga-Ram Chary, California Institute of Technology

Co-Investigators:
Harry Teplitz, Spitzer Science Center
Mark Dickinson, NOAO
Charles Lawrence, JPL

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 15.8

Abstract:
Optical/near-infrared photometric redshifts of 13 red galaxies in GOODS favor z>5 redshift solutions which indicate that they are extremely massive galaxies with stellar masses exceeding 1E11 Msun. If true, these galaxies contribute the bulk of the stellar mass density at z~6 and the past star-formation in these galaxies is responsible for reionizing the intergalactic medium at z>>6. The majority of these galaxies have however found to be faint 24 micron sources which would instead suggest that they are luminous infrared galaxies (LIRGs) with L(IR)~3E11 Lsun at z~2. We propose ultradeep Spitzer/IRS LL spectroscopy which will measure the redshifts of two representative, optically invisible (i>27 mag) sources in this class and distinguish between these two widely disparate hypotheses. The detection of polycyclic aromatic hydrocarbons (PAH) in the spectra of these sources would imply that photometric redshifts of dusty infrared luminous galaxies are unreliable - a fundamental obstacle in estimating the comoving luminosity density of the Universe as a function of redshift. It would allow the shape of the dust extinction curve to be constrained and rule out the Balmer-"break" color selection as a reliable tracer of redshift. By virtue of being the deepest IRS/LL observations, it would yield the first measures of PAH line strengths in high redshift LIRGs. This will help refine the mid-infrared PAH templates that are used to estimate bolometric luminosities of galaxies detected in various mid-infrared surveys, including those which will be undertaken by WISE. The absence of PAH in the proposed spectra would imply the presence of Compton-thick AGN and/or confirm that we have identified the galaxies responsible for reionization without the need for changing the stellar initial mass function at high redshift. Spitzer offers the only opportunity to resolve this important conundrum until the James Webb Space Telescope.

Spitzer Space Telescope - General Observer Proposal #30600

Solving the Mystery of the Lyman Alpha Blobs

Principal Investigator: James Colbert
Institution: Spitzer Science Center

Technical Contact: James Colbert, Spitzer Science Center

Co-Investigators:
Harry Teplitz, Spitzer Science Center
Brian Siana, Spitzer Science Center
Paul Francis, Australian National University
Bruce Woodgate, Goddard Space Flight Center
Povilas Palunas, University of Texas at Austin
Gerard Williger, University of Louisville

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap MipsPhot
Hours Approved: 30.4

Abstract:
We propose IRS Long Low and MIPS 24 micron imaging of all the Ultraluminous Infrared Galaxies (ULIRGs) associated with high-redshift, Lyman alpha blobs (LABs). The physical origin of the LABs is still unknown, with the two most likely models shocks from supernova-driven winds and escaping AGN illumination. Only with mid-infrared spectroscopy can we definitively measure the PAH strengths and PAH-to-continuum ratios of these UV-bright ULIRGS, quantifying the relative contributions of AGN versus starburst. We will also be sensitive to the broad 9.7 micron silicate feature, which can be used to estimate extinction to the embedded mid-IR sources. Half of all known LAB ULIRGs lie at z=3.09, moving the majority of strong PAH features out the 24 micron filter. None of these z=3.09 LABs have been detected at 24 micron, despite SCUBA 850 micron detections, so for this half of the sample we propose deep MIPS 24 micron imaging in order to either detect the sources or provide strongly constraining upper limits on 24 micron flux. The 850/24 micron ratio measures the relative contribution of hot and cold dust emission, which places strong constraints on AGN energy contributions.

Spitzer Space Telescope - General Observer Proposal #3699

Measuring the Mass, SFR, and Ages of Galaxies Within the z=2.38 Filament

Principal Investigator: James Colbert
Institution: Spitzer Science Center

Technical Contact: James Colbert, Spitzer Science Center

Co-Investigators:
Harry Teplitz, Spitzer Science Center
Povilas Palunas, University of Texas, Austin
Gerard Williger, John Hopkins University
Bruce Woodgate, Goddard Space Flight Center
Paul Francis, Australian National University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 20.6

Abstract:
We propose to obtain Spitzer images of the central 25x15 arcminutes of a z=2.38 filament of Lya-emitters. As the largest structure known above z=2, it represents a strong opportunity to test the predictions of hierarchical CDM models at high density. By combining IRAC and MIPS 24 micron observations, we will obtain ages, dust content, star formation rates, and masses for the Lya-emitters. We will also search the filament for the reddened star-forming galaxies which are predicted to cluster in higher density regions, such as the ultraluminous infrared galaxies (ULIGs). This field is also home to four (of 8 known) members of a recently discovered new class of object, the high-redshift extended Lya "blob’’. These Lya blobs may directly show the formation of galaxies via the infall of intracluster gas or the outflow of enriched gas into the ICM, depending on their origin. Our IRAC and MIPS 24 micron observations can distinguish between the various models for the energy source that powers these objects.

Spitzer Space Telescope - Directors Discretionary Time Proposal #499

Confusion-Limited 16 Micron Imaging: Completing the Spitzer Legacy

Principal Investigator: James Colbert
Institution: Spitzer Science Center

Technical Contact: James Colbert, Spitzer Science Center

Co-Investigators:
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Casey Papovich, Univ. Arizona
Emeric Le Floc'h, University of Hawaii
Ranga Chary, SSC

Science Category: high-z galaxies
Observing Modes: IrsPeakupImage
Hours Approved: 15.2

Abstract:
We propose to obtain the first (and only) significant confusion-limited 16 micron imaging with the Spitzer Space Telescope. We will achieve a sensitivity 3-4 times deeper than any previous 16 micron observation from any facility. We will target the ultradeep IRAC region within GOODS-N, creating a mid-IR legacy field where every Spitzer instrument observed down its respective confusion limit. We will measure galaxy number counts at suitable depth to compare with the deepest measurements at 24 microns. Given the interplay between the number density, luminosity evolution, and spectral properties which change with obscuring material and gas fraction, number counts are inherently complex in the mid-IR. The combination of 24 and 16 micron number counts are required to disentangle the many potential evolutionary scenarios of the LIRGs and ULIRGs at redshifts of z>1.5. Reaching 16 micron depths of 10 uJy, we will for the first time be able to detect MIR emission of a significant percentage of z>1.5 LIRGs in more than one waveband, critical for differentiating the many LIRG/ULIRG models as well as identifying silicate absorption. At the highest redshifts (z>2), deep 16 micron will also provide a measurement of the hot-dust component of Compton-thick AGN candidates.

Spitzer Space Telescope - General Observer Proposal #50183

Starburst or AGN dominance in submm-luminous candidate AGN

Principal Investigator: Kristen Coppin
Institution: Durham University

Technical Contact: Kristen Coppin, Durham University

Co-Investigators:
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Sungeun Kim, Sejong

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap IrsStare IrsPeakupImage
Hours Approved: 58.4

Abstract:
It is widely believed that starbursts/ULIRGs and AGN activity are triggered by galaxy interactions and merging; and sub-mm selected galaxies (SMGs) seem to be simply high redshift ULIRGs, observed near the peak of activity. In this evolutionary picture every SMG would host an AGN, which would eventually grow a black hole strong enough to blow off all of the gas and dust leaving an optically luminous QSO. In order to probe this evolutionary sequence, a crucial sub-sample to focus on would be the "missing link" sources, which demonstrate both strong starburst and AGN signatures and to determine if the starburst is the main power source even in SMGs when we have evidence that an AGN is present. The best way to determine if a dominant AGN is present is to look in the mid-IR for their signatures, since often even deep X-ray observations miss identifying the presence of AGN in heavily dust-obscured SMGs. We have selected a sample of SMGs which are good candidates for harboring powerful AGN on the basis of their IRAC colours (S8um/S4.5um>2). Once we confirm these SMGs are AGN-dominated, we can then perform an audit of the energy balance between star-formation and AGN within this special sub-population of SMGs where the BH has grown appreciably to begin heating the dust emission. The proposed observations with IRS will probe the physics of how SMGs evolve from a cold-dust starburst-dominated ULIRG to an AGN/QSO by measuring the level of the mid-IR continuum, PAH luminosity, and Si absorption in these intermediate 'transitory' AGN/SMGs.

Spitzer Space Telescope - Directors Discretionary Time Proposal #250

Mid-IR observations of z=2, BzK selected galaxies

Principal Investigator: Emanuele Daddi
Institution: NOAO

Technical Contact: Emanuele Daddi, NOAO

Science Category: high-z galaxies (z>0.5
Observing Modes: MipsPhot
Hours Approved: 10.2

Abstract:
The cosmic epoch at redshifts between 1.5 and 2.5 appears to be the time of major formation and assembly of massive galaxies. Results from the K20 and other surveys have shown that massive galaxies with seemingly large star-formation rates are common at these epochs. We showed that massive z=2 objects can be readily isolated using photometry in only B, z and K bands. As a part of the Spitzer Fellowship program, we propose to obtain deep 24 micron observations with Spitzer+MIPS of a 350 arcmin square region where about 500 z=2 massive galaxy candidates have been selected through their BzK colors, and for many of which spectroscopic redshifts are being measured from VLT+VIMOS spectra. A large fraction of these galaxies have very red optical colors that suggest severe dust reddening. Measuring the 24 micron emission of massive z=2 galaxies will be crucial to trace the presence of dust, thus constraining their star-formation rates and contribution to the z=2 star-formation rate density. Coupled to the optical-IR photometry and optical spectra that are already available, these observations will allow to better understand the role of BzK selected objects in galaxy formation and assembly at z=2.

Spitzer Space Telescope - General Observer Proposal #50512

Mid-IR Spectroscopy of gas-rich disk galaxies at z=1.5

Principal Investigator: Helmut Dannerbauer
Institution: MPIA

Technical Contact: Helmut Dannerbauer, MPIA

Co-Investigators:
Emanuele Daddi, CEA
David Elbaz, CEA
Mark Dickinson, NOAO
Glenn Morrision, UH-IfA Hawaii
Daniel Stern, JPL, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 15.2

Abstract:
We have recently obtained the first detection of CO in two ordinary massive z=2 galaxies. These massive disk galaxies were observed with the IRAM Plateau de Bure Interferometer, selected to lie in the mass-star formation rate correlation at z~1.5, thus being representative massive high-z galaxies. The CO detection implies that giant molecular gas reservoirs are present in these sources, with gas fractions reaching 50-70% of the total galaxy masses. With an infrared luminosity of L(FIR)~10^12 L(sun), these BzK disk-like galaxies are borderline ULIRGs but with star formation efficiency similar to local spirals, and an order of magnitude lower than in submm galaxies, unveiling a new formation mode previously unknown in the distant universe. We propose here IRS spectroscopy of these two CO detected galaxies at z=1.5 in order to unveil their mid-IR rest frame spectral properties and measuring the equivalent widths of PAH features at 6.2, 7.7, 8.6 and 11.3 micron and of the 9.7 micron silicate absorption. The extreme richness in molecular gas in these sources should affect their mid-IR spectral properties, and we will investigate how the diversity in gas/star ratios in distant galaxies is important for the interpretation of mid-IR luminosities of the high-z populations. In particular, the fact that these ULIRGs behave like scaled up spiral galaxies in their star formation properties could be reflected in their mid-IR spectral properties. Obtaining the PAH ratios will be crucial to constrain better the CO to H2 mass conversion ratio Xco. These observations will represent a legacy from Spitzer for the years to come for the interpretations of mid-IR properties of distant star forming galaxies.

Spitzer Space Telescope - Directors Discretionary Time Proposal #494

Deep spectroscopic observations of a z=4.3 HyLIRG with indications of Pa alpha and PAH emission

Principal Investigator: Kalliopi Dasyra
Institution: SSC

Technical Contact: Kalliopi Dasyra, SSC

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Science Category: high-z galaxies
Observing Modes: IrsMap
Hours Approved: 5.1

Abstract:
We request IRS observations of J1717+6009, a z=4.27 source that is an outlier in redshift, IR luminosity, and spectral properties in the 5mJy Spectroscopic Legacy project 5MUSES, which surveyed the XFLS, ELAIS-N1, ELAIS-N2, XMM, and Lockman Hole fields. With rest-frame 4.6 and 13.3 micron luminosities of 5*10^13 L_sun, this source is a bright Hyperluminous Infrared Galaxy. Its rest-frame UV/optical spectra show broad absorption lines that are associated with strong outflows. J1717+6009 is an exceptionally rare candidate for the study of coeval AGN accretion, feedback, and star-formation activity at z>4. It is unique because it shows tentative evidence for both hydrogen recombination and PAH feature emission in the MIR. The existing ~4-min long IRS observations per spectral order, which were obtained after the cycle 5 deadline, have low S/N (4.5-7.5 sigma) detections at the Pa alpha, the PAH 3.3, and the PAH 6.2 micron wavelengths. We request new IRS observations, which will last in total 5.1 hours, to allow for a reliable detection of the 3.3 and 6.2 micron PAH features and several rest-frame NIR hydrogen lines. The flux ratios of NIR and optical/UV hydrogen lines will help us estimate the AGN gas column density. The widths of the broad hydrogen lines can constrain the mass and the accretion rate of the black hole in this AGN. The luminosity of the PAH features will help us estimate the star formation that the host galaxy is undergoing. If successful, these deep observations will establish Spitzer as the observatory to pioneer the detection of PAHs at z>4, and will lay the foundations for the use of the JWST MIRI instrument for the study of star formation up to the era of reionization using the 3.3 micron PAH feature.

Spitzer Space Telescope - Theoretical Research Proposal #20283

High-Redshift Galaxies in GOODS: Simulations vs. Observations

Principal Investigator: Romeel Dave
Institution: University of Arizona

Technical Contact: Romeel Dave, University of Arizona

Co-Investigators:
Kristian Finlator, University of Arizona

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 50877.0

Abstract:
We propose to carry out detailed comparisons of cosmological hydrodynamic simulations of galaxy formation versus Spitzer/IRAC and HST/ACS observations of z~4 "B-dropout" galaxies in the Great Observatories Origins Deep Survey. The goals are to (1) Test whether current simulations of galaxy formation produce results compatible with high-redshift galaxy observations; (2) Constrain model parameters, particularly those associated with dust extinction and galactic feedback; and (3) Provide detailed interpretations of observed broad-band colors in terms of galaxy physical properties such as stellar mass and extinction within a self-consistent cosmological scenario. We will carry out the comparisons by "observing" simulated galaxies through the appropriate broad band filters, computing each galaxy's magnitudes from its star formation history using population synthesis models. From this, we will gain insights into the physical processes that govern galaxy formation at these epochs, and provide a baseline concordant model that can be used to compare simulations to a wider range of observations such as galaxy clustering, redshift evolution, extragalactic background light, and galaxy properties observed at non-optical/NIR wavelengths.

Spitzer Space Telescope - Theoretical Research Proposal #30065

Comparing Simulations and Observations of Reionization-Epoch Galaxies

Principal Investigator: Romeel Dave
Institution: University of Arizona

Technical Contact: Romeel Dave, University of Arizona

Co-Investigators:
Kristian Finlator, University of Arizona

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 56649.0

Abstract:
We propose to test and constrain models of early galaxy formation through comparisons with observations of reionization-epoch (z>6) galaxies observed using Spitzer. The goals are to (1) Make predictions for z>6 objects using state-of-the-art cosmological hydrodynamic simulations of galaxy formation tailored to study the reionization epoch; (2) Develop a publicly-available tool called SPOC designed to obtain detailed constraints on physical properties of observed galaxies through comparisons with simulated galaxy catalogs; and (3) Use SPOC to test and constrain models of galaxy formation through comparisons with rapidly- advancing observations in the new frontier of early universe studies. The results of this study will yield deeper insights into the galaxy formation process at these mostly unexplored epochs, with implications for understanding the formation of massive galaxies, studying the topology and evolution of IGM reionization, and designing future surveys to detect first objects. The SPOC tool will facilitate a closer connection between observations and theory by enabling the community to interpret data within the framework of current hierarchical structure formation models, in turn providing detailed tests of these models that is essential for driving the field forward.

Spitzer Space Telescope - Theoretical Research Proposal #40047

TOGA: A Web Interface for Testing Galaxy Formation Models Against Observations

Principal Investigator: Romeel Dave
Institution: University of Arizona

Technical Contact: Romeel Dave, University of Arizona

Co-Investigators:
Kristian Finlator, University of Arizona

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 31706.0

Abstract:
Comparisons between galaxy surveys and hierarchical sturucture formation models are a key driver for progress in understanding galaxy formation. In order to facilitate such comparisons, we propose to establish a website to disseminate simulation data in a manner that may be directly compared against galaxy survey data. The website, called TOGA, will enable users to (1) download photometric catalogs (including physical properties) of simulated galaxies from a suite of state-of-the-art hydrodynamic simulations of galaxy formation, and (2) run an SED fitter on individual galaxy photometry to determine the likelihood that a given observed galaxy can be reproduced in a particular model. These tools will enable detailed comparisons between models and data tailored to individual surveys, and will be particularly useful for high-redshift galaxy studies where Spitzer data is crucial for constraining physical properties. The two tools work together to test predictions of both the bulk properties of galaxies and the properties of individual galaxies, enabling the most comprehensive, detailed, and fair model testing possible. The overall goal is to understand in detail the success and especially the failures of current hierarchical galaxy formation models when compared with the rapidly advancing galaxy survey data. The TOGA website will be operational by Fall 2007, with improvements planned throughout 2008.

Spitzer Space Telescope - General Observer Proposal #20389

The Environmental Dependence of Galaxy Star Formation Rates

Principal Investigator: Vandana Desai
Institution: Caliornia Institue of Technology

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Bianca Poggianti, Osservatorio Astronomico di Padova
Gregory Rudnick, NOAO
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Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsScan
Hours Approved: 7.4

Abstract:
We are requesting 29.6 hours of observations with MIPS in order to study the star formation rates of galaxies out to the infall regions (30'x30') of 4 well-studied high redshift (z = 0.8) clusters from the ESO Distant Cluster Survey (EDisCS). These observations will provide star formation rates that are unbiased by dust for galaxies in a wide range of local environments, and for clusters with a variety of masses. Our goals are to establish the dependence of galaxy star formation rates on local galaxy density at z=0.8, determine whether there are environments where the star formation is enhanced over the field, and understand how dust obscuration depends upon environment.

Spitzer Space Telescope - General Observer Proposal #50581

Spitzer South Ecliptic Pole Survey

Principal Investigator: Mark Devlin
Institution: University of Pennsylvania

Technical Contact: Mark Devlin, University of Pennsylvania

Co-Investigators:
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Sophia Kahn, ALMA
Chris Pearson, ESA
Mai Shirahata, ISAS/JAXA

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsScan
Hours Approved: 91.6

Abstract:
The Balloon-borne Large Aperture Submillimeter Telescope, a precursor to Herschel-SPIRE, had a very successful long duration flight from Antarctica in December 2006. Two extragalactic fields were mapped in exquisite detail, discovering more submillimeter sources than all of the ground-based "blank sky" surveys put together. One deep field, centered on GOODS-S, already has extensive Spitzer imaging, and here we request MIPS time for the second field, a strip of ~10 square degrees centered near the South Ecliptic Pole. This is a unique extragalactic survey field because of the combination of BLAST 250, 350 and 500 micron maps with deep mutli-band mid- and far-IR imaging from the Akari satellite. The addition of Spitzer data at 24 and 70 microns will enable us to pursue several inter-related science goals. Firstly, we can construct detailed spectral energy distributions for many galaxies, which can then be used as templates for studying the fainter, higher redshift population. Secondly, our proposed MIPS depths of 1 sigma = 56 (3600) micro-Jy at 24 (70) microns, should be sufficient to yield identifications for the bulk of BLAST sources, enabling detailed studies of the evolution of LIRGs and ULIRGs in the crucial z=1-3 range. And thirdly, careful stacking of the MIPS 24 micron sources on the BLAST maps should allow us to resolve most of the far-IR background, and study the populations which are responsible for making it. The SEP field has existing or planned coverage for many ground-based observatories, and is also part of the Herschel HERMES Guaranteed Time project, as well as being ideally placed for ALMA follow-up. The missing ingredient is the deep mid-IR imaging which only MIPS can provide.

Spitzer Space Telescope - Legacy General Observer Proposal #169

Great Observatories Origins Deep Survey (GOODS)

Principal Investigator: Mark Dickinson
Institution: NOAO

Technical Contact: Peter Eisenhardt, JPL

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David Elbaz, CEA Saclay/UC Santa Cruz
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Massimo Stiavelli, STScI
Marianne Takamiya, Gemini Obs
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Megan Urry, STScI
Robert Williams, STScI
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Edward Wright, UCLA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 647.0

Abstract:
We propose a SIRTF Legacy Project, the Great Observatories Origins Deep Survey, to study galaxy formation and evolution over a wide range of redshift and cosmic lookback time. The survey will determine the galaxies' mass assembly history, stellar populations, and energetic output from star formation (SF) and AGN. By observing at lambda >3um, SIRTF measures the rest-frame near- and mid-IR light from objects at 1<z<6, but very deep observations are needed, to detect "ordinary" objects at these high redshifts. We propose to survey approximately 300 arcmin^2 at 3.6-8um with IRAC and at 24um with MIPS, reaching far deeper flux limits than observations planned by the GTO programs. The survey builds on the deepest observations of NASA's other Great Observatories, HST and Chandra, and on a partnership with astronomers at Gemini and ESO, with a commitment of extensive VLT support. The IRAC observations will be capable of detecting rest-frame near-IR light from progenitors of galaxies like the Milky Way out to z=4, and will enable us to study the galaxy stellar mass distribution versus

cosmic history. The MIPS observations will provide the best opportunity to detect emission from dust-obscured SF in ordinary, Lyman break galaxies out to z=2.5, and, in concert with the Chandra data, will enable a census of supermassive central black holes in obscured and unobscured AGN. An Ultradeep IRAC field will probe the faintest sources and provide the best lower limits to the extragalactic background light at 3.6-8um. By combining space- and ground-based observations, we will create a public data archive extending from X-ray through centimeter radio wavelengths, with a large sample of objects out to the highest known redshifts. This survey will give a uniquely comprehensive history of galaxies, from early epochs to the relatively recent past, and will serve as a bridge to future exploration in these wavelength and redshift regimes with NGST.

Spitzer Space Telescope - Directors Discretionary Time Proposal #196

Great Observatories Origins Deep Survey (GOODS) Validation Observations

Principal Investigator: Mark Dickinson
Institution: NOAO

Technical Contact: Peter Eisenhardt, JPL

Co-Investigators:
The GOODS Team ,

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 10.0

Abstract:
Validation observations of the Great Observatories Origins Deep Survey (GOODS).

Spitzer Space Telescope - Legacy General Observer Proposal #30948

A Deep-Wide Far-Infrared Survey of Cosmological Star Formation and AGN Activity

Principal Investigator: Mark Dickinson
Institution: NOAO

Technical Contact: David Frayer, SSC/Caltech

Co-Investigators:
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Haojing Yan, Spitzer Science Center
Pieter van Dokkum, Yale University
Paul van der Werf, Leiden Observatory

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot MipsScan
Hours Approved: 397.0

Abstract:
Spitzer is creating a vast legacy of 24 micron imaging, with hundreds of thousands of sources detected at cosmological distances. In principle, 24 micron data are the most sensitive probe of dust-enshrouded star formation and distant active galactic nuclei. In practice, at z > 1, they sample mid-infrared wavelengths complex in structure (PAH emission and silicate absorption) and physics (PAH excitation, metallicity dependence, extinction, warm dust and hidden AGN). Other data are needed to understand MIR emission, to calibrate its relation to star formation, to establish its dependence on other galaxy properties, to measure how many atypical objects there are, and to learn how to account for them in conclusions drawn from deep surveys. We propose a program of very deep MIPS imaging geared toward 70 micron detection of 1000 "normal" IR-luminous galaxies at 0.5 < z < 2.5 at wavelengths which trace thermal dust emission which more directly correlates with physical properties of interest such as star formation rates. We will survey 2200 square arcmin in three premier deep survey fields using far-infrared, radio and submillimeter data to measure bolometric luminosities, dust temperatures and masses, to quantify the

population of Compton-obscured AGN, and to calibrate the use of 24 micron data for studying high redshift galaxy evolution.

Spitzer Space Telescope - General Observer Proposal #30823

Pushing the Far-IR Capability of Spitzer in the Study of High-Redshift ULIRGs

Principal Investigator: Charles Dowell
Institution: Jet Propulsion Laboratory

Technical Contact: Charles Dowell, Jet Propulsion Laboratory

Co-Investigators:
Colin Borys, University of Toronto (Canada)
Eiichi Egami, University of Arizona
Michael Zemcov, Cardiff University (UK)

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 60.4

Abstract:
We propose deep MIPS 70 and 160 micron observations of a sample of submillimeter-selected high-redshift ultraluminous infrared galaxies (ULIRGs). For the first time, we will explore the diversity of their far-infrared spectral distributions -- in particular, on the Wien side of the graybody peak -- and measure accurately the integrated infrared luminosity. The targets are drawn from a sample of 850 micron sources at z > 1 amplified by foreground galaxy clusters, where the lensing allows us to measure galaxies which would otherwise be too faint for detection and may also lower the confusion noise. Our program is complemented by ground-based 350 micron imaging, which quantifies the graybody spectrum.

Spitzer Space Telescope - Legacy General Observer Proposal #40021

A Spitzer Public Legacy survey of the UKIDSS Ultra Deep Survey

Principal Investigator: James Dunlop
Institution: Institute for Astronomy, Royal Obs. Edinburgh

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
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Eiichi Egami, University of Arizona
Angela Mortier, Institute for Astronomy, Royal Obs. Edinburgh
Harry Ferguson, Space Telescope Science Institute
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Rob Ivison, Royal Observatory Edinburgh
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Gavin Dalton, University of Oxford
Matt Jarvis, University of Oxford
Sebastien Foucaud, University of Nottingham
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Garth Illingworth, UC Santa Cruz
Ryan Quadri, Yale University
Casey Papovich, University of Arizona
David Schiminovich, Columbia University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsScan
Hours Approved: 292.0

Abstract:
We propose a public legacy program of Spitzer IRAC+MIPS imaging of the ~1 square degree UKIDSS Ultra Deep Survey (UDS). The UDS is by far the largest, deep near-infrared (JHK) survey in existence, and the first capable of sampling truly representative cosmological volumes (100x100 Mpc) out to the highest redshifts (z>6). The UDS is an uniquely powerful resource for studying galaxy formation and evolution and already contains ~100,000 galaxies (>20,000 at z>2). However, the key to unlocking the full potential of the UDS lies in combining the ground-based near-infrared data with appropriately deep Spitzer imaging. The proposed Spitzer data will be invaluable for providing robust measurements of both stellar mass and starformation rates, and will allow the first statistical study of the evolution of the high-mass end of the galaxy mass function out to z=6. Moreover, the proposed Spitzer imaging will allow the evolution of starforming and passive galaxies to be studied separately, and help delineate the link between stellar mass assembly and starformation at high redshift. The UDS will continue to provide ever-increasing depth for the next 5 years, and will be the deepest, contiguous degree-scale infrared survey for the foreseeable future. This proposal is ideally timed to allow immediate and full exploitation of the first world-public UDS release in January 2008, but will also provide a uniquely powerful data-set of lasting legacy value for future exploitation with JWST and ALMA in the next decade.

Spitzer Space Telescope - General Observer Proposal #41011

MIPS 24 um Snapshot Survey of Massive Galaxy Clusters

Principal Investigator: Eiichi Egami
Institution: University of Arizona

Technical Contact: Eiichi Egami, University of Arizona

Co-Investigators:
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Jean-Paul Kneib, OAMP, Marseille
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Johan Richard, Caltech
Dario Fadda, IPAC/Caltech
Frederic Boone, Obs-PM, France

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 22.3

Abstract:
Gravitatinoal lensing by massive clusters of galaxies offers a very powerful and yet cheap means to improve the sensitivity of a given telescope/instrument combination. The use of gravitational lensing is especially powerful in the infrared wavelengths because cluster cores are dominated by early-type galaxies, which usually emit very little in the infrared. Therefore, infrared sources detected in cluster cores are almost always background sources. Here, we propose to conduct a MIPS 24 $\\mu$m snapshot survey of massive galaxy clusters with the goal of more of such stongly-lensed high-redshift galaxies. We will also study infrared-luminous brightest cluster galaxies (BCGs). This survey should be able to supply many interesting targets to follow up with SCUBA2, Herschel, and ALMA.

Spitzer Space Telescope - Directors Discretionary Time Proposal #280

IRS Spectroscopy of a Typical Lyman Break Galaxy

Principal Investigator: Richard Ellis
Institution: Caltech

Technical Contact: Brian Siana, Spitzer Science Center

Co-Investigators:
Johan Richard, Caltech
Harry Teplitz, Caltech
Ian Smail, Durham
Jean-Paul Kneib, Caltech
Mark Swinbank, Durham
Alastair Edge, Durham
Harald Ebeling, Institute for Astronomy
Max Pettini, Cambridge

Science Category: High-z Galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 0.9

Abstract:
We request Director’s discretionary time on the Spitzer Space Telescope (SST) to determine the restframe mid-infrared spectral properties of a typical L* Lyman break galaxy (LBG) at z=3.07. Our proposed SST study of this galaxy requests a total of 11 hrs integration: 2 hrs with IRAC and MIPS at 24/70 microns to obtain photometry of the source at restframe wavelengths of 0.8-17 microns and 9 hrs exposure with IRS in LL1/SL1 to probe the 3-8 micron PAH and the shape of the continuum emission. This study is only feasible because of a 30x boost to the light-gathering power of Spitzer provided by a foreground gravitational lens - allowing us to use these observations to address questions which are drivers of the James Webb Space Telescope (JWST) science case: yielding insights into the star formation properties of a normal, young galaxy seen 12 Gyrs ago.

Spitzer Space Telescope - Directors Discretionary Time Proposal #473

The Physics of High Redshift Galaxies: Star Formation, Chemistry and Gas Flows

Principal Investigator: Dawn Erb
Institution: Harvard-SAO

Technical Contact: Dawn Erb, Harvard-SAO

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 11.0

Abstract:
I will use rest-frame UV and optical spectra, models of chemical evolution and star formation, and stellar mass and age determinations from ground-based and Spitzer photometry to constrain the properties of galaxies at z~2-3, the peak era of star formation and black hole accretion in the universe. I will focus on understanding the youngest and lowest mass galaxies, and on refining measurements of chemical abundances and using them to constrain the magnitudes of galactic inflows and outflows.

Spitzer Space Telescope - Archive Research Proposal #50640

Study of Galaxy Counts and Stellar Excesses in IRS Peak-Up Archival Observations

Principal Investigator: Sergio Fajardo-Acosta
Institution: Spitzer Science Center

Technical Contact: Sergio Fajardo-Acosta, Spitzer Science Center

Co-Investigators:
Harry Teplitz, Spitzer Science Center
James Colbert, Spitzer Science Center
Lee Armus, Spitzer Science Center
Vassilis Charmandaris, University of Crete

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 75000.0

Abstract:
The IRS Peak-Up arrays are read out in parallel to every Short-Low spectrum taken during the Spitzer mission. We propose to mine this extensive set of more than 170,000 Peak-Up images, which are amply distributed across the sky. We propose to use these images for two main programs: (i) to study galaxy counts in moderately deep 16 micron images over a wide area; and (ii) to search for infrared excesses from stars. The 16 micron Peak-Up images include almost a square degree of low-background data at exposure times of at least 100 sec. Of these, about 300 square arcmin have exposure times greater than 15 minutes. These data will include 5,000--10,000 galaxies with 16-micron flux densities > 120 micro-Jy. This deep survey is unique because such coverage cannot be achieved in dedicated pointed observations, due to the small Peak-Up field of view. The IRS Peak-Up blue and red filters sample the SEDs of stellar sources at 16 and 22 microns. The stellar systems we will study are main-sequence and evolved stars. We expect to detect at least several hundred stars in the Peak-Up images, and expect to find excesses in about 10% of main-sequence stars, plus a higher percentage of dust shells around evolved stars. The intended goal of this study is the detection of new and unique phenomenology in main-sequence and evolved stars. We propose to release catalogs of point sources, as added-value products for the community. Through this program we will expand the impact of Spitzer observations for ancillary discoveries.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #137

IRAC observation of galaxies at z>5

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 11.1

Abstract:
Galaxies at very high redshifts are holding secrects on galaxy formation in the early universe. Generally, those galaxies are too faint to be detected even in very deep Optical and NIR imaging. People are successful in detecting those galaxies behind clusters where their fluxes are magnified by the foreground clusters as gravitation lens. In this program, we carry out a deep IRAC imaging of the cluster A370, where 6 galaxies at redshifts higher than 5 are detected using the narrow band techinque, and confirmed spectroscopically. IRAC observation will provide their SED and colors in rest-frame optical bands, allow us to study their stellar components.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #211

IRAC Imaging of a Cluster of Galaxies at $z=2.39$ and Extremely Red Objects

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Co-Investigators:
Myungshin Im, SSC
Mark Lacy, SSC

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 2.0

Abstract:
IRAC Imaging of a Cluster of Galaxies at $z=2.39$ and Extremely Red Objects Myungshin Im (SSC) Mark Lacy (SSC) Abstract: This program is a deep IRAC imaging of a field near a known z=2.4 radio galaxy, 53W002. This field is also known to contain a proto-cluster of galaxies at z=2.4 (Windhorst et al. 1998, ApJ), and has been observed deeply in B,V,I,J, and H by HST, and in J and K by Subaru. Recent studies have revealed a number of z=2.4 galaxy candidates, and Extremely Red Objects (EROs) in this field. Two of the EROs are J-band dropouts, which could be either dusty/old galaxies at $z \\simeq 2.4$ or Lyman break galaxies at $z \\simeq 12.5$. With our IRAC imaging data, we will study: (1) The nature of J-band dropouts: deep IRAC ch1 and ch2 images will provide a strong indiciation whether the J-band dropouts are at z ~ 2 or at z ~ 12.5. If they are at z ~ 12.5, they will have a flux of about 1.5 microJy in ch1 and ch2. If they are at z ~ 2, they will have a flux of about 3 microJy or more; (2) The nature of EROs: we will study the spectral energy distribution of EROs, to estimate their redshifts and to study their stellar population; (3) Photometric redshift of galaxies in the field; we will use photometric redshift techniques to estimate redshifts of galaxies in the field. If this field indeed covers a z=2.4 cluster of galaxies as claimed, we expect to discover a large number of galaxies which show a SED peak at 5.5 micron (= redshifted 1.6 micron stellar emission peak). (4) Stellar population of galaxies: We will study stellar population of the spectroscopically confirmed z=2.4 galaxies. The IRAC bands corresponds to redshfited NIR wavelengths for such galaxies, thus will be useful for setting a stronger constraint on their stellar mass and star formation history.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #214

IRAC and MIPS imaging of the HDF_S

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Co-Investigators:
Pauline Barmby, SAO
Myungshin Im, SSC
Steve Willner, SAO
Mike Pahre, SAO
Zhong Wang, SAO
Marijn Franx, Leiden Obs.
Huub Rottgering, Leiden Obs.
Paul van der Werf, Leiden Obs.

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 14.0

Abstract:
We will image the WFPC2 field of the Hubble Deep Field South with IRAC, in four bands (3.5-8 micron). Combined with the ultra-deep VLT near-infrared imaging, we will determine the spectral energy distributions of the high redshift galaxies to the restframe K band. These SED's will be modeled using stellar population synthesis models.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30327

IR Spectroscopy of Massive Galaxies at z>2

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Co-Investigators:
Jiasheng Huang, SAO
Steve Willner, SAO
Dimitra Rigopoulou, Oxford
Gillian Wilson, SSC
Tracy Webb, Univeristy of McGill
Rob Ivison, Edinburgh
Sukanya Chakrabarti, Harvard Univ
Chris Conselice, University of Norttingham

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 22.1

Abstract:
More and more galaxies at z>2 are detected at 24 micron. Energy sources which power the emission at 24micron remain unknown for most of those galaxies. Previous IRS studies of objects at high red shifts focused on extreme red and 24 micron luminous objects, and found that most of them are AGN. We propose IRS observations on a sample of massive galaxies at 2.5<z<3.0 with M>10^11 solar mass, f(24micron)>0.5 mJy, and f(20cm)>0.02mJy. That most massive galaxies are detected at 24micron implies a rapid star formation occuring on these galaxies. The high star formation rate helps to explain the formation of massive galaxies at high redshifts. Nevertheless AGN contribution to the 24micron flux cannot be ruled out. The IRS spectroscopy is essential in understanding various energy sources contributing to the 24micron flux of massive galaxies. Combining both the PAH emission flux at 7.7 microns and the 20cm flux density, we will be able to obtain a better star formation rate for these massive galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40537

IRS Observation of IR luminous LBGs

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, Smithsonian Astrophysical Observatory

Co-Investigators:
Dimitra Rigopoulou, Oxford
Lin Yan, SSC
Tracy Webb, McGill University
Matt Ashby, SAO
Steve Willner, SAO
Casey Papovich, U Arizona
Delphine Marcillac, U Arizona

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap IrsPeakupImage
Hours Approved: 47.3

Abstract:
Lyman-Break Galaxies (LBGs) and Submillimeter Galaxies (SMGs) are star-forming galaxies at high-redshifts, selected in very different ways. A large amount of spectroscopic data are now available for LBGs, and consequently we have an increasingly meaninful understanding of their physical properties. By contrast SMGs (i.e., high-redshift ULIRGs) are notoriously faint and difficult to identify at visible wavelengths, making it extremely hard even to measure their redshifts. However, we have recently discovered (Huang etal 2005) a population that links LBGs and SMGs: Infrared-Luminous Lyman Break Galaxies (ILLBGs). ILLBGs strongly resemble SMGs in the infrared, yet are surprisingly bright at visible wavelengths. This permits 1.) high S/N study of their rest-frame UV spectra, 2.) measurement of differences in physical properties between normal blue LBGs and ILLBGs, and 3.) comparison of ILLBGs to their local ULIRG/LIRG couterparts. We have recently completed a new, large photometric survey for LBGs in the Extended Groth Strip (EGS) field, in which we detected 6500 LBG candidates. Amoung these, 220 have clear detections in the MIPS 24 micron band -- in other words, they are ILLBGs. This is the largest ULIRG/LIRG sample at z=3 in existence. We ask for four nights of GMOS time to carry out a spectroscopic study of this important population that links LBGs and SMGs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40689

Study AGN and Galaxy Environment and Evolution Since z=1: IRAC imaging of the DEEP2 fields

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, Smithsonian Astrophysical Observatory

Co-Investigators:
Steve Willner, SAO
Mat Ashby, SAO
Pauline Barmby, SAO
William Foreman, SAO
Christine Jones-Foreman, SAO
Ryan Hickox, SAO

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 14.3

Abstract:
We propose to carry out an IRAC imaging of the field 2 in the Deep Extragalactic Exploration Prober-2 (DEEP2) survey, as a part of a joint Spitzer and Chandra program. We perform multi-wavelength studies of galaxies and AGNs in a substantially large redshift sample with high resolution spectra observed with DEIMOS in DEEP2 . Our science goal is to study AGN enviroment and evolution since z=1. The IRAC colors and X-ray luminosities are essentail in selecting AGNs up to z=1. The IRAC bands also probe the rest-frame NIR bands (H and K) for galaxies at z=1, permitting to derive the rest-frame K-band luminosity function at z=1.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #8

The IRAC Deep Survey

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsScan
Hours Approved: 232.1

Abstract:
The IRAC Deep survey is the major IRAC GTO science program. The primary objective of this program is to study the formation and evolution of normal galaxies to redshifts z>3. Identifying the initial epoch of galaxy formation and understanding the evolution of the galactic star formation rate as a function of redshift are two of the most important goals of observational astronomy. We select the Groth strip as our survey field which is also a survey field for the DEEP project, an ultra deep redshift survey project using Keck telescopes. The depth of the survey will be 6 uJy for 10sigma at the 8um band. This survey will cover 10'X2 deg area. This coverage will allow us to construct a luminosity function for L_* galaxies at z=3.

Spitzer Space Telescope - General Observer Proposal #3630

Very Deep IRAC imaging of MS1054-03: the nature of high redshift, near IR selected galaxies

Principal Investigator: Marijn Franx
Institution: Leiden Observatory

Technical Contact: Marijn Franx, Leiden Observatory

Co-Investigators:
Pieter van Dokkum, Yale University
Natascha Forster Schreiber, MPE- Garching
Ivo Labbe, Leiden Observatory
Greg Rudnick, MPA Garching
Hans-Walter Rix, MPIA Heidelberg
Paul van der Werf, Leiden Observatory
Garth Illingworth, UC Santa Cruz
Alan Moorwood, ESO
Jiasheng Huang, Harvard Smithsonian Center for Astrophysics
Mariska Kriek, Leiden Observatory
Stijn Wuyts, Leiden Observatory

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 7.2

Abstract:
We have obtained deep very Js, H, Ks imaging with the VLT on several fields with excellent optical imaging, in order to study high redshift galaxies. Using these Near-IR images, we identified a class of galaxies with Js - Ks color larger than 2.3. Photometric redshifts and spectroscopic follow-up showed that their mean redshift is 2.5 +- 0.7. These galaxies are complementary to Lyman break selected galaxies: the overlap is minimal, and the rest-frame optical colors of the J-K selected galaxies are much redder. Their contribution to the stellar mass density is comparable to that of Lyman breaks in our fields. We propose to obtain images of these galaxies with IRAF on Spitzer from 3.6 to 8 micron, covering our field around the cluster MS1054--03. This field is unique as it has the largest number of spectroscopically confirmed Js - Ks selected objects, and has several galaxies with rest frame optical spectroscopy. The Spitzer images will allow much improved photometric redshifts, SED modeling and mass estimates of these "red" galaxies, providing unique insight into their star formation history and evolutionary status. The deep Spitzer imaging will be one of the essential pieces to understand the link between these galaxies and "normal" Lyman break galaxies, and to obtain a comprehensive view of galaxy formation.

Spitzer Space Telescope - General Observer Proposal #20147

Ultra-Deep MIPS-70 Imaging of GOODS CDF-S

Principal Investigator: David Frayer
Institution: SSC/Caltech

Technical Contact: David Frayer, SSC/Caltech

Co-Investigators:
Ranga-Ram Chary, SSC
Mark Dickinson, NOAO
David Elbaz, CEA
Dario Fadda, SSC
Bahram Mobasher, STSCI
Jason Surace, SSC
Harry Teplitz, SSC
Lin Yan, SSC

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 34.5

Abstract:
We propose ultra-deep MIPS 70um imaging of the GOODS Chandra Deep Field South (CDF-S). The goal of these observations is to determine the infrared properties of the highest redshift sources detectable by Spitzer with MIPS-70. In particular, we will derive source counts at the faintest possible depths and measure the infrared luminosity function out to z~1.5. We will also measure the 70um/24um flux density ratios to constrain what fraction of the infrared background arises from infrared-cool, starburst dominated luminous infrared galaxies versus infrared-warm AGN. Ultraluminous infrared galaxies contribute significantly to the total star-formation at high-redshift and are expected to be detected at flux levels near the confusion limit of the MIPS-70 band (~1-3 mJy). These observations are motivated by the GOODS philosophy of obtaining the deepest possible images from NASA's Great Observatories (HST, Chandra, and Spitzer) and will greatly build upon our knowledge of the high-redshift universe. The observations of GOODS CDF-S will complement the GO-1 70um observations of GOODS HDF-N. Observations in the south will allow us to constrain the cosmic variance in the faint counts and will provide a list of southern high-z infrared luminous galaxies for follow-up studies with future telescopes, such as ALMA.

Spitzer Space Telescope - General Observer Proposal #3325

Confusion-Limited 70um Imaging of the GOODS Hubble Deep Field North

Principal Investigator: David Frayer
Institution: SSC/Caltech

Technical Contact: David Frayer, SSC/Caltech

Co-Investigators:
Ranga-Ram Chary, SSC
Mark Dickinson, NOAO
David Elbaz, CEA Saclay
Dario Fadda, SSC
David Henderson, SSC
Bahram Mobasher, STSCI
Jason Surace, SSC
Harry Teplitz, SSC
Lin Yan, SSC

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 34.6

Abstract:
We propose confusion-limited MIPS 70um imaging of the GOODS Hubble Deep Field North (HDF-N). The goal of these observations is to determine the infrared properties of the highest redshift sources detectable by the MIPS on Spitzer. In particular, we will derive source counts at the faintest possible depths and measure the infrared luminosity function out to z~1.5. We will also measure the 70um/24um flux density ratios to constrain what fraction of the infrared background arises from infrared-cool, starburst dominated luminous infrared galaxies versus infrared-warm AGN. Ultraluminous infrared galaxies contribute significantly to the total star-formation at high-redshift and are expected to be detected at flux levels near the confusion limit of the MIPS-70 band. Due to the much lower than expected in-flight performance of the 70um detectors and the loss of over half the array due to cabling issues, the planned observations of the HDF-N by the MIPS-GTO team will not reach the confusion level or the depth required to detect high-redshift sources at 70um. We propose to observe the HDF-N field to the ultimate depth at 70um. These observations are motivated by the GOODS philosophy of obtaining the deepest possible images from NASA's Great Observatories (HST, Chandra, and Spitzer) and will greatly build upon our knowledge of the high-redshift universe by probing the far-infrared band to unprecedented depths.

Spitzer Space Telescope - General Observer Proposal #40363

Deep MIPS-70 and 160-micron Imaging of the z=1.16 SMG-P4

Principal Investigator: David Frayer
Institution: California Institute of Technology

Technical Contact: David Frayer, California Institute of Technology

Co-Investigators:
Harry Teplitz, IPAC
Lee Armus, IPAC
Minh Huynh, IPAC

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 3.5

Abstract:
We propose deep MIPS-70 and 160-micron observations of the z=1.16 submillimeter galaxy (SMG) P4. SMG-P4 is a composite AGN+starburst system showing large PAH equivalent widths indicating that the infrared emission arises predominantly from star-formation activity. The current data suggest that the far-infrared (FIR) spectral energy distribution (SED) is shifted to lower dust temperatures (cooler FIR colors) than that found for most local ULIRGs, but is consistent with the constraints on the high-redshift SMGs from ultradeep 70-micron imaging. Observations at 70 and 160-micron near the FIR peak are needed to constrain the SED, bolometric luminosity, star formation rate, and dust mass of the system.

Spitzer Space Telescope - General Observer Proposal #20643

Testing the Preposterous Universe with Infrared Supernovae

Principal Investigator: Peter Garnavich
Institution: University of Notre Dame

Technical Contact: Peter Garnavich, University of Notre Dame

Co-Investigators:
Chris Stubbs, Harvard-Smithsonian Center for Astrophysics
Brian Schmidt, The Australian National University
Robert Kirshner, Harvard-Smithsonian Center for Astrophysics
Nicholas Suntzeff, CTIO/NOAO
Chris Smith, CTIO/NOAO
John Tonry, University of Hawaii
Alex Filippenko, University of California, Berkeley
Kevin Krisciunas, Notre Dame
Peter Challis, Harvard-Smithsonian Center for Astrophysics
Bruno Leibundgut, European Southern Observatory
Adam Riess, STScI
Thomas Matheson, NOAO
Armin Rest, CTIO/NOAO
Alejandro Clocchiatti, Universidad Catolica de Chile
Saurabh Jha, University of California, Berkeley
Gajus Miknaitis, University of Washington
Andy Becker, University of Washington
Jason Spyromilio, European Southern Observatory
Weidong Li, University of California, Berkeley
Jesper Sollerman, Stockholm Observatory
Michael Wood-Vasey, Harvard-Smithsonian Center for Astrophysics
Maria Elena Salvo, The Australian National University
Claudio Aguilera, CTIO/NOAO
Ryan Chornock, University of California, Berkeley
Stephane Blondin, European Southern Observatory
Malcolm Hicken, Harvard-Smithsonian Center for Astrophysics

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 83.4

Abstract:
The current standard cosmological model has been called "preposterous" because it requires a finely tuned dark energy component. We propose a stringent test of the accelerating universe using type Ia supernovae observed in the infrared rest-frame K-band. At redshifts near z=0.6, the K-band slides nicely into the IRAC 3.6 micron band. The infrared has a number of exceptional properties. The effects of dust extinction are minimal, reducing a major systematic that has been suspected of dimming high-redshift supernovae. Also, recent work indicates that type Ia supernovae are true standard candles in the infrared meaning that evolutionary biases will be reduced. We find that good signal-to-noise measurements of 4 type Ia events at z~0.6 will differentiate between an accelerating and low-density universe at more than the 99% confidence level, and make a critical test of the dark energy paradigm. Studying high redshift supernovae in the infrared is not possible from the ground and rest-frame K-band observations can only be done with Spitzer and IRAC. NASA and DOE are currently considering the optimum mission concept to investigate the properties of the dark energy. This proposed experiment will test the feasibility of using SNIa in the infrared as a reliable way of mapping the expansion history of the universe with the Joint Dark Energy Mission.

Spitzer Space Telescope - Archive Research Proposal #40823

A SIMPLE Proof that Lyman Alpha Emitters are Galaxies in the Act of Formation

Principal Investigator: Eric Gawiser
Institution: Rutgers

Technical Contact: Eric Gawiser, Rutgers

Co-Investigators:
Kamson Lai, Harvard-Smithsonian CfA
Jiasheng Huang, Harvard-Smithsonian CfA
Giovanni Fazio, Harvard-Smithsonian CfA
Caryl Gronwall, Penn State
Robin Ciardullo, Penn State
Kevin Schawinski, Oxford

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 63281.0

Abstract:
Lyman Alpha Emitting galaxies (LAEs) seen at high redshift appear to be galaxies in the act of formation. They are currently the most promising candidates for the progenitors of typical spiral galaxies like the Milky Way. The LAEs tend to be younger, lower in mass, and less chemically evolved than the better-studied Lyman Break Galaxies (LBGs). Deep IRAC imaging allows us to study the star formation history of these objects to gain a better understanding of the process of galaxy formation. We will use archival IRAC images of the Extended Chandra Deep Field-South from the SIMPLE (Spitzer IRAC/MUSYC Public Legacy in ECDF-S) and GOODS Legacy Programs combined with ground- and space-based photometry in UBVRIzJK to study the Spectral Energy Distributions of our sample of 162 Lyman Alpha Emitters at z=3.1. 47 of these LAEs have confirmed spectroscopic redshifts. We will perform the identical analysis on a sample of 34 spectroscopically confirmed Lyman Break Galaxies at 2.7<z<3.9 to compare the star formation histories of these two families of high-redshift galaxies. At this redshift, the IRAC bands trace the rest-frame optical radiation which will reveal or eliminate the presence of an underlying population of evolved stars. We will use models containing both young and old stellar populations in order to search for evidence of prior epochs of star formation. If the older component is absent in most LAEs, they can be proved to be undergoing their first burst of star formation, meaning that they represent fundamental building blocks of present-day galaxies. We will also use the archival MIPS GTO images of this field to determine the fraction of LAEs and LBGs hosting low-luminosity or heavily obscured AGN that could not be detected through X-rays in the existing Chandra and XMM catalogs.

Spitzer Space Telescope - Archive Research Proposal #50805

Comparing the Stellar Populations of Star-forming Galaxies at z=2

Principal Investigator: Eric Gawiser
Institution: Rutgers

Technical Contact: Eric Gawiser, Rutgers

Co-Investigators:
Kamson Lai, Harvard-Smithsonian CfA
Jia-Sheng Huang, Harvard-Smithsonian CfA
Giovanni Fazio, Harvard-Smithsonian CfA
Kevin Schawinski, Oxford University
Caryl Gronwall, Penn State University
Robin Ciardullo, Penn State University
Nicholas Bond, Rutgers University
Lucia Guaita, P.U. Catolica
Nelson Padilla, P.U. Catolica

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 75000.0

Abstract:
Published results from our Cycle 4 Archival program show that Lyman Alpha Emitting galaxies (LAEs) at z=3.1 appear to be galaxies in the act of formation. These objects are currently our most promising candidates for the progenitors of present-day L* galaxies like the Milky Way, as they are younger, lower in mass, and less chemically evolved than z~3 Lyman Break Galaxies (LBGs). Deep IRAC images allow us to study the star formation history of these objects through multi-band spectral energy distribution (SED) fitting. By doing this with a sample of z=3.1 LAEs, we have begun to place constraints on the process of galaxy formation in the early universe. Here we propose to extend our study to lower redshifts, using a sample of LAEs at z=2.1, along with a continuum-selected sample of spectroscopically-confirmed star-forming galaxies (SFGs) between 1.5<z<3. To do this, we will combine archival IRAC data from the GOODS and SIMPLE (Spitzer IRAC/MUSYC Public Legacy in E-CDFS) surveys of the Extended Chandra Deep Field South with ground- and space-based photometry in UBVRIzJK. We will perform a uniform two-population SED analysis using the Maraston models, a Salpeter IMF, and the Calzetti dust law. This will enable us to directly compare the star formation histories of LAEs to those of continuum-selected SFGs at both z=2 and z=3, probe the evolution in these objects, and determine which have properties most consistent with being the progenitors of z=0 L* galaxies. In addition, we will subdivide our galaxy samples into those detected at 8 microns with IRAC and those present in the 24 micron public FIDEL image of the field. This will test whether MIR-detected galaxies at z~2 are as massive as those at z~3. Finally, we will use the FIDEL 24 and 70 micron images to determine the fraction of SFGs and LAEs that host low-luminosity or heavily obscured AGN, which cannot be detected in Chandra and XMM imaging.

Spitzer Space Telescope - General Observer Proposal #30607

The brightest Extremely Red Objects in the Sky from 2MASS/SDSS fields

Principal Investigator: Antonis Georgakakis
Institution: Imperial College

Technical Contact: Antonis Georgakakis, Imperial College

Co-Investigators:
Kirpal Nandra, Imperial College
Ioannis Georgantopoulos, Athens Observatory
Michael Rowan-Robinson, Imperial College

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 3.8

Abstract:
We propose mid- to far-IR photometry to explore the nature of the brightest (K<14.5) dusty Extremely Red Objects (EROs; R-K>5) on the sky, identified over an unprecedented area of 5300deg2, by cross-correlating SDSS and 2MASS. These systems are over 100 times brighter at any wavelength compared to typical EROs in deep pencil-beam surveys, and they likely represent the most nearby/bright tail of this population. These systems, largely overlooked in the optical, are also likely to be the most massive galaxies in the process of formation we know todate and therefore are interesting in their own right. The proposed mid- and far-IR observations will allow us to explore the nature of this population by deconvolving the different emission components to: (i) assess the relative contribution of AGN/starburst activity to the bolometric luminosity, (ii) quantify the dust properties and estimate stellar masses, (iii) explore similarities with high-z dusty galaxies (e.g. sub-mm sources) and (iv) build a high quality dusty template SED library over a wide wavelength baseline (UV to far-IR) which will provide an invaluable template set for the interpretation of fainter dusty EROs found in deep pencil-beam surveys.

Spitzer Space Telescope - General Observer Proposal #50823

Spatially-Resolved Mid-IR Imaging of Lensed Ly-Break Galaxies at z>2

Principal Investigator: Michael Gladders
Institution: Carnegie Observatories

Technical Contact: Michael Gladders, Carnegie Observatories

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 3.6

Abstract:
We propose IRS spectroscopy and IRAC and MIPS photometry of two newly discovered bright strongly lensed Lyman-break galaxies (LBGs). These two LBGs are of comparable brightness to the oft-studied MS 1512-cB58, but appear in much greater isolation with respect to the lensing foreground. In particular, both are well isolated from their respective lensing cluster's central galaxies, even at Spitzer spatial resolution at longer wavelengths. Observations of strongly lensed galaxies such as those proposed here offer a unique and direct window into the spectral properties of starforming galaxies in situ at the peak of the universe's star formation history.

Spitzer Space Telescope - Directors Discretionary Time Proposal #496

IRS Observations of a Strongly Lensed LIRG Behind the Bullet Cluster

Principal Investigator: Anthony Gonzalez
Institution: University of Florida

Technical Contact: Anthony Gonzalez, University of Florida

Co-Investigators:
Marusa Bradac, UCSB
Doug Clowe, Ohio University
Christine Jones, Harvard-Smithsonian Center for Astrophysics
Maxim Markevitch, Harvard-Smithsonian Center for Astrophysics
Greg Rudnick, NOAO
Casey Papovich, Texas A&M
Dennis Zaritsky, University of Arizona

Science Category: high-z galaxies
Observing Modes: IrsMap IrsPeakupImage
Hours Approved: 6.0

Abstract:
We propose to observe a luminous infrared galaxy at z~2.7 that is highly lensed (factor of ~50 magnification) by the Bullet Cluster. This galaxy is a strong 24 micron and submillimeter source due to this magnification, yet the intrinsic infrared luminosity of this galaxy is lower than any other obscured galaxies previously observed with IRS at these redshifts. We will use IRS spectra and peak-up imaging to (1) obtain a spectroscopic redshift, (2) quantify the AGN contribution to the observed 24 micron emission, and (3) determine the star-formation rate from the Paschen alpha line. IRS is required because there is no other means of achieving these objectives; DDT is required because the 24 micron data on which this program is based was obtained after the Cycle 5 deadline.

Spitzer Space Telescope - Theoretical Research Proposal #20067

Interpreting the SPITZER View of Galaxy Formation and Evolution

Principal Investigator: Fabio Governato
Institution: University of Washington

Technical Contact: Fabio Governato, University of Washington

Co-Investigators:
Mauro Giavalisco, STSCi
Julianne Dalcanton, University of Washington
Thomas Quinn, University of Washington
Beth Willman, NYU
Lucio Mayer, ETH, Zurich
Octavio Valenzuela, Univ. of Washington

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 85000.0

Abstract:
We request the equivalent of about 9 months of salary funding for the PI to direct the comparison between the prediction of breakthrough N-body simulations of galaxy formation with the detailed, panchromatic observables of the internal structure of field galaxies provided by GOODS, GLIMPSE and SINGS. We will focus on (a) star formation rates and histories (SFH) as a function of galaxy stellar mass and morphology (b) the cosmic SFH at high redshift (c) the evolution of galaxy sizes and disk surface brightness of spiral galaxies and specifically of the progenitors of our own Milky Way and (d) the evolution of disks and spheroids through dynamical instabilities and the formation of the thick/thin disk components. Our project carries significant improvements over previous work: -We resolve in a full cosmological context the ISM and stellar structure of a small set of galaxies down to giant star-forming regions with a sub-kpc spatial resolution. -We describe SN feedback and star formation with a physically motivated model that reproduces the basic properties of z=0 galaxies. -We will provide predictions directly comparable with observed quantities obtained with Spitzer's instruments, including the effects of dust reprocessing on the SED of galaxies. -We sample galaxy masses from giant spirals to dwarfs. -We include in our team observers strongly involved with some of the mentioned Spitzer's surveys. -We will update the freely available and widely used software TIPSY (Theoretical Image Processing System) developed by co-PI T.Quinn to produce images from simulations in the passbands of Spitzer's instruments. Delivery of results will happen between Summer 05 and Spring 06. 80% of the simulations have been completed to date using 2.5e5 CPU hrs.

Spitzer Space Telescope - Directors Discretionary Time Proposal #262

An Ultra-Deep Spitzer Spectral Survey

Principal Investigator: George Helou
Institution: Caltech

Technical Contact: George Helou, Caltech

Co-Investigators:
M. Harwitt,
J.-L. Puget, Institut d'Astrophysique Spatiale, France
H. Roussel, MPIA
P. Appleton, SSC
K. Sheth, SSC
J.D. Smith, U. Arizona
D. Dale, U. Wyoming

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 46.3

Abstract:
We propose to undertake an ultra-deep unbiased extragalactic spectral survey with the IRS in low-resolution mode, to probe the high-end tail of the line-to-continuum ratio in galaxies, and to look for galaxies with unusually high infrared line emission that might escape detection or escape notice in continuum surveys. Such a search is in large part motivated by the potential for novel types of objects, either detected primarily in the lines, or having abnormally high line-to-continuum ratios, either way enabling new insights and new approaches in the study of galaxies. In addition to the potential scientific yield of this experiment, the immediate tangible benefit will be to ascertain how well the noise in IRS data converges for very long integration times, enabling comparably deep integrations in other contexts, e.g., targeted searches for weak line emission. Additional benefits will result from new techniques for flat fielding and background subtraction within the data set.

Spitzer Space Telescope - General Observer Proposal #50726

Looking for the End of Star Formation and the Transformation of Future Cluster Galaxies

Principal Investigator: Bradford Holden
Institution: University of California Observatories/Lick Obs

Technical Contact: Bradford Holden, UCO/Lick Obs

Co-Investigators:
Shannon Patel, UCO/Lick Observatory
Arjen van der Wel, Johns Hopkins University
Daniel Kelson, OCIW
Garth Illingworth, UCO/Lick Observatory

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 19.7

Abstract:
Star forming galaxies comprise <4% of the massive galaxy population in clusters at z~1. In contrast, this fraction is 40% in the field at the same redshift. The average cluster will double to triple in mass between z~1 and today, and both theory and observations show that this mass assembly occurs mostly through the infall of groups of galaxies from the field. Therefore, massive galaxies in these groups must have stopped forming stars before they merged with the cluster in order to preserve the low fraction of star-forming cluster galaxies. Theoretical models also suggest that the group environment is where the cessation of star-formation is most effective. We intend to look for evidence of this by surveying groups of galaxies that will fall into two z=0.83 clusters of galaxies. Our spectroscopic survey is >90% complete for massive galaxies in one of the clusters - a total 2245 redshifts in the cluster and its outskirts - and the survey of the second cluster is ongoing. From the current catalogs, we have selected 10 groups of galaxies in the outskirts that will become part of the cluster by the present epoch. Our proposed MIPS and IRAC observations, when combined with the data we have in hand, will help determine the star-formation and stellar mass content of galaxies in these groups. We expect to see a distinct reduction in the fraction of massive star-forming galaxies and/or in the average star-formation rate for galaxies in these groups. If this is correct, the processes that transform galaxies into the passively evolving, red-sequence cluster members occurs in the infalling groups, and not necessarily in the cluster core.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #117

IRS Exploration program

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: James R. Houck, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap IrsStare
Hours Approved: 10.8

Abstract:
This short program includes a variety of objects which will be observed in a combination of lo-res and hi-res IRS modes. This project has multiple scientific goals. The proposed experiments are considered fairly challenging for the IRS capabilities, but have potential for new unexpected discoveries.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #11

Dust at High Redshift

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Tom Soifer, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 3.5

Abstract:
The goal is to probe the properties of dust at high redshifts by obtaining the spectra of sources where the infrared emission is believed to be thermal dust emission. The presence/absence of PAH/Silicate emission/absorption in these systems will address the evolution of the dust content in systems at significant lookback times. The targets chosen are all z>0.9 in which a strong dust continuum has been detected.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #126

The Most Luminous Lyman Break Galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Harry Teplitz, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 5.1

Abstract:
We will obtain Spitzer imaging and spectroscopy of the most luminous Lyman Break Galaxies. These objects were identified by SDSS spectra, and are 5-10 brigher than typical LBGs. The observations will characterize the nature of these sources in relation to hyperluminous starbursts. We will determine if there is an AGN contribution to their luminosity.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #138

The Star Formation Histories of High-Redshift Cluster Galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: James Higdon, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 2.9

Abstract:
Undestanding the star formation histories of galaxies in the early universe is a key goal of observational astrophysics. The most straightforward way to do this is to measure the strengths of both the evolved and young stellar components for samples of galaxies at high redshift. We will use 3-hours of Spitzer Space Telescope time to obtain deep IRAC and MIPS images in order to measure the rest-frame near- and mid-infrared emission from fourteen robustly star forming galaxies in the z=2.313 Coup Fourre' galaxy cluster, discovered in our ultra-deep emission line survey. The combined rest-frame UV to mid-IR spectral energy distributions will (1) constrain the evolved stellar populations in the cluster galaxies, allowing us to (2) model their star formation histories (e.g., recent starburst or exponentially decaying SFR, etc.) with Starburst99 and Pegase. Moreover, we will (3) identify highly obscured cluster galaxies and (4) measure photometric redshifts for objects dominated by evolved stars throughout the 8 Mpc2 IRAC & MIPS fields of view. Selecting cluster galaxies based on both massive star formation and evolved stellar content will yield a more complete census of star and galaxy formation in an epoch when the Universe was only 20% of its current age.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #13

IRS Spectra + IRAC/MIPS imaging of EROs

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Tom Soifer, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 2.5

Abstract:
Extremely Red Objects (EROs) are believed to be either dusty starbursts or passively evolving elliptical galaxies. In either case they are believed to be at a redshift of z=1-2. If these are starbursts, they would produce a major fraction of the star formation in the z=1-2 range. If they are passively evolving ellipticals they would force the epoch of galaxy formation back substantially beyond z=5. This program involves IRS spectra of 2 specific EROs, HR10 and CADIS 16hr ERO1, as well as IRAC and MIPS imaging and followup spectroscopy of 4 targets from the CADIS 9 hr field.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #16

IRS observations of X-ray Background Sources

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Daniel Weedman, National Science Foundation

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 9.6

Abstract:
Optically faint or unidentifiable sources from Chandra deep surveys in SSA13, AXAF-South, Lockman Hole, Groth NE, and from XMM-Deep will be selected for IRS lo res observations with the objective of determining spectroscopic redshifts for optically obscured X-ray sources. IRS observations will be obtained only for sources found to have MIPS 24 micron fluxes above about 0.7 mJy.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #198

Tidal Dwarf Galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Sarah Higdon, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsStare
Hours Approved: 10.9

Abstract:
Tidal Dwarf Galaxies (TDG's) are formed from material stripped from the disks of spiral galaxies, which are undergoing tidal interactions with a nearby companion. These galaxies provide important clues to our understanding of galaxy formation, evolution and cosmic recycling. Using the IRS we will measure the star formation activity in 6 TDG candidates. We will measure the ionization state ([NeII] 12.8 um, [NeIII] 15.6 um and [NeV] 14.3um and [OIV] 25.9 um), the density in the ionized gas ([SIII] 18.7um/33.5um), the PAH fractions at 5.5-9um and 11-12.2um and possibly (optimistic here!) molecular hydrogen emission form PDRs at H2 (S0) 28um and H2 (S1) at 17um. In addition to the IRS observations we will map both the Guitar and Stephan's Quintet with IRAC. This will enable us to compare the PAH fraction in the dwarf galaxy to that of its parent. Similarly we will compare our observation of the proposed TDG at the southern tip of NGC 4038 with the GT observations of the central region of the Antennae. This program compliments two existing GT programmes: 1) the high-Z program - these observations enable us to observe in fine detail the nearby/present day analogs of galaxy formation in the early universe. 2) Blue Compact Dwarf programme - On first inpsection BCD's and TDG's appear the same: BCDs are similar in size to TDG's, but TDG's may not have a large dark matter halo component (affecting the long term stability of an object) and BCD's typically have a much lower metallicity. We will be able to compare the star formation activity in terms of the ionization state and PAH fraction in the two galaxy types.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30184

Spitzer Observations Of A Z=2.3 Galaxy Cluster

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: James R. Houck, Cornell University

Co-Investigators:
James Higdon, Cornell University
Sarah Higdon, Cornell University
Terry Herter, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 3.0

Abstract:
Understanding the development of large scale structure and the evolution of galaxies in high-redshift clusters are key goals of observational astrophysics. We have identified a cluster of 14 luminous H-alpha emission line sources within a ~2 Mpc diameter region at z=2.3 towards the quasar FBQS J1416+2649. The J1416 cluster represents one of the richest known high-z galaxy clusters. We will use 3-hours of Spitzer Space Telescope time to otbain deep IRAC 3.6-8.0 um and MIPS 24 um images of the J1416 cluster in order to measure the rest-frame near- and mid-infrared emission from the 14 robustly star forming (or AGN dominated) galaxies. The final rest-frame optical to mid-infrared spectral energy distribution will be used to (1) constrain the evolved stellar populations in the cluster galaxies, allowing us to (2) model their star formation histories (i.e., recent starburst or exponentially decaying SFR, etc.) with Starburst99 and Pegase. Moreover, we will (3) identify highly obscured cluster galaxies and AGN and (4) estimate photometric redshifts for objects dominated by evolved stars throughout the young galaxy cluster. Selecting cluster galaxies based on both massive star formation and evolved stellar content will yield a more complete census of star and galaxy formation in an important epoch.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30226

IRS Spectroscopy of Silicate Dropouts at z~1.5

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Harry Teplitz, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 9.0

Abstract:
We request 9 hours of IRS spectrscopy to follow up strongly silicate absorbing ULIRGs at z~1.5. We have previously obtained 16 and 24 micron imaging of targets in the Bootes field to look for the sources with the most extreme 16/24 color. These are expected to be the signature of strong silicate absorption redshifted into the 24 micron filter. These sources are likely to be obscured AGN. The fraction of such AGN at z>1 has important implications for the sources of the IR and X-ray background.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30334

IRS Spectroscopy of Starburst-Dominated ULIRGs at 2 < z < 3

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Vandana Desai, Caliornia Institue of Technology

Co-Investigators:
Vandana Desai, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 34.9

Abstract:
We request 34.9 hours of Spitzer time to obtain mid-infrared IRS LL1 spectra of 16 extreme (f(24)/f(R) > 1000) infrared sources selected from the NOAO Deep Wide-Field Survey Bootes field. Each target displays a 1.6 micron rest-frame stellar bump indicating that 1) it has a redshift in the range 2 < z < 3; and 2) its infrared luminosity is primarily generated by reprocessed starlight, rather than AGN-heated dust. These spectra will allow us to study the mid-infrared properties of the most luminous starburst-dominated galaxies to z=3. We will also confirm the stellar bump as an indicator of starburst domination and calibrate the bump photometric redshifts for extreme, high redshift sources.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30364

A systematic Spitzer-IRS survey of obscured starburst galaxies at 1.0<z<1.9

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
Duncan Farrah, Cornell University
Sarah Higdon, Cornell University
James Higdon, Cornell University
Dan Weedman, Cornell University
Harding Smith, UCSD
Mari Polletta, UCSD

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 59.8

Abstract:
We propose deep IRS observations of 32 starburst dominated ULIRGs over 1.0<z<1.9, selected from the SWIRE Lockman field. This redshift range marks the peak epoch of star formation, galaxy evolution and large-scale structure formation over the history of the Universe. Obscured starburst galaxies at this epoch are therefore thought to be signposts of the formation of massive (>2L*) galaxies, and probably local massive structures such as galaxy clusters, but their properties and evolution are poorly constrained. Previous studies with Spitzer have tried to study distant obscured starbursts, but used simple selection methods that resulted in AGN dominated samples. Here, we employ a physically motivated selection method that has been directly validated with previous IRS observations to assemble a large sample of obscured starbursts at z~1.5 for observation with IRS. By obtaining high quality spectra of our targets we will (1) determine their contribution to 24 micron source counts at faint fluxes, and thus reconcile source count models with observations, (2) measure obscurations, star formation rates and AGN luminosities, to establish the likely formation history of local >2L* galaxies, and (3) determine accurate redshift distributions for use in clustering analyses of larger samples. We also include IRS observations of a complementary sample; optically faint 70 micron sources in the same field. Both count models and SED modelling indicate these galaxies are obscured starbursts at 0.5<z<1.0, so their star formation rates and luminosities will make for insightful comparisons with the higher redshift sample.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40039

The Starburst Luminosity Function at High Redshift

Principal Investigator: James Houck
Institution: Cornell University

Technical Contact: Daniel Weedman, Cornell University

Co-Investigators:
Carol Lonsdale, University of California, San Diego
Mari Polletta, University of California at San Diego
Duncan Farrah, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 20.0

Abstract:
Our previous IRS observations have shown that sources selected from the SWIRE survey based on the presence of redshifted photospheric continuum in the IRAC bands always show strong PAH emission features in the IRS spectra, and with a narrow dispersion between 1.6u continuum and 7.7u PAH rest frame flux density. This suggests a link between these two parts of the spectrum which may allow us to derive star formation rates for large samples of these high-redshift, starburst-dominated ULIRGs using the IRAC fluxes. A selection effect favors z ~ 2 because the PAH emission at 7.7u enhances the MIPS 24u flux at such redshifts. To understand the selection effects and to calibrate better the PAH vs. IRAC fluxes, new observations are proposed for 15 SWIRE sources with photometric z ~ 2 but at the extreme of the fv(24u)/fv(5.8u) ratio, having minimal values of this ratio. This will determine if such sources have weak MIPS 24u flux because the PAH features are truly weak, or because they are at redshifts which remove this feature from the MIPS band.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40441

IRS Spectra of the Highest Redshift Sources in the Bootes Field

Principal Investigator: James Houck
Institution: Cornell University

Technical Contact: Vandana Desai, California Institute of Technology

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 24.0

Abstract:
The formative phase of the most massive galaxies may be extremely luminous, characterized by intense star formation and AGN activity. Few such galaxies have been unambiguously identified at high redshift, and thus far we have been restricted to studying low-redshift ultraluminous infrared galaxies as possible analogs. We have recently discovered a sample of objects which may represent this early phase in galaxy formation, and we are undertaking an extensive multiwavelength study of this population. These objects are optically extremely faint (R > 25), but bright at mid-infrared wavelengths (f(24) >= 0.5 mJy). Mid-infrared spectroscopy with Spitzer/IRS reveals that they lie at 2 < z < 3, implying luminosities of ~10^13 Lsun. Their mid-infrared SEDs fall into two broad categories. Sources with brighter 24 micron flux densities exhibit power-law SEDs and mid-infrared spectra characteristic of AGN; fainter sources show the redshifted 1.6 micron bump from a stellar population and mid-infrared PAH emission characteristic of star formation. How do these star-forming extreme bump sources relate to other high-redshift populations, such as the submillimeter galaxies? To find out, we have obtained IRS spectroscopy and MIPS 70 and 160 micron imaging for 16 extreme bump sources at z~2. We aim to obtain a similar data set for a sample of 8 extreme bump sources at 2.5 < z < 3. In this GTO proposal, we request 24 hours to obtain low-resolution IRS spectroscopy of these 8 sources. Our primary goals are to verify their photometric redshifts and to determine whether AGN activity or star formation dominates the mid-infrared luminosity. Accurate redshifts are necessary for estimating the bolometric luminosities, star formation rates, and stellar masses for these sources. In a separate small GO proposal, we request 70 and 160 micron imaging of these same sources in order to improve on the bolometric luminosity and star formation estimates that we can obtain with 24 micron data alone.

Spitzer Space Telescope - General Observer Proposal #3720

Identification and Stellar Content of the Mysterious SCUBA Galaxies

Principal Investigator: Jiasheng Huang
Institution: CfA

Technical Contact: Jiasheng Huang, CfA

Co-Investigators:
Steve Willner, SAO
Paul van der Werf, Leiden University
Kirston Knudsen, Leiden University
Tracy Webb, Leiden University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 7.4

Abstract:
Extragalactic sub-millimeter sources (often referred to as "SCUBA galaxies") represent an ultraluminous population that may account for the bulk of star formation at high redshift. Yet little is known about these galaxies because they are so difficult to study -- or even detect -- at optical and NIR bands. Early observations with IRAC detected SCUBA galaxies with remarkable ease. This was the first detection of light from the evolved stellar component of SCUBA sources, which are presumably dusty galaxies at high redshifts. We here propose IRAC observations of five fields with excellent SCUBA data including 32 sources. The IRAC measurements will determine the basic physical parameters of these galaxies, such as position, redshift, and luminosity of the normal stellar populations. These parameters will establish the evolution of SCUBA galaxies and are a necessary step in determining the star formation history of the early Universe. This study will represent a huge advance in both numbers of galaxies and knowledge of their properties.

Spitzer Space Telescope - General Observer Proposal #40801

Deep IR imaging of Submillimeter Galaxies detected by SMA: Unambiguously Identifying SMGs at High Redshifts

Principal Investigator: Jiasheng Huang
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, Smithsonian Astrophysical Observatory

Co-Investigators:
Mat Ashby, SAO
Joshua Younger, Harvard University
Giovanni Fazio, SAO
Grant Wilson, Univ. of Massachusetts at Amherst
Min Yun, Univ. of Massachusetts at Amherst
Tracy Webb, McGill Univ.
David Sanders, Univ. of Hawaii
Nick Scoville, Caletch
David Hughes, Inaoep
Itziar Aretxaga, Inaoep
James Lowenthal, Smith College
David Wilner, SAO
Lin Yan, SSC
Emeric Le Floc'h, Univ. of Hawaii
Olivier Ilbert, Univ. of Hawaii

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsPeakupImage MipsPhot
Hours Approved: 37.4

Abstract:
In 2007 January, we detected no fewer than five AzTEC 1.1 mm galaxies via high-resolution interferometric imaging with the Sub-Millimeter Array (SMA) atop Mauna Kea at 890 microns. Despite the fact that these sources are all radio-quiet SMGs, with the high S/N SMA detections in the narrow SMA beam we unambiguously determine the position of the AzTEC galaxies with subarcsecond accuracy. All the counterparts, which lie in the SCOSMOS survey, are detected by IRAC at 3.6 and 4.5 microns in the existing SCOSMOS mosaics. Only two are detected at the longer IRAC wavelengths, however, and none are detected in the existing 24 micron data. Furthermore, only two are detected at optical wavelengths. These sources thus present (incomplete) SEDs that appear consistent with their being either 1. deeply dust-enshrouded galaxies at z=2, or 2. a distant z=4 population of very luminous objects. Because they are so optically faint, only broadband imaging such as Spitzer can provide will permit construction of their rest-frame optical-near-IR SEDs. This appears to be the only way to discriminate between the two possibilities for the origin of SMGs that are radio-quiet. Accordingly, we ask for 37.4 h to carry out a very deep imaging program utilizing all three Spitzer instruments to construct the SEDs for the four SMGs in our sample.

Spitzer Space Telescope - General Observer Proposal #30526

Star formation rates in a sample of redshift 6.6 galaxies

Principal Investigator: Esther Hu
Institution: University of Hawaii

Technical Contact: Esther Hu, University of Hawaii

Co-Investigators:
Lennox Cowie, Institute for Astronomy

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 13.6

Abstract:
We propose to observe a sample of six spectroscopically confirmed Lyman alpha emitting galaxies at a redshift of 6.6. These objects, which were found using wide field narrow band imaging, lie in a small filament in the outer regions of the SSA22 field. Because of their spatial grouping they can be efficiently observed with IRAC to obtain their rest frame optical spectral energy distributions and to measure the strength of the H alpha line which lies in the 4.5 micron channel. We will combine this with measurements of the rest frame UV from Nicmos/HST observations to estimate star formation rates and limits on the dust extinction from these objects and to determine if there is evidence of earlier star fomation in these galaxies. We will use the measured star formation rates for the individual galaxies and the measured number densities from the wide field surveys to estimate the cosmic star formation densities contributed by the Lyman alpha emiiting galaxies at these redshifts and compare this with results derived from color break galaxy searches.

Spitzer Space Telescope - General Observer Proposal #20218

Unveiling the Evolution of Lyman Break Galaxies: IRAC Survey of GOODS-N Flanking Fields

Principal Investigator: Ikuru Iwata
Institution: National Astronomical Observatory of Japan

Technical Contact: Ikuru Iwata, National Astronomical Observatory of Japan

Co-Investigators:
Kouji Ohta, Dpt. Astronomy, Kyoto Univ.
Masayuki Akiyama, Subaru Telescope, NAOJ
Kentaro Aoki, Subaru Telescope, NAOJ
Naoyuki Tamura, Dpt. of Physics, Univ. of Durham, UK
Gaku Kiuchi, Dpt. Astronomy, Kyoto Univ.
Mataka Andoh, Dpt. Astronomy, Kyoto Univ.

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 13.0

Abstract:
We propose a wide-field IRAC survey of the "flanking fields" of the northern Great Observatories Origins Deep Survey (GOODS) field, where we have deep optical images and have selected a sample of LBGs at z ~ 5. With IRAC we intend to wipe an about 300 sq. arcmin field with sensitivity sufficient to detect relatively bright LBGs, z(AB)< 24.5. Using LBGs' flux densities from rest-frame UV to near-infrared wavelengths we aim to constrain the star formation history of them and estimate their ages and stellar mass. Although past works using optical to near-infrared images have succeeded in depicting the history of mass assembly up to z = 3, there has never been information at z > 4. The capability of Spitizer in deep imaging at mid-IR should enable us to open the door to the higher redshift. Since our observation will increase the number of bright LBGs which must be rare in a deeper and narrower survey, it is complementary to the GOODS only with an expense of about 13 hours. From the studies we have made so far it is found that there is a hint of an evolution of LBG population from z~5 to z~3 (i.e., from the cosmic age of 2 Gyr to 1 Gyr), and the luminosity dependence ("down-sizing") in the evolution process of LBGs is suggested. So our LBG sample should provide indispensable clues to understand the evolutionary process of galaxies in the early universe. The detailed properties such as morphology, spectral features, metallicity of bright LBGs are being examined with follow-up observations. In addition, by the comparison of IRAC images and deep optical images, we will construct a large sample of luminous MIR-bright galaxies at 2.5 < z < 3.5. They would be dusty star forming galaxies and passively evolving massive galaxies undetected through Lyman break technique, and should enable us to make an unbiased view of galaxies at z~3. Since the data are for the flanking fields of a multi-band very deep survey, they should be valuable for wide range of studies.

Spitzer Space Telescope - General Observer Proposal #40957

An Independent search for Starbursting/AGN components within a Lyman Alpha Blob at High Redshift

Principal Investigator: Matt Jarvis
Institution: University of Hertfordshire

Technical Contact: Daniel Smith, Oxford University

Co-Investigators:
Daniel Smith, University of Oxford
Mark Lacy, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 2.0

Abstract:
We propose to image a newly discovered Lyman Alpha Blob thought to be ionized by a "cold accretion" process using MIPS at 24 um, and all four IRAC channels. The ionizing sources of Lyman Alpha Blobs remain unclear; these observations are designed to provide an independent test for the presence of starbursting or AGN components.

Spitzer Space Telescope - General Observer Proposal #50660

Galaxies, AGN, and Environment at z=1: IRAC observations of DEEP2

Principal Investigator: Christine Jones
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Ryan Hickox, Harvard-SAO

Co-Investigators:
Alison Coil, University of Arizona
Benjamin Weiner, University of Arizona
Kevin Bundy, University of Toronto
Michael Cooper, University of Arizona
Richard Cool, University of Arizona
Darren Croton, University of California, Berkeley
Marc Davis, University of California, Berkeley
Peter Eisenhardt, JPL
Daniel Eisenstein, University of Arizona
Sandy Faber, UCSC/UCO Lick
William Forman, SAO
David Koo, UCSC/UCO Lick
Stephen Murray, SAO
Casey Papovich, University of Arizona
Daniel Stern, JPL
Christopher Willmer, University of Arizona
Steven Willner, SAO

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 16.6

Abstract:
The Spitzer view of the z=1 Universe is spectroscopy starved. Only 5 sq. deg. of the sky have been surveyed with very deep (24th mag) spectroscopy that probes z>1 galaxies, and only about half of this area has been observed with Spitzer. Cosmic variance is severe even at z>1 and limits our ability to measure the evolution of galaxies and AGN at these epochs. DEEP2 is the premier z>1 wide-field survey, but only 1.5 sq. deg. of it has Spitzer coverage. Here we propose to more than double the overlap between Spitzer and DEEP2, with IRAC coverage of two fields that contain ~16,000 high-quality Keck spectra of galaxies at 0.7<z<1.5 and ~20,000 PRIMUS redshifts at z<1. Both fields have recently been observed with Chandra. With these data we will study the distribution of stellar mass, star formation, and dark matter halo masses (via clustering) in diverse types of galaxies and AGN, across a wide range of environments, as a function of redshift. IRAC data will provide robust stellar masses (especially for blue galaxies) and allow us to identify at least 50% more AGN than are found in the X-ray and optical bands alone, revealing a unbiased view of the AGN population to high levels of obscuration. We will use the dense DEEP2 sampling to determine small-scale environments and clustering of galaxies and AGN as a function of stellar mass, color and luminosity. We will also be able to compare IRAC-based stellar masses with DEEP2 dynamical masses. The proposed observations will increase the overlap between IRAC and DEEP2 by a factor of 2.3. This will greatly increase the statistical power of the survey, reduce cosmic variance, and allow measurements of environment and clustering in multiple bins of AGN luminosity or stellar mass, needed to constrain galaxy and AGN evolution models. DEEP2 is the only survey that provides high-quality galaxy spectra and precise redshifts over a large volume at high redshift; these observations will therefore produce a lasting legacy dataset for studying the z=1 Universe.

Spitzer Space Telescope - Directors Discretionary Time Proposal #277

Infrared Observations of Dusty Quasar Absorption Systems: Dust Composition and Absorber Environment

Principal Investigator: Varsha Kulkarni
Institution: Univ. of South Carolina

Technical Contact: Varsha Kulkarni, Univ. of South Carolina

Co-Investigators:
Donald G. York, University of Chicago
Giovanni Vladilo, Trieste Astronomical Observatory
Daniel E. Welty, University of Chicago

Science Category: High-z Galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 10.0

Abstract:
Damped Lyman-alpha (DLA) absorption systems in quasar spectra dominate the neutral gas content in galaxies and offer tools for studying evolution of metals and dust in galaxies. However, recent observations indicate that the majority of DLAs appear to have low metallicities and low star formation rates at all redshifts studied, contrary to most chemical evolution models. One possible explanation of this dilemma is that the current DLA samples are biased due to dust selection effects. Recently, several highly dusty quasar absorption systems have been discovered in the Sloan Digital Sky Survey. These dusty absorbers appear to be chemically more enriched than the general DLA population, suggestive of more massive or disturbed galaxies, and may contribute signif icantly to the global metal content. Here we propose to obtain IR spectra of 10 quasars that show such dusty absorbers based on various optical/UV features of the quasar spectra. These IRS spectra will allow the first systematic survey of the 9.7 micrometer silicate absorption feature in these dusty absorbers. We also propose IRAC imaging for 3 of the dustiest fields to search for IR emission from the companion galaxies as well as diffuse dust emission in the environment surrounding these chemically enriched absorber galaxies. The proposed observations will offer the first mid-IR look at the properties of these unique high-redshift galaxies and allow us to study the composition of their dust and star formation in their environment. These observations will ultimately help in understanding whether the dusty absorbers and their companion galaxies may form a link between the metal-poor, quiescent DLAs and the actively star-forming Lyman-break galaxies (LBGs). Spitzer is the only existing facility that can offer the necessary wavelength coverage and sensitivity.

Spitzer Space Telescope - General Observer Proposal #50783

Interstellar Dust in Distant Galaxies: A Spitzer Study of Dusty Damped Lyman-alpha Absorbers

Principal Investigator: Varsha Kulkarni
Institution: Univ. of South Carolina

Technical Contact: Varsha Kulkarni, Univ. of South Carolina

Co-Investigators:
Daniel E. Welty, University of Chicago
Donald G. York, University of Chicago
Giovanni Vladilo, Osservatorio Astronomico di Trieste

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 36.3

Abstract:
Understanding the nature of interstellar dust grains in distant galaxies is crucial for investigating the chemical evolution of galaxies and for correcting observations of high-redshift objects used for cosmological studies. However, very little is known about the nature of dust in the distant Universe. Absorption line systems in quasar spectra, especially the damped Lyman-alpha (DLA) absorbers, provide excellent venues for directly studying dust in distant galaxies, selected independently of the galaxy luminosities. A subset of dusty metal-rich absorption systems has been discovered using the Sloan Digital Sky Survey and radio surveys. These absorbers appear to be more massive and chemically more evolved than the general DLA population, and may contribute significantly to the global metal content. Here we propose IR spectroscopy of 10 quasars with intervening dusty DLAs to study the 9.7 micron silicate absorption feature, and in a few cases also the 18 micron silicate feature. In a recent exploratory study, we have made the first identifications of the silicate features in a few DLAs with Spitzer IRS spectra, and developed the techniques for analyzing them. Although relatively shallow, the features can be detected at a statistical level of > 10-15 sigma. The profile of the detected features resembles those seen in diffuse interstellar clouds, and in laboratory amorphous olivine. The features appear to be somewhat deeper than expected from the tau_{9.7} vs. E(B-V) relation for Galactic diffuse interstellar clouds, suggesting different dust extinction properties. We now wish to examine whether these properties are common in other DLAs and study trends with redshift, metallicity, and depletions, by studying the silicate features in other DLAs. Our sample contains both diffuse and molecular clouds spanning look-back times of 2-9 Gyr. Spitzer IRS is the only instrument available to further explore the new window on the dust in the distant Universe opened up by our exploratory study.

Spitzer Space Telescope - General Observer Proposal #30873

The ages and star formation rates of massive galaxies at z=2-3

Principal Investigator: Ivo Labbe
Institution: Carnegie Instition of Washington

Technical Contact: Ivo Labbe, Carnegie Instition of Washington

Co-Investigators:
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Danilom Marchesini, Yale
Ryan Quadri, Yale
Tracy Webb, McGill
Mariska Kriek, Leiden Observatory
Greg Rudnick, NOAO

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 27.4

Abstract:
Using deep multiwavelength surveys from MUSYC, GOODS, and FIRES, and IR selection techniques we are now able to select galaxies at z>2 by stellar mass. Detailed optical-to-infrared photometry has recently revealed that massive M > 10^11 Msun galaxies at z=2-3 are on average already surprisingly red (J_ab - K_ab ~ 1.5). Studies in FIRES and GOODS have demonstrated that IRAC and MIPS are critical to determine the origin of these red colors. Thanks to Spitzer we can now distinguish galaxies that are ‘‘red and dead’’ from those that are actively forming stars and enshrouded by dust. Nevertheless, inferences for galaxy formation scenarios are severely limited by field-to-field variance. Strong clustering causes density fluctuations by more than a factor of 3 on fields the size of GOODS. Worse, current estimates of the space densities of dead galaxies differ by a factor of 10. It is imperative to extend to new and larger fields. Unfortunately, the fundamental obstacle is the lack of sufficiently deep J and K-band imaging in available IRAC fields. Because deep wide area NIR imaging is excessively time-consuming to obtain, we face delays of years before we can improve on current results. Therefore, to immediately enhance the scientific return of IRAC and MIPS, we propose to observe the *only* substantial fields with deep NIR imaging in the J,H, and K-band that are available *now*: the MUSYC survey, comprising 4 fields of 100 arcmin^2 each. These fields are very compelling for follow-up with Spitzer, as they are also the main focus of our Gemini/GNIRS ‘‘Key Science Program’’ obtaining very deep NIR spectra on massive distant galaxies. This unique program is producing dozens of direct measurements of the Balmer/4000 A break and Balmer decrement in z=2-3 massive galaxies, providing independent estimates of the ages, star formation rates, and extinctions. Ultimately, such NIR spectra will be crucial to calibrate the constraints that IRAC and MIPS place on the stellar populations of high redshift galaxies.

Spitzer Space Telescope - Directors Discretionary Time Proposal #247

An ultra-deep IRS spectrum to search for Halpha emission from the galaxies which reionized the Universe

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Harry Teplitz, Spitzer Science Center

Co-Investigators:
Andy Bunker, University of Exeter
Jean-Paul Kneib, Observatoire Astronomique Marseille-Provence
Harry Teplitz, SSC

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 24.0

Abstract:
The ionizing radiation produced by the known population of z~6-7 galaxies falls short of that required to reionize the Universe by a factor ~5. Quasars in this redshift range show Gunn-Peterson troughs, however, indicating that a significant fraction of the intergalactic medium is neutral at these redshifts, and that reionization probably occurred just before this epoch. This implies a large population of starbursting galaxies at z~7-12. In this DDT program we will test the feasibility of using the SL module of IRS to detect Halpha emission from this population. To boost our sensitivity, we will use the lensing effect of the cluster A2218. We request 24hr of observing time to take a single, deep integration at a position corresponding to magnification >10 by the cluster. If our observations reach the required sensitivity we will apply for a full survey using ~8 slit positions in GO3. Even this single observation will place unique constraints on the nature of the reionizing population which will not be rivalled until the advent of JWST.

Spitzer Space Telescope - Directors Discretionary Time Proposal #50262

Spectroscopic confirmation of two candidate z~8 galaxies with IRS

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
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Jason Surace, Spitzer Science Center
Harry Teplitz, Spitzer Science Center
Phil Appleton, IPAC
Matt Ashby, CfA
Joe Hora, CfA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 12.1

Abstract:
We wish to obtain spectroscopic confirmation of two candidate z~8 galaxies with IRS, selected from the IRAC calibration field using IRAC and HST/ACS photometry. These galaxies have been selected to have an excess in the IRAC [5.8] band, corresponding to H-alpha emission at z~7-9. If confirmed, these galaxies will allow us to to directly constrain the stellar mass density in massive galaxies at z>7 for the first time, besides giving us an estimate of the star formation rate density at those redshifts in a much larger comoving volume than currently possible with any other dataset. The IRAC calibration field, a low background region near the North Ecliptic Pole, has the deepest IRAC data ever taken.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #65

SED's of Galaxies with a Range of UV to Submm Properties

Principal Investigator: Charles Lawrence
Institution: JPL

Technical Contact: Peter Eisenhardt, JPL

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 17.3

Abstract:
The Lyman Break population is bright at rest UV wavelengths. The SCUBA population is bright at far IR wavelengths. In this program I investigate the SED's of galaxies with a wide range of UV and submm fluxes. Besides very blue objects such as cB58 and very red objects such as HR10, the sample includes galaxies like LBDS 53W091 which are faint in both the UV (red) and the far IR and appear to have only an old stellar population even though they are at substantial redshift.

Spitzer Space Telescope - General Observer Proposal #30519

A far-IR exploration of the diversity of Ultra-Luminous Infrared Galaxies at 2<z<3

Principal Investigator: Emeric Le Floc'h
Institution: University of Arizona

Technical Contact: Emeric Le Floc'h, U. Arizona

Co-Investigators:
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Matthew Ashby, Smithsonian Astrophysical Observatory
Colin Borys, Caltech
Katherine Brand, NOAO
Vassilis Charmandaris, University of Crete
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Herve Dole, Institut d'Astrophysique Spatiale
Peter Eisenhardt, JPL
Sarah Higdon, Cornell University
Jim Higdon, Cornell University
Buell Jannuzi, NOAO
Casey Papovich, University of Arizona
Howard Smith, Smithsonian Astrophysical Observatory
Krystal Tyler, University of Arizona
Dan Weedman, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 25.4

Abstract:
We propose to characterize the far-IR properties of a population of Ultra-Luminous Infrared Galaxies recently discovered by Spitzer at 2<z<3. Showing a broad range of spectral energy distributions (SEDs) between 0.1mic and 12mic rest-frame, these objects are all characterized by 24mic-to-optical colors and mid-IR luminosities much larger than any other sources known at similar redshifts. They pose therefore a serious challenge for our understanding of galaxy formation. We will perform deep MIPS 70/160mic imaging of this population, which will provide constraints on their total infrared SEDs, their bolometric luminosities, dust temperatures and total dust masses. This will allow us to explore the diversity of these objects and the dominant processes and mechanisms (e.g., activity of star formation, accretion of material around active nuclei) powering their prodigious emission in the mid-infrared.

Spitzer Space Telescope - General Observer Proposal #20303

Exploring with far-infrared observations the most Luminous Mid-Infrared galaxies of the high redshift Universe

Principal Investigator: Emeric Le Floc'h
Institution: University of Arizona

Technical Contact: Emeric Le Floc'h, U. Arizona

Co-Investigators:
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Matthew Ashby, CfA-Harvard
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Vassilis Charmandaris, Cornell University
Vandana Desai, Caltech/SSC
Arjun Dey, NOAO
Herve Dole, IAS-Orsay (France)
Peter Eisenhardt, JPL
Sarah Higdon, Cornell University
Jim Higdon, Cornell University
Buell Jannuzi, NOAO
Casey Papovich, University of Arizona
Dan Weedman, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 14.0

Abstract:
We propose to observe at 70 and 160microns a recently-discovered population of 2<z<3 sources characterized by extreme mid-infrared to optical colors. These objects have mid-infrared luminosities 5-10 times larger than any other galaxies known at similar redshifts (i.e., SCUBA/VLA or Balmer/Lyman-break sources). Their properties pose a serious challenge for our understanding of galaxy formation. Spitzer far-infrared observations will provide constraints on their total infrared spectral energy distribution, bolometric luminosity, dust temperature and total dust mass. This will allow us to explore the dominant mechanisms (e.g., star-forming activity, accretion surrounding supermassive black-holes) triggering their prodigious emission in the mid-infrared.

Spitzer Space Telescope - General Observer Proposal #3216

Mid-Infrared spectral properties of luminous starbursts and active nuclei at redshift z>0.6 : exploring the distant Universe with IRS

Principal Investigator: Emeric Le Floc'h
Institution: University of Arizona

Technical Contact: Emeric Le Floc'h, U. Arizona

Co-Investigators:
Lei Bai, University of Arizona (USA)
Alison Coil, University of Berkeley (USA)
Herve Dole, IAS-Orsay (France)
Eiichi Egami, Univeristy of Arizona (USA)
David Elbaz, CEA-Saclay (France)
Roberto Gilli, Osservatorio Astrofisico di Arcetri (Italy)
Jiasheng Huang, CfA/Harvard (USA)
Nicholas Konidaris, UCO/Lick Observatory (USA)
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George Rieke, University of Arizona (USA)
Jane Rigby, University of Arizona (USA)
J.D. Smith, University of Arizona (USA)
Christopher Willmer, UCO/Lick Observatory (USA)

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 18.5

Abstract:
In the very recent years, deep cosmological surveys at infrared and submillimeter wavelengths have revealed the existence of a strongly evolving population of dust-enshrouded and luminous objects at high redshift. The activity of these sources mainly originates from star formation and can also be powered by accretion of matter around super massive black holes. Thus far, a critical step in understanding their role in the cosmic history has been the adoption of local spectral templates of luminous infrared galaxies as a foundation to infer the amount of their evolution. Yet, recent mid-infrared spectral results at redshifts z < 0.6 show a more complex interplay among star formation, AGN, and photo-dissociation regions that seriously challenge the use of local templates and correlations. This proposal aims to extend such spectral studies to higher redshifts (z ~ 0.6 to 1) and thus earlier lookback times, to assess the level and role of each of the processes. The unique capabilities of the recently-commissioned Spitzer Space Telescope provide unprecedented access to the nature of such objects. We therefore propose to perform IRS spectroscopy for a sample of luminous infrared galaxies at 0.6<z<1 that we already identified using our GTO MIPS 24 micron data, and which also have spectroscopic redshifts measured by the DEEP consortium. The multi-wavelength characterization of these luminous sources and the comparison of their mid-infrared spectral properties with those typically found in the local Universe will allow us to gain a better insight into the nature of this population and the evolution it has underwent to the present-day Universe.

Spitzer Space Telescope - General Observer Proposal #20706

Lyman Break Galaxies at z>5: Young Galaxies in a Young Universe?

Principal Investigator: Matthew Lehnert
Institution: Max Planck Institut fuer extraterrestrische Physik

Technical Contact: Matthew Lehnert, MPE

Co-Investigators:
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Natascha Forster Schreiber, MPE
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Stephane Charlot, IAP/MPA
Pascale Jablonka, Paris Observatory Meudon
Claire Halliday, MPA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 39.5

Abstract:
Using SST Legacy IRAC data in the CDFS from GOODS and our own GO-1 IRAC data, we have found that z>5 Lyman Break Galaxies (LBGs) appear typically to have formed most of their stars over approximately a crossing time (<100 Myrs). This combined with their apparent strong clustering and relatively low number density suggests that the population is highly stochastic (or colloquially, they have a short "duty cycle"). These results are from only 2 regions of about 160 sq arcmin each, and limited numbers of sources (especially with measured redshifts), cosmic variance, and the likely stochastic nature of these high redshift sources emphasizes the need for more areas with spectroscopically confirmed high redshift LBGs to get an unbiased view of the population characteristics. We are therefore proposing to expand these already exciting results to image 10 more fields of a combined area of about ~450 sq arcmin for which over the next year we will obtain approximately 100 spectroscopically confirmed z>5 galaxies in the 3.6, 4.5, 5.8 and 8.0 micron bands with IRAC. When combined with our existing deep optical data on these fields, we can determine the complete observed SEDs of the sources to 4.5 microns, and possibly to 8 microns (as we have done for the other fields). Using these SEDs we can determine approximate star formation histories, extinctions, photometric masses, and photometric redshifts for those sources for which we fail to get redshifts. This will allow us to determine: (1) if the galaxies contributed significantly to reionization which looks unlikely if reionization occurred at z~17 or we fail to begin to find significant numbers of galaxies older than 100 Myrs at these redshifts, (2) are likely to be driving winds and thus contribute significantly to the early metal-enrichment of the IGM, (3) the actual star-formation rate density at z~5.5, (4) how strongly the sources are correlated, refining their estimated duty cycle and bias, and many other issues of fundamental importance to cosmology.

Spitzer Space Telescope - General Observer Proposal #50562

The nature of dark gamma-ray burst host galaxies

Principal Investigator: Andrew Levan
Institution: University of Warwick

Technical Contact: Andrew Levan, University of Warwick

Co-Investigators:
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Pall Jakobsson, University of Hertfordshire
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Evert Rol, University of Leicester
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Klaas Wiersema, University of Leicester
Robert Priddey, University of Hertfordshire

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 13.3

Abstract:
A fraction of gamma-ray bursts are dark in the optical and even in the nIR. These bursts, localised only via their X-ray afterglows probably include bursts in highly obscured, extreme star forming regions, and may originate from decidely different environments from optically bright gamma-ray bursts. We have an intensive programmeaimed at understanding these environments via studies of host galaxies. This includes approved time on Chandra, HST and the VLT. These facilities provide precise positions and characterize the optical magnitudes and morphologies of the host galaxies. However, strong discriminators between different host galaxy types lie in the mid-IR, where dust emission can be more directly probed. Here we propose to use Spitzer to study the host galaxies of bursts which show clear optical suppression. This will allow the construction of complete spectral energy distributions of these dark burst host galaxies, enable photometric redshifts to be determined for a fraction of the GRB host population not previously open to detailed study, and provide measures of dust content, stellar mass and star formation rates in these hosts. These observations will allow us to understand the environments of dark GRBs, how they relate to the bright bursts, and how the bulk GRB population traces starformation.

Spitzer Space Telescope - General Observer Proposal #50308

Are the brightest Lyman Alpha Emitters at z=5.7 primeval galaxies?

Principal Investigator: Christopher Lidman
Institution: European Southern Observatory

Technical Contact: Christopher Lidman, European Southern Observatory

Co-Investigators:
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Eduard Westra, Mount Stromlo and Siding Spring Observatories
Emanuela Pompei, European Southern Observatory
Leonardo Vanzi, European Southern Observatory
Klaus Meisenheimer, Max Planck Institute for Astronomy
Christian Tapken, Max Planck Institute for Astronomy

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 22.4

Abstract:
Wide-field, narrow-band surveys have proven to be effective at finding very high redshift galaxies that emit brightly in the Lyman alpha line, the so-called Lyman alpha emitters (LAEs). It was through this technique that the most distant spectroscopically confirmed galaxy, a galaxy at z=6.96, was discovered. Considerable effort is currently being spent on discovering these galaxies at ever higher redshifts by extending this technique into the near-IR. In contrast to this effort, there has been relatively little work on understanding these galaxies. In particular, how do LAEs relate to other high redshift galaxies, such as the galaxies discovered through broad band drop out techniques, and, perhaps, more importantly, what role do LAEs play in re-ionising the universe. We recently discovered two extremely luminous LAEs at z=5.7. These LAEs are among the brightest LAEs ever discovered at this redshift. In a recent paper by Mao et al. the brightest LAEs are associated to the most massive halos. We propose to use the IRAC 3.6 micron imager on Spitzer to measure the rest-frame optical flux of the these LAEs. With additional data from the near-IR (rest-frame UV) and very deep optical spectra around the Lyman alpha line, we propose to make a detailed study of the spectral energy distribution from the Lyman alpha line to the rest frame optical of these exceptional LAEs. These data will enable us to estimate the age and mass of the stellar burst that produces the Lyman alpha line, to estimate the contribution from an older stellar population, if any, and to estimate the fraction of Lyman continuum photons that can escape the galaxy and are thus available to reionise the universe.

Spitzer Space Telescope - Legacy General Observer Proposal #142

The SIRTF Wide-area InfraRed Extragalactic Survey

Principal Investigator: Carol Lonsdale
Institution: Caltech

Technical Contact: David Shupe, Spitzer Science Center

Co-Investigators:
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Fan Fang, IPAC/Caltech
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JoAnn O'Linger, IPAC/Caltech
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Richard Puetter, Univ. of Calif., San Diego
Michael Rowan-Robinson, Imperial College, London
David Shupe, IPAC/Caltech
Harding Smith, Univ. of Calif., San Diego
Gordon Stacey, Cornell Univ.
Jason Surace, IPAC/Caltech
Cong Xu, IPAC/Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsScan
Hours Approved: 851.0

Abstract:
We propose a wide-area, high latitude, imaging survey to trace the evolution of dusty, star-forming galaxies, evolved stellar populations, and AGN, as a function of environment from z~2.5 to the current epoch. Building on ISO's heritage, SWIRE complements smaller, deeper GTO (Guaranteed Time Observer) surveys, and paves the way for FIRST. With MIPS 5 sigma sensitivities of 0.45/2.75/17.5 mJy at 24/70/160 microns over 100 square degrees (424 hrs), and 7.3/9.7/27.5/32.5 microJy at 3.6/4.5/5.8/8.0 microns for 55 square degrees (IRAC: 427 hrs), we will deliver highly uniform source catalogs and high-resolution, calibrated images, providing an unprecedented view of the evolution of galaxies, structure, and AGN on co-moving scales up to several hundred Mpc. SWIRE will, for the first time, directly address the clustering of evolved stellar systems (IRAC) vs active star-forming systems and AGN (MIPS) in the same volume. Extensive modeling suggests that the Legacy Extragalactic Catalog may contain in excess of 2 million IR-selected galaxies dominated by (1) luminous infrared galaxies, Lfir>10^11 L_sun, up to 40,000 with z > 2; (2) ~10^6 early-type galaxies (~4x10^5 with z>2); (3)~30,000 classical AGN and as many as 250,000 dust-obscured QSO/AGN. Pixon image reconstruction will optimize spatial resolution, reduce confusion noise and improve sensitivity, and will be delivered to the SSC. These fields will have extensive data at other wavebands, particularly in the optical, near-IR and X-ray; further ground-based imaging will be undertaken at NOAO and other observatories. SWIRE Legacy data will be will be combined with a wide range of X- ray, optical, infrared, submm and radio data, largely available through IPAC's Infrared Science Archive (IRSA), as part of this legacy.

Spitzer Space Telescope - General Observer Proposal #3241

Massive spheroids in formation: A spectroscopic study of (sub)mm galaxies

Principal Investigator: Dieter Lutz
Institution: MPE

Technical Contact: Dieter Lutz, MPE

Co-Investigators:
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Andrew Baker, MPE
Matthew Lehnert, MPE
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Randolf Klein, MPE
Amiel Sternberg, Tel Aviv University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 43.1

Abstract:
During the last few years, submm and mm surveys and follow-up thereof have revolutionized our view of the high redshift universe by showing that a substantial fraction of star formation and AGN activity at high redshift occurs in luminous dusty galaxies. These objects likely represent a key step in the formation of massive galaxies and pose a crucial challenge for our understanding of galaxy formation and of the co-evolution of spheroids and central black holes. Given their dusty nature, extinction-insensitive tools of rest frame mid-infrared spectroscopy are uniquely suited to provide a deeper understanding of starburst and AGN activity and of the physical conditions in these galaxies. We have pioneered these techniques using data from the Infrared Space Observatory and applied them to local ultraluminous infrared galaxies. Deep Spitzer-IRS spectroscopy now makes it possible for the first time to detect PAH emission features, AGN continua, and signatures of absorption in faint but important high redshift targets. We propose to obtain high quality rest-frame ~5.5-9.5micron low-resolution IRS spectra of a moderate size sample spanning the full range of properties of the submm and mm population in an unbiased way, by selection from blank field and cluster lens surveys only. Our targets include the brightest high z submm and mm sources with interferometric identification and range from optically well-detected galaxies to very faint sources with K_Vega>22.5. These data will allow us to (i) determine or confirm redshifts, (ii) determine the relative importance of star formation and AGN and search for trends of the starburst/AGN energy production ratio within the population, (iii) search for indicators giving further clues to the prevailing physical conditions, like signatures of extreme obscuration. Quality of spectra and an unbiased sample are decisive in using the power of mid-infrared spectroscopy to answer these questions on the pivotal (sub)mm galaxy population.

Spitzer Space Telescope - General Observer Proposal #40009

The Physical Nature and Age of Lyman Alpha Galaxies

Principal Investigator: Sangeeta Malhotra
Institution: Arizona State U.

Technical Contact: Sangeeta Malhotra, Arizona State U.

Co-Investigators:
James Rhoads, Arizona State University
Arjun Dey, National Optical Astronomy Observatories
Steven Finkelstein, Arizona State University
Norman Grogin, Arizona State University
Bahram Mobasher, Space Telescope Science Institute
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JunXian Wang, University of Science and Technology of China
Buell T. Jannuzi, National Optical Astronomy Observatories

Science Category: stellar populations
Observing Modes: IracMap
Hours Approved: 20.0

Abstract:
In the simplest scenario, strong Lyman alpha emission from high redshift galaxies would indicatethat stellar populations younger than 10 Myrs dominate the UV. This does not, however, constrain the stellar populations older than 100 Myrs, which do not contribute to UV light. Also, the Lyman alphaline can be boosted if the interstellar medium is both clumpy and dusty. Different studies withsmall samples have reached different conclusions about the presence of dust and old stellarpopulations in Lyman alpha emitters. We propose HST-NICMOS and Spitzer-IRAC photometry of 35 Lyman-alpha galaxies at redshift4.5<z<6.5, in order to determine their spectral energy distribution (SED) extending throughrest-frame optical. This will allow us to measure accurately (1) The total stellar mass in theseobjects, including old stars which may have formed at redshifts (z > 8) not easily probed by anyother means. (2) The dust extinction in the rest-frame UV, and therefore a correction to theirpresent star-formation rates. Taken together, these two quantities will yield the star-formation histories of Lyman alphagalaxies, which form fully half of the known galaxies at z=4-6. They will tell us whether these areyoung or old galaxies by straddling the 4000A break. Data from NICMOS is essential for these compactand faint (i=25-26th magnitude AB) high redshift galaxies, which are too faint for good near-IRphotometry from the ground.

Spitzer Space Telescope - General Observer Proposal #20229

Cosmic Evolution of Dust and Star Formation: Emission Line Galaxies in the Subaru Deep Field

Principal Investigator: Matthew Malkan
Institution: UCLA

Technical Contact: Matthew Malkan, UCLA

Co-Investigators:
Kazu Shimasaku, University of Tokyo
Nobunari Kashikawa, National Astronomical Observatory of Japan
Masanori Iye, National Astronomical Observatory of Japan
Kentaro Motohara, Institute of Astronomy, Univ. of Tokyo
Tadayuki Kodama, National Astronomical Observatory of Japan

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 29.4

Abstract:
The Subaru Deep Field (SDF) is the only large (770 sq arcmin) region of the sky with ultradeep optical, UV, near-IR and narrowband imaging. The latter has provided 2600 galaxies with Balmer, [OIII], [OII, or Lyalpha emission lines. Our extensive followup spectroscopy has confirmed the reliability of this method of selecting star-forming galaxies in 9 redshift windows from z=0.1 to 1.5. With a deep MIPS-24 observation we will obtain a definitive calibration of reddening-corrected star formation rates using the 3 leading indicators--UV continuum from young stars, optical emission lines from HII regions, and thermal re-radiation from warm dust. The direct comparison of 3 independent methods in the same galaxy sample will allow us to determine the role played by dust extinction, and to correct for it accurately. We wil thenl derive the cosmic evolution of star formation from a look-back time of 10 Gyrs to the present in typical galaxies, not just those in the high end of the luminosity function. With deep IRAC photometry for the same field, we will optimize our photometric redshift estimates, and determine the total stellar masses of many thousands of galaxies. These will include optical line-emitters, Lyman break galaxies, Lyman-alpha emitters and red galaxies over wide spans of redshift. We will measure where the stars form, as well as when, and determine how star formation correlates with galaxy mass as a function of cosmic time. Our field of view is large enough to overcome cosmic variance, and also to measure the clustering properties of these various groups of galaxies.

Spitzer Space Telescope - General Observer Proposal #30008

Identifying z>7 galaxies from J-dropouts

Principal Investigator: Matthew Malkan
Institution: UCLA

Technical Contact: Matthew Malkan, UCLA

Co-Investigators:
Alaina Henry, UCLA
Harry Teplitz, Spitzer Science Center
James Colbert, Spitzer Science Center
Brian Siana, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 7.0

Abstract:
NICMOS Parallel Imaging campaigns covered enough sky (250 pointings) with enough sensitivity in the 110W and 160W filters to identify 6 extremely red resolved sources which are prime candidates for J-band dropouts. Their complete absence of detectable J band flux can be caused by an opaque Lyman cut-ff at z=8--10. We propose to followup these candidates with NICMOS imaging and jointly propose Spitzer IRAC photometry. Deep F110W and Spitzer/IRAC 3.5/4.8 micron imaging will confirm if any of these candidates are indeed Lyman Break galaxies observed less than 500 Myrs after the Big Bang. Genuine LBGs will remain undetected in F110W, while being detected with flat spectra in the IRAC bands. The combined SED will provide information about the stellar mass of these galaxies, and the possible presence of evolved stars or dust reddening. The proposed observations will be sensitive enough to detect the F110W flux from galaxies as red as (J-H)=2.8 (AB mags, 5 sigma). If any of the candidates are detected with bluer colors, they will most likely be exceptional Distant Red Galaxies at z of 4 to 6. The proposed data will constrain the stellar populations of these extraordinarily red galaxies, which would be candidates for the earliest, most massive galaxies which formed.

Spitzer Space Telescope - Directors Discretionary Time Proposal #296

Confirming a z~10 galaxy with IRAC

Principal Investigator: Matthew Malkan
Institution: UCLA

Technical Contact: Alaina Henry, UCLA

Co-Investigators:
Alaina Henry, UCLA
James Colbert, SSC
Brian Siana, SSC
Harry Teplitz, SSC
Patrick McCarthy, OCIW

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 11.2

Abstract:
The NICMOS Parallel Survey covered enough sky to find rare, luminous J-dropout Lyman Break Galaxies (LBGs) at z>8. We used IRAC to observe six LBG candidates with extemely red J110-H160 colors. One of these has the blue H160 - IRAC2 color expected of a z=10 galaxy. It remains undetected in IRAC1, suggesting the presence a Balmer/4000 Angstrom break. These extreme colors make this galaxy the best known z=10 candidate. The best fit photometric redshift is z=9.6, although some degeneracy remains, and the galaxy can be fit (less well) by a z=2.5 model. To break this degneracy, we propose deep IRAC observations to detect the source in channels 1 and 3. With this five point SED, we will not only determine the redshift- we will also constrain properties such as extinction. If this galaxy is confirmed as a z=10 LBG, it has important implications for galaxy formation and models which describe the reionization of the intergalactic medium.

Spitzer Space Telescope - General Observer Proposal #50057

Uncovering the First Galaxies

Principal Investigator: Matthew Malkan
Institution: UCLA

Technical Contact: Alaina Henry, UCLA

Co-Investigators:
Alaina Henry, University of California, Los Angeles
James Colbert, Spitzer Science Center
Brian Siana, Spitzer Science Center
Harry Teplitz, Spitzer Science Center
Patrick McCarthy, Carnegie Observatories

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 22.2

Abstract:
The identification of UV-luminous sources at the epoch of reionization is just barely possible with current technology, requiring large area coverage and tremendous depth in the near- and mid-IR. In Spitzer Cycle 3, we demonstrated that the combination of HST pure parallel NICMOS imaging and Spitzer/IRAC followup identifies good candidates for LBGs at 7<z<10. Followup with DDT time confirmed the SED of one object as most probably z~9. Based on that success, we propose to expand our search by obtaining deep IRAC photometry on seven new candidates identified as 'J band dropouts'. Compared to deep surveys of small volumes, our wide area search is advantageous, because the redshifts of these brighter candidates can be more readily confirmed. The proposed IRAC data will rule out low-z interlopers with dusty, red colors and refine the photometric redshift estimate for the sources. The discovery of z>7 galaxies in this survey would resolve the outstanding question of whether the luminous galaxy population has evolved significantly from z=3-4 to z=7. This in turn, will answer the question of whether star formation at z>6 can reionize the intergalactic medium. Such luminous galaxies at very high redshift would provide an ionizing background which is sufficient fo ionize the intergalactic medium-- something which fainter galaxies, alone, may not be able to do. Even if no candidate galaxies are confirmed by the proposed observations, we will place stringent upper limits on the reionizing photons present at z>7.

Spitzer Space Telescope - General Observer Proposal #50182

The LSD project: stellar mass, dynamics and mass-metallicity relation at z=3

Principal Investigator: Filippo Mannucci
Institution: INAF - Istituto di Radioastronomia/Firenze

Technical Contact: Filippo Mannucci, INAF-Firenze

Co-Investigators:
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Roberto Maiolino, INAF - Osservatorio di Roma
Giovanni Cresci, MPE - Muenchen
Alessandro Marconi, Univ. di Firenze
Guia Pastorini, Univ. di Firenze

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 22.3

Abstract:
A large observational effort with the ESO telescopes allowed us to obtain deep, spatially resolved, near-IR spectra of a complete sample of Lyman-break Galaxies (LBGs) at z~3.1. These observations were used to obtain, for the first time, the metallicity and the dynamical properties of a sample of galaxies that, albeit small, represents the total population of the LBGs. We propose to use IRAC to accurately determine the stellar mass of these galaxies to address two closely related issues: 1) measure the mass-metallicity relation at z~3 and its evolution to z=0, to study the chemical version of galaxy "downsizing'' and compare the results with the expectations of recent models of galaxy evolution involving stellar and AGN feedback and galaxy merging; 2) compare the dynamical with the stellar mass, and relate these quantities with gas mass, SFR and metallicity to obtain the evolutive stage of the galaxies. The IRAC observations are a crucial step to obtain a reliable stellar mass and obtain a full descriptions of this unique sample of LBGs.

Spitzer Space Telescope - General Observer Proposal #3554

The Growth of Stellar Mass at z > 2: Spitzer Imaging of the Gemini Deep Deep Survey Fields

Principal Investigator: Patrick McCarthy
Institution: Carnegie Institution of Washington

Technical Contact: Patrick McCarthy, Carnegie Institution of Washington

Co-Investigators:
Lin Yan, Spizter Science Center
Roberto Abraham, University of Toronto
Karl Glazebrook, Johns Hopkins University
Hsiao-Wen Chen, MIT
Sandra Savaglio, Johns Hopkins University
David Crampton, HIA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 10.9

Abstract:
We propose to image three of the Gemini Deep Deep Survey fields in the four IRAC bands. We will use the rest-frame 1-3 micron luminosity and our spectroscopic redshifts to measure the stellar mass in galaxies at z ~ 2. Photometric redshifts from the IRAC photometry and our deep 8-band B through K images, as well as on going deep spectroscopy, will allow us to extend our study of stellar masses to higher redshifts and lower masses, thus spanning most of the galaxy assemble epoch. This small program makes maximum use of the unique aspects of Spitzer by building on the deepest redshift survey to date.

Spitzer Space Telescope - General Observer Proposal #50287

Constraining Galaxy Formation With Passive Stellar Populations at z~1.5

Principal Investigator: Elizabeth McGrath
Institution: University of California, Santa Cruz

Technical Contact: Elizabeth McGrath, University of California, Santa Cruz

Co-Investigators:
Alan Stockton, Institute for Astronomy, Univ. of Hawaii

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 11.1

Abstract:
There is a growing amount of observational evidence from studies of ?passive galaxies? at high redshift that at least some massive galaxies formed very early in the history of the Universe. These galaxies contain stellar populations that are already >1?2 Gyr old at the observed epoch, with no significant recent star formation. At z~1.5, our HST ACS and NICMOS imaging of seven such galaxies reveals a range of morphologies, including exponential disks, deVaucouleurs ellipticals, and even a possible ?dry merger,? where the apparent lack of gas prevents new episodes of merger-induced star formation from occurring. This range in morphologies indicates that several different mechanisms could be important in building up the most massive galaxies in the Universe. In order to place tighter constraints on galaxy formation scenarios, we need to eliminate any remaining doubts about the nature of the stellar populations in these galaxies. Using Spitzer IRAC and improved population syntheses models, we can finally break the age-metallicity degeneracy that plagues shorter-wavelength observations. Photometry from the 4 IRAC bands will constrain the long-wavelength portion of the spectral energy distributions, yielding important information about the dust and metal content of these galaxies, as well as unprecedented accuracy in the age measurements. Together, this information will help constrain when the first major epoch of star formation occurred, and how the first massive galaxies formed.

Spitzer Space Telescope - Theoretical Research Proposal #50387

Infrared Properties of High-z Galaxies

Principal Investigator: Kentaro Nagamine
Institution: University of Nevada, Las Vegas

Technical Contact: Kentaro Nagamine, University of Nevada, Las Vegas

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 50000.0

Abstract:
We propose to compute the SEDs of high-redshift galaxies in cosmological hydrodynamic simulations using the spectrophotometric code GRASIL (Silva et al. 1998) with the wavelength coverage from 100 angstroms to 1 meter. The proposed method will improve the earlier work in the treatment of infrared (IR) emission from dust in high-z star-forming galaxies, by performing the calculation in a more ab initio fashion. Based on the computed SEDs and magnitudes in IRAC/MIPS bands, we will generate the light-cone output of galaxies by stitching numerous simulation output, and examine the number counts, redshift distribution, luminosity functions (LFs) and color-color diagrams by comparing with the Spitzer results directly. In particular, we will assess the validity of the recent claim by Lacey et al. that a top-heavy IMF is necessary to explain the strong evolution of mid-IR LF at 0<z<2 observed by the Spitzer. The clustering of IR galaxies at 0<z<2 will also be computed and compared with the SWIRE results. Finally we will study the IR properties of massive galaxies at z~6 that were identified by the Spitzer IRAC observations. Our work will provide testable theoretical framework to interpret rich observational datasets provided by Spitzer, and improve physical understanding of galaxy formation and evolution.

Spitzer Space Telescope - General Observer Proposal #50402

The most luminous H2 emitters in the Universe? AGN Feedback, Warm Molecular Gas, and the Impact of the Radio Jets in High-z Radio Galaxies

Principal Investigator: Nicole Nesvadba
Institution: Observatoire de Paris-Meudon

Technical Contact: Patrick Ogle, Caltech

Co-Investigators:
Francois Boulanger, Institut d'Astrophysique Spatiale
Patrick Ogle, IPAC
Philip Appleton, IPAC
Pierre Guillard, Institut d'Astrophysique Spatiale
Alain Omont, IAP
Matthew Lehnert, Observatoire de Paris-Meudon
Lee Armus, IPAC
Guilaine Lagache, Institut d'Astrophysique Spatiale

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 49.8

Abstract:
Strong negative feedback from supermassive black holes has been proposed to solve one of the outstanding problems in galaxy evolution models -- the "hierarchy problem" where the most massive galaxies formed early and rapidly. We propose to test this hypothesis through observations of 5 powerful radio galaxies at z~2 with IRS in the LH and LL mode to study the properties of the warm molecular emission in these galaxies. If this hypothesis is correct, and these galaxies are driving strong outflows, outflows powerful and robust enough to solve this problem, we should observe broad, luminous H_2 emission lines in all sources, with widths of 1000 km/s or more, similar to what is observed in the rest-frame optical emission lines and luminositiies corresponding to relatively high temperatures and large H_2 mass, comparable or greater than the H_2 masses inferred from CO observations. This will be the first detection of H_2 at high redshift in sources, which have all the properties of being among the most luminous H_2 emitters in the universe. All of these targets are well-studied. They have near-infrared integral field spectroscopy revealing large velocity shears and dispersions, large enough so that the optical line emitting gas will escape even the most massive galaxy halos, large molecular masses from CO observations (few x 1e10 solar masses), and high resolution multi-frequency radio maps to infer both jet power and radio morphology to gauge the impact of relativistic electrons on the ambient ISM of the host galaxy. The missing component in all these studies is of course the impact the radio jet on the molecular gas, where most of the mass in these objects may in fact lie. As such, these observations are crucial to substantially increase our rudimentary understanding of the outflows driven by powerful AGN, and their yet largely unknown influence on the properties of the most massive galaxies.

Spitzer Space Telescope - General Observer Proposal #30862

Probing the Activity in High-Z ULIRGs: High Resolution Spectroscopy in Neon and Argon Lines

Principal Investigator: Thomas Nikola
Institution: Cornell University

Technical Contact: Thomas Nikola, Cornell University

Co-Investigators:
Gordon Stacey, Cornell University
Steven Hailey-Dunsheath, Cornell University
Sarah Higdon, Cornell University
Duncan Farrah, Cornell University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 15.0

Abstract:
We propose to investigate the nature of a sample of high luminosity infrared bright galaxies in the redshift range of 0.6 to 3 through complete IRS high resolution spectroscopy. Our sample focuses on systems that we will observe in March 2006 in their 158 micron [CII] line emission using Cornell's submm grating spectrometer, ZEUS on the CSO. The combined [CII] and Spitzer IRS spectroscopy will comprise the thesis work of Cornell student Steven Hailey-Dunsheath. The combined data sets will (1) Determine the hardness of the ambient interstellar radiation fields thereby tracing the most massive stars on the main sequence, or revealing the presence of an AGN. (2) Determine the total ionizing flux from stars, hence the relative importance of starformation to accretion in creating the IR luminosity of these sources. (3) Determine the strength of the ambient far-UV radiation fields, hence the physical sizes of the starforming regions. The sources proposed here are among the most distant, and most luminous sources known in the Universe. As such, they are heavily studied by many research groups. We propose deep IRS high resolution spectroscopy for these sources, for which we have built a scientific case coupled to research going on in our group at Cornell. It is clear that the spectra that we obtain will be invaluable for many other science programs including future programs involving Herschel, and JWST. We therefore welcome and encourage collaborations.

Spitzer Space Telescope - General Observer Proposal #30391

The Impact of AGN on Galaxy Evolution

Principal Investigator: Frazer Owen
Institution: NRAO

Technical Contact: Frazer Owen, NRAO

Co-Investigators:
Carol Lonsdale, IPAC/UCSD
Gene Smith, UCSD
Mari Polletta, UCSD
Dave Shupe, IPAC
Belinda Wilkes, CfA
Roy Kilgard, CfA
Glenn Morrison, Hawaii IfA

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsScan
Hours Approved: 60.6

Abstract:
We propose a nearly confusion-limited MIPS survey (24, 70, 160 microns) of the 1046+59 field to address the connection and relative importance of black-hole-driven and star-formation-driven evolution in massive galaxies. The SWIRE/Lockman deep field has the deepest-ever achieved VLA 20cm image, 2.7 microJy rms, and this winter we will add the deepest ever 90cm survey. This field is also centered on an array of 70ks Chandra pointings with deep optical/near-IR imaging and ongoing spectroscopic observations. Our goal is to use radio/X-ray/FIR diagnostics to learn the importance of AGN during the most luminous phase of galaxy formation. Because the expected 70 and 160 microns flux densities are below the Spitzer confusion limit for most individual sources, we propose to use stacking on subsets of similar sources from existing radio, X-ray images and the our proposed, deeper 24 micron survey to reach the needed sensitivity. In order to have enough sources with similar properties in absolute luminosity and redshift to use this technique we need this sensitive MIPS survey of a 0.37 degree area in our deep field with its unique ancillary data.

Spitzer Space Telescope - General Observer Proposal #40443

Survey of Paschen Alpha in High Redshift Galaxies

Principal Investigator: Casey Papovich
Institution: University of Arizona

Technical Contact: Casey Papovich, University of Arizona

Co-Investigators:
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Marcia Rieke, University of Arizona
Jane Rigby, Carnegie Observatories
Gregory Rudnick, NOAO
Christopher Willmer, University of Arizona

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 36.0

Abstract:
All studies of high redshift galaxies rely on the star formation rates (SFRs) based on local calibrations, normally made against neutral hydrogen recombination lines. Of these lines, Paschen-alpha suffers the least from dust extinction, and is a direct tracer of the ionizing radiation from young stars. No test of SFR indicators against Paschen-alpha at high redshift has been attempted. Although for z > 2 Paschen-alpha is accessible to Spitzer/IRS, star-forming galaxies at these redshifts are too faint intrinsically. Here, we propose to measure Paschen-alpha in six gravitationally lensed, star-forming galaxies at 2 < z < 3. These galaxies are magnified by factors of 4-30, making it possible to measure the Paschen-alpha line in typical star-forming galaxies at these redshifts directly with Spitzer. We also request joint near-IR spectroscopy with the Gemini telescopes to measure H-alpha (and H-beta when possible) in order to correct the attenuation in Paschen alpha. We will then compare the Paschen alpha line luminosity against other tracers of the SFR commonly used at high redshifts: e.g., the UV luminosity; the rest-frame mid-IR emission features and luminosity; and the far-IR luminosity. Our galaxy sample spans the complete range of star-forming galaxy type at 2 < z < 3, and therefore these measurements will provide our best SFR comparison yet obtained at high redshift.

Spitzer Space Telescope - General Observer Proposal #50372

Survey of Paschen Alpha in High Redshift Galaxies

Principal Investigator: Casey Papovich
Institution: Steward Observatory, U. Arizona

Technical Contact: Casey Papovich, Steward Observatory, U. Arizona

Co-Investigators:
Gregory Rudnick, NOAO
Eiichi Egami, University of Arizona
Marcia Rieke, University of Arizona
Jane Rigby, OCIW
Suresh Sivanandam, University of Arizona
J.-D. Smith, University of Arizona
Christopher WIllmer, University of Arizona

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 43.2

Abstract:
All studies of high redshift galaxies rely on the star formation rates (SFRs) based on local calibrations, normally against neutral hydrogen recombination lines. Of these lines, Paschen-alpha suffers the least from dust extinction, is a direct tracer of the ionizing radiation from young stars. Yet no test of SFR indicators at high redshifts against Paschen-alpha has been attempted. Although for z > 2 Paschen-alpha is accessible to Spitzer/IRS, star-forming galaxies at these redshifts are too faint intrinsically. In Cycle 4, we started a program to measure Paschen-alpha in five gravitationally lensed, star-forming galaxies at 2 < z < 3. Here, we propose to extend this program, obtaining observations of six additional lensed galaxies. We also request joint near-IR spectroscopy and imaging with the Gemini telescopes to measure H-alpha (and H-beta when possible) and to correct the attenuation in Paschen alpha. We will then compare the Paschen alpha line luminosity against other tracers of the SFR commonly used at high redshifts: e.g., the UV luminosity; the rest-frame mid-IR emission features and luminosity; and the far-IR luminosity. Our galaxy sample spans the complete range of star-forming galaxy type at 2 < z < 3, and therefore these measurements will provide our best SFR comparison yet obtained at high redshift.

Spitzer Space Telescope - General Observer Proposal #40597

Probing the Peak of the Dust SED of the z=3.9 Quasar APM 08279+5255

Principal Investigator: Dominik Riechers
Institution: Max-Planck-Institut fuer Astronomie

Technical Contact: Dominik Riechers, Max-Planck-Institut fuer Astronomie

Co-Investigators:
Fabian Walter, MPIA
Axel Weiss, MPIfR
Chris Carilli, NRAO

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 0.2

Abstract:
We propose to obtain a total of 111.1 seconds of 24, 70, and 160 Âμm MIPS photometry of the strongly lensed z=3.9 quasar APM 08279+5255, enough to detect the source in all three bands at high signal-to-noise. Our models show that the dust SED is composed of a cold starburst component and a warm AGN component, and it peaks around 100 Âμm. However, the peak itself is poorly constrained so far, and thus also the derived properties (masses, temperatures) of the subcomponents. Together with our existing high resolution observations of the dust and molecular gas, the proposed observations are imperative to further constrain the spectral properties of this unique high redshift source, and thus the processes powering its extreme bolometric luminosity. The unique lensing strength of this distant source allows to obtain the proposed observations very efficiently at an unparalleled high science-to-integration time ratio.

Spitzer Space Telescope - General Observer Proposal #50784

Star Formation Signatures in Quasar Host Galaxies Throughout Cosmic Times

Principal Investigator: Dominik Riechers
Institution: Max-Planck-Institut fuer Astronomie

Technical Contact: Dominik Riechers, Max-Planck-Institut fuer Astronomie

Co-Investigators:
Lee Armus, SSC/Caltech
Fabian Walter, Max-Planck-Institute for Astronomy (MPIA)
Chris Carilli, National Radio Astronomy Observatory (NRAO)
Aaron Evans, Stony Brook
Patrick Ogle, SSC/Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 38.9

Abstract:
We propose to obtain deep Spitzer IRS spectroscopy of nine QSOs at 1.4<z<4.5. The goal is to detect PAH features in these sources which would give the first direct evidence that star formation is actively commencing in these early objects. The establishment of PAH emission as a star formation indicator in distant galaxies is a key result of the Spitzer mission, and has dramatically improved our understanding of star formation in AGN-starburst systems out to high redshift. Our sources are selected by their high far-infrared (FIR) luminosities and the detection of massive reservoirs of molecular gas in their host galaxies. These selection criteria have proven to be highly efficient to find PAH-bright AGN-starburst systems. Such systems appear to follow a PAH-FIR luminosity relation of purely star-forming galaxies, which indicates that they are sites of massive star formation. The proposed sources are the last ones missing to complete PAH observations of a sample of all known dust and molecular gas-rich quasars between z=0 and 4.5 (43 sources in total), extending it to significantly higher redshifts and FIR luminosities. Such observations will help to answer the question if the central black holes and stellar bulges indeed form in a coeval fashion in the early universe (as suggested by the tight 'M_BH-sigma_bulge' relation found in late-type galaxies in the local universe). This observing cycle offers the last opportunity to obtain such observations for the forseeable future.

Spitzer Space Telescope - Directors Discretionary Time Proposal #531

First Clues to Star Formation in the "High Redshift Tail" of Submillimeter Galaxies

Principal Investigator: Dominik Riechers
Institution: Caltech

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
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Emanuele Daddi, CEA
Helmut Dannerbauer, MPIA
Chris Carilli, NRAO
Fabian Walter, MPIA
Ranga-Ram Chary, SSC/Planck
Alexandra Pope, NOAO
Glenn Morrison, Hawaii
Mark Dickinson, NOAO
David Elbaz, CEA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 23.7

Abstract:
We propose to obtain ultra-deep Spitzer IRS spectroscopy of the z=4.055 submillimeter galaxy (SMG) GN20, the first spectroscopically confirmed member of the high redshift tail of SMGs, and the most infrared-luminous, starbursting SMG without any evidence for AGN activity. The goal is to detect PAH and mid-IR continuum emission. Through spectral decomposition, this will provide the most direct evidence that the huge IR luminosity in this source is indeed powered by star formation (rather than a deeply buried, Compton-thick AGN), confirming, for the first time, that SMGs can indeed be extreme sites of star formation at rates (SFRs) exceeding 2000 M_sun/yr. This study builds upon our previous investigation of the mid-IR properties of SMGs in the GOODS-N field, and extends it to the maximum possible luminosity/SFR range and time baseline (i.e., redshift range). It will enable us to investigate whether or not the relations between PAH strength and the (F)IR and CO luminosities established at z=2 hold out to z=4. Apart from being exceptionally IR- and CO-luminous for a presumably starburst-dominated SMG (i.e., likely very PAH-luminous, and thus detectable), it is also the most distant SMG where bright PAH features fall within the wavelength range of IRS. We obtained a reliable redshift for this source only earlier this year, i.e., several months after the final cryo deadline (cycle 5). The only possibility to obtain PAH observations of this first z>4 SMG with a secure redshift for the forseeable future thus is through Spitzer DDT, as proposed here. At last grasp, this program will achieve a long-sought yet unachieved goal of the Spitzer mission - to detect PAH emission out to z>4, star formation dominated galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30775

IRS Spectroscopy of Gravitationally Lensed z>1 Infrared-Luminous Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Eiichi Egami, U. Arizona

Co-Investigators:
Eiichi Egami, Steward Observatory, University of Arizona
Jane Rigby, Steward Observatory, University of Arizona
Delphine Marcillac, Steward Observatory, University of Arizona
Jean-Paul Kneib, OAMP, Marseille/France
Graham Smith, University of Birmingham
Dean Hines, Space Science Institute

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 49.9

Abstract:
Cosmological deep surveys have detected 24 um sources down to ~50 uJy in a number of well-studied fields (e.g., HDF-N, CDF-S), enabling us to study infrared galaxies out to z~3. Unfortunately, very little is known about the mid-infrared spectral properties of the ~<0.3 millijansky sources that dominate the number counts. At such faint flux levels, IRS spectroscopy becomes prohibitively expensive in terms of exposure time. To examine the mid--infrared spectral properties of sub-mJy 24um sources, we propose an IRS spectroscopic survey that targets gravitationally lensed, z>1, 24 um-selected galaxies behind massive galaxy clusters. These massive clusters have amplified our targets by factors of 3--20 (and in one case, 180!), which would save hundreds of hours in observing time compared to unlensed sources. Thus, we can probe the nature of sources near the 24 um confusion limit with 50 hours of Spitzer time. These IRS spectra will directly constrain the spectral shapes of the faint, z>1 galaxies that constitute ~40% of the 24um deep survey number counts, thus providing crucial constraints to models. They will allow us to estimate the PAH strength in moderate--luminosity galaxies and thus constrain the AGN contribution; to calibrate photometric redshift algorithms; and to explore the faint-end slope of the luminosity function.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40409

IRS Spectroscopy of Gravitationally Lensed z>1 Infrared-Luminous Galaxies

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Eiichi Egami, University of Arizona

Co-Investigators:
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Eiichi Egami, Univ. of Arizona
Delphine Marcillac, Univ. of Arizona
Casey Papovich, Univ. of Arizona
Christopher Willmer, Univ. of Arizona
Johan Richard, Caltech
Jean-Paul Kneib, Laboratoire d'Astrophysique de Marseille
Graham Smith, Univ Birmingham
Dean Hines, Space Science Institute
Dario Fadda, NASA Herschel Science Center / Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 37.9

Abstract:
MIPS has detected 24um sources down to 50 uJy in well-studied fields (e.g., HDF-N, CDF-S), enabling us to study infrared galaxies out to z~3. Unfortunately, very little is known about the mid-infrared spectral properties of the ~<300 uJy sources that dominate the number counts, because IRS spectroscopy at these fluxes requires prohibitively expensive exposure times. Last cycle, we began solving this problem by targeting gravitationally lensed 24um sources behind lensing clusters. Their fluxes have been amplified by factors of 3--22. As a result, 1--2 hr integrations per LL setting produce high-quality spectra of sources with apparent flux densities of 500--1000 uJy, but intrinsic flux densities of only 30--250 uJy. To date, we have obtained spectra for 12 sources, showing a range of spectral properties (from PAHs to featureless continua). The goals are to characterize the spectral properties of the sources that dominate the 24um number counts (and how their spectra differ from low-redshift analogues); and test & recalibrate photometric redshift methods for faint 24um sources. These goals require the largest sample possible. Here, we propose IRS spectroscopy of 8 additional targets, newly identified from the MIPS GTO 24um images, and gravitationally amplified 3--10x. We can thus build up the sample necessary to characterize the nature of sources at 24um confusion limit.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50621

Obscured Activity and Stellar Mass in z~0.7 Post-starburst Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Aleks Diamond-Stanic, University of Arizona

Co-Investigators:
Christy Tremonti, University of Arizona
John Moustakas, New York University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot IrsPeakupImage
Hours Approved: 11.1

Abstract:
We are proposing 3.6-24 micron imaging of a sample of z~0.7 post-starburst galaxies. These galaxies are presumed to be late-stage mergers that have evolved past their ULIRG/quasar phase and are in transition to becoming early-type galaxies. We have detected outflowing winds with velocities ranging from 500-2200 km/s for 2/3 of the sample, so it is tempting to conclude that these spectacular outflows are the result of feedback from an AGN that has expelled cold gas quenched star formation. However, it is not clear that the existing near-UV and optical data are telling the full story. With Spitzer, we can verify whether or not these "post-starburst" galaxies are truly quiescent by measuring the amount obscured star formation and black hole activity. We will also be able to determine how significant the recent starburst event was by accurately measuring stellar mass using the red end of the stellar SED. If these galaxies do have non-negligible dust emission, we will be able to use broad-band colors as blunt tools to measure spectral features and compare to known star-forming galaxies, AGNs, and LIRGs. If not, we will have strong evidence that the feedback event has been able to halt galaxy-wide star formation.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #81

The Deep Infrared Sky

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Marcia Rieke, The University of Arizona

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MIPS MipsScan MipsTp
Hours Approved: 235.9

Abstract:
The Deep Infrared SkyM. Rieke, MouldTo determine the source of the cosmic infrared background requires imaging at sufficiently deep levels to detect the individual sources producing the background. The highest redshift, most luminous sources will be powered by powerful starbursts or by non-thermal process driven by massive black holes in the object's nucleus. SIRTF photometric data alone will not be able to distinguish these two power sources based on experience from the Ultra-Luminous Infrared Galaxies discovered by IRAS. The simplest method of distinguishing between starbursts and AGN is to examine x-ray fluxes. Three layers of surveying will be used to detect adequate numbers of galaxies at both moderate and faint fluxes. Because only IRAS data are available between 1- and 175μm, some surveying to moderate depth is required to get adequate numbers of galaxies for tying IRAS data to the deepest counts. Deeper surveys will be conducted in selected areas, all with deep x-ray observations. A few SIRTF fields of view will be observed to hard confusion limits.

Spitzer Space Telescope - Directors Discretionary Time Proposal #493

Bolometric Luminosities of 3 New Bright Lensed Galaxies

Principal Investigator: Jane Rigby
Institution: OCIW

Technical Contact: Jane Rigby, OCIW

Co-Investigators:
Mike Gladders, U. Chicago
Casey Papovich, Texas A&M
Hsiao-Wen Chen, U. Chicago

Science Category: high-z galaxies
Observing Modes: IracMap IrsMap
Hours Approved: 6.1

Abstract:
We propose DDT observations of three recently--discovered, very bright, lensed galaxies. We propose IRAC, 24, and 70 um photometry and IRS LL1 spectra for SDSS1226+2152, an extremely bright UV--selected galaxy at z=2.93. Because this galaxy is a full magnitude brighter in g-band than cB58 (the longstanding Rosetta Stone), its optical spectrum provides a resolved, high-S/N window into stellar populations, star formation, and star formation history at high redshift. Spitzer observations will constrain the stellar mass, measure the bolometric luminosity, and measure the 7.7um aromatic luminosity. Because this galaxy was not discovered until Jan 2008, it could not have been proposed in Cycle 5. We also propose 70um photometry for two UV-selected lensed galaxies at z=1.7 and z=2.73, RCS0327-1326 and SDSS1527+0652. These galaxies were discovered in late 2007. Photometry at 70um will measure the bolometric luminosities of these three galaxies. LL1 spectroscopy for S1226 will accurately measure the 7.7um aromatic luminosity. Together, these observations will enable us to: * determine the spectral energy distributions of Lyman break galaxies; * test whether the strange SED of cB58 is anomalous or typical; * test whether the aromatic--to--bolometric luminosity ratios of these galaxies evolve with redshift (as do IR--selected lensed galaxies); compare near-IR, mid-IR, and optical diagnostics of star formation rate; * and work to understand the relationship between IR--selected and UV--selected star--forming galaxies.

Spitzer Space Telescope - General Observer Proposal #30475

Evolution of Star Formation in Galaxy Clusters at z=0.8

Principal Investigator: Kenneth Rines
Institution: Yale University

Technical Contact: Kenneth Rines, Harvard University

Co-Investigators:
Rose Finn, Siena College
Lisa Kewley, IfA, Hawaii

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 2.1

Abstract:
In this very short (2.1 hr) program, we propose to study the relations between different tracers of star formation rates in cluster galaxies and their evolution to high redshift. Spitzer enables observations of mid and far-infrared emission from star-forming galaxies at high redshift. We will combine archival and proposed Spitzer observations to conduct detailed studies of the star formation rates (SFRs) of galaxies in four clusters at z~0.80 and compare infrared SFR estimates to optical estimates where extinction is important. At z=0.80, H-alpha is redshifted into a near-infrared window free of strong atmospheric OH lines, enabling deep NIR spectroscopy and narrowband imaging. SFRs at high redshifts are often estimated from UV continuum or [OII] emission; these tracers may underestimate true SFRs by a factor of 2 at this redshift. Infrared observations of clusters at moderate redshift show that IR estimates of the total SFR in some clusters is 10-100 times larger than the total found in galaxies with [OII] emission. Combining the proposed Spitzer observations with Subaru spectroscopy and HST and Chandra data will (1) directly measure the relations between various SFR tracers and their evolution, (2) determine the impact of metallicity and extinction on these estimates, (3) measure correlations between SFRs and density, (4) measure the impact of the hot intracluster medium on SFRs, and (5) improve our understanding of systematic uncertainties in estimating the star formation history of clusters and the universe.

Spitzer Space Telescope - General Observer Proposal #40793

Water ice and warm CO in extremely obscured ULIRGs at z~2

Principal Investigator: Anna Sajina
Institution: Spitzer Science Center

Technical Contact: Anna Sajina, Spitzer Science Center

Co-Investigators:
Lin Yan, Spitzer Science Center
Henrik Spoon, Cornell University
Kalliopi Dasyra, Spitzer Science Center
Moshe Elitzur, University of Kentucky

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap IrsStare
Hours Approved: 40.6

Abstract:
Spitzer spectra have enabled detailed studies of the physical properties of the dense, obscuring medium surrounding local deeply embedded nuclei. We propose to extend these studies to z~2 with observations of a sample of 10 z~2 highly obscured ULIRGs, selected from our existing large sample. By obtaining high S/N ratio spectra covering the rest-frame 3-8 microns for this sample we can derive a quantitative description of: (1) the hot inner obscuring shell as given by the 3-5micron hot dust continuum, and the 4.67micron CO gas absorption feature; (2) the cold outer obscuring shell as given by the silicate feature and 3.0 and 6.0micron water ice absorption; and (3) the star-formation activity outside the buried nucleus as probed by the PAH 6.2 micron feature. The proposed spectra will allow a direct comparison with ongoing studies of highly obscured sources locally. Given the upcoming end of the Spitzer mission, and hence lack of opportunity in the near future for mid-IR spectroscopy of high-z ULIRGs, the proposed data will be invaluable in current and future efforts to understand these enigmatic sites of black hole growth and nuclear star formation.

Spitzer Space Telescope - Legacy General Observer Proposal #20070

S-COSMOS: The Spitzer Deep Survey of the HST COSMOS 2-Degreee ACS Field

Principal Investigator: David Sanders
Institution: University of Hawaii

Technical Contact: David Sanders, University of Hawaii

Co-Investigators:
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Bahram Mobasher, Space Telescope Science Institute
Mauro Giavalisco, Space Telescope Science Institute
Alberto Franceschini, Universita di Padova
Kartik Sheth, Spitzer Science Center, IPSC, Caltech
Jason Surace, Spitzer Science Center, IPAC, Caltech
David Frayer, Spitzer Science Center, IPAC, Caltech
Alvio Renzini, European Southern Observatory - Garching
Herve Aussel, CNRS - Saclay
George Helou, Spitzer Science Center, IPAC, Caltech
Lin Yan, Spitzer Science Center, IPAC, Caltech
Chris Impey, University of Arizona
Andrew Blain, California Institute of Technology
Bidushi Battacharya, Spitzer Science Center, IPAC, Caltech
Daniela Calzetti, Space Telescope Science Institute
Chris Carilli, Associated Universities, Inc. (NRAO)
Eva Schinnerer, MPE - Heidelberg
Marcella Carollo, Eidgenossiche Technische Hochschule (ETH)
Andrea Comastri, Universita' degli Studi di Bologna
Emanuele Daddi, University of Arizona
Richard Ellis, California Institute of Technology
Michael Fall, Space Telescope Science Institute
Gunther Hasinger, MPE - Garching
Olivier LeFevre, Observatoire de Marseille
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Michael Liu, University of Hawaii
Simon Lilly, Eidgenossiche Technische Hochschule (ETH)
Mike Rich, University of California Los Angeles
Patrick Shopbell, California Institute of Technology
Yoshi Taniguchi, Tohoku University
Jonathan Williams, University of Hawaii
Meg Urry, Yale University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsScan
Hours Approved: 220.0

Abstract:
We propose a deep imaging survey with Spitzer using both the IRAC and MIPS detectors to observe the HST-COSMOS 2-square degree field. COSMOS is a nearly completed HST Treasury program (Cy12-13) that is specifically designed to probe the coupled formation and evolution of galaxies and large-scale structure on scales up to 2x10^14 M_sun during the formative era of galaxy, AGN, and clusters (z~0.5-3). The COSMOS survey also includes extensive muulti-wavelength imaging from X-ray to radio (XMM, GALEX, Subaru, NOAO, VLA and CSO) and spectroscopic surveys (VLT and Magellan). The Spitzer observations proposed here complete this survey with vital infrared coverage at 3-160 microns. IRAC imaging is critical for deriving stellar masses (with minimized extinction); MIPS imaging will be used to determine tar formation rates, and AGN activity for enormous samples of galaxies (> 10^5). COSMOS specifically probes the dependence of morphological properties, star formation, and galaxtic masses on the clustering environment over the last 75% of cosmic history. For the first time, COSMOS will yield statistics of high-redshift sources free from cosmic variance, and enable the discovery and characterization of relatively rare objects. COSMOS is thus the necessary complement to deeper but smaller surveys (e.g. GOODS). Our team will immediately release the Spitzer observations, along with our other multi-wavelength COSMOS data and source catalogs, to the astronomical community to ensure maximum scientific return from this survey.

Spitzer Space Telescope - Legacy General Observer Proposal #30143

S-COSMOS: The MIPS Deep Survey of the COSMOS 2-sqdeg Field

Principal Investigator: David Sanders
Institution: University of Hawaii

Technical Contact: David Frayer, SSC/Caltech

Co-Investigators:
Nick Scoville, California Institute of Technology
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David Frayer, Spitzer Science Center, IPAC, Caltech
Kartik Sheth, Spitzer Science Center, IPAC, Caltech
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George Helou, Spitzer Science Center, IPAC, Caltech
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Bahram Mobasher, Space Telescope Science Institute
Alvio Renzini, European Southern Observatory - Garching
Mike Rich, University of California Los Angeles
Eva Schinnerer, MPE - Heidelberg
Patrick Shopbell, California Institute of Technology
Yoshi Taniguchi, Tohoku University
Meg Urry, Yale University
Jonathan Williams, University of Hawaii

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsScan
Hours Approved: 396.2

Abstract:
We propose a deep imaging survey with the Spitzer MIPS detectors to observe the full HST-COSMOS 2-sqdeg field. COSMOS is an approved HST Treasury program that is specifically designed to probe the coupled formation and evolution of galaxies and large-scale structure on scales up to 2x10^14 M_sun during the formation era of galaxies, AGN, and clusters (z~0.5-2.5). The Spitzer observations proposed here are needed to complement our Cycle2 IRAC-deep imaging of the full COSMOS field, plus the multi-wavelength images of the COSMOS field from X-ray to radio, including very deep multi-band images (20 filters) from the Subaru telescope. The COSMOS field is also currently the target of a massive spectroscopic redshift survey with the VLT (50,000 spectra down to I~25). The MIPS-deep data are critical for deriving star formation rates, and AGN activity of galaxies and their dependence on morphological properties and clustering environment over the last 90% of the cosmic history. For the first time, COSMOS will yield statistics of high-redshift sources with greatly reduced cosmic variance, and enable the discovery and characterization of relatively rare objects. COSMOS is thus the necessary complement to deeper but much smaller (>100x) surveys (GOODS and UDF). As part of our Legacy status, our team will immediately release our Spitzer observations, along with our other

multi-wavelength COSMOS data and source catalogs, to the astronomical community to ensure maximum scientific return from this survey.

Spitzer Space Telescope - Archive Research Proposal #20792

What Drives the Differential Evolution of Lyman Break Galaxies?

Principal Investigator: Marcin Sawicki
Institution: UCSB

Technical Contact: Marcin Sawicki, UCSB

Co-Investigators:
David Thompson, Caltech

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 61000.0

Abstract:
Analysis of the luminosity function of Lyman Break Galaxies in our deep, wide Keck Deep Fields survey robustly shows that the evolution of the LBG population is differential with luminosity from z~4 to z~3. Two of the possible mechanisms driving this evolution relate to (1) changes in the properties of dust and (2) changes in the duration of starbursting episodes in sub-L* LBGs. We will use archival Spitzer IRAC, HST, and ground-based imaging of GOODS and the HDFs to compare the spectral energy distributions of LBGs as a function of redshift and luminosity and search for related differences in reddening and starburst age. Finding such differences will not only identify the processes responsible for the evolution of the luminosity function but will thereby also point us towards the underlying physical mechanisms that control how galaxies form and evolve at high redshift. The non-detection of such differences will mean that the responsible mechanism lies elsewhere and will give impetus to other lines of attacking the problem. We have experience in analyzing the spectral energy distributions of Lyman Break Galaxies and request salary and other support to allow us to extend our techniques to higher redshifts, larger samples, and fainter objects with no spectroscopic redshifts that we need to help understand the observed evolution of the luminosity function. Significantly, our analysis will compare LBG subsamples in a differential and hence very robust way and thus will help us understand how galaxies are assembled at high redshift.

Spitzer Space Telescope - Legacy General Observer Proposal #50286

IRS Legacy Survey of the Green Valley in COSMOS

Principal Investigator: Nicholas Scoville
Institution: California Institute of Technology

Technical Contact: Nicholas Scoville, California Institute of Technology

Co-Investigators:
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Lin Yan, Spitzer Science Center / Caltech
David Sanders, University of Hawaii
Mara Salvato, California Institute of Technology
Olivier Ilbert, University of Hawaii
Peter Capak, Spitzer Science Center / Caltech
Emeric Le Floc'h, University of Hawaii
Kartik Sheth, Spitzer Science Center / Caltech
David Frayer, Herschel Science Center / Caltech
Jason Surace, Spitzer Science Center / Caltech
Eva Schinnerer, Max Planck Institute for Astronomy
Jean-Paul Kneib, Observatoire Astronomique de Marseille-Provence -
Henry McCracken, CNRS, Institut d'Astrophysique de Paris

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 85.6

Abstract:
We propose IRS low resolution spectroscopy of a complete flux-limited sample of 116 MIPS 24micron selected galaxies in the HST/ACS-COSMOS survey field at z = 0.3-0.4 and z=0.65-0.85. All of the galaxies have S(24) > 0.7 mJy and confirmed IRAC counterparts. The IRS observations will yield the PAH and silicate features, the mid-IR continuum SED and the Ne emission lines (for the brighter sources). These tracers will provide diagnostics for the nature of the energy sources (starburst and/or AGN) in these dust obscured galaxies. This COSMOS IRS Legacy survey will sample the full range of optical (e.g. U-V) color and absolute optical magnitude exhibited by luminous infrared-selected galaxies at our selected redshifts. Our large and complete sample of 24 micron sources will allow us to better understand the role played by IR-selected galaxies in galaxy evolution, and will provide a critical test of evolutionary models which suggest that sources in the Green Valley represent a transition stage as dusty spirals in the Blue Cloud merge and evolve into massive gas-poor elipticals on the Red Sequence.

Spitzer Space Telescope - Directors Discretionary Time Proposal #50030

Unveiling the Mystery of 24-micron-only Sources with IRS Spectrocopy

Principal Investigator: David Shupe
Institution: Spitzer Science Center

Technical Contact: David Shupe, Spitzer Science Center

Co-Investigators:
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Carol Lonsdale, Univ. of Virginia
Seb Oliver, Univ. of Sussex
Mari Polletta, IAP
Michael Rowan-Robinson, Imperial College, London
Matthew Thomson, Univ. of Sussex
Duncan Farrah, Cornell University
David Frayer, NASA Herschel Science Center
Mattia Vaccari, Univ. of Padova

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 4.4

Abstract:
Ten 24-micron-only sources have been discovered in a search through the entire 45-square-degree SWIRE survey. These are bright 24 micron sources (F(24) > 0.5 mJy) undetected in any other bands. They represent a rare (1 per 5-15 sq deg) population of the reddest mid-infrared sources known so far. On the basis of lack of proper motion, we rule out the hypothesis that they are asteroids. The very high ratios of 24 micron to IRAC fluxes implied by non-detection of IRAC means that these are very unusual, extremely obscured objects. The non-detections at every other wavelengths to our depths, including the optical and MIPS 70 micron and 160 micron bands, make it even more difficult to explain them with any known populations (e.g. Compton-thick AGNs or obscured starbursts). With detection at only a single wavelength, the only room for exploration accessible is in the mid-infrared, where these sources are detected. We propose, in this last cryogenic cycle, to obtain IRS spectra in order to measure the redshifts and to unveil the nature of these mysterious sources through SED fitting. The LL1 and LL2 modules of the IRS are requested, covering rest frame wavelengths of 4.7-12.7 microns at z=2, 3.5-9.5 microns at z=3, and 2.8-7.6 microns at z=4. If these sources are indeed high-z obscured AGNs or starbursts (but with much higher attenuation than those previously detected), the PAH features or broken power-laws will show up in the IRS spectra. These will further extend our knowledge on these extreme populations. It will be even more exciting if the 24-micron-only sources are found to form an entirely new population!

Spitzer Space Telescope - General Observer Proposal #30832

The First IRS Spectrum of a Lyman Break Galaxy

Principal Investigator: Brian Siana
Institution: Spitzer Science Center

Technical Contact: Brian Siana, Spitzer Science Center

Co-Investigators:
Harry Teplitz, Spitzer Science Center
James Colbert, Spitzer Science Center
David Frayer, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap IrsPeakupImage
Hours Approved: 21.8

Abstract:
A significant portion of the star-formation in the high redshift universe resides in the ultraviolet-luminous Lyman Break Galaxies (LBGs). Although they are UV bright, the bulk of their luminosities are emitted in the far-infrared (FIR). Unlike the population of luminous infrared galaxies (LIRGs and ULIRGs), LBGs are typically too faint in the MIR to for Spitzer spectroscopy. We propose deep IRS spectroscopy of the lensed Lyman-Break Galaxy (LBG) MS1512-cB58. The factor of ~30 magnification provides the only opportunity to obtain a MIR spectrum of a typical (L*) LBG. We will measure the strength of the PAH features, allowing a comparison with Lbol as measured from longer wavelength photometry. We will also fit the shape of the warm dust (VSG) continuum and compare it to expectations from the IRAC-to-MIPS70 SED.

Spitzer Space Telescope - General Observer Proposal #40817

Harnessing High Redshift Beacons: IRS Spectra of Lensed Lyman Break Galaxies

Principal Investigator: Brian Siana
Institution: Spitzer Science Center

Technical Contact: Brian Siana, Spitzer Science Center

Co-Investigators:
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Richard Ellis, California Institute of Technology
Mark Swinbank, Durham University
Harry Teplitz, Spitzer Science Center
Johan Richard, California Institute of Technology
Max Pettini, University of Cambridge
Jean-Paul Kneib, Laboratoire d'Astrophysique de Marseiile
Kristen Coppin, Durham University
Harald Ebeling, University of Hawaii
Alastair Edge, Durham University

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsMap IrsPeakupImage MipsPhot
Hours Approved: 16.3

Abstract:
Star-formation at high redshift occurs in two types of galaxies: dusty Ultra-Luminous Infrared Galaxies (ULIRGs) and UV-bright Lyman Break Galaxies (LBGs). In both populations dust absorbs most of the ultraviolet (UV) light from young stars and re-emits the energy in the infrared (IR). Therefore, detailed studies of the dust and the infrared SEDs of these galaxies are critical for understanding these important evolutionary stages in galaxy formation. ULIRGs at z ~ 2-3 are luminous enough for both submm detection and Spitzer IRS spectroscopy, so much has been learned recently about their interstellar medium and IR SEDs. LBGs are too faint to be detected with submm imaging or IRS spectroscopy so little can be discovered about their dust content and IR SEDs prior to JWST and ALMA. Fortunately, there exist a few rare examples of LBGs which are strongly lensed by a foreground cluster or galaxy, and are magnified by factors of 10-30. We can therefore study in detail the infrared properties of this otherwise inaccessible population. Our group will obtain (in an approved Cycle-3 program) IRS spectroscopy of the most famous LBG, cB58, but it is clearly dangerous to draw wide-ranging conclusions about the LBG population based on this single object. We therefore propose for a detailed Spitzer study of the only other known bright lensed LBGs: the "Cosmic Eye" and the "8-O'clock Arc". The requested program uses IRS spectroscopy, IRS Peak-Up 16 micron, MIPS 70 micron, and IRAC imaging to fully characterize the gas and dust in the ISM of these galaxies and determine the shape of the IR SEDs. Together, the three lensed sources span the full range of star-formation rates and dust attenuation levels observed in LBGs. Therefore, we can correlate these properties with the infrared SEDs and emission-line properties (PAHs) and apply the correlations when examining the entire LBG population.

Spitzer Space Telescope - General Observer Proposal #50419

The First Investigation of the 3.3 Micron PAH Feature at High Redshift: Preparation for the Warm Mission, WISE, and JWST

Principal Investigator: Brian Siana
Institution: Spitzer Science Center

Technical Contact: Brian Siana, Spitzer Science Center

Co-Investigators:
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Ranga Chary, Spitzer Science Center
Lee Armus, Spitzer Science Center
Mark Dickinson, NOAO
Minh Huynh, Spitzer Science Center
James Colbert, Spitzer Science Center
David Frayer, NASA Herschel Science Center
Carrie Bridge, Spitzer Science Center
Andreea Petric, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 22.0

Abstract:
The Polycyclic Aromatic Hydrocarbon (PAH) emission features in the mid-IR allow us to study the properties of dust in star-forming galaxies. The 3.3 micron feature is unique amongst these, as it probes the smaller dust grains and is very sensitive to the ionization level of the PAHs. Its importance is increased at high redshift (z > 2), as other PAH features begin to redshift out of the wavelength range of Spitzer IRS or JWST and it is the only dust emission feature accessible at z > 3 with Spitzer. At high redshift, where star-formation rates are higher and stellar masses are lower, the 3.3 micron feature may have markedly higher equivalent widths than observed in local starbursts. In fact, there is evidence that the 3.3 micron feature significantly affects the IRAC (as well as Akari, WISE and JWST) fluxes in star-forming galaxies at z < 2, which may influence stellar mass and photometric redshift estimations. Despite its importance for future high-redshift studies of dust in starburst galaxies, there have been no reported detections of the 3.3 micron feature with Spitzer. We propose IRS Short-Low spectroscopy of nine star-forming galaxies at z ~ 0.75 in the GOODS fields, to detect the 3.3 micron feature and determine how it correlates with the 6.2 & 7.7 features, warm dust measured at 16/24/70 microns, and the total infrared luminosity as inferred from the radio-IR correlation. With these data, we can predict the effects of the 3.3 micron feature on existing (Spitzer, Akari) and future (WISE, Spitzer Warm Mission) photometric surveys, and determine how to best use JWST spectra to quantify dust properties at the highest redshifts.

Spitzer Space Telescope - General Observer Proposal #3143

A Panoramic 24-um/HST Survey for Obscured Activity in Clusters at z~0.5

Principal Investigator: Ian Smail
Institution: Insitute for Computational Cosmology

Technical Contact: Ian Smail, Insitute for Computational Cosmology

Co-Investigators:
Richard Ellis, Astronomy Department, Caltech
Alastair Edge, ICC, Durham
Tommaso Treu, UCLA
Graham Smith, Astronomy Department, Caltech
Jean-Paul Kneib, Caltech/Toulouse

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 16.3

Abstract:
We propose to use MIPS to obtain high quality panoramic 24um mid-IR imaging of galaxies within two rich clusters at z~0.5 which are the subject of an extremely wide-field imaging with HST and massive spectroscopic coverage with ground-based telescopes. We aim to test recent claims for a previously unidentified obscured-starburst population in distant clusters. These galaxies show radio synchotron and mid-IR emission indicative of current strong star formation, but have classical ''Post-starburst'' optical spectra. The proposed mid-IR imaging will trace the photometric signatures of dust-obscured activity in morphologically- and spectrally-classified samples of galaxies from the high-density cores of the clusters out to their turn-around radii, ~5 Mpc, where they merge into the surrounding field. This will allow us to construct the evolutionary cycle for galaxies as they are accreted onto a cluster, by tracing the variation in their activity as a function of their environment parameterised in terms of their local galaxy, gas and dark matter density. Using these data we will distinguish between the environmental variations characteristic of the different proposed triggering mechanisms. The results of our analysis will provide a clearer view of the physical processes responsible for driving this behaviour as well as the prevelence of dust and obscured starbursts in distant cluster and field galaxies.

Spitzer Space Telescope - Directors Discretionary Time Proposal #26

First Look Survey -- Extragalactic Component

Principal Investigator: Tom Soifer
Institution: Spitzer Science Center

Technical Contact: Lisa Storrie-Lombardi, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsScan
Hours Approved: 62.5

Abstract:
The SIRTF First Look Survey extragalactic component is designed to: 1. detect enough extragalactic sources at unexplored sensitivity levels to generate a representative sample and reduce the uncertainties in the source counts, 2. characterize the dominant source populations with both MIPS and IRAC data from SIRTF plus ancillary surveys at optical, near-infrared, and radio wavelengths, and, 3. explore the cirrus foreground at moderately high abs(b), and its effect on point-source detectability. This component is comprised of MIPS and IRAC surveys of four square degrees in the SIRTF northern continuous viewing zone (CVZ) and 1 square degree in the Elais N1 field. A verification survey covering a small region of the CVZ and Elais fields is also included.

Spitzer Space Telescope - General Observer Proposal #20593

A MIPS Study of Star Formation in a Protocluster at z=2.1

Principal Investigator: Spencer Stanford
Institution: University of California, Davis

Technical Contact: Spencer Stanford, University of California, Davis

Co-Investigators:
George Miley, Leiden University
Wil van Breugel, UC-Merced
Ranga-ram Chary, SSC/Caltech
Huub Rottgering, Leiden University
Peter Eisenhardt, JPL
Bram Venemans, Leiden University
Jaron Kurk, Arcreti
Rogier Overzier, Leiden University
Andrew Zirm, Leiden University

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 8.7

Abstract:
Spitzer is uniquely able to provide the data we need to make an unbiased estimate of the total amount of current star formation in galaxies in protoclusters. Such information is crucial to understanding the relative formation timescales of the stellar populations, their galaxies, and even the intracluster medium of the host protoclusters. We propose to obtain deep MIPS 24 micron observations of the protocluster MRC~1138-262 at z=2.1. The rest frame wavelengths sampled by the MIPS bandpass will contain the strong PAH feature at 7.7 microns, so the data will be sensitive to current star formation. The proposed depth would detect an L^* luminous IR galaxy with L(IR) = 10^{11} L_sun at the 5 sigma level.

Spitzer Space Telescope - General Observer Proposal #50189

A Close Look at z>5 Galaxy Analogues in the Local Universe

Principal Investigator: Elizabeth Stanway
Institution: University of Bristol

Technical Contact: Elizabeth Stanway, University of Bristol

Co-Investigators:
Luke Davies, University of Bristol
Matthew Lehnert, GEPI, Observatoire de Paris, France
Laura Douglas, Gepi, Observatoire de Paris, France
Malcolm Bremer, University of Bristol

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsStare
Hours Approved: 16.5

Abstract:
Lyman break galaxies (LBGs) at high redshifts (z>5) probe the earliest stages of massive galaxy formation, exploring a low-metallicity/low-mass regime seldom seen in today's universe. In order to overcome the difficulty of studying the most distant objects, we have identified a rare set of local galaxies with rest-frame ultraviolet-optical properties similar to those of z>5 LBGs from the joint GALEX-SDSS databases. We propose to extend our study of these galaxies into the infrared, studying their stellar, dust and gas content, and for the first time obtaining a true estimate of the specific star formation density in this mode of star formation. In particular, these observations should help answer several key unknowns about the highest redshift LBGs. With IRS spectroscopy we will determine whether the molecular gas is too heated to continue star formation for an extended period, explaining the short-lived and stochastic star formations seen at z=5. Photoionization analysis of ratios of high ionization potential forbidden lines available in combination with the strong, narrow optical emission lines will determine the hardness of the ionising spectrum. Finally, a full UV-Far-IR SED employing data from GALEX, SDSS, IRAC and MIPS will allow us to relate these intense starbursts to other known starbursts, in particular the amount of dust emission per unit mass and quantity of obscured star formation in these systems.

Spitzer Space Telescope - General Observer Proposal #20190

Bolometric Star Formation Rates as a Function of Large-Scale Environment at Z~2

Principal Investigator: Charles Steidel
Institution: California Institute of Technology

Technical Contact: Charles Steidel, California Institute of Technology

Co-Investigators:
Naveen Reddy, California Institute of Technology
Alice Shapley, University of California at Berkeley
Dawn Erb, California Institute of Technology
Max Pettini, Institute of Astronomy, University of Cambridge
Kurt Adelberger, Carnegie Institution of Washington
Jiasheng Huang, Harvard-Smithsonian Center for Astrophysics
Pauline Barmby, Harvard-Smithsonian Center for Astrophysics

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 22.8

Abstract:
We propose Spitzer/MIPS 24 micron observations in the HS1700+643 field to study the bolometric energy production from galaxies within and surrounding the most significant cluster-scale over-density at z>1.5, at a time when massive galaxies were forming most of their stars. This over-density is at z=2.300, placing the strong 7.7 micron feature observed in star-forming galaxies in the MIPS 24 micron filter, and therefore makes MIPS observations ideally suited for studying the star formation rates and energetics of galaxies as a function of environment. Stellar population modeling of broad-band UV to Spitzer/IRAC SEDs indicates significant differences in the ages and masses of galaxies within and outside of the proto-cluster. The proposed MIPS observations will allow us to determine if these differences extend to the bolometric energy output of galaxies in the proto-cluster and surrounding environment in a manner that is completely independent of the degeneracies of SED modeling and uncertainties in extinction. The extensive multi-wavelength data in the field containing the proto-cluster will allow for the unprecedented opportunity to compare MIPS-inferred bolometric SFRs with UV and Halpha estimates on a galaxy-by-galaxy basis to establish star formation relations for galaxies with a wide range in ages, stellar masses, and luminosities at z~2. Spitzer/MIPS observations of the HS1700+643 proto-cluster therefore offer the opportunity to understand star-formation and its environmental dependencies in a unique and well-studied laboratory at high redshift.

Spitzer Space Telescope - General Observer Proposal #30416

Galaxies, AGN, and Environment: A High Dynamic Range Study at z=1.5-3

Principal Investigator: Charles Steidel
Institution: California Institute of Technology

Technical Contact: Charles Steidel, California Institute of Technology

Co-Investigators:
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Alice Shapley, Princeton University
Dawn Erb, Harvard-Smithsonian Center for Astrophysics
Max Pettini, Cambridge University
David Law, California Institute of Technology
Thiago Goncalves, California Institute of Technology
Milan Bogosavljevic, California Institute of Technology

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 33.8

Abstract:
We propose Spitzer IRAC (3.6/5.8 micron) and MIPS (24 micron) observations in the fields of two very bright QSOs, HS1549+1933 (z=2.844) and Q2343+1225 (z=2.574), in which we have been conducting intensive spectroscopic surveys of galaxies and AGN in the redshift range 1.5<z<3. The objective is to study the dependence of galaxy stellar mass, age, and bolometric luminosity on large-scale environment during the peak epoch of star formation and supermassive black hole accretion. Our spectroscopic results in these two fields have revealed that the bright QSOs in both cases reside in large-scale over-densities likely to become virialized rich clusters by z=0, in each case containing multiple additional QSOs/AGN at the same redshift. The proposed observations, in concert with our very dense spectroscopic sampling of these fields, provide a rare opportunity to examine the details of the relationship between galaxies/AGN and their environments over a large dynamic range in the properties of both: the galaxy sample spans two orders of magnitude in stellar mass and bolometric luminosity, the AGN span 4 orders of magnitude in UV luminosity, and the environments probed extend from proto-cluster to proto-void. The presence of the very bright QSOs provides access to information on the large-scale influence of the energetics of the galaxies and AGN in the foreground. In particular, we will use IRAC observations to measure the stellar masses and ages of galaxies and MIPS observations to measure bolometric SFRs of galaxies and dust obscuration for AGN across the entire sample, whose large-scale context is already known.

Spitzer Space Telescope - General Observer Proposal #3285

The Missing Link in the Galaxy Formation Paradigm: Direct Observations of Energetic Feedback at z~1.5-2.5

Principal Investigator: Charles Steidel
Institution: California Institute of Technology

Technical Contact: Charles Steidel, California Institute of Technology

Co-Investigators:
Naveen Reddy, California Institute of Technology
Dawn Erb, California Institute of Technology
Alice Shapley, University of California at Berkeley
Kurt Adelberger, Carnegie Institution of Washington
Max Pettini, Institute of Astronomy, Cambridge
Wallace Sargent, California Institute of Technology
Robert Simcoe, Massachusetts Institute of Technology

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 16.6

Abstract:
We propose to investigate the large-scale effects of feedback on galaxy formation and the intergalactic medium (IGM) in the redshift range z=1.5-2.5, the peak epoch for star formation and black hole accretion in the history of the universe. We have carefully chosen fields with bright background QSOs whose spectra probe the neutral gas and metal content of the IGM, and obtained optical and near-infrared imaging and spectroscopy of ~200 star-forming galaxies in the same volumes. Spitzer IRAC and MIPS observations will provide unprecedented constraints on the galaxies' ages, stellar masses, bolometric star-formation rates, and the correlation of these properties with the effects of feedback from star formation. These observations will be highly complementary to the very large Spitzer investment in the GOODS and GTO fields, where we will provide the same ground-based support to obtain a complete picture of the galaxy formation process when it was at its most spectacular.

Spitzer Space Telescope - General Observer Proposal #3329

The Most Massive Galaxies at Every Epoch: A Comprehensive Spitzer Survey of High-Redshift Radio Galaxies

Principal Investigator: Daniel Stern
Institution: JPL/Caltech

Technical Contact: Daniel Stern, JPL/Caltech

Co-Investigators:
Carlos De Breuck, ESO
Andrew Zirm, Leiden University
Arjun Dey, NOAO
Mark Dickinson, STScI
Peter Eisenhardt, JPL/Caltech
Robert Fosbury, ESO
Mark Lacy, Spitzer Science Center
Patrick J. McCarthy, Carnegie Observatories
George Miley, Leiden University
Alessandro Rettura, ESO
Brigitte Rocca-Volmerange, IAP
Adam Stanford, UC-Davis/Livermore National Laboratory
Harry Teplitz, SSC
Wil van Breugel, UC-Merced/Livermore National Laboratory
Joel Vernet, Arcetri

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 28.0

Abstract:
We propose a comprehensive survey of 70 high-redshift radio galaxies at 1 < z < 5.2. At each epoch, high-redshift radio galaxies are the most massive galaxies known, as evidenced by their tight observed-frame K-z relation which traces the bright envelope of field galaxies. We propose Spitzer observations to study the rest-frame near-IR stellar luminosity - redshift relation, a more fundamental measurement which provides the stellar masses of these systems. Most z>3 radio galaxies are strong sub-mm sources. MIPS observations will determine if the sub-mm flux is strongly contaminated by hot, AGN-related dust and will probe the on-going star-formation rates of these systems.

Spitzer Space Telescope - Legacy General Observer Proposal #40839

SDWFS: The Spitzer Deep, Wide-Field Survey

Principal Investigator: Daniel Stern
Institution: JPL/Caltech

Technical Contact: Daniel Stern, JPL/Caltech

Co-Investigators:
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Matthew Ashby, CfA
Jamie Bock, JPL/Caltech
Colin Borys, Caltech
Kate Brand, STScI
Mark Brodwin, JPL/Caltech
Michael J. I. Brown, Monash University
Richard Cool, University of Arizona
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Steve Croft, LLNL/UC-Davis
Arjun Dey, NOAO
Peter Eisenhardt, JPL/Caltech
Daniel Eisenstein, Steward Observatory
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Norman Grogin, Johns Hopkins University
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Amy Mainzer, JPL/Caltech
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Adam Stanford, UC-Davis; IGPP/LLNL
Ian S. Sullivan, Caltech
Wil van Breugel, LLNL/UC-Merced
Edward L. (Ned) Wright, UCLA
Steve Willner, CfA

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 201.0

Abstract:
We propose to remap the 8.5 square degree Bootes field (AKA, the "IRAC Shallow Survey") three times during Cycle 4, effectively quadrupling the total exposure time and doubling its photometric depth. This 201 hr legacy project, the Spitzer Deep, Wide-Field Survey (SDWFS), occupies a unique position in area-depth survey space and will be invaluable for investigations ranging from probing the diffuse infrared background from primordial galaxies to identifying the coldest Galactic brown dwarfs. The combined area and depth will allow us to push galaxy cluster surveys to z~2.5. Shallow surveys such as SWIRE, FLS, and the IRAC Shallow Survey have difficulties probing galaxy evolution beyond z~1.5 while deep surveys such as SCOSMOS, EGS, and GOODS have insufficient volume to identify statistically meaningful samples of rich clusters. The SDWFS proposed 3.6 and 4.5 micron imaging will detect normal galaxies out to z~3, while the proposed 5.8 and 8 micron imaging will enable investigations into the warm dust components and the role of AGN in these galaxies. By cadencing the IRAC observations, SDWFS will also open the largely unexplored territory of mid-infrared variability, a powerful tool for identifying and studying active galaxies. Naturally, a program of this breadth has a wide range of astronomical uses; we highlight the key investigations which our science team will pursue. Undertaking this endeavor in this Cycle will permit identification of rare mid-IR variables which could still be observed during the cryongenic mission.

Spitzer Space Telescope - General Observer Proposal #30240

Spectral-Energy Distributions of Galaxies with Old Stellar Populations in Radio-Source Fields at z ~ 2.5

Principal Investigator: Alan Stockton
Institution: University of Hawaii

Technical Contact: Alan Stockton, University of Hawaii

Co-Investigators:
Elizabeth McGrath, Institute for Astronomy, University of Hawaii

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 23.2

Abstract:
Our program to identify luminous galaxies with apparently old stellar populations in radio source fields has discovered a number of such galaxies at z ~ 2.5. We have been engaged in obtaining high-resolution imaging of these objects with HST NICMOS and with ground-based adaptive optics on 8 to 10 m telescopes. The results for the small sample we have been able to observe so far are (1) that massive disks of old stars seem to predominate, in some cases with no evidence for any bulge component at all; and (2) that, for some objects, it is difficult to distinguish between radial-surface-brightness models because the galaxies, though highly luminous (2--3 L*), have effective radii as small as 500 pc. In both cases, the galaxies look nothing at all like present-epoch ellipticals. These morphologies have strong implications for mechanisms for the formation of massive galaxies in the early universe, but it is important at this point to nail down the spectral-energy distributions of the stellar populations in these galaxies better than we can from ground-based observations alone. We are proposing deep Spitzer IRAC (all bands) and MIPS (24 micron) observations of 6 fields for which we have our best examples of luminous galaxies with apparently pure old stellar populations. The Spitzer observations can do 3 important things: (1) By greatly extending the baseline on the longward side of the 4000 A break beyond the short H to K interval, the IRAC observations can help define the dominant stellar population and its age much better; (2) the IRAC photometry can also check for evidence for a highly reddened young-to-moderate-age population that would have no effect at optical and near-IR wavelengths; and (3) the MIPS 24 micron photometry can test for the presence of a highly luminous but heavily obscured starburst.

Spitzer Space Telescope - General Observer Proposal #50032

Spectral Energy Distributions of Galaxies with Old Stellar Populations in Radio-Source Fields with 2.8 < z < 3.6

Principal Investigator: Alan Stockton
Institution: University of Hawaii

Technical Contact: Alan Stockton, University of Hawaii

Co-Investigators:
Elizabeth McGrath, University of California, Santa Cruz

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap MipsPhot
Hours Approved: 16.3

Abstract:
We and others have found massive (~2-3 X 10^11 solar mass in stars) galaxies at z~2.5 that are overwhelmingly dominated by stars that already at least 1 Gyr old at the observed redshift. Our HST NICMOS and Keck adaptive-optics observations of all such galaxies that we have found so far indicate that they are either dominated by disks of old stars or are so compact (r_e ~ 500 pc) that we cannot clearly distinguish between different radial-surface-brightness profiles. In either case, they are strikingly unlike massive galaxies found at the present epoch. Here we propose to obtain deep, well-sampled imaging in the 4 IRAC bands as well as imaging in the MIPS 24-micron band of the fields of 7 powerful steep-spectrum radio sources with 2.8 < z < 3.6. This redshift range will extend to higher redshifts our current successful ground-based and Spitzer search for massive galaxies with exclusively old stellar populations at z ~ 2.5. Such objects will then be subjects for laser-guided adaptive optics morphological studies. The proposed observations, together with our previous cycle 2 and cycle 3 observations and our continuing ground-based imaging program, will also allow the detailed characterization of other galaxies down to ~ L* in the environments of powerful radio sources with 2.3 < z < 4.1.

Spitzer Space Telescope - Directors Discretionary Time Proposal #293

The nature of JD0910+46: a candidate z~10 galaxy

Principal Investigator: Nial Tanvir
Institution: U. Leicester

Technical Contact: Nial Tanvir, U. Leicester

Co-Investigators:
Andrew Levan, University of Warwick
James Rhoads, Arizona State University
Andrew Fruchter, Space Telescope Science Institute
Malcolm Bremer, University of Bristol
Robert Priddey, University of Hertfordshire
Jens Hjorth, University of Copenhagen
Evert Rol, University of Leicester
Pall Jakobsson, University of Hertfordshire

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 2.2

Abstract:
The earliest galaxies in the Universe should have formed at very high redshifts, z>10, based both on models of hierarchical structure formation, and on observations of the microwave background polarization by WMAP that require significant ionization of the intergalactic medium before z=10. However, direct observation of sources at z>7 remains highly challenging due to their scarcity and faintness. We recently identified a bright, spatially extended J-band dropout, JD0910+46, that is an promising candidate for a z>10 galaxy. Its spectral energy distribution is more extreme than any previously reported: It is undetected in J, with a very red J-H color, yet is quite blue in H-K. It appears to be the best candidate to date for a z>10 galaxy: These colors are natural for a Lyman break, but model SEDs of either "old" or dusty galaxies at more moderate redshifts (z~3) cannot easily reproduce the observed combination of red J-H and blue H-K color. Yet we do not feel the case for z>10 can be adequately resolved with existing optical and NIR data alone. Spitzer/IRAC photometry will convincingly distinguish between different models and so elucidate the nature of this remarkable source. Should it turn out to be at a lower redshift it will provide an important example of the kinds of interloper which may contaminate samples of high-z candidates based on the dropout technique.

Spitzer Space Telescope - General Observer Proposal #20599

16 micron Imaging of GOODS North

Principal Investigator: Harry Teplitz
Institution: Spitzer Science Center

Technical Contact: Harry Teplitz, Spitzer Science Center

Co-Investigators:
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David Elbaz, CEA Saclay
James Colbert, SSC
Brian Siana, UCSD
Delphine Marcillac, CEA Saclay
Casey Papovich, UA
Emeric Le Floc'h, UA
David Koo, UCSC
Andrew Phillips, UCO/Lick

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsPeakupImage
Hours Approved: 38.1

Abstract:
We propose to obtain 16 micron imaging of the entire Northern GOODS field (150 square arcmin) to a depth of 33 microJy (3sigma) using the IRS Blue Peak Up imaging capability. These data will fill in the gap in wavelength coverage between the IRAC 8 micron and the MIPS 24 micron imaging of the field. Deep 16 micron data is needed in order to disentangle the combined influences of the 9.7 micron silicate absorption feature and warm dust continuum which fall in the 24 micron filter at 1<z<1.6. Study of the mid-infrared SED is crucial to accurately calibrate MIR dust emission as a tracer of star formation at high redshift, where direct spectroscopy is impossible with IRS except for the most luminous objects.We will infer the PAH and silicate absorption strength from the 16 to 24 micron ratio and compare them in detail to ground-based spectral properties, such as metallicity and nebular line strength. The proposed survey should detect an order of magnitude more z>1 ULIRGs and LIRGs than have previously been detected at this wavelength. The dataset will also be applicable to a broad range of other topics including the correlation of SFR with merger activity and the search for highly extincted AGN. We note that the GOODS-North has the advantage of the deepest Chandra pointing (2 Ms), which will be needed to constrain the AGN properties of the faintest sources. We will release fully calibrated mosaics and catalogs through GOODS.

Spitzer Space Telescope - Directors Discretionary Time Proposal #252

Ultradeep IRS Spectroscopy in GOODS South

Principal Investigator: Harry Teplitz
Institution: Spitzer Science Center

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
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Ranga-Ram Chary, SSC
David Frayer, SSC
Andrew Blain, Caltech
Henrik Spoon, Cornell University
Vassilis Charmandaris, Univ. of Crete
Alexandra Pope, University of British Columbia
Douglas Scott, University of British Columbia
Ski Antonucci, UCSB

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap IrsStare
Hours Approved: 31.6

Abstract:
Currently approved (GO-2) spectroscopic Spitzer surveys of sub-mm sources are limited to flux densities brighter than f_24~0.3 mJy. To study the dominant population of IR-luminous galaxies (10^11 - 10^12 Lsun at 1<z<3), requires us to attempt spectroscopy of sources a factor of fainter, at the 0.1 mJy level. The IRS has never obtained spectra of an object that faint, so potential systematic limitations remain unknown. Nonetheless, understanding the nature of IR-luminous sources at high redshift is a fundamental piece of the galaxy evolution puzzle. To disentangle the AGN and starburst contribution to the luminosity of such sources requires measurement of the MIR spectral features (PAH, silicates, etc). We propose observations of two faint (~0.15 mJy) soures in the Southern GOODS field. One target is a typical LIRG at z=1.09; the other is a soft-band Chandra source at z=2.69, with a high LIR/Lx indicating that it may contain a strong starburst. We request 31.6 hours of DD time in order to perform the observations and analysis in time to publicize the results in advance of GO-3. We will make our initial analysis available in November on the SSC website and in a poster at the SSC science conference.

Spitzer Space Telescope - General Observer Proposal #3661

16 micron Imaging of GOODS-South and the UDF

Principal Investigator: Harry Teplitz
Institution: Spitzer Science Center

Technical Contact: Harry Teplitz, Spitzer Science Center

Co-Investigators:
Mark Dickinson, STScI
David Elbaz, CEA Saclay
Ranga-Ram Chary, Spitzer Science Center
James Colbert, Spitzer Science Center
Daniel Stern, JPL

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 17.9

Abstract:
We propose to obtain 16 micron imaging of the UDF and Southern GOODS field, using the IRS Blue Peak Up imaging capability. These data will fill in the gap in wavelength coverage between the IRAC 8 micron and the MIPS 24 micron imaging of the field. The 16 micron imaging is crucial to accurately calibrate mid-IR dust emission as a tracer of star formation at high redshift. This calibration is necessary not only for the proposed program, but for 24 micron imaging of z>1 sources in GOODS and other deep surveys as well. We will measure the global density of dust enshrouded star formation at its apparent peak near z=1. The dataset will also be applicable to a broad range of other topics including the correlation of SFR with merger activity and the search for highly extincted AGN. Some effort by the team will be required to reduce the non-standard 16 micron data. We will release fully calibrated mosaics through the GOODS multi-observatory data archive.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50031

IRS Spectra of Complete Samples with fv(24u) > 5 mJy and R > 20 mag

Principal Investigator: Daniel Weedman
Institution: National Science Foundation

Technical Contact: Daniel Weedman, National Science Foundation

Co-Investigators:
James Houck, Cornell University
Duncan Farrah, Cornell Universtiy
Emeric Le Floc'h, University of Hawaii
Kate Brand, Space Telescope Science Institute

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 41.8

Abstract:
We propose to finish IRS spectroscopy of a complete sample of 65 extragalactic sources having fv(24u) > 5 mJy and R > 20 mag within the 20 square degrees of the Bootes, FLS, and SWIRE Lockman survey fields. These criteria arise because our previous complete samples in Bootes and the FLS to 10 mJy showed that only 4 of 99 sources have R > 20; three of these are very luminous, deeply absorbed sources with 0.5 < z < 1.3 and represent half of such sources discovered in this redshift range. Because of the importance of comparing to large populations of ULIRGs at lower and higher redshift and determining evolution, it is crucial to discover more such objects at these intermediate redshifts. Of the 65 sources in the complete sample, new spectra are needed for 35, and we propose to obtain these spectra.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #136

Follow-up of Extragalactic SWIRE Sources

Principal Investigator: Michael Werner
Institution: JPL

Technical Contact: Harding Smith, IPAC

Science Category: high-z galaxies (z>0.5
Observing Modes: IrsStare
Hours Approved: 3.8

Abstract:
We propose to make IRS long-low spectrometer observations of 6 galaxies in the SWIRE Lockman Deep Field (RA = 10h45m; Dec=+59d), selected to be high redshift, extremely luminous IR galaxies (from photo-z) or other unique candidates from optical/IRAC/MIPS/radio color-color relations. For S_24 = 1.0 mJy (10 sigma SWIRE detection) a complete 14-40 micron spectrum may be obtained in 1 hr integration with S/N ~ 5 in the continuum from 13--30 microns, with modest re-binning. From our survey model we expect several hundred IR-bright galaxies to this flux density limit, tens of them with z>2.

Spitzer Space Telescope - Archive Research Proposal #20543

Detecting Clusters of Galaxies at 1 < z < 2 in the SWIRE Legacy Fields.

Principal Investigator: Gillian Wilson
Institution: Caltech

Technical Contact: Gillian Wilson, Caltech

Co-Investigators:
Mike Gladders, Carnegie Observatories
Henk Hoekstra, University of Victoria
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Adam Muzzin, University of Toronto
Jason Surace, Caltech
Howard Yee, University of Toronto

Science Category: high-z galaxies (z>0.5)
Dollars Approved: 57232.0

Abstract:
We propose to apply an infrared adaptation of the two-filter Cluster Red-Sequence (CRS) technique to detect a large (500-1000) sample of clusters at 1.0 < z < 1.8 in the 50 square degree SWIRE Legacy Survey. We hope to discover the elusive population of "young" clusters, the "missing-link" in the evolution of proto-clusters discovered at z > 2 to the mature population found at z < 1. In addition to providing a huge boost to cluster evolution studies, discovering this elusive population would also be crucial to our "big picture" of observational cosmology. For example, the evolution of the cluster mass function N(M, z) can place strong constraints on the equation of state of the mysterious dark energy. We have already applied the CRS technique successfully (albeit with a non-optimal filter combination) to the Spitzer First Look Survey and find it to be a very powerful and efficient new tool for detecting clusters of galaxies at high redshift. The CRS technique has the huge additional advantage, not only of detecting clusters in this redshift regime, but of providing very accurate redshifts for the clusters, based solely on the color of their passively evolving red sequence. We plan to release our final catalog as soon as possible. Such a catalog of homogeneously selected clusters in this unexplored redshift range would provide an invaluable resource to the cluster community and would undoubtedly result in numerous follow-up studies. Our Spitzer cluster catalog will also lay the groundwork for future Sunyaev-Zeldovich telescopes capable of detecting > 10,000 cluster candidates at z > 1 but which will require the clusters to be followed up using a CRS technique to determine a photometric redshift. This very unique project can currently only be achieved with the SWIRE dataset (area is vital because rich clusters are so rare). Our project will contribute to Spitzer's legacy by providing substantial returns to the entire cluster community at very little cost.

Spitzer Space Telescope - General Observer Proposal #20629

Characterize the 24micron Population with Systematic IRS Sepctroscopy

Principal Investigator: Lin Yan
Institution: Caltech

Technical Contact: Lin Yan, Caltech

Co-Investigators:
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Lee Armus, SSC/Caltech
Tim Heckman, University of Johns Hopkins
Harry Teplitz, SSC/Caltech
Bruce Draine, Princeton University
Dario Fadda, SSC/Caltech
Phil Choi, SSC/Caltech
Dave Frayer, SSC/Caltech
Anna Sajina, University of British Columbia

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 181.0

Abstract:
With its exquisite sensitivity, the 24um band has yielded the most valuable data on obscured star formation at cosmological distances, and the IRS has demonstrated its diagnostic power by detecting Aromatic Features out to z ~ 2 (Yan et al 2005). Understanding the 24um population can only be achieved with systematic spectroscopy at the mid-IR, coupled with secure redshifts and diagnostics from optical spectra. We propose IRS spectroscopy at 7-38um of an unbiased sample of 159 sources from the First Look Survey (FLS) for which optical spectra are or will be available. These targets have 24um flux density greater than 0.9mJy, and are selected to be representive of infrared galaxies over a wide redshift range. The proposed spectra will provide an essential library for interpreting enormous amount of mid-IR imaging data from Spitzer, then WISE and JWST; we waive the proprietary period, and will release the reduced 1D specrta to the public archive. This unbiased datset will allow us to determine how the energy output from PAH emission in dusty starbursts changes as a function of luminosity and redshift. We will also estimate the relative frequencies of AGN, starburst and composite systems, thus deriving the true obscured star formation density. Utilizing a rich variety of mid-IR spectral diagnostics, including continuum slopes, line and PAH ratios, the strength of PAH emission and silicate absorption, we will study in detail the physical conditions of the ISM in galaxies with intense star formation and AGN activities in early cosmological epochs, and understand the dust emission processes which build both galaxies and blackholes.

Spitzer Space Telescope - General Observer Proposal #30431

Mid-IR Ultra-Deep Spectroscopy of the Cosmic Infrared Background

Principal Investigator: Lin Yan
Institution: Caltech

Technical Contact: Lin Yan, Caltech

Co-Investigators:
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Herve Dole, Institut d'Astrophysique Spatiale, Orsay, France
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Henrik Spoon, Cornell University
Catherine Cesarsky, European Southern Observatory
Sylvain Veilleux, University of Maryland
Dave Sanders, University of Hawaii
George Helou, Spitzer Science Center, Caltech
Frank Bertoldi, University of Bonn
Hector Flores, Observatoire de Paris-Meudon, France
Dave Frayer, Spitzer Science Center, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsMap
Hours Approved: 307.0

Abstract:
We propose to obtain low resolution, mid-IR spectra of a sample of 48 galaxies at z~1 and 2 with 24um flux densities between 0.15-0.5mJy in the CDFS. These sub-mJy 24um sources are shown to dominate the Cosmic Infrared Background (CIB) emission at 70 & 160um (Dole et al. 2006). Their redshift distribution peaks around 1, with a secondary peak at z~2. This implies these sources are LIRGs and ULIRGs at z=1 and 2, respectively. Measurements of IR luminosity functions support these findings and directly show these populations are responsible for more than 70% of the total (UV+IR) luminosity density at z=0.8-2.5. The proposed program is the natural extension of our previous studies of brighter, mJy 24um galaxies. Our primary goal is to characterize the mid-IR spectral properties of the galaxies producing the bulk of CIB. Specifically, we will disentangle the AGN/SB contribution to mid-IR emission, thus constrain the estimate of bolometric luminosities. The proposed spectra, in combination with brighter samples from previous IRS surveys, will allow us to trace the evolution of AGN/SB ratio, strength of PAH emission and mid-IR opacities as a function of L(ir) and z. The deep mid-IR spectra, together with the existing multi-wavelength dataset, will provide the lasting legacy for the astronomical communities for many years to come.

Spitzer Space Telescope - General Observer Proposal #3407

Filling the IRAC Gap in a Deep MIPS 24-micron Field

Principal Investigator: Haojing Yan
Institution: JPL

Technical Contact: Haojing Yan, JPL

Co-Investigators:
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Ranga-Ram Chary, Spitzer Science Center
Mark Dickinson, STScI
Peter Eisenhardt, JPL
David Elbaz, CEA Saclay, France
Harry Ferguson, STScI
Norman Grogin, STScI
Leonidas Moustakas, STScI
Daniel Stern, JPL
Lin Yan, Spitzer Science Center

Science Category: high-z galaxies (z>0.5)
Observing Modes: IracMap
Hours Approved: 4.4

Abstract:
As a validation test of the GOODS MIPS program, the Spitzer Space Telescope has obtained a very deep 24-micron exposure covering four MIPS pointings in the ELAIS-N1 field (80 minutes per pointing). These data are public and will be released to the community in the context of the First Look Survey. These observations constitute the deepest ever image of the 24-micron sky to date, and will remain as one of the deepest other than the GOODS observations themselves. This 24-micron field is uniquely important, especially in addressing the mass assembly history of typical luminosity galaxies 1 < z < 2. The MIPS observations are already complemented by deep IRAC data (2 hours per pointing --- also the deepest non-GOODS public data set), but with only 2-band coverage at each position. We propose to complete the full, 4-channel IRAC coverage over the entire MIPS 24-micron field. With the full spectral coverage provided by the IRAC, we will be able to provide redshift estimates for the vast majority of the 24-micron sources. A significant fraction of the 24-micron sources have no R-band counterparts to AB=24.7 mag, which means optical spectroscopic redshifts for these objects are presently impossible. With this IRAC data set, we will greatly boost the diagnostic power of the unique 24-micron data. The proposed observation can be finished in 4.4 hours, including overhead. We request no proprietary period and the data will be released to the public as part of the First Look Survey.

Spitzer Space Telescope - General Observer Proposal #3748

IRS Spectroscopy of Dusty Galaxies at z ~ 1 - 2: Bridging the gap between ISO and SCUBA

Principal Investigator: Lin Yan
Institution: Caltech

Technical Contact: Lin Yan, Caltech

Co-Investigators:
Dave Frayer, Caltech
Dario Fadda, Caltech
Lee Armus, Caltech
Ranga Chary, Caltech
Harry Teplitz, Caltech
Jason Surace, Caltech
George Helou, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 65.0

Abstract:
We propose to obtain mid-infrared spectra for a sample of dusty galaxies in the Spitzer First Look Survey. We specifically target reddened starbursts in the unexplored epoch from z ~ 1 - 2 by using a24-micron to R-band and 24-micron to 8-micron color-color cut. Our targets are selected to have 24-micron flux brighter than 1 mJy. The proposed IRS data will allow us to cleanly separate AGNs from starbursts, and measure the mid-infrared luminosity function and infrared luminosity density due to star formation alone. We will determine the evolution of dusty galaxies at 1<z<2, and test the ISO model prediction that they contribute 20-30% of cosmic infrared background. The spectra will provide redshifts derived from PAH features for infrared bright, but optically extremely faint ULIRGs. This dataset can serve as a critical test of the utility of IRS for measuring the redshifts of more distant and fainter galaxies that are beyond the limits of ground-based 10-meter telescopes. The MIR spectra will provide a set of templates which are necessary for the interpretation of the fainter 24-micron population targeted by many wide area imaging surveys.

Spitzer Space Telescope - General Observer Proposal #40025

Revealing Physical Nature of Infrared Luminous Galaxies at 0.3<z<2.7 Using HST and Spitzer

Principal Investigator: Lin Yan
Institution: Caltech

Technical Contact: Lin Yan, Caltech

Co-Investigators:
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Anna Sajina, Spitzer Science Center/Caltech
Tim Heckman, The Johns Hopkins University
George Helou, Spitzer Science Center
David Frayer, Spitzer Science Center/Caltech
Nick Scoville, Caltech

Science Category: high-z galaxies (z>0.5)
Observing Modes: MipsPhot
Hours Approved: 65.0

Abstract:
We aim to determine physical properties of IR luminous galaxies at 0.3<z<2.7 by requesting coordinated HST/NIC2 and MIPS 70um observations of a unique, 24um flux-limited sample with complete Spitzer mid-IR spectroscopy. The 150 sources investigated in this program have S(24um) > 0.8mJy and their mid-IR spectra have already provided the majority targets with spectroscopic redshifts (0.3<z<2.7). The proposed 150~orbits of NIC2 and 66~hours of MIPS 70um will provide the physical measurements of the light distribution at the rest-frame ~8000A and better estimates of the bolometric luminosity. Combining these parameters together with the rich suite of spectral diagnostics from the mid-IR spectra, we will (1) measure how common mergers are among LIRGs and ULIRGs at 0.3<z<2.7, and establish if major mergers are the drivers of z>1 ULIRGs, as in the local Universe. (2) study the co-evolution of star formation and blackhole accretion by investigating the relations between the fraction of starburst/AGN measured from mid-IR spectra vs. HST morphologies, L(bol) and z. (3) obtain the current best estimates of the far-IR emission, thus L(bol) for this sample, and establish if the relative contribtuion of mid-to-far IR dust emission is correlated with morphology.

Spitzer Space Telescope - General Observer Proposal #3453

IRS spectroscopy of strongly lensed faint high redshift submillimeter galaxies: star formation and extinction

Principal Investigator: Paul van der Werf
Institution: Leiden Observatory

Technical Contact: Colin Borys, Caltech

Co-Investigators:
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Kirsten Kraiberg Knudsen, Leiden Observatory
Tracy Webb, Leiden Observatory
Andrew Blain, California Institute of Technology
Jean-Paul Kneib, California Institute of Technology

Science Category: high-z galaxies (z>0.5)
Observing Modes: IrsStare
Hours Approved: 5.0

Abstract:
We propose to obtain IRS (Long-Low) spectra of 2 strongly lensed faint submillimeter galaxies at z=2.5 and 2.8. These galaxies are gravitationally lensed by foreground clusters, with amplification factors >10. Intrinsically however, their 850 micron fluxes are about 0.8 mJy. The sub-mJy submm population is important since the integrated background is believed to be dominated by such galaxies, as inferred from the steepness of the submm counts at brighter flux levels. Lyman break galaxies on the other hand are believed to have somewhat lower fluxes, at the level 0.1-0.4 mJy. Since all of these flux levels are below the blank-field confusion limit, they can only be probed using gravitational lenses. Our sources are thus unique objects, providing the only present opportunity to study the faint submm population at flux levels where the transition towards the relatively unobscured Lyman break galaxies occurs. Here we propose IRS spectroscopy of both of these objects, aimed at characterizing the dusty star forming interstellar medium (ISM) of these faint submm sources. Our spectra will probe the rest-frame 5.5-11 micron region, where aromatic features are diagnostic of star formation, and silicate absorption provides a measure of absorbing material. We will compare the results to local (ultra)luminous infrared galaxies and to similar observations of intrinsically much more luminous sources included in GTO Spitzer programs. The silicate absorption will be especially relevant for the faint submm sources studied here, which may be less obscured than their more luminous cousins, and where the underlying starburst may begin to shine through.

Spitzer Space Telescope - General Observer Proposal #40026

Characterizing the Stellar Populations in Lyman-Alpha Emitters and Lyman Break Galaxies at 5.7<z<7 in the Subaru Deep Field

Principal Investigator: Eiichi Egami
Institution: University of Arizona

Technical Contact: Eiichi Egami, University of Arizona

Co-Investigators:
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Richard Ellis, Caltech
Johan Richard, Caltech
Daniel Stark, Caltech
Jean-Paul Kneib, Observatoire de Marseille
Jiasheng Huang, CfA
Kristian Finlator, University of Arizona
Romeel Dave, University of Arizona

Science Category: cosmology
Observing Modes: IracMap
Hours Approved: 102.0

Abstract:
The epoch of reionization marks a major phase transition of the Universe, during which the intergalactic space became transparent to UV photons. Determining when this occurred and the physical processes involved represents the latest frontier in observational cosmology. Over the last few years, searches have intensified to identify the population of high-redshift (z>6) galaxies that might be responsible for this process, but the progress is hampered partly by the difficulty of obtaining physical information (stellar mass, age, star formation rate/history) for individual sources. This is because the number of z>6 galaxies that have both secure spectroscopic redshifts and high-quality infrared photometry (especially with Spitzer/IRAC) is still fairly small. Considering that only several photometric points are available per source, and that many model SEDs are highly degenerate, it is crucial to obtain as many observational constraints as possible for each source to ensure the validity of SED modeling. To better understand the physical properties of high-redshift galaxies, we propose here to conduct HST/NICMOS (72 orbits) and Spitzer/IRAC (102 hours) imaging of spectroscopically confirmed, bright (z<26 mag (AB)) Ly-alpha emitters (LAEs) and Lyman-break galaxies (LBGs) at 5.7<z<7 selected from the Subaru Deep Field. Spectroscopic redshifts remove one critical free parameter from SED modeling while bright source magnitudes ensure high-quality photometric data. By making accurate determinations of stellar masses, ages, and star-formation histories, we will specifically address the following major questions: (1) Do LAEs and LBGs represent physically different galaxy populations at z>6 as suggested recently? (2) Is Ly-alpha emission systematically suppressed at z>6 with respect to continuum emission? (i.e., are we reaching the epoch of incomplete reionization?), and (3) Do we see any sign of abnormally young stellar population in any of the z>6 galaxies?

Spitzer Space Telescope - Legacy General Observer Proposal #50249

Ultra-Deep MIPS Imaging of the Lockman Hole

Principal Investigator: Eiichi Egami
Institution: Steward Observatory, University of Arizona

Technical Contact: Eiichi Egami, Steward Observatory, University of Arizona

Co-Investigators:
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George Rieke, University of Arizona
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Christopher Willmer, University of Arizona

Science Category: cosmology
Observing Modes: MipsScan MipsTp
Hours Approved: 101.7

Abstract:
The Lockman Hole is the region on the sky with the lowest HI column density, which translates into the lowest X-ray absorption, lowest dust extinction, and lowest infrared cirrus emission. This makes the Lockman Hole the cosmic window through which the deepest and cleanest images of the Universe can be obtained at a variety of wavelengths. Because of this, it has been the prime target for many deep surveys in the past, and therefore offers superb data sets, especially in the X-ray, submm, and radio. Despite all these advantages the Lockman Hole offers, it has not been imaged with MIPS to the depth comparable to those of GOODS/HDF-N, GOODS/CDF-S, and EGS. Considering that Spitzer is nearing the end of its cryogenic mission, we believe that it is extremely important to conduct equally deep MIPS imaging of the Lockman Hole in Cycle 5. Ultra-deep MIPS imaging of the Lockman Hole is especially crucial for Herschel, which will obtain deep 24'x24' images of the Lockman Hole at 100, 160, 250, 350, and 500 um as part of the Guaranteed time programs. Here, we propose to obtain confusion-limited MIPS maps of the Lockman Hole as an essential part of the Spitzer legacy. Such ultra-deep MIPS maps will nicely complement the Herschel data in the near future. A new and innovative aspect of this proposed program is the attempt to perform absolute calibration of the ultra-deep MIPS maps with carefully designed Total Power Mode observations. Such observations, attempted for the first time here with MIPS, will allow us to characterize the properties of the cosmic infrared background with a much improved accuracy and precision. The ultra-deep maps will also have powerful applications in determining the spectral energy distributions of high-redshift infrared galaxies, and in studying the properties of active galactic nuclei with strong obscuration in the X-ray.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30478

The Evolution of Galaxy Dark Matter and Stellar Mass to z = 1.2 : IRAC Imaging of the Deep Lens Survey Field F2

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Gillian Wilson, Caltech

Co-Investigators:
Jiasheng Huang, Harvard Smithsonian Center for Astrophysics
Mark Lacy, SSC / Caltech
Jason Surace, SSC / Caltech
Gillian Wilson, California Institute of Technology

Science Category: Cosmology
Observing Modes: IracMap
Hours Approved: 34.5

Abstract:
We propose to image 4 square degrees with IRAC (to 120s depth) to carry out a unique project to directly compare the stellar mass content of galaxies with the masses of their dark halos. The IRAC observations will complement a parallel ground-based weak lensing analysis of the same field, currently being undertaken by the Deep Lens Survey (DLS) team. The proposed field is one of five fields comprising the ultradeep BVRz' 20 square degree DLS survey. We will photometrically (and spectroscopically) subdivide galaxies by redshift, luminosity and morphological type, measure average dark matter halos from the full 20 square degrees and average stellar mass for galaxies of the same type from the 4 square degree field. This dataset will allow us to study the evolution of baryons relative to the dark matter to z = 1.2

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30328

DEEP IRAC and MIPS Imaging of an Overdensity Filament at z=3.09

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Jiasheng Huang, CfA

Co-Investigators:
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Matt Ashby, SAO
Pauline Barmby, SAO
Tracy Webb, University of McGill
Dimitra Rigopoulou, Oxford University
Toru Yamada, National Astronomical Obs. Japan
Gillian Wilson, SSC

Science Category: cosmology
Observing Modes: IracMap MipsPhot
Hours Approved: 32.0

Abstract:
Galaxy clusters and protoclusters at high redshifts are very rare objects despite exhausive multi-wavelength searching in the sky. Objects of this kind bear rich information on formation of clusters and evolution of large scale structure. Simulations predict that clusters form in overdense regions in the universe; thus an overdense region is an ideal place to search for clusters. A overdense filament with a linear scale of 56Mpc at z=3.09 is found in the SSA22 region. This filament is traced by Lyman Alpha Emitters, Lyman Break Galaxies , Lyman Alpha Blobs. This region provides various types of galaxies at z=3.09, which may correspond to different stages in galaxy evolution in the dense environment. We propose both deep IRAC and MIPS 24micron imaging of this region. We will be able to analyze the stellar populations and obtain stellar mass for galaxies at different locations in the filament with the IRAC photometries, and also locate galaxies with strong star formation in the filament with the MIPS detection. This anlysis will reveal the formation process of galaxies in a dense environment like this filament.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #79

Proto-Clusters Around High-Redshift Radio Galaxies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Peter Eisenhardt, JPL

Science Category: cosmology
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 14.0

Abstract:
High-redshift radio galaxies (HzRGs) provide our most robust examples of massive galaxies at early cosmic epoch. In biased galaxy formation models, we therefore expect associated galaxy overdensities around HzRGs. In this program we undertake deep IRAC, MIPS, and IRS observations of two distant radio galaxies, each of which once held the record for most distant galaxy known. These fields have also been subjected to deep optical (ground-based and Hubble) and sub-mm observations. We will attempt to identify possible galaxy proto-clusters surrounding these high-redshift AGN.

Spitzer Space Telescope - General Observer Proposal #30871

Spitzer Observations of the Highest-Redshift Gamma-Ray Bursts

Principal Investigator: Derek Fox
Institution: Penn State University

Technical Contact: Derek Fox, Penn State University

Co-Investigators:
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S. R. Kulkarni, California Insitute of Technology
D. A. Frail, National Radio Astronomy Observatory
B. P. Schmidt, Australia National University
P. A. Price, University of Hawaii
H.-S. Park, Lawrence Livermore National Laboratory
A. Gal-Yam, California Institute of Technology
A. Soderberg, California Institute of Technology
S. B. Cenko, California Institute of Technology
F. A. Harrison, California Institute of Technology
S. Shectman, Carnegie Observatories
E. Persson, Carnegie Observatories

Science Category: cosmology
Observing Modes: IracMap
Hours Approved: 38.9

Abstract:
We propose to use the Spitzer Space Telescope to study the infrared (3.6 to 8.0 micron) afterglow emission of GRBs from the ‘‘dark ages’’ of the universe, z>6. Current theories of the early universe predict the first star formation activity at z~20, and since GRBs are associated with the deaths of massive stars they may be expected at this epoch as well, before the formation of the first quasars. Our candidate high-redshift afterglows will be identified in ground-based near-infrared imaging as fading sources with red H-Ks color, H-Ks > 3.0 mag. For these bursts, 4-band IRAC imaging can provide the crucial additional color information that will distinguish afterglows at z>12.7 (H-band drop-outs) from those within high-extinction environments at z>6 (rest-frame E_(B-V)>0.8). We request time to carry out two high-impact Spitzer TOO campaigns during the cycle. The confirmation of even a single z>6 burst will have immediate implications for theories of the early universe, formation of the first nonlinear structures, the nature of the earliest stars, and cosmology.

Spitzer Space Telescope - Legacy General Observer Proposal #50148

MIPS AGN and Galaxy Evolution Survey

Principal Investigator: Buell Jannuzi
Institution: National Optical Astronomy Observatory (NOAO)

Technical Contact: Buell Jannuzi, NOAO

Co-Investigators:
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Colin Borys, California Institute of Technology
Daniel Eisenstein, University of Arizona
Emeric Le Floc’h, University of Hawaii
Ben Weiner, University of Arizona
Lee Armus, California Institute of Technology
Kate Brand, STScI
Mark Brodwin, NOAO
Michael Brown, Monash University
Richard Cool, University of Arizona
Vandana Desai, Spitzer Science Center
Arjun Dey, NOAO
Mark Dickinson, NOAO
Herve Dole, Institut d’Astrophysique Spatiale
Jane Morrison, University of Arizona
Casey Papovich, University of Arizona
Pablo Perez-Gonzalez, Universidad Complutense de Madrid
George Rieke, University of Arizona
Marcia Rieke, University of Arizona
Daniel Stern, JPL/California Institute of Technology
Idit Zehavi, Case Western Reserve University

Science Category: cosmology
Observing Modes: MipsScan
Hours Approved: 129.5

Abstract:
We propose a far-IR survey of the 9 square degree Bootes field of the NOAO Deep Wide-Field Survey (NDWFS) to 5-sigma flux limits of 0.2, 12.8 and 120 mJy to detect approximately 60000, 3000, and 400 sources at 24, 70 and 160 microns respectively. By combining observations at different roll angles, our maps will have excellent control of detector drifts, enabling precise fluctuation analyses in all three maps. In combination with the matching X-ray, UV, optical, near-IR, and mid-IR photometry, variability data, and the 22,000 spectroscopic redshifts for the field, we have three primary goals. First, we will survey the evolution of LIRGS/ULIRGS to redshifts of 0.6/1.3 at 24 microns and 0.4/0.8 at 70 microns. Over 500 0.6<z<1.0 ULIRGS will be identified, which will allow us to estimate their characteristic halo masses using a cross-correlation analysis. Second, we will search for obscured AGN at all redshifts, particularly sources with 10<A_V<100 that will be missed in mid-IR selected samples. These sources could represent up to 50% of the AGN in the field. Third, we will use "stacking" analyses to measure the FIR properties of sources as a function of luminosity, redshift, and type, cross-correlation analyses to locate FIR emission associated with known populations, and auto-correlation analyses to characterize FIR emission associated with unknown populations. These latter analyses require our high fidelity maps. Combined with its ancillary data, the MAGES survey will provide a long term resource for studying the sources of FIR emission with an excellent balance between depth (for source detection) and area (for correlation analysis and minimizing cosmic variance).

Spitzer Space Telescope - Directors Discretionary Time Proposal #279

IRS Verification of Candidate z>8 Sources

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Richard Ellis, Caltech
Daniel Stark, Caltech
Johan Richard, Caltech
Harry Teplitz, SSC

Science Category: Cosmology
Observing Modes: IrsMap
Hours Approved: 47.2

Abstract:
The reionization of neutral hydrogen which rendered the Universe transparent to UV photons and terminated the ‘dark ages’ was a landmark event in cosmic history. Determining the nature and redshift distribution of the sources responsible represents the current frontier in studies of the first galactic systems. We request 47.2 hours with IRS to verify the redshifts of two candidate Ly-alpha emitters located from a comprehensive survey for lensed sources in the redshift range 8<z<10. Spectroscopic confirmation of only 1-2 objects would suggest that low luminosity star-forming sources provide a significant contribution to the UV flux necessary for cosmic reionization.

Spitzer Space Telescope - General Observer Proposal #40311

The Masses and Ages of Galaxies in the Era of Reionization

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Andrew Bunker, University of Exeter
Richard Ellis, Caltech
Kuenley Chiu, University of Exeter
Elizabeth Stanway, University of Bristol
Daniel Stark, Caltech
Laurence Eyles, University of Exeter

Science Category: cosmology
Observing Modes: IracMap
Hours Approved: 72.0

Abstract:
Our understanding of the z~6 galaxy population is mostly based on observations in the relatively small GOODS fields, and is thus vulnerable to the effects of cosmic variance. We propose to use IRAC to followup 6 deep fields observed with the now defunct HST/ACS to sample a substantially larger volume at these redshifts. We previously identified a population of star-forming galaxies at z~6 through the Lyman-break technique (I-drops) and confirmed many with spectroscopy on Keck/Gemini/VLT. We used IRAC observations in the GOODS-S field to discover significant Balmer/4000A breaks in many of these I-drops, indicating dominant stellar populations with ages of 200-700Myr and formation redshifts of z~7-18. We suggested that these massive galaxies could have contributed signficantly to the reionization of the universe at z>7 through earlier vigorous episodes of star formation. However, our sample is small, as it comprises only a handful of bright and isolated z~6 galaxies. The GOODS dataset covers two pointings, and our quantitative conclusions are limited by cosmic variance. To properly constrain the stellar mass density and contribution of earlier star formation to reionization, requires a larger sample over many different sightlines. We have deep ACS I- and z-band images in 6 fields (deeper than GOODS), from which we generated extensive catalogs of I-drop galaxies. With IRAC imaging, we can measure their ages and stellar masses through stellar population fitting. By observing with all 4 IRAC channels we can also constrain the metallicities and dust reddenings of galaxies at z~6; our analysis of GOODS-South favors low extinction and low metallicity, but a larger sample observed out to 8um is crucial to confirm this important finding. By quadrupling the number of sightlines, and the number of z~6 galaxies with Spitzer detections, we can address whether the presence of established systems at z=6 suggests long-lived sources at earlier epochs (z>7) played a key role in reionizing the Universe.

Spitzer Space Telescope - General Observer Proposal #40370

A Unique IR, SZE, and X-ray Galaxy Cluster Survey

Principal Investigator: Spencer Stanford
Institution: University of California, Davis

Technical Contact: Spencer Stanford, University of California, Davis

Co-Investigators:
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Anthony Gonzalez, University of Florida, Gainesville
Peter Eisenhardt, JPL
Mark Brodwin, Caltech
John Carlstrom, University of Chicago
Hans Bohringer, MPE
Guenther Hasinger, MPE
Ruediger Kneissl, MPIfR

Science Category: cosmology
Observing Modes: IracMap
Hours Approved: 77.0

Abstract:
We propose to image a single 12 square degree area with IRAC. The area is unique in that it is being imaged by three mm-wave experiments - SPT, ACT, and APEX - as they conduct Sunyaev-Zel'dovich Effect surveys for galaxy clusters. We have also begun to survey with XMM this same area to provide an X-ray selected galaxy cluster catalog. We have already obtained griz images of this area in an NOAO optical imaging survey to provide crucial photometric redshifts at z < 1. The proposed IRAC data will allow us to determine phot-z for the SZE cluster candidates up to at least z = 1.5, to uniformly select galaxies and AGN for carrying out clustering analyses, to estimate galaxy masses, and to cross check the SZE and X-ray cluster selection functions within the same area. Compared to other similar total areas surveyed by IRAC previously, our survey area has the distinct advantages of 1) being targetted by the new generation of mm-wave surveys, and 2) being the target of moderately deep XMM imaging.

Spitzer Space Telescope - Archive Research Proposal #50622

Hunting for z'-dropout z > 6.5 Quasars in the SWIRE Legacy Fields

Principal Investigator: Gillian Wilson
Institution: University of California Riverside

Technical Contact: Gillian Wilson, University of California Riverside

Co-Investigators:
Mark Lacy, Spitzer Science Center / Caltech
Jonathan Gardner, Goddard Space Flight Center
Howard Yee, University of Toronto
Patrick Lowrance, Spitzer Science Center / Caltech
Adam Muzzin, Yale University
Jason Surace, Spitzer Science Center / Caltech

Science Category: cosmology
Dollars Approved: 100000.0

Abstract:
A total of 13 quasars at 6 < z < 6.43 have been successfully detected by the Sloan Digital Sky Survey (SDSS) and Canada-France High-z Quasar Survey (CFHQS) using an i'-dropout technique. We propose to extend the search for quasars to z > 6.5 by targeting z'-dropout sources using deep z-band imaging from the Spitzer Adaptation of the Red-sequence Cluster Survey (SpARCS) combined with IR imaging from the Spitzer SWIRE Legacy Survey. Extrapolation from the quasar luminosity function suggests that there will be 13 quasars at z > 6, and 2 quasars at z > 8 within the 50 square degrees of the SpARCS/SWIRE fields that are brighter than the SWIRE detection limit. Very high redshift quasars are required as targets for The James Webb Space Telescopes's scientific goal of studying "The End of the Dark Ages: First Light and Reionization", and the work proposed here would develop techniques which could be applied to a Spitzer Warm Mission Survey for high-redshift quasars. Successful detection of high redshift quasars will require careful matching of the optical and Spitzer catalogs, efficient star-galaxy separation, and extensive modelling of Spitzer colors to distinguish as efficiently as possible between quasars and other extremely red optical-IR "contaminating" sources e.g., cool stars and dusty galaxies. We also propose to search for "Y" dwarfs, the coolest, and as yet undiscovered, class of brown dwarf.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #66

DIRBE Dark Spots

Principal Investigator: Ned Wright
Institution: UCLA

Technical Contact: Ned Wright, UCLA

Science Category: cosmology
Observing Modes: IracMap
Hours Approved: 51.7

Abstract:
GTO DIRBE dark spot program.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #78

Distant Galaxy Clusters

Principal Investigator: Ned Wright
Institution: UCLA

Technical Contact: Ned Wright, UCLA

Science Category: cosmology
Observing Modes: IracMap
Hours Approved: 5.4

Abstract:
GTO high-z cluster program.

Spitzer Space Telescope - Archive Research Proposal #40836

A Systematic Study of the Global Stellar Mass Density at 0.5<z<6

Principal Investigator: Haojing Yan
Institution: Observatories of the Carnegie Institution of Washi

Technical Contact: Haojing Yan, OCIW

Science Category: cosmology
Dollars Approved: 77635.0

Abstract:
Global stellar mass density is one of the two basic quantities that describe the global star formation activities in the universe, and the study of its evolution is of fundamental importance in understanding the mass assembly history of galaxies. However, the measurement of this quantity remains scarce, largely due to the lack of deep, wide-field IR imaging data that are critical in estimating the stellar masses of galaxies. Spitzer/IRAC offers an unprecedented opportunity in advancing this study. The investigator proposes to carry out a systematic study of the stellar mass density at 0.5<z<6, utilizing the existing IRAC data from these three Spitzer Legacy Surveys: GOODS, SIMPLE, and S-COSMOS. These IRAC surveys have order-of-magnitude improvement in both depth and coverage as compared to the near-IR surveys used by any pre-Spitzer studies beyond the local universe, and hence will result in the best measurement of the stellar mass density to date. This program will also produce the largest sample of galaxies with estimates of redshifts, stellar masses and ages, being least affected by cosmic variance. This catalog will enable many follow-up studies on different subjects, and will be made public.

Spitzer Space Telescope - Directors Discretionary Time Proposal #1100

70 Micron Imaging of Arp 94

Principal Investigator: Philip Appleton
Institution: Caltech

Technical Contact: Philip Appleton, Caltech

Science Category: interacting/merging galaxies
Observing Modes: MipsPhot
Hours Approved: 0.3

Abstract:
MIPS 70 micron imaging of the Arp 94 galaxy.

Spitzer Space Telescope - General Observer Proposal #20369

Spitzer Imaging and Spectroscopy of Collisional Ring Galaxies

Principal Investigator: Philip Appleton
Institution: Caltech

Technical Contact: Philip Appleton, Caltech

Co-Investigators:
Lee Armus, SSC-Caltech
Joseph Mazzarella, IPAC-Caltech
Barry Madore, Carnegie Observatories (OCIW)
Curtis Struck, Iowa State University
Seppo Laine, SSC-Caltech
Thomas Jarrett, SSC-Caltech
Beverly Smith, East Tennessee State University
Armando Gil de Paz, Carnegie Observatory (OCIW)
William Reach, SSC-Caltech
Vassilis Charmandaris, Cornell University
Steven Lord, HSC-Caltech
Kirk Borne, George Mason University

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 12.0

Abstract:
We propose Spitzer imaging and IRS spectroscopy of a sample of twelve collisional ring galaxies. These galaxies exhibit radially-expanding massive-star forming rings which are believed to be the gravitational response of the target disk to a head-on collision of a companion through its center. Among the most luminous kinds of galaxy found by GALEX in the UV, these collisional systems are particularly suitable for studying interstellar dust under a wide variety of excitation conditions and metallicities. Spitzer imaging and MIR-spectroscopy, in combination with a large body of ancillary data and models, will allow us to: 1) determine the SEDs of massive star formation knots around the rings from the UV to the far-IR, and 2) investigate how the properties of dominant dust grain populations vary with the large range of conditions seen in the rings, 3) investigate how the strength of PAH--features varies with metallicity, and 4) search for (dust enshrouded) secondary star formation sites inside the rings predicted to be triggered by the collapse of molecular clouds in the wake of the ring passage. Understanding the response of dust grains to a wide range of excitation conditions in collisional systems will contribute to our understanding of the rest-frame mid-IR properties of high redshift galaxies seen in deep Spitzer surveys.

Spitzer Space Telescope - General Observer Proposal #50764

The Search for Powerful Molecular Hydrogen Emission in Hickson Compact Groups

Principal Investigator: Philip Appleton
Institution: Caltech

Technical Contact: Philip Appleton, Caltech

Co-Investigators:
Patrick Ogle, SSC-caltech
Robert Antonucci, UC Santa Babara
Francois Boulanger, IAS Paris
Vassilis Charmandaris, U. of Crete
Eiichi Egami, U. of Arizona
Pierre Guillard, IAS Paris
Emeric Le Floc'h, IfA hawaii
Lourdes verdes-Montenegro, IdAA
Min Yun, UMASS

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 48.1

Abstract:
We propose to search for powerful molecular hydrogen emission in 29 Hickson Compact Groups of galaxies. The proposal is the first systematic attempt to understand the new class of H2-powerful galaxies, called MOHEGs, which have recently been discovered by Spitzer. These galaxies are characterized as having huge luminosities emitted in the pure-rotational lines of H2 in the MID-IR, and are very likely shock excited. This proposal targets the very environments in which MOHEGs have been discovered, and will for the first time attempt to understand the conditions that lead to this activity. The results will have lasting value for IR astronomy, providing a starting point for similar searches of H2 bright galaxies at high-z with the next generation of IR telescopes.

Spitzer Space Telescope - General Observer Proposal #20193

IRS Spectral Mapping of Major Mergers

Principal Investigator: Lee Armus
Institution: Spitzer Science Center

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
J.D. Smith, University of Arizona
Vassilis Charmandaris, University of Crete
John Hibbard, NRAO
Min Yun, University of Massachusetts
Berhard Brandl, University of Leiden
Jason Surace, SSC
Seppo Laine, SSC
Francois Schweizer, OCIW
Tom Jarrett, IPAC
Aaron Evans, SUNY Stony Brook

Science Category: interacting/merging galaxies
Observing Modes: IrsMap
Hours Approved: 44.9

Abstract:
Interactions and mergers are important drivers of galaxy evolution. Minor mergers can puff-up galactic disks, produce bars and rings, and facilitate on-going star-formation through delivery of fresh fuel to the parent galaxy. Major mergers, those between more or less equal mass galaxies, can completely disrupt the stellar and gaseous morphologies of both systems, transform spirals into massive ellipticals, and fuel both powerful starbursts and massive nuclear black holes. At high redshifts, mergers are responsible for the rapid rise in the number counts seen in deep imaging surveys, and the genesis of some of the most luminous galaxies observed. We propose to use the IRS on Spitzer in spectral mapping mode to study both the morphology and the spectral properties of the gas and dust in a sample of eight nearby, IR bright merging galaxies that span the range from early (NGC 4676, NGC 6621, and NGC 7592) to mid (NGC 2623, NGC 520 and NGC 6240) to late (NGC 3921 and NGC 7252) major mergers. With these data we will be able to measure the spatial variations and evolution in the hot and warm dust, search for buried AGN, and directly couple the dust and ionized gas properties, even in regions that are complete opaque in the optical.

Spitzer Space Telescope - General Observer Proposal #50172

Spectroscopy of IR Galaxies Over The Merger Sequence

Principal Investigator: Carrie Bridge
Institution: Spitzer Science Center

Technical Contact: Carrie Bridge, Spitzer Science Center

Co-Investigators:
Harry Teplitz, Spitzer Science Center
Lee Armus, Spitzer Science Center
Raymond Carlberg, University of Toronto
Chris Conselice, Univeristy of Nottingham
Phil Appleton, Spitzer Science Center

Science Category: interacting/merging galaxies
Observing Modes: IrsStare
Hours Approved: 32.4

Abstract:
Locally, ~50% of LIRGs and 95% of ULIRGs are driven by galaxy mergers, which provide the primary means of triggering star formation and AGN activity. However, at z>0.7 the dominate mechanisms responsible for the IR emission in LIRG galaxies may be different from those locally, as only 30% of z=0.7 LIRGs exhibit merger signatures and the remaining 70% appear to be undisturbed spiral galaxies. Although the merger process itself is the same at both high and low redshift, the galaxies involved in the mergers are not. At higher redshift, galaxies have higher gas mass fractions, meaning more fuel for star formation and AGN, can have smaller bulges, and are less likely to have bar structures. These differences can affect the onset, strength and relative contribution to their IR luminosity from starbursts and AGN. Using the CFHTLS-Deep Catalog of Interacting Galaxies we have identified 24 (>1mJy at 24um) early to late stage IR bright mergers, between 0.45<z<1.0, based on tidal signatures, for deep MIR spectroscopy. Using Mid-IR spectral diagnostics, we will quantify the relative IR contribution from star formation and AGN, the onset of these processes, and how they compare to local analogs, all as a function of merger stage.

Spitzer Space Telescope - General Observer Proposal #3360

The Connection between ULXs and Infrared Star-Forming Regions in the Merging Pair of Galaxies NGC 4485/90

Principal Investigator: Edward Colbert
Institution: Catholic University of America

Technical Contact: Edward Colbert, Catholic University of America

Co-Investigators:
Ann Hornschemeier, Johns Hopkins University
Timothy Roberts, University of Leicester
Sangeeta Malhotra, Space Telescope Science Institute
Martin Ward, University of Leicester

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsMap
Hours Approved: 9.3

Abstract:
We propose IRAC imaging of the starburst galaxy system NGC 4485/90, and pointed IRS spectral mapping for eight locations within the galaxies. NGC 4485/90 houses an extraordinarily large number of Ultra-luminous X-ray sources (ULXs), and has a dense array of HII star-forming (SF) regions. We will use IRAC images to study correlation statistics between the the six ULXs and nearby IR-luminous SF regions. The IRS spectral mapping data is to be taken for rectangular regions centered on the six ULXs, and for two comparison regions in NGC 4490. These spectra will be used to measure physical characteristics (e.g. density, excitation) of the gas in the SF regions and to diagnose properties (e.g. luminosity, hardness) of the components of the ionizing radiation. Our proposed Spitzer observations will help distinguish between competing models for ULXs, and will greatly complement on-going X-ray spectral diagnostic work, which is currently only possible for very X-ray bright ULXs.

Spitzer Space Telescope - General Observer Proposal #3544

IRAC and MIPS Observations of the Interacting Galaxies IC 2163 and NGC 2207

Principal Investigator: Debra Elmegreen
Institution: Vassar College

Technical Contact: Debra Elmegreen, Vassar College

Co-Investigators:
Bruce Elmegreen, IBM T.J. Watson Research Center
Michele Kaufman, Ohio State University
Kartik Sheth, CalTech
Elias Brinks, Instituto Nacional de Astrofisica
Magnus Thomasson, Onsala Space Observatory
Curt Struck, Iowa State University

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 1.8

Abstract:
We propose IRAC and MIPS observations of the interacting galaxies IC 2163 and NGC 2207 in order to find and measure the properties of embedded young massive clusters (YMC), determine the luminosities and masses of clusters and gas in an extraordinary region that may contain a black hole inside a YMC, measure the dust temperatures and column densities in dozens of clouds in NGC 2207 that were also observed in HI and in extinction using IC 2163 as a background source, and look for the IR counterparts of enhanced radio continuum ridges that are associated with galactic-scale tidal shocks. The results should clarify an observation that is peculiar to these galaxies and a few other sources of enhanced YMC formation relative to lower mass clusters. The data could also reveal the first evidence of mutual disk scraping in a grazing collision. As this galaxy pair is among the most thoroughly observed and modeled of all interacting (non-merger) systems, the SST observations combined with our other data and models will allow us to determine the history of tidal deformations, gas flow, and star formation over the 40 My since perigalacticon.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30860

MIPS Observations of Four Infrared Bright Nearby Galaxies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Zhong Wang, Smithsonian Astrophysical Observatory

Co-Investigators:
Zhong Wang, Harvard-Smithsonian Center for Astrophysics
Jason Surace, SSC
Steve Willner, CfA
Mathew Ashby, CfA
Jiasheng Huang, CfA
Howard Smith, CfA
Mike Pahre, CfA

Science Category: interacting/merging galaxies
Observing Modes: MipsPhot
Hours Approved: 0.3

Abstract:
We propose to observe four nearby infrared lumnious galaxies with MIPS as part of our existing GTO program on Interacting/starburst galaxies. These four galaxies were omitted in earlier programs only for techincal reasons and their addition to the body of data already collected is an important final step to bring the observational part of this GTO program to completion. We already obtained high quality IRAC data of these galaxies and MIPS data would help us determine the bolometric luminosities of individual regions in them, and provide better estimates of the local star formation rate. These four galaxies sample relative late stages of the merger process and are expected to offer further clues to the final outcome of the merger process, as well as the detailed distribution of star forming activities and their potential relationship to the formation of active galactic nucleii found near the center region.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #32

Probing a Sample of Interacting and Ultraluminous Galaxies

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Zhong Wang, Smithsonian Astrophysical Observatory

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot MipsScan
Hours Approved: 23.1

Abstract:
Galaxies closely interacting (or merging) with each other may trigger a wide range of activities, including star formation. These could profoundly alter the course of ordinary galactic evolution. Some of these objects are spectacular nearby examples of galaxy-galaxy interactions. Others, known as ULIGs (ultraluminous infrared galaxies), are among the most luminous objects in the local universe. High sensitivity, high resolution infrared data are essential in studying these galaxies, because a majority of them are found to be rich in gas and dust, making extinction a significant limiting factor at shorter wavelengths. We propose to image a limited sample of interacting and ultraluminous galaxies with IRAC and MIPS. Our main goal is to accurately measure the amount and extent of star forming activities and to explore their relationship to the dynamics of gravitational interaction.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50696

Completing MIPS imaging for the Spitzer Interacting Galaxy study

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
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Howard Smith, CfA
Matt Ashby, CfA
Tom Cox, CfA
Jiasheng Huang, CfA
Chris Mihos, Case Western
Luigi Spinoglio, IFSI-CNR, Rome
Zhong Wang, CfA
Steve Willner, CfA
Eduardo Gonzalez-Alfonso, Universidad de Alcala
Jason Surace, IPAC

Science Category: interacting/merging galaxies
Observing Modes: MipsPhot
Hours Approved: 2.8

Abstract:
We propose to complete the MIPS coverage of a coherent set of Spitzer observations of a large representative sample of 110 nearby interacting galaxies. Galaxy interactions is a complex process that involves time-dependent scenarios affecting the evolution of all the participants. However, existing projects focus on sometimes small samples of galaxies chosen because they have the most active star formation, are bright in well-known optical emission line diagnostics, or otherwise obviously distinguished. The 110 galaxies we propose to study form a sample independent of obvious current activity; instead, it is based on physical proximity and relative velocity such that the pair is a likely candidate for interaction. We also limit the sample to relatively nearby galaxies (cz < 4000 km/sec), so that detailed spatialy resolved measurements can be obtained from the existing data. All the objects have been observed with IRAC, IRS, and all but the ones we propose have been observed with MIPS. By combining morphological, photometric and spectroscopic analyses of this sample, we will map the star-forming activity and we will study its connection with AGN activity and the interaction type and severity. This approach distinguishes itself in that it systematically traces the changes in a large sample of galaxies covering a variety of interaction types. Comparisons with simulations of galaxy interactions, will provide constraints to the theoretical models, and the influence of environmental factors (e.g. the initial gas content or the massive halos) on the final outcome of the interaction, including the energetics of a possible AGN component. Since galaxy-galaxy interactions are more ubiquitous at earlier epochs, this study should also improve our understanding of the early history of galaxy evolution.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #21

Spectroscopic Study of Star Formation in Interacting Galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Bernhard Brandl, Sterrewacht Leiden

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 36.0

Abstract:
The objective of our program is to study the properties of starbursts triggered by closely interacting galaxies in different states of their merging process. The properties of the starbursts may vary with location, dynamics, age, metallicity, distribution of gas and dust in the overlap region, and the presence of AGN. We will use the 4 IRS modules to measure the excitation of the gas and solid-state features in the mid-infrared spectra of a sample of 11 relatively nearby, spatially resolved interacting systems. In addition we will use IRAC and MIPS on a subset of our sample for complementary imaging.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40621

Spitzer/IRS View of Very Metal-pool Mergers

Principal Investigator: Jim Houck
Institution: Cornell University

Technical Contact: Yanling Wu, Cornell University

Co-Investigators:
Yanling Wu, Cornell University
Simon Pustilnik, Special Astrophysical Observatory of Russian Acade
Alexei Kniazev, South African Astronomical Observatory
Vassilis Charmandaris, University of Crete

Science Category: interacting/merging galaxies
Observing Modes: IrsMap IrsStare
Hours Approved: 6.2

Abstract:
We propose to study the mid-IR spectra of several candidate interacting/merging dwarf galaxies with very low-metallicity. They are representatives of a small group of local objects that best approximates the properties common to high-redshift low-mass young galaxy mergers: very metal-poor, gas-rich and interacting. Groundbased observations have identified the dwarf that show morpholog and velocity profiles characteristic of larger scale mergers. We propose to approach the problem via the rotational lines of warm molecular hydrogen. We will extend previous ISO and Spitzer investigations that have shown the H2 line to be effective markers of merging activity. We will use the H2 lines as indicators of strong shocks produced by merging activity. Here, we discuss the current data set and our approach to avoiding false positive "dwarf mergers." In addition we will also use this sample to study high-ionization lines of Ne and S. We will add these new data to our ongoing study of PAH emission in low-metallicity but high-excitation environments.

Spitzer Space Telescope - General Observer Proposal #3550

Star Formation and Galaxy Evolution During a Supersonic Cluster Merger

Principal Investigator: Christine Jones
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Christine Jones, Smithsonian Astrophysical Observatory

Co-Investigators:
Maxim Markevitch, SAO
Anthony Gonzalez, University of Florida
Michael Pahre, SAO
William Forman, SAO

Science Category: interacting/merging galaxies
Observing Modes: IracMap
Hours Approved: 2.5

Abstract:
1E0657-56 (z=0.296), one of the hottest and most luminous X-ray clusters, is the only known example of a major supersonic cluster merger. The Chandra image of this merging cluster shows a sharp bow shock that leads the merging ‘‘bullet’’ subcluster. Not only are the cluster’s X-ray properties unique, but the merger is occurring in the plane of the sky. This fortuitous geometry allows us to calculate, without model dependent geometrical assumptions, the ambient density, temperature, and pressure that the merging galaxies experience. We also know which galaxies have traversed the cluster core and, since the merger velocity is measured from the X-ray observations, the time since these galaxies traversed the core. Because the gas velocity is discontinuous at the shock, the galaxies behind it will experience one third the ram pressure exerted on galaxies ahead of the shock. Therefore, Spitzer IRAC observations of this supersonic merger will, for the first time, provide star formation rates for galaxies at a well measured time after experiencing known external pressures. In particular, we will study the effects of changing external pressure on the star formation rates of galaxies ahead, within, and directly behind the shock using the 6.2um PAH feature, redshifted into the IRAC 8.0um bandpass. Combining Spitzer observations with X-ray and ground-based images (and spectroscopy) will yield new insights into galaxy evolution during cluster mergers.

Spitzer Space Telescope - Theoretical Research Proposal #30183

Infrared Predictions from Simulations of Merging Galaxies

Principal Investigator: Patrik Jonsson
Institution: University of California, Santa Cruz

Technical Contact: Patrik Jonsson, University of California, Santa Cruz

Co-Investigators:
T.J. Cox, Harvard University/CfA
Brent Groves, Max-Planck Institute for Astrophysics
Jennifer Lotz, NOAO
Joel Primack, University of California, Santa Cruz

Science Category: interacting/merging galaxies
Dollars Approved: 100145.0

Abstract:
We propose to develop a radiative-transfer model which can create panchromatic simulated observations from hydrodynamic simulations. With such a model it will be possible to make detailed predictions of Spitzer observations such as IRAC/MIPS fluxes and IRS spectra. The model, which will be based on a new Monte-Carlo implementation enabling unprecedented spectral resolution, will include a photoionization model of star-forming regions, PAH emission and dust-induced infrared spectral features like silicate absorption. We will then use this model in our ongoing program of simulating interacting and merging galaxies and generate a public library of IR images and spectra which can be compared directly to Spitzer observations of interacting galaxies. The particular strength of these simulations is the inherent connection between the dynamical state of the galaxies, such as morphology and star-formation rate, and the predicted infrared luminosities, colors and spectral features. Using these outputs, we will investigate whether observed IR-luminous galaxies at redshifts around 1, as observed in recent deep redshift surveys, and galaxies at higher redshift, as seen by SCUBA, are merger-driven starbursts.

Spitzer Space Telescope - General Observer Proposal #20671

Unveiling the hidden star forming regions in interacting galaxies

Principal Investigator: Ernest Krmpotic
Institution: Max Planck Institut fuer Astronomie

Technical Contact: Ernest Krmpotic, Max Planck Institut fuer Astronomie

Co-Investigators:
Ulrich Klaas, Max Planck Institut fuer Astronomie
Dietrich Lemke, Max Planck Institut fuer Astronomie

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 3.5

Abstract:
We propose to map 6 closely interacting galaxy pairs with the IRAC and MIPS cameras on board the Spitzer Space Telescope. The selected luminous infrared galaxy pairs (Lfir~1-15 x 10^10 Lsun) have 100micron flux densities greater than 10 Jy and typical extent of 2-3 arcmin with nuclei separations between 45 and 150 arcsec. The objects exhibit low f60/f100 ratios indicative for large amounts of cold dust. The galaxy interactions are known to play a crucial role in triggering starbursts by means of redistribution of ISM due to strong tidal forces. We expect the dust to fragment in individual knots and to be in different evolution stages; hence that very cold dust concentrations, expected to be in pre-starburst phase, can coexist with those heated by already active starburst. Taking into account the unprecedented sensitivity and spatial resolution of Spitzer combined with the spatial scale and sufficient brightness of the objects, we set our goals to resolve the individual dust knots of down to 5% of the integral flux. These observatinos will contribute an essential part to the multi wavelength dataset of our full sample of 12 interacting galaxy pairs. For the majority of the sample we already have obtained the data in the submm/mm and NIR wavelength regime. The completed datarecord will enable us to address some of the intriguing questions of star formation/starbursts on the galactic scale, e.g.: 1) Location and extent of the starburst activity inside an interacting galaxy pair; 2) The determination of the number of dust knots, including their masses and evolutionary status; 3) The strength of the starburst activity in dependence of the projected distance; 4) The influence of the galaxy structure and the orbital dynamics of the encounter on the gas dynamics and the evolution.

Spitzer Space Telescope - General Observer Proposal #40459

A mid-infrared study of Hickson Compact Groups: Probing the Effects of Environment in Galaxy Interactions

Principal Investigator: Emeric Le Floc'h
Institution: Institute for Astronomy, University of Hawaii

Technical Contact: Emeric Le Floc'h, IfA, U. Hawaii

Co-Investigators:
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Manolis Xilouris, National Observatory of Athens
Martha Haynes, Cornell University
Sara Slater, Harvard University

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 7.3

Abstract:
It has become increasingly evident that interactions and the merging of galaxies have contributed substantially to their evolution, both in terms of their stellar population and their morphological appearance. Since truly isolated galaxies are the exception rather than the rule, the immediate environment of galaxies has therefore direct implications on their dynamical evolution. Here we propose to use the unique imaging capabilities of Spitzer to study with IRAC and MIPS a sample of 13 Hickson Compact Groups (HCGs) for which we have already obtained the deepest near-IR images to-date. HCGs are systems of 4 or more galaxies located within a small area on the sky and that exhibit evidence of interactions. Reflecting a strong local density enhancement, they occupy a unique position in the framework of galaxy evolution, bridging the range of galaxy environments characteristic of the field, loose groups and rich clusters. However, the lack of deep high spatial resolution wide field mid-IR imaging of those systems has so far left open numerous questions regarding the star forming properties of their member galaxies: are compact groups a transient dynamical phenomenon? How do they evolve? Is their compact configuration the precursor to the formation of field ellipticals? Are they characterized by warm infrared colors as the interacting galaxy pairs or is star formation suppressed as in the center of rich clusters? Are they dynamically closed systems or can they replenish the intergalactic medium with reprocessed material in the form of star forming tails or dwarf galaxies? The Spitzer observations will allow us to address all these issues and to estimate for the first time the distribution and the total dust content in these groups. Such data will add in a systematic way a missing piece to the puzzle of how the proximity of several interacting galaxies affects their evolution.

Spitzer Space Telescope - General Observer Proposal #50191

Pushing star formation to the limit: probing the Schmidt-Kennicutt law in extreme environments

Principal Investigator: Ute Lisenfeld
Institution: Universidad de Granada

Technical Contact: Ute Lisenfeld, Universidad de Granada

Co-Investigators:
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Jonathan Braine, Observatoire de Bordeaux, France
Elias Brinks, University of Hertfordshire, England
Kevin, C. Xu, California Institute of Technology
Mederic Boquien, University of Massachusetts, USA
Frederic Bournaud, Saclay, France

Science Category: interacting/merging galaxies
Observing Modes: MipsPhot
Hours Approved: 2.5

Abstract:
We propose to study star formation (SF) in extreme environments in order to test to breaking point the many prescriptions that have been proposed that predict under which conditions SF occurs. In particular we will investigate (i) what sets the threshold for SF and (ii) what determines, once above this threshold, the rate of SF. So far, studies dedicated to this question have been based only on data of spiral and dwarf galaxies. We argue that in order to make progress, observations are needed of SF in extreme environments, such as intergalactic SF regions. We propose to study the relation between SF and SF rate (SFR), and the neutral (atomic and molecular) gas in a sample of 13 intergalactic SF regions, spanning a wide range of luminosities. All targets have a wealth of ancillary data, mainly obtained by us such as HI, CO, Halpha, and GALEX UV. Although the latter two are indicators of unobscured SF, we know that even in intergalactic SF regions there is dust and considerable extinction. It is therefore crucial to obtain MIPS 24 um maps to determine the total SF (obscured and unobscured). A modest 2.5 hrs total time spent on 13 targets is guaranteed to deliver a substantial return on investment in the form of a much improved understanding of the sufficient and necessary conditions for SF to take place.

Spitzer Space Telescope - General Observer Proposal #20440

The Relationship of Dust Emission to the Interaction History of NGC 6876 and NGC 6872 in the Pavo Group

Principal Investigator: Marie Machacek
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Marie Machacek, Smithsonian Astrophysical Observatory

Co-Investigators:
Christine Jones, Smithsonian Astrophysical Observatory
William R. Forman, Smithsonian Astrophysical Observatory

Science Category: interacting/merging galaxies
Observing Modes: IracMap
Hours Approved: 0.3

Abstract:
The Pavo group, with dominant elliptical galaxy NGC 6876 and large spiral galaxy NGC 6872, hosts a rich spectrum of interactions between between the galaxies and the group IGM, as evidenced by tidally distorted arms and stellar bridges in the spiral, a probable binary black hole at the nucleus of the dominant elliptical, and a hot, expansive X-ray trail between NGC 6872 and NGC 6876 caused by the high velocity motion of the large spiral through the Pavo group core. We propose to use IRAC observations in all four channels to study the dust distributions in and near NGC 6876 and NGC 6872 in the Pavo group to determine the relationship of dust to other stellar and ISM tracers of the interaction, such as X-ray, Halpha, and HI emissions. These observations will resolve ambiguities in current interaction models for the Pavo system and sharpen our understanding of the physical consequences of such interactions on the evolution of galaxy groups.

Spitzer Space Telescope - General Observer Proposal #40118

Star Formation in the Tidal Streams of the M81 Group

Principal Investigator: Susan Neff
Institution: NASA Goddard Space Flight Center

Technical Contact: Susan Neff, NASA Goddard Space Flight Center

Co-Investigators:
Zhong Wang, Smithsonian Astrophysical Observatory
Min Yun, University of Massachusetts
David Thilker, Johns Hopkins University
Rene Walterbos, New Mexico State University
Christina Chiappini, Trieste Universtiy
Todd Tripp, University of Massachusetts
Rob Kennicutt, Cambridge University
Thomas Cox, Smithsonian Astrophysical Observatory
Paul Ho, Smithsonian Astrophysical Observatory

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsScan
Hours Approved: 67.0

Abstract:
We propose to obtain sensitive wide-field MIR and FIR images of the central part of the M81 galaxy group, particularly of the tidal streams surrounding and connecting the four most massive members of the group (M81, M82, NGC3077 and NGC 2976). These observations will be compared with existing or planned observations at other wavelenths, and will be used to explore the recent star formation activity, associated radiation field, and details of the galaxy transformation processes throughout the group. We will use IRAC and MIPS to obtain images of the emission from PAHs and warm dust as well as from any old stars present in the tidal streams between the galaxies. Our observations should be sufficiently sensitive to detect star formation activity expected from a few times 10^20 cm^-2 HI column density, and will cover most of the 3degree diameter region imaged in 21cm HI. By combining the Spitzer images with our imaging data from ultraviolet (GALEX), optical/NIR (SDSS, 2MASS, Ha survey), CO (FCRAO), and HI (VLA, GBT, DRAO) surveys, we will be able to conduct an extensive, quantitative analysis of the spatial distribution of and relationships between 1) the total star formation present in the streams (both hidden and directly visible), 2) *all* of the cold gas and dust, 3) the ionizing radiation field, 4) the galaxies' interaction history including formation of tidal dwarf galaxies, and 5) the recent star formation chronology in the streams. Spitzer data is crucial to this analysis because it provides information on obscured star formation and dust that is otherwise unavailable. The high quality of extant data, as well as dynamical models of the interactions, make the M81 group an exceptional laboratory for exploring star formation processes outside of galaxy disks. The M81 group is one of the few systems where this sort of analysis can be made with spatial resolution better than 100pc.

Spitzer Space Telescope - General Observer Proposal #50454

Mid-Infrared Imaging of the Taffy Colliding Galaxy Pairs UGC 813/6 and Arp 261

Principal Investigator: Beverly Smith
Institution: East Tennessee State University

Technical Contact: Beverly Smith, East Tennessee State University

Co-Investigators:
Curt Struck, Iowa State University
Mark Hancock, East Tennessee State University
Mark Giroux, East Tennessee State University
Jeong-Sun Hwang, Iowa State University

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 4.0

Abstract:
In Taffy galaxies, a head-on collision between two gas-rich equal-mass galaxies has occurred, stripping out a large quantity of gas from the disks, and creating a radio continuum-bright bridge between the two galaxies. To better understand the physics of dust formation, excitation, and destruction, an examination of the dust properties in these unusual systems would be useful. We propose to use Spitzer to obtain mid-infrared images of two candidate Taffy systems, UGC 813/6 and Arp 261. We will use these images to search for dust associated with the bridge, and to test for PAH destruction or dust heating by shocks during the impact. We will compare the data for these two systems with archival Spitzer data for the first Taffy galaxy discovered, UGC 12914/5. We will also compare with results from a Spitzer imaging survey of nearby interacting galaxies that we have recently completed, and with numerical simulations of the collisions between the galaxies.

Spitzer Space Telescope - General Observer Proposal #50689

SAINTS: Star Formation and the ISM in Nearby Tidal Streams

Principal Investigator: Beverly Smith
Institution: East Tennessee State University

Technical Contact: Beverly Smith, East Tennessee State University

Co-Investigators:
Sarah Higdon, Georgia Southern University
Mark Hancock, East Tennessee State University
James Higdon, Georgia Southern University
Curt Struck, Iowa State University

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 30.8

Abstract:
We propose to obtain high quality mid-infrared spectra of a sample of nearby tidal dwarf galaxies and tidal streams. At the present time, the properties of the interstellar matter in tidal features are not well-known. We will determine the strengths of the PAH features relative to the dust continuum, the hardness of the ISRF from the [Ne III]/[Ne II] and [S IV]/[S III] line ratios, the quantity of warm molecular gas from the H2 lines, as well as the neon and sulfur abundances. We will compare these quantities to those of normal dwarf and spiral galaxies. We have already acquired considerable data for most of our sample, including Spitzer broadband images, GALEX UV images, optical images, and HI maps. Tidal features may contribute significantly to the intergalactic medium, and some may evolve into independent galaxies. Since interactions are more common at high redshift, studying nearby examples are important for interpreting the results of high redshift surveys.

Spitzer Space Telescope - General Observer Proposal #3247

Spirals, Bridges and Tails: Star Formation and the Disturbed ISM in Colliding Galaxies before Merger.

Principal Investigator: Curtis Struck
Institution: Iowa State University

Technical Contact: Curtis Struck, Iowa State University

Co-Investigators:
Philip Appleton, IPAC
Vassilis Charmandaris, Cornell University
William Reach, IPAC
Beverly Smith, East Tennessee State University

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 31.4

Abstract:
We propose to use Spitzer's unprecedented sensitivity and wide spatial and spectral evolution to study the distribution of star formation in a sample of colliding galaxies with a wide range of tidal and splash structures. Star forming environments like those in strong tidal spirals, and in extra-disk structures like tails were probably far more common in the early stages of galaxy evolution, and important contributors to the net star formation. Using the Spitzer data and data from other wavebands, we will compare the pattern of SF to maps of gas and dust density and phase distribution. With the help of dynamical modeling, we will relate these in turn to dynamical triggers, to better understand the trigger mechanisms. We expect our observations to complement both the SINGS archive and the archives produced by other GO programs, such as those looking at merger remnants or tidal dwarf formation.

Spitzer Space Telescope - General Observer Proposal #3403

A Mid/Far-Infrared Imaging Survey of Advanced Major-Merger Remnants: Fine-Structure Elliptical Galaxies

Principal Investigator: Jason Surace
Institution: Spitzer Science Center

Technical Contact: Jason Surace, Spitzer Science Center

Co-Investigators:
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Francine Marleau, Spitzer Science Center, Caltech
Lin Yan, Spitzer Science Center, Caltech
Aaron Evans, Stony Brook University

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 11.9

Abstract:
We propose to observe in the mid and far-infrared twelve moderate-age elliptical galaxies which are believed to be the direct descendants of major galaxy-galaxy mergers. The new observations will trace the old stellar population as well as reveal the presence, physical characteristics, and distribution of any dust present in the systems. The observations will help connect the heavily-studied, very dusty starburst-dominated mergers seen locally and "normal" elliptical galaxies, and provide insight into the behavior of stars and dust in late-stage mergers.

Spitzer Space Telescope - General Observer Proposal #30603

Probing the Distribution of Star Formation and Dust in a Unique, Transforming Spiral Galaxy

Principal Investigator: Todd Tripp
Institution: University of Massachusetts

Technical Contact: Todd Tripp, University of Massachusetts

Co-Investigators:
Limin Song, University of Massachusetts
Min Yun, University of Massachusetts
David Bowen, Princeton University

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 2.7

Abstract:
We have identified a spiral galaxy (NGC4319) that appears to be in the process of transforming into an S0 galaxy. This spiral is embedded in X-ray emitting hot gas in the NGC4291 group, and it appears that ram pressure has stripped most of the H~I out of the galaxy making it H~I deficient and molecule-rich. Using a background Seyfert galaxy behind NGC4319, we have detected an array of ultraviolet absorption lines from the ISM of NGC4319 using high-resolution spectrographs on HST and FUSE. We find that the H~I column density is surprisingly low, but nevertheless we detect 17 absorption lines of H_2 from the J = 0, 1, 2, and 3 rotational levels. We have also observed the galaxy with the FCRAO 14m telescope, and we detect CO emission from the barred center. Here we propose to map NGC4319 and 3 nearby companion galaxies (in the same group) with IRAC and MIPS to investigate the following questions: (1) How does ram pressure and tidal stripping affect star formation in NGC4319? (2) Is there hidden spiral structure in the 3 companion S0 and elliptical galaxies (e.g., as observed by Pahre et al. in other lenticulars)? (3) How has ram pressure and tidal stripping affected the dust in these galaxies? (4) Is dust being ejected into the IGM of the group? Combined with our unique information from ultraviolet spectroscopy already obtained, this program will provide valuable insight on the effects of ram pressure and tidal stripping on galaxy evolution.

Spitzer Space Telescope - General Observer Proposal #3187

The Evolution of Activity in Massive Gas-Rich Mergers

Principal Investigator: Sylvain Veilleux
Institution: University of Maryland

Technical Contact: Sylvain Veilleux, University of Maryland

Co-Investigators:
Reinhard Genzel, MPE, UC Berkeley [co-PI]
Eckhard Sturm, MPE [Project Scientist]
Dieter Lutz, MPE
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Matthew Lehnert, MPE
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David Sanders, University of Hawaii, Institute for Astronomy
Robert Joseph, University of Hawaii, Institute for Astronomy
Alan Stockton, University of Hawaii, Institute for Astronomy
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Joe Mazzarella, IPAC, Caltech
Steve Lord, IPAC, Caltech
Hagai Netzer, Tel Aviv University
Amiel Sternberg, Tel Aviv University
Chris Mihos, Case Western Reserve University
Olivier Guyon, Subaru Telescope
Kaliopi Dasyra, MPE

Science Category: interacting/merging galaxies
Observing Modes: IrsStare
Hours Approved: 95.3

Abstract:
We wish to study in detail the basic physical processes involved in creating massive early type hosts on the one hand, and growing/feeding embedded massive black holes on the other hand, in major galaxy mergers. This is an important question since 50% of cosmic star formation at high-z and most of the big BHs appear to be formed in this process, which we need to better understand in a local laboratory, in order to apply this knowledge to high z. We want to test the 'Sanders' (1988) scenario that massive ellipticals as well as QSO-like (> 10^8 Msun) black holes are formed when two big, gas rich galaxies merge. We want to understand how and at what rate during the various stages of the merger black holes are fed and grow in mass. We want to verify whether the output BHs are typical of QSOs and whether this process adheres to the local BHmass-sigma relationship. Our approach is unique and goes much beyond the proposed GTO and Legacy programs in this area. Taking an unbiased set of 54 local Universe active mergers and QSOs, we first need to fully understand the structural properties of each galaxy merger as well as the time/phase at which we see it. This we get from our near-IR/optical data sets, which is the first such complete investigation. Then we need to assign to each system the amount of radiation/energy produced in star formation and BH accretion. This information we get (and only can obtain) from mid-IR spectroscopic data which will be acquired with SST. The SST data we propose to get for the first time allow obtaining the key fine-structure line diagnostics for a large sample, and for the first time, for QSOs. With our previous ISO spectroscopy we have pioneered the basic technique. Here we wish to apply these techniques to a full sample that allows the exploration of evolution.

Spitzer Space Telescope - General Observer Proposal #20187

Local Benchmarks for the Evolution of Interacting Galaxies

Principal Investigator: C. Kevin Xu
Institution: California Institute of Technology

Technical Contact: C. Kevin Xu, California Institute of Technology

Co-Investigators:
Roc Cutri, California Institute of Technology, IPAC
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Yu Gao, UMASS
Jiasheng Huang, Harvard-Smithsonian Center for Astrophysics
Carol Lonsdale, California Institute of Technology, IPAC
Nanyao Lu, California Institute of Technology, IPAC/SSC
Joe Mazzarella, California Institute of Technology, IPAC
Jason Surace, California Institute of Technology, IPAC/SSC

Science Category: interacting/merging galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 35.3

Abstract:
We propose to obtain IRAC and MIPS maps for a sample of close major-merger pairs of galaxies selected from the joint 2MASS/SDSS-DR3 database. This is to provide a highly accurate and unbiased local benchmark for studies on evolution of interacting galaxies. The parent sample (46 pairs) is {\\bf complete}, consisting of all physical pairs (in 3000 deg^2) with the primary brighter than K=12.5, projected separations of ${\\rm 5 \\leq r \\leq 20 h^{-1}}$ kpc and stellar mass ratios $\\leq 2.5$ ('major-mergers'). Other samples of local interacting galaxies selected from photographic plates are severely biased. The existing Spitzer programs on local IR selected galaxies and on Arp peculiar galaxies won't be able to constrain the average SFR of interacting galaxies as a population. Similarly, the low density of local interacting galaxies means that existing Spitzer areal surveys such as SWIRE won't be able to provide such a local sample. The K-band luminosity function and the differential pair fraction for these pairs provide the local benchmark for the density evolution of interacting galaxies. With the proposed Spitzer observations, we aim to obtain in the first time the unbiased statistics on the SFR and SF strength (SFR per unit stellar mass) of local binary galaxies. This will provide the local benchmark for the luminosity evolution of interacting galaxies. The proposed sample (26 pairs, 52 galaxies) includes all S+S and E+S pairs in the parent sample which have measured redshifts for both components (i.e. spectroscopically confirmed pairs). Multiband (ugrizJHK) images and optical spectrographs available in the SDSS-DR3 and 2MASS database, and the UV images taken from the GALEX All-Sky survey will provide additional information for the star formation activities in these sources.

Spitzer Space Telescope - General Observer Proposal #20140

The Spitzer Interacting Galaxies Survey : Investigating the connection between activity and galaxy interactions

Principal Investigator: Andreas Zezas
Institution: Harvard-Smithsonian Center for Astrophysics

Technical Contact: Andreas Zezas, Harvard-CfA

Co-Investigators:
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Matthew Ashby, Harvard-Smithsonian Center for Astrophysics
Eduardo Gonzales-Alfonso, Universidad de Alcala de Henares,
Sarah Higdon, Cornell
Jiasheng Huang, Harvard-Smithsonian Center for Astrophysics
Chris Mihos, Case Western Reserve University
Luigi Spinoglio, IFSI-CNR, Rome, Italy
Jason Surace, Caltech-IPAC
Zhong Wang, Harvard-Smithsonian Center for Astrophysics
Steve Willner, Harvard-Smithsonian Center for Astrophysics
Thomas Cox, Harvard-Smithsonian Center for Astrophysics
Mike Pahre, Harvard-Smithsonian Center for Astrophysics

Science Category: interacting/merging galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 49.0

Abstract:
We propose a sensitive, coherent study of a representative sample of 110 nearby interacting galaxies. Our goal is to investigate, using a large statistically meaningful sample, how galaxy interactions induce galactic activity either in the form of widespread star-formation or AGN activity. We will use deep IRAC, IRS and MIPS observations to penetrate the obscuration that characterizes galactic nuclei and star-forming regions in order to map the star-forming activity throughout the galaxies and detect and measure AGN activity. This in concert with simulations of galaxy interactions will allow us to address questions like : (1) how do interactions trigger star-formation; (2) how large concentrations of gas and dust in the central regions may promote or hide AGN activity and (3) if and how star-forming and AGN activity relates with the parameters of the interaction. Our team includes experts in Spitzer post-pipeline data reduction, analysis and theoretical modeling. Although we plan an extensive analysis and modeling effort, we intend the release the data to the community with no proprietary period once the sample is completed.

Spitzer Space Telescope - Theoretical Research Proposal #50093

X-ray Effects on Spitzer IRS Emission-Line Diagnostics

Principal Investigator: Nicholas Abel
Institution: University of Cincinnati

Technical Contact: Nicholas Abel, University of Cincinnati

Co-Investigators:
Philip Stancil, University of Georgia
Shobita Satyapal, George Mason University

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 50000.0

Abstract:
Recent investigations into x-ray irradiated atomic and molecular gas (XDRs) present a challenge to interpreting IRS observations of AGNs, ULIRGs, and protoplanetary disks. XDR models predict strong [Ne II], [Ar II], and [S III] emission, spectral diagnostics which are usually assumed to emerge from H II regions. These diagnostics are widely used to infer physical properties such as galaxy energetics, density, and the shape of the spectral energy distribution. A non-H II region component represents a gap between observation and theory. IRS observations cannot distinguish between XDR and H II emission, due to insufficient spectral resolution. Without sufficient resolution, the best way to separate out the H II and XDR components of [Ne II], [Ar II], and [S III] in the IRS spectrum is to calculate the contribution of each region to the total intensity. To date, no XDR + H II region calculation exists. The goal of this proposal is to understand the role of XDRs and H II regions to important IRS spectral diagnostics. We will determine the effect of the XDR on the IRS spectroscopy by including important XDR processes into the spectral synthesis code Cloudy. These processes include charge transfer reactions between multiply ionized Ne, S, and Ar with H and H2, collisional excitation of [Ne II], [Ar II], and [S III] with H and H2, and other high energy atomic and molecular processes. We will use these theoretical tools to study, over a wide range of physical conditions, the contribution XDRs makes to the overall emission of important IRS emission-line diagnostics. In so doing, we will provide a way to separate out the XDR and H II components in IRS observations, increasing the scientific return of Spitzer. The theoretical improvements will make Cloudy the only computer simulation capable of modeling H II regions and XDRs self-consistently. In addition, since Cloudy is a publicly available code, the results of this proposal will be immediately available to the astrophysical community.

Spitzer Space Telescope - Directors Discretionary Time Proposal #239

AGN Spectral Energy Distributions of GLAST Telescope Network Program Objects

Principal Investigator: Jeff Adkins
Institution: Deer Valley High School

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Linda Stefaniak, Allentown High School
Steve Rapp, Linwood Holton Governor's School
Doris Daou, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 0.4

Abstract:
The Gamma-Ray Large Area Space Telescope (GLAST) has a proposed observing list that includes AGNs and Polars bright enough to be observed optically by amateurs and students. This observing list is maintained by the "GLAST Telescope Network" (GTN) and includes a number of objects that have yet to be observed by the Spitzer Space Telescope. Our project will observe one of these objects with the Spitzer MIPS and the IRAC instruments to determine their Spectral Energy Distribution (SED), which will be compared to a computer model of disk emission in order to determine what component of the SED is due to the disk and what component is due to synchrotron radiation induced by the jets. In addition we will observe our program objects prior to, simultaneously with, and after Spitzer observes them. This gives a direct connection from Spitzer research to student activities in the classroom.

Spitzer Space Telescope - Directors Discretionary Time Proposal #269

AGN Spectral Energy Distributions of GLAST Telescope Network Program Objects II

Principal Investigator: Jeff Adkins
Institution: Deer Valley High School

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Linda Stefaniak, Allentown High School
Steve Rapp, Linwood Holton Governor's School
Mark Lacy, Spitzer Science Center

Science Category: AGN/Quasars/Radio Galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 0.4

Abstract:
The Gamma-Ray Large Area Space Telescope (GLAST) has a proposed observing list that includes AGNs and Polars bright enough to be observed optically by amateurs and students. This observing list is maintained by the "GLAST Telescope Network" (GTN) and includes a number of objects that have yet to be observed by the Spitzer Space Telescope. In the first year of the Spitzer Teacher Observing Program, our project observed one of these objects (4C 29.45) with the Spitzer MIPS and the IRAC instruments as well as ground based instruments. These observations were used to determine its Spectral Energy Distribution (SED), which was compared to a model of disk emission in order to determine if there was a component of the SED due to synchrotron radiation induced by the jets. In this proposal we will observe another target from the list and expand our efforts to create simultaneous observations through radio telescopes, optical telescopes (large and small), and other instruments as the opportunity arises.

Spitzer Space Telescope - General Observer Proposal #20475

The Einstein Cross Quasar: The Hottest Dust Around a Quasar in the Universe?

Principal Investigator: Eric Agol
Institution: University of Washington

Technical Contact: Eric Agol, University of Washington

Co-Investigators:
Varoujan Gorjian, Jet Propulsion Laboratory
Amy Kimball, University of Washington

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare
Hours Approved: 4.0

Abstract:
The Einstein Cross radio-quiet quasar images show microlensing by stars in the lens galaxy which allows constraints to be placed on the size of the ultraviolet and infrared emission regions. Preliminary ground-based data indicates that this quasar has the hottest dust of any known quasar. We propose to measure the mid-infrared spectral energy distribution with IRAC and IRS to determine whether most of the dust emission comes from dust near the sublimation temperature. In addition, we will look for the presence of PAH features. These measurements, in conjunction with microlensing measurements, will provide a probe of accretion disk physics, an indication of the dust composition, and an estimate of the size of the infrared emission region which can be used in simulations of lensing by dark matter substructure.

Spitzer Space Telescope - General Observer Proposal #3124

A census of AGN activity in the local Universe

Principal Investigator: David Alexander
Institution: Instiute of Astronomy, University of Cambridge

Technical Contact: David Alexander, Durham University

Co-Investigators:
Andrew Fabian, Institute of Astronomy
Franz Bauer, Institute of Astronomy
Kazushi Iwasawa, Institute of Astronomy

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 18.1

Abstract:
It is well established that almost all galaxies harbor a central super-massive black hole (SMBHs). However, how many of these SMBHs are actively accreting? The answer to this question can provide constraints on the growth of local SMBHs, form the basis for determining the definitive obscured/unobscured local AGN ratio, better define the fraction of nearby galaxies that harbor AGNs, and further our understanding of the AGN contribution to the infrared and X-ray backgrounds. Amazingly, this fundamental question has not yet been fully answered. We propose here for IRS high-resolution spectroscopy and MIPS 24 micron imaging of a distance-limited (<15 Mpc) infrared selected galaxy sample to provide a census of AGN activity in the local Universe. Our observations are designed so that we can detect even weak AGN components in our galaxy sample.

Spitzer Space Telescope - General Observer Proposal #40918

Spitzer IRS Identification of Distant Compton-Thick AGN in GOODS-N

Principal Investigator: David Alexander
Institution: Durham University

Technical Contact: David Alexander, Durham University

Co-Investigators:
Ranga-Ram Chary, SSC
Mark Dickinson, NOAO
David Elbaz, CEA/Saclay
David Frayer, SSC
Minh Huynh, SSC
Alexandra Pope, NOAO

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 72.9

Abstract:
Deep X-ray surveys have identified large numbers of Active Galctic Nuclei (AGN) in a relatively obscuration-independent manner. However, there is considerable evidence that >50% of luminous AGNs are unidentified in even in the deepest X-ray surveys, most likely due to Compton-thick or near Compton-thick absorption of the intrinsic X-ray emission. These AGNs should be present in deep Spitzer surveys due to thermally reprocessed AGN emission by dust in the absorbing material. Here we propose for Spitzer-IRS spectroscopy of 14 candidate z<1 Compton-thick AGN identified on the basis of "warm" IR colors from the combination of the ultra-deep Chandra, 24um-MIPS and 70um-MIPS observations in GOODS-N. We will identify AGN activity in these sources from the presence of weak PAH emission, a warm IR continuum, and/or a Si 9.7um absorption feature. These observations will be used to directly quantify the ubiquity of Compton-thick AGN out to z~1, and to assess their contribution to the IR background and ‘‘contamination’’ to IR-derived estimates of the star-formation history.

Spitzer Space Telescope - General Observer Proposal #50818

Discovering Compton-thick AGN over the Widest XMM-Newton Field

Principal Investigator: David Alexander
Institution: Durham University

Technical Contact: David Alexander, Durham University

Co-Investigators:
Jonathan Gelbord, Durham University
Martin Ward, Durham University
Andrew Goulding, Durham University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 23.2

Abstract:
Deep X-ray surveys have identified large numbers of AGNs in a relatively obscuration-independent manner. However, there is considerable evidence that >50% of luminous AGNs remain undetected, most of which will be heavily obscured by Compton-thick material. We have used the widest XMM-Newton survey (the Serendipity Survey) to select AGNs in the SDSS that have luminous [OIII] emission but are X-ray undetected down to faint limits, implying ~two orders of magniude of extinction (i.e., likely to be Compton thick). Here we propose for Spitzer-IRS low-resolution spectroscopy and MIPS~24um and 70um observations of 15 objects to measure the dust-reradiated emission from AGN and star-formation components, to confirm if they are Compton-thick AGNs. The sample probes regions of the z-L_AGN plane (z~0.1-0.2; L_X, abs~3x10^41-3x10^43 erg/s) that are not well sampled by deeper narrow-field X-ray surveys.

Spitzer Space Telescope - General Observer Proposal #20525

Which FR-I Radio Galaxies Host Broad-Line Radio Galaxies or Quasars?

Principal Investigator: Robert Antonucci
Institution: University of California, Santa Barbara

Technical Contact: David Whysong, National Radio Astronomy Observatory

Co-Investigators:
David Whysong, University of California, Santa Barbara
Pat Ogle, NASA Jet Propulsion Laboratory
Makoto Kishimoto, University of Edinburgh

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 40.1

Abstract:
According to the simplest Unified Model, all radio galaxies contain hidden quasars surrounded by opaque dusty tori. In that case all radio galaxies should produce strong reprocessed IR emission from the obscuring tori. We've shown with Keck mid-IR imaging and the first of our Cycle 1 data on FR II radio galaxies that this is false: while all of the most luminous FR IIs have hidden broad line radio galaxies or quasars, only SOME of the FR IIs at lower luminosity have them! Here we propose to test the FR Is in a similar way. Contrary to popular belief, many of those DO have visible or hidden broad-line nuclei. By identifying which are which, we can infer the probably energy source for each. If a hidden broad line radio galaxy, most of the power is though to come from accretion and most of their luminosity is radiative; otherwise by default probably most of the power comes from black hole rotation and emerges in the form of the the kinetic luminosity of the radio jet. This difference is likely to be manifest in the detailed radio source properties. We will also look for AGN narrow emission lines, and compare our spectra with dusty torus models.

Spitzer Space Telescope - General Observer Proposal #3624

Unified Models and Power Sources in Radio-Loud AGN

Principal Investigator: Robert Antonucci
Institution: University of California, Santa Barbara

Technical Contact: David Whysong, National Radio Astronomy Observatory

Co-Investigators:
Patrick Ogle, NASA / JPL
David Whysong, University of California, Santa Barbara

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 27.0

Abstract:
We propose a simple observational program that will test the unification hypothesis for quasars and FR-II radio galaxies, constrain models of the dusty torus, and determine if the AGN are powered by thermal accretion or a non-thermal (probably rotational) mechanism. Spitzer is uniquely capable of carrying out this investigation with its unprecedented sensitivity. It has been shown directly by optical spectropolarimetry that many of the most powerful FR-II radio galaxies contain quasars hidden by opaque dusty tori; there is substantial statistical evidence that this is true for most or all of them. At somewhat lower powers the situation is not yet clear. Our work and that of others suggests that only a subset of radio galaxies have hidden quasars. We seek to establish this one way or the other and to determine which radio galaxies do or do not have hidden quasars. Spitzer data will also clarify whether statistical anomolies associated with the identification of radio galaxies with quasars can be understood as effects of a large population of physically smaller radio galaxies that lack hidden quasars. This would limit and define the applicability of the Unified Model. For theory, it would determine whether there are black-hole powered sources with just kinetic luminosity and without significant radiative accretion luminosity . Such non-thermal AGN would then have to be attributed to tapping rotational energy. We will also examine and compare the other observational properties of the two types of radio galaxies (hidden quasar or not), providing insight into the physics of the two types of power (accretion and rotation).

Spitzer Space Telescope - General Observer Proposal #50795

Non-thermal infrared emission - a unique window on radio galaxy lobes

Principal Investigator: Robert Antonucci
Institution: University of California, Santa Barbara

Technical Contact: Robert Antonucci, UC Santa Barbara

Co-Investigators:
Lawrence Rudnick, UMN
Christian Leipski, UCSB

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 7.7

Abstract:
Powerful radio galaxies play an essential role in the dynamics and thermodynamics of the intracluster medium. Fundamental questions exist, however, about their energy budget - how much energy is transferred and how they apparently distribute it uniformly. High sensitivity Spitzer observations offer a unique and critical tool for probing the energetics of lobes of radio galaxies and the physics of the relativistic particle acceleration process. The work on e.g. M87 has already shown that the energy going into particle acceleration may seriously affect the amount available for heating the external medium. In this last cold cycle, it is critical to establish whether this is a common phenomenon in radio galaxy lobes, spanning a range of morphologies as in our targets, or whether this is simply another special feature of M87. In order to achieve this goal we here propose to obtain deep IRAC observations of six radio galaxies with exceptionally bright and highly structured radio lobes.

Spitzer Space Telescope - General Observer Proposal #40553

Cadenced IRAC Monitoring of Infrared-Variable AGNs

Principal Investigator: Matthew Ashby
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
Joseph Hora, Harvard-Smithsonian Astrophysical Observatory
Jason Surace, Spitzer Science Center/CalTech
Howard Smith, Harvard-Smithsonian Astrophysical Observatory
Jessica Krick, Spitzer Science Center/CalTech

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 10.0

Abstract:
We have analyzed IRAC imaging data from 87 Spitzer visits to a very well-studied field, the IRAC Dark Calibration Field (IRAC-CF) near the north ecliptic pole. With this extensive dataset we have already identified a unique sample of 40 infrared-variable galaxies which we are now working to characterize with respect to variability amplitudes and timescales, panchromatic SEDs, and host morphologies, among other quantities. Unfortunately, we have found that the continual change in the spacecraft roll angle means that our sources are typically observed for at most six months at a time by each IRAC FOV in succession -- in other words, the visibility windows are exactly out of phase. Thus the existing data, despite the fact that they extend over more than three years starting in 2003 December, present large, unavoidable gaps that frustrate the time-delay analysis we wish to perform on exactly the timescales known to be common in active galaxies. Such an analysis, especially for a sizable, unbiased sample such as we now have, holds unique promise for measuring the colors and temperatures of infrared-varying AGN, and will have much to say about the underlying physical models of the infrared AGN emission. Accordingly we ask for just 10 h to gather IRAC photometry in the gaps that would otherwise accrue in Cycle 4.

Spitzer Space Telescope - General Observer Proposal #50201

Cadenced IRAC Monitoring of Infrared-Variable AGNs, Part II

Principal Investigator: Matthew Ashby
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
Joseph Hora, Harvard-Smithsonian CfA
Morgan Fouesneau, University of Strasbourg, France
Jessica Krick, Spitzer Science Center/CalTech
Jason Surace, Spitzer Science Center/CalTech
Howard Smith, Harvard-Smithsonian CfA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 8.0

Abstract:
We have analyzed IRAC imaging data from all 97 Spitzer visits to a very well-studied field, the IRAC Dark Calibration Field (IRAC-CF) near the north ecliptic pole. With this extensive dataset we have already identified a unique sample of 30 IR-variable galaxies which we are now working to characterize with respect to variability amplitudes and timescales, panchromatic SEDs, and host morphologies, among other quantities. Unfortunately, the continual change in spacecraft roll angle means that our sources are typically observed for at most six months at a time by each IRAC FOV in succession -- in other words, the visibility windows are exactly out of phase. Thus the existing data, despite the fact that they extend over more than four years, present large, unavoidable gaps that frustrate the time-delay analysis we wish to perform on exactly the timescales known to be common in active galaxies. This has only changed beginning in 2007 July: since that time cadenced IRAC observations have been carried out in synchrony with the IRAC-CF dark-calibration observations as part of our approved Cycle-4 program (PID 40553). Here we are proposing to continue this successful AGN monitoring campaign until the end of the cryogenic mission. The resulting timelines (covering 1500 days thus far and expected to run ultimately to some 2200+ days), will be a unique legacy of the Spitzer mission. This dataset, especially for the sizable, unbiased AGN sample we now have, holds unique promise for measuring the colors and temperatures of IR-varying AGN, and will have much to say about the underlying physical models of the infrared AGN emission. Accordingly we ask for just 8 h to gather IRAC photometry in the temporal gaps that would otherwise accrue in Cycle 5.

Spitzer Space Telescope - General Observer Proposal #30119

Infrared Emission from the Smallest Active Galaxies

Principal Investigator: Aaron Barth
Institution: University of California, Irvine

Technical Contact: Aaron Barth, University of California, Irvine

Co-Investigators:
Jenny Greene, Harvard-Smithsonian Center for Astrophysics
Luis Ho, Observatories of the Carnegie Institution of Washi

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 26.1

Abstract:
Virtually all of our current knowledge of black hole demographics, both in nearby inactive galaxies and in AGNs, comes from observations of black holes with masses between a few million and a few billion solar masses in host galaxies with stellar velocity dispersions between about 70 and 400 km/sec. Searching for smaller black holes in low-mass galaxies can yield important clues to the origin and early evolution of supermassive black holes, and AGN surveys are the best available way to identify such objects. Using the Sloan Digital Sky Survey, we have identified 19 Seyfert 1 galaxies with black hole mass below 10^6 solar masses (Greene & Ho 2004), and 20 Seyfert 2 galaxies having stellar velocity dispersions smaller than 70 km/sec as determined by new Keck observations. These AGN samples offer a unique opportunity to study the very early growth stages of black holes and their host galaxies. Spitzer observations of mid-infrared emission will be the best available calorimeter of the energetics of these tiny AGNs. Our primary goal is to determine the infrared contribution to the bolometric luminosities, which will be a key to understanding the black hole accretion rates. From the infrared spectral shapes we will constrain the dust temperatures and search for silicate features in emission or absorption that may indicate the presence of an obscuring torus, and which will help to determine whether the Type 1 and Type 2 objects differ primarily as a result of our viewing angle, as in classic AGN unified models. PAH features and narrow emission lines will be used to diagnose the relative contributions of AGN and star formation to the infrared luminosity. To accomplish these goals, we request IRS staring-mode spectroscopy in the SL2, SL1, LL2, and LL1 settings for our Sloan-selected sample of 19 Seyfert 1s and 20 Seyfert 2s, as well as NGC 4395 and POX 52, which are the prototypical nearby examples of Seyfert nuclei in dwarf host galaxies.

Spitzer Space Telescope - General Observer Proposal #20719

IRS Spectroscopy of 3CR Radio Galaxies

Principal Investigator: Stefi Baum
Institution: Rochester Institute of Technology

Technical Contact: Stefi Baum, Rochester Institute of Technology

Co-Investigators:
Catherine Buchanan, Rochester Institute of Technology
Christopher O'Dea, Rochester Institute of Technology
David Axon, Rochester Institute of Technology
Jack Gallimore, Bucknell University
Andrew Robinson, Rochester Institute of Technology
William Sparks, Space Telescope Science Institute
Eric Perlman, University of Maryland, Baltimore County
Alice Quillen, University of Rochester
David Floyd, Space Telescope Science Institute

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 17.0

Abstract:
Radio galaxies are among the largest and most powerful objects in the universe and, due to their interaction with their environment, are excellent objects to study the role of nuclear activity in galaxy evolution. However the interaction between radio-emitting active nuclei and their host galaxies on parsec scales is poorly understood. This is complicated by our lack of understanding of the relation between different classes of radio galaxy, defined by radio and optical properties. We propose to obtain IRS spectra of a sample of nearby radio galaxies in order to address fundamental questions about the nature of radio galaxies and their interaction with their environment. Low-resolution spectral maps of the central few kiloparsecs of these galaxies will enable us to probe the dusty central regions surrounding the active nucleus in these objects and to compare the classes of FRI and FRII radio galaxies. The IRS observations proposed here will be used along with archival IRAC and MIPS photometry to model the mid- to far-infrared spectral energy distributions (SEDs) of nearby radio galaxies. These SEDs will be compared with the IR SEDs of radio-quiet Seyfert galaxies, being obtained in a current Spitzer program, in order to understand how the interaction between an active nucleus and its host galaxy scales with host type, mass, and luminosity, black hole mass, and radio power.

Spitzer Space Telescope - General Observer Proposal #50644

Constraints on Accretion Disk Physics in Low Luminosity Radio Galaxies

Principal Investigator: Stefi Baum
Institution: Rochester Institute of Technology

Technical Contact: Stefi Baum, Rochester Institute of Technology

Co-Investigators:
Jacob Noel-Storr, Rochester Institute of Technology
Christopher O'Dea, Rochester Institute of Technology

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 1.7

Abstract:
It is currently believed that essentially all galaxies harbor a massive black hole in their nuclei. If this is true, then it becomes hard to understand why we do not see the luminosity released by the inevitable accretion of the galaxy ISM onto the black hole in all galaxies. The differences in AGN output between the two classes of narrow-line radio galaxies (FRI and FRII) may hold the vital clue. High radio luminosity FRIIs generally show strong high-excitation narrow lines and are believed to be the obscured counterparts of radio loud quasars. Low radio luminosity FRIs by contrast have weaker, low-ionization lines and low ratios of optical to radio luminosities. A large difference in accretion rate and radiative efficiency between FRI and FRIIs would explain the difference in the optical properties and also provide a new unification between different classes of active galaxies in which the dominant parameter is accretion rate. Spitzer IRAC and MIPS observations already exist for most of a well defined sample of FRIs. However, the previously observed objects are the "famous" ones, e.g., M87, M84, NGC315, 3C264, 3C31. Thus, the existing datasets are highly selected. Here we propose a very small request to complete the sample. We propose IRAC observations in all 4 bands, and MIPS photometry at 24 and 70 microns of 8, and 7 sources, respectively, for a total request of 1.7 hrs. These observations will complete the sample at very little cost in observing time. The large amount of existing complmentary data at multiple wavebands will greatly enhance the legacy value of the proposed observations. By completing the sample, the proposed IRAC and MIPS observations will produce a well defined and very well studied sample of nearby low luminosity radio galaxies. We will use the completed sample to investigate the properties of the accretion disk radiation, and the circumnuclear obscuring material.

Spitzer Space Telescope - General Observer Proposal #20651

The low-redshift 3CRR sources: missing data

Principal Investigator: Mark Birkinshaw
Institution: University of Bristol

Technical Contact: Mark Birkinshaw, University of Bristol

Co-Investigators:
Peter Barthel, University of Groningen
Paul Green, Smithsonian Institution Astrophysical Observatory
Dean Hines, University of Arizona
Eric Hooper, University of Texas
Charles Lawrence, Jet Propulsion Laboratory
Howard Smith, Smithsonian Institution Astrophysical Observatory
Ilse van Bemmel, Space Telescope Science Institute
Belinda Wilkes, Smithsonian Institution Astrophysical Observatory
Steve Willner, Smithsonian Institution Astrophysical Observatory
Diana Worrall, Smithsonian Institution Astrophysical Observatory

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 1.2

Abstract:
We propose MIPS observations of 3C 338 to conclude the program of IRAC and MIPS imaging photometry of the complete sample of $z < 0.1$ 3CRR radio galaxies that was awarded time in AO1. These MIPS observations were expected from a GTO program, but are no longer in the ROC. The overall aims of the study are (1) to measure the energy outputs of the active nuclei and test the relationship between radio power and nuclear properties expected under unified schemes; (2) to study orientation effects in the IR emission of the nuclei by comparing their IR properties with radio-derived indications of orientation; (3) to confirm the unusual IR colors of the host galaxies, which we interpret in terms of dusty debris from a recent encounter; and (4) to construct wide-band spectra for the radio jets, and so test our prediction of spectral breaks in the mid-IR arising from the existence of a maximum electron energy. The data received so far confirm the feasibility of this program, and we wish to obtain the 3C 338 MIPS images since this is one of the few cD galaxies in the sample at the core of an X-ray bright cluster, and to avoid compromising the legacy value of the overall dataset.

Spitzer Space Telescope - General Observer Proposal #3418

The low-redshift 3CRR sources

Principal Investigator: Mark Birkinshaw
Institution: University of Bristol

Technical Contact: Mark Birkinshaw, University of Bristol

Co-Investigators:
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Paul Green, Smithsonian Institution Astrophysical Observatory
Dean Hines, University of Arizona
Eric Hooper, University of Texas
Charles Lawrence, Jet Propulsion Laboratory
Howard Smith, Smithsonian Institution Astrophysical Observatory
Ilse van Bemmel, Space Telescope Science Institute
Belinda Wilkes, Smithsonian Institution Astrophysical Observatory
Steve Willner, Smithsonian Institution Astrophysical Observatory
Diana Worrall, Smithsonian Institution Astrophysical Observatory

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 33.5

Abstract:
We propose a program of IRAC and MIPS imaging photometry of the complete sample of z < 0.1 3CRR radio galaxies. These images will provide excellent information on the IR colors of the galaxies and active nuclei, and detect IR emission from several of the radio jets. We will use the data (1) to confirm the unusual IR colors of the host galaxies, which we interpret in terms of dusty debris from a recent encounter, which may have provided the fuel for the current radio activity of the nuclei; (2) to measure the energy outputs of the nuclei, and test the relationship between radio power and nuclear properties expected under unified schemes (and barely hinted at in the ISO database); (3) to study orientation effects in the IR emission of the nuclei, by comparing their IR properties with radio-derived indications of orientation; and (4) to construct wide-band spectra for the radio jets, and so test the universality of the maximum electron energy that appears from our radio to X-ray spectra, which we expect to result in a spectral break in the mid-IR at flux density levels accessible only to the Spitzer Space Telescope.

Spitzer Space Telescope - General Observer Proposal #3327

Catching the bulk of non-thermal radiation from hot-spots: proving particle acceleration in extragalactic radio sources

Principal Investigator: Marco Bondi
Institution: Istituto di Radioastronomia

Technical Contact: Marco Bondi, Istituto di Radioastronomia

Co-Investigators:
Gianfranco Brunetti, Istituto di Radioastronomia
Giancarlo Setti, Dipartimento di Astronomia, Univ. di Bologna
Karl-Heinz Mack, Istituto di Radioastronomia

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 3.1

Abstract:
We request 3.1 hours of IRAC (3.6 through 8.0 mum) and MIPS (24 mum only) observations of a small sample of extragalactic hot-spots (HSs) with published sensitive radio and optical data. HSs are compact regions in the radio lobes of powerful extragalactic radio sources emitting synchrotron radiation. In these regions electrons are re-accelerated through shocks. In the last years, arcsecond resolution radio, optical and X-ray observations of hot-spots have allowed to understand and model the physics of acceleration in these regions. Infrared observations are particularly relevant since the emitting properties of the HSs in this band are almost unknown and it is in this domain that the selected hot-spots are expected to release the bulk of their synchrotron emission. The proposed observations represent a unique possibility to test the existent models of shock emission and clearly discriminate between different interpretations, in particular whether a single or multiple electron population is responsible for the broad-band synchrotron emission.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40128

Line emission associated with the Northern inner radio lobe of Centaurus A

Principal Investigator: Mairi Brookes
Institution: Jet Propulsion Laboratory

Technical Contact: Mairi Brookes, Jet Propulsion Laboratory

Co-Investigators:
Charles Lawrence, JPL
Alice Quillen, Rochester
Daniel Stern, JPL
Varourjan Gorjian, JPL
John-David Smith, University of Arizona
Vassilis Charmandaris, University of Crete

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 7.0

Abstract:
We propose observations which will quantitatively measure the impact of high energy jets in the radio galaxy Centaurus A upon its host galaxy NGC5128. This will be done by searching for emission lines associated with the Northern Inner radio lobe. SL/LL observations of the northern inner radio lobe will search for molecular hydrogen in association with UV emission in this region which is in excess of the jet synchrotron emission expectation, again providing constraints on the excitation mechanism. If shocks are present it is possible that other emission lines, such as [OIV] may be present also. This unique source offers the opportunity to study the details of jet-host galaxy interaction in a relatively nearby system (3.4Mpc).

Spitzer Space Telescope - General Observer Proposal #20753

The origin of extended Lyman-alpha around a z=4.5 QSO

Principal Investigator: Andrew Bunker
Institution: University of Exeter

Technical Contact: Daniel Stern, JPL/Caltech

Co-Investigators:
Daniel Stern, Jet Propulsion Laboratory

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 6.2

Abstract:
We have discovered extended Lyman-alpha emission around a z=4.5 QSO in a deep long-slit spectrum with Keck/LRIS. The line emission extends 5arcsec beyond the continuum of the QSO and is spatially asymmetric. This extended line emission has a spectral extent of 1000km/s, much narrower in velocity spread than the broad Lyman-alpha from the QSO itself and slightly offset in redshift. No evidence of continuum is seen for the extended emission line region. This phenomenon is rare in QSOs which are not radio loud, and this is the first time it has been observed at z>4. It is possible that the QSO is illuminating the surrounding cold gas of the host galaxy, with the ionizing photons producing Lyman-alpha fluorescence. As suggested by Haiman & Rees (2001), this "fuzz" around a distant quasar may place strong constraints on galaxy formation and the extended distribution of cold, neutral gas. Alternatively, the Lyman-alpha may be powered locally by star formation in a galaxy-wide starburst. By searching for stellar continuum at longer wavelengths with IRAC, we can discriminate between these theories. We have also discovered a Lyman-alpha "blob" at the QSO redshift and only 23arcsec (150kpc) away: MIPS imaging will reveal whether this is a ULIRG-like buried source, or if it is being photoionized by the QSO.

Spitzer Space Telescope - General Observer Proposal #50792

The nature of low-ionization BAL QSOs

Principal Investigator: Gabriela Canalizo
Institution: University of California, Riverside

Technical Contact: Gabriela Canalizo, University of California, Riverside

Co-Investigators:
Mariana Lazarova, University of Califonia, Riverside
Mark Lacy, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 16.4

Abstract:
The rare subclass of optically-selected QSOs known as low-ionization broad absorption line (LoBAL) QSOs show show signs of high-velocity gas outflows and reddened continua indicative of dust obscuration. Recent studies show that galaxies hosting LoBAL QSOs tend to be ultraluminous infrared systems that are undergoing mergers and that have young (< 100 Myr) stellar populations. Such observations support the idea that LoBAL QSOs represent a short-lived phase early in the life of QSOs, when powerful AGN-driven winds are blowing away the dust surrounding the QSO. If so, understanding LoBALs may be crucial in the study of phenomena regulating black hole and galaxy evolution, such as AGN feedback and the early stages of nuclear accretion. Such claims, however, are based on results from very small samples that may have serious selection biases. We are therefore taking a more aggressive approach by conducting a systematic study of a volume limited sample of LoBAL QSOs at 0.5 < z < 0.6 drawn from SDSS. We propose to obtain far-IR fluxes with MIPS to construct SEDs for these objects and determine whether they are truly exclusively found in ultraluminous infrared systems. We also propose to obtain IRS spectra to estimate star formation rates from PAH features.

Spitzer Space Telescope - General Observer Proposal #3296

Particle Acceleration in Two 3CR Quasar Hotspots

Principal Investigator: Chi Cheung
Institution: Brandeis University

Technical Contact: Chi Cheung, Brandeis University

Co-Investigators:
John Wardle, Brandeis University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 2.3

Abstract:
We propose Spitzer Space Telescope 4.5+8.0 micron IRAC imaging of the high power hotspots in two powerful 3CR quasars. Their faint optical counterparts were recently detected by us with the Hubble Space Telescope. The optical, and proposed infrared data, will allow us to measure the high energy slope of the hotspot synchrotron spectra. Utilizing archival VLA and MERLIN data in the centimeter wavelength range, these multi-wavelength observations give us adequate constraints on the overall shape of the spectra, which will allow us to test a simple prediction from particle acceleration theory.

Spitzer Space Telescope - General Observer Proposal #20623

The bolometric output of luminous obscured AGN

Principal Investigator: Andrea Comastri
Institution: INAF-Bologna, Italy

Technical Contact: Andrea Comastri, INAF-Bologna, Italy

Co-Investigators:
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Francesca Pozzi, INAF- Bologna, Italy
Francesca Civano, Dipartimento di Astronomia, Bologna, Italy
Lucia Pozzetti, INAF-Bologna, Italy
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Carlotta Gruppioni, INAF-Bologna, Italy
Marcella Brusa, Max-Planck-Institut für extraterrestrische Physik,
Fabrizio Fiore, INAF-Roma, Italy
Paolo Ciliegi, INAF-Bologna, Italy
Roberto Maiolino, INAF-Arcetri, Italy
Giovanni Zamorani, INAF-Bologna, Italy

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 44.9

Abstract:
We propose Spitzer observations with both IRAC and MIPS of a well defined sample of hard X-ray selected obscured AGN serendipitously discovered by XMM-Newton in the 2-10 keV band. The key scientific issues we plan to address with the proposed broad-band infrared observations are: (a) A solid estimate of the bolometric luminosity of accretion-powered, obscured sources and of the correlations between hard X-ray properties (luminosity, obscuration, spectral slope) and infrared spectral energy distribution. (b) To recover the nuclear spectral energy distribution of those AGN for which the presence of supermassive black hole is inferred from the X-ray emission but which remains elusive from observations at optical-UV and near-infrared wavelengths. (c) A probe of the physical status of the dense circumnuclear matter responsible of the X-ray obscuration and dust reprocessed infrared emission by comparison with the AGN unified model predictions. The proposed sample, selected from a shallow, large area, hard X-ray survey (HELLAS2XMM), contains the most luminous members of the population of highly obscured AGN responsible for the X-ray background. It is thus well suited for a pilot Spitzer program (40 hours) which will allow us to investigate the so far poorly known spectral energy distribution of luminous, obscured Type II quasars in the mid-and far-infrared domains.

Spitzer Space Telescope - Archive Research Proposal #20680

Studying the Populations of Radio Sources in the Bootes Deep Field

Principal Investigator: Steve Croft
Institution: LLNL

Technical Contact: Steve Croft, University of California, Davis

Co-Investigators:
Wil van Breugel, LLNL
Wim de Vries, UC Davis
Adam Stanford, UC Davis

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 50000.0

Abstract:
Our very deep low-frequency (325 MHz) radio observations of the Bootes deep field provide an excellent opportunity to study the evolution of the most distant and powerful radio galaxies, in addition to examining the "normal" radio galaxies which make up the bulk of the radio population at more moderate redshifts. Many previous studies have focussed on the most extreme objects, and we wish to put these studies into context by carrying out a census of the radio population over a range in radio spectral index down to sub-mJy radio flux levels. The release into the archive this semester of the IRAC and MIPS data in this field make this project tractable and timely. By extracting SED information from the Spitzer data, combined with data from the NOAO Deep Wide Field Survey and radio flux and radio "color" (spectral index) information, we can understand the different populations of AGN and starburst galaxies and connections between them. By measuring correlation functions we can understand their clustering and their interrelationships with their environments. The Spitzer data will allow us to fit IR luminosity functions for the radio sources, and in conjunction with other statistical tools, to determine the evolution of these objects. And comparison with other studies of this field will enable us to tell how the various populations of radio sources are related to other types of object. The Spitzer, NDWFS and 1.4 GHz radio data on this field already provide a tantalising opportunity to discover the connections between the IR, optical and radio populations; the addition of our low-frequency radio data provides a key discriminator which will enable us to understand these populations more fully.

Spitzer Space Telescope - Directors Discretionary Time Proposal #469

Joint Spitzer and AGILE observations of the blazar 3C 454.3

Principal Investigator: Immacolata Donnarumma
Institution: INAF, ISAF-Rome

Technical Contact: Immacolata Donnarumma, INAF, ISAF-Rome

Co-Investigators:
Filippo D'Ammando, INAF-IASF Rome

Science Category: AGN/Quasars/Radio Galaxies
Observing Modes: IrsStare
Hours Approved: 0.8

Abstract:
We require SPITZER IRAC and MIPS observations for multifrequency follow-up of the blazar 3C 454.3. During the last three days AGILE is revealing a strong activity in the gamma-rays band. Joint Spitzer and AGILE observations offers the unprecedented great opportunity to study the correlated variability in the low and high energy peaks. This will contribute to improve the understanding of the structure of the inner jet, the origin of the seed photons for the IC process and then discriminating the different emission models in the red blazars during their high gamma-rays activity. The AGILE Team is going to activate a similar ToO to Swift, while a monitoring in the optical energy band is occurring thanks to WEBT. Therefore Spitzer observation of this blazar will give a unique and extraordinary opportunity to investigate its electromagnetic emission on a wide energy range in its strong flaring activity and then to determine its Spectral Energy Distribution. SSC Note: IRS SL/LL observations were approved for this ToO program.

Spitzer Space Telescope - General Observer Proposal #3348

Probing jet physics with the TeV blazar PKS 2155-304

Principal Investigator: Guillaume Dubus
Institution: Ecole Polytechnique

Technical Contact: Guillaume Dubus, Ecole Polytechnique

Co-Investigators:
Berrie Giebels, Laboratoire Leprince-Ringuet
Stefan Wagner, Landessternwarte Heidelberg

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 8.8

Abstract:
Blazars offer unique opportunities to understand the physics of relativistic jets. TeV emission from the blazar PKS 2155-304 has been detected in every single pointing of the newly built HESS array of Cherenkov telescopes in 2002-3. Our goal is to understand this new regime of low-level TeV emission which could not until now be studied for lack of sensitivity. We propose to obtain IR and TeV observations of the blazar PKS 2155-304. Spitzer observations between 24-160 microns would offer precious constraints on the synchrotron emission from the bulk of the non-thermal distribution of particles. The ability of Spitzer to obtain precise photometry would enable the first measurements of IR variability, providing insights into the acceleration and cooling timescales.

Spitzer Space Telescope - Theoretical Research Proposal #40095

The AGN Obscuring Torus

Principal Investigator: Moshe Elitzur
Institution: University of Kentucky

Technical Contact: Moshe Elitzur, University of Kentucky

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 90870.0

Abstract:
The generally held view of active galactic nuclei (AGN) is that of a supermassive black hole surrounded by an obscuring toroidal structure, with much of the AGN observed diversity simply explained as the result of viewing this axisymmetric geometry from different angles. The torus consists of a large number of individually very optically thick dusty clouds which absorb a fraction of the nuclear luminosity and re-radiate it in infrared. However, because of theoretical difficulties, models of the torus IR emission traditionally employed smooth density distributions. We have recently developed the basic formalism for handling dusty cloud distributions, and our clumpy torus models have already been utilized successfully in analysis of Spitzer observations. This proposal requests support for the implementation of a full treatment of the dust grain mixture in our torus model calculations. From the results we will find the variation in dust composition and abundance in clouds across the interface between the torus and the broad lines region, and provide detailed model predictions for the reverberation response in near-IR and emission line spectrum. This will open up a new type of analysis, in which Spitzer observations are combined with reverberation measurements to shed light on the origin and dynamics of clouds around the AGN central black-hole. The results of this proposal will be incorporated into a web site that enables users to fit IR observations with clumpy torus models with their own sets of input parameters.

Spitzer Space Telescope - General Observer Proposal #3551

Unravelling the Nature of Dusty Tori in Radio-Loud Active Galactic Nuclei

Principal Investigator: Martin Elvis
Institution: Harvard-Smithsonian Center for Astrophysics

Technical Contact: Martin Elvis, Harvard-CfA

Co-Investigators:
Hermine Landt, Harvard-Smithsonian Center for Astrophysics
Moshe Elitzur, University of Kentucky

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 8.0

Abstract:
The lack of broad emission lines in some narrow-line active galactic nuclei (AGN) has been explained by orientation effects: an optically thick, dusty torus obscures the broad emission line region in AGN oriented at large angles with respect to our line of sight. However, details of the physical state of the obscuring torus remain little known to this day. In fact, recent models indicate that the obscurer is possibly made up of a few clouds instead of having a continuous density distribution. An effective way to test present models is based on their distinct predictions for the inclination angle dependence of the emitted infrared spectral energy distribution (SED) and the 10 micron silicate feature. Here we propose a total of 8.2 hrs with the Spitzer Space Telescope in order to map the infrared SED with IRAC and MIPS and the depth of the 10 micron silicate feature with IRS for 12 radio-loud AGN with known inclination angles (range 20 - 60 deg). Having elliptical galaxy hosts these AGN will not have a starburst as a major contaminant of their far-infrared emission. Our observations will allow us to constrain the filling factor, scale and geometry of the obscurer in AGN. The result will be a deeper understanding of AGN.

Spitzer Space Telescope - General Observer Proposal #40453

Radio-jet driven AGN-feedback on neutral and molecular gas

Principal Investigator: Bjorn Emonts
Institution: Columbia University

Technical Contact: Patrick Ogle, Spitzer Science Center

Co-Investigators:
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Patrick Ogle, SCC, Caltech
Clive Tadhunter, University of Sheffield
Tom Oosterloo, ASTRON

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 7.5

Abstract:
We propose to obtain low and high resolution IR spectra of a sample of nearby powerful radio galaxies that show fast (>1000 km/s) outflows of neutral hydrogen (HI) gas. These HI outflows are most likely driven by jet-ISM interactions and can reach outflow rates comparable to those of starburst driven outflows in Ultra Luminous Infra-Red Galaxies -- they are therefore likely the missing component of AGN feedback in the nearby universe. Our proposed Spitzer observations are aimed to study in detail the H2 emission lines in these powerful radio galaxies in order to inventory the warm molecular gas in these galaxies, find evidence for jet-induced shocks in the ISM and estimate outflow rates of molecular gas. This should allow us to verify whether jet-cloud interactions are indeed the main driving mechanism of these massive outflows and to get a better idea about the total mass outflow rates in these nearby radio galaxies.

Spitzer Space Telescope - General Observer Proposal #30877

A Mid-Infrared Survey of the Warm ISM and Star Formation in Molecular Gas-Rich Radio Galaxies

Principal Investigator: Aaron Evans
Institution: Stony Brook University

Technical Contact: Aaron Evans, Stony Brook University

Co-Investigators:
Lee Armus, SSC
Jason Surace, SSC
Tatjana Vavilkin, Stony Brook University
Dean Hines, Space Science Center
Joseph Mazzarella, IPAC
Jeremy Lim, ASIAA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 19.6

Abstract:
We propose Spitzer observations to assess the properties of the warm ISM and star formation in a complete sample of 15 CO-detected, local radio galaxies. Eight of these galaxies were detected in CO as part of a millimeter-wave survey of a complete IRAS flux-limited sample of 33 low-redshift (z <~ 0.1) radio galaxies, and are observed to have morphologies consistent with major/minor galaxy mergers or interactions and extended (7-14" = 2-8 kpc) CO disks. In addition, 7 of the radio galaxies were detected in a recent volume-limited (z < 0.05) CO survey. The CO luminosities of these galaxies translate into 0.4-7x10^9 M_sun of cold molecular gas (H_2). Spitzer low and high-resolution IRS will detect warm H_2 emission, broad PAH emission, and high ionization lines, enabling (i) a determination of whether the warm-to-cold H_2 ratio correlates with AGN (e.g., high ionization lines) or starburst (strong PAH) activity, (ii) a measurement of the grain size and ionization state of PAH, and (iii) a measure of the relative contribution of nuclear PAH emission to the mid-IR nuclear emission. Spitzer IRAC observations will be used to measure the luminosity and extent of PAH, and will be compared with the CO maps to determine if PAH traces star formation. Finally, MIPS observations will be combined with IRS/IRAC and 2MASS data, and multi-component dust models will be fit to the continuum emission so that the temperature and mass of the dust component(s), and thus the H_2-to-dust mass ratios, can be calculated. Data from this proposal will be compared with archival and GTO data of nearby IR galaxies, starbursts and other gas-rich systems in order to assess the relationship of gas-rich radio galaxies with other types of "active" galaxies. The IR and CO brightness of the galaxies, and the spatial extent of molecular disks mapped thus far, makes this the best suited sample for assessing the properties of the warm ISM and star formation in luminous AGN with Spitzer.

Spitzer Space Telescope - #20371

We propose to study why most supermassive black holes in the local universe appear to be X-ray faint or quiescent. Possible explanations are that: the accretion power is carried out by a jet; or, the nuclei are obscured by dust; or, accretion occurs at very low radiative efficiency (ADAF models); or, most of the infalling gas ends up forming stars instead of being accreted by the black hole. Spitzer observations will give us the key to complete our study of the broad-band spectral energy distribution for a sample of X-ray-faint SMBH nuclei in elliptical galaxies. We shall determine how much of the total energy is really radiated by their nuclei, and test those alternative scenarios quantitatively.

Principal Investigator: Giuseppina Fabbiano
Institution: Harvard-Smithsonian Center for Astrophysics

Technical Contact: Roberto Soria, Harvard-CfA30

Co-Investigators:
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Alessandro Baldi, Harvard-Smithsonian Center for Astrophysics

Science Category: IracMap MipsPhot
Hours Approved: 0.0

Abstract:

Spitzer Space Telescope - General Observer Proposal #30402

Two Extreme IR-weak Quasars at z~6: Probing Dust Evolution

Principal Investigator: Xiaohui Fan
Institution: The University of Arizona

Technical Contact: Xiaohui Fan, The University of Arizona

Co-Investigators:
Dean Hines, University of Arizona
Linhua Jiang, University of Arizona
Lei Hao, Cornell University
Gordon Richards, Johns Hopkins University
Michael Strauss, Princeton University
Nadia Zakamska, Princeton University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsMap IrsPeakupImage MipsPhot
Hours Approved: 21.1

Abstract:
We propose to carry out deep Spitzer observations of two z~6 quasars with unusual IR properties to constrain the properties of dust in their environments. Most of the high-redshift (z>4.5) quasars we have observed in our GO-1 and GTO programs have rest-frame near to mid-IR spectral energy distributions similar to those of low-redshift quasars, suggesting very similar dust properties, and indicating that most dust tori form in short timescales at high redshift. However, two objects stand out as highly unusual: SDSS J1411+1217,(z=5.93) has an IR SED consistent with a pure power-law, with no IR excess due to hot dust (T > 1000 K). SDSS J0005-0006 (z=5.85) is completely undetected in our GO-1 24 micron MIPS observation, indicating an IR deficit; its SED is consistent with a pure disk model without a dust torus. Such dust-deficient AGN have not been found at either high or low redshift; the IR/optical flux ratios of these two sources are lower than those of all known type I objects at low redshift with Spitzer photometry. Their IR properties could be due to a complete lack of a dust torus at early epochs, or moderate obscuration in the mid-IR. We will obtain deep Spitzer photometry at 8, 16 and 24 micron for J0005-0006, aiming to detect or put stringent upper limit on its hot dust emission. We will carry out deep photometry at 16 micron and low-resolution IRS spectroscopy for the brighter J1411+1217 in order to constrain dust models. These new observations will shed light on the possible evolution of dust properties in the earliest luminous quasars.

Spitzer Space Telescope - General Observer Proposal #3198

Infrared Spectral Energy Distributions of the Most Distant Quasars

Principal Investigator: Xiaohui Fan
Institution: The University of Arizona

Technical Contact: Xiaohui Fan, The University of Arizona

Co-Investigators:
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William N. Brandt, PSU
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Pierre Cox, IAS, Paris
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Emeric Le Floch, Arizona
Gordon T. Richards, Princeton
George Rieke, Arizona
Donald P. Schneider, PSU
Michael A. Strauss, Princeton
Marianne Vestergaard, Arizona
Fabian Walter, NRAO

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 15.0

Abstract:
We propose to obtain high S/N Spitzer photometry of a flux-limited sample of thirteen luminous quasars at 5.7 < z < 6.4 selected from the Sloan Digital Sky Survey. They are the thirteen most distant quasars known to date, near the end of the cosmic reionization epoch. The Spitzer observations will be carried out in all the IRAC bands, the MIPS 24 micron band, and for the brightest sources, in the MIPS 70 micron band. These observations will provide the first high S/N Spitzer measurement of luminous objects at z>6, and establish the basic infrared characteristics of the most distant quasars. The Spitzer observations sample the rest-frame near to mid-IR, a wavelength range that has never been probed before at this redshift, where the radiation begins to be dominated by hot dust in the quasar environment and where the SED might peak. High quality X-ray, optical/near-IR, sub-millimeter and radio observations of this sample have either been acquired or planned. Combined with measurements in other wavelengths, the Spitzer data will allow us to measure the bolometric luminosity of z~6 quasars and to estimate the accretion rate and efficiency of the earliest billion solar mass black holes in the universe. Comparing with low-redshift samples, including the Spitzer GTO sample at 0 < z < 5, we will study the evolution of quasar SEDs to the first billion years of cosmic history, constraining physical models of the highest-redshift quasars. Finally, combining with sub-millimeter and radio molecular gas observations, we will study dust properties in the quasar environment and the AGN/starburst connection in the earliest massive galaxies.

Spitzer Space Telescope - General Observer Proposal #3221

Lineless Quasars at High-Redshift: BL Lacs or A New Class of Unbeamed Quasars?

Principal Investigator: Xiaohui Fan
Institution: The University of Arizona

Technical Contact: Xiaohui Fan, The University of Arizona

Co-Investigators:
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Wiliam N. Brandt, PSU
J. Serena Kim, Arizona
Donald P. Schneider, PSU
Michael A. Strauss, Princeton

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 4.5

Abstract:
The Sloan Digital Sky Survey (SDSS) has recently discovered a class of high-redshift quasars with no or extremely weak optical emission lines. Their redshifts are determined by the presence of strong Lyman break and Lyman Limit Systems. Their nature remains unknown: they could be analogs of BL Lac objects at high redshift, a new type of unbeamed quasar whose broad emission-line region is very weak or absent, or a combination of both. The proto-type object, SDSS J1532-0039 (z=4.6), lacks other signatures of a typical BL Lac object: it has no detectable radio or X-ray emission and is not strongly polarized or variable in the optical. Other objects in the sample show a variety of radio and X-ray properties. We propose to obtain Spitzer IRAC and MIPS 24 micron photometry of four lineless quasars at z = 4 - 4.6, two of which are radio/X-ray quiet, and the other two are radio/X-ray loud. The Spitzer photometry will probe the spectral region where there is a dramatic contrast between beamed synchrotron emission in BL Lac objects and thermal dust emission in unbeamed quasars: we expect a factor of 5 difference in Spitzer fluxes between the two cases. It will reveal the nature of the IR emission mechanism, and unambiguously determine whether these lineless quasars are beamed sources similar to BL Lac objects, or a new type of unbeamed quasar.

Spitzer Space Telescope - General Observer Proposal #40356

Evolution of Hot Dust Emission in z>6 Quasars

Principal Investigator: Xiaohui Fan
Institution: University of Arizona

Technical Contact: Xiaohui Fan, University of Arizona

Co-Investigators:
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Niel Brandt, Penn State
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Dean Hines, Space Science Institute
Klaus Meisenheimer, MPIA
Gordon Richards, Drexel University
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Fabian Walter, MPIA
Ran Wang, NRAO

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsPeakupImage MipsPhot
Hours Approved: 14.9

Abstract:
Strong hot dust emission from dust torus surrounding the central engine is an ubiquitous feature among Type-1 quasars at low redshift. In our previous GTO and GO-1 Spitzer programs, we observed a sample of quasars at 4<z<6.4 to probe the evolution of hot dust at the highest redshift. While most quasars in this sample also show prominent hot dust emission at 24 micron, two objects at z~6 have extremely weak IR emission with SEDs consistent with power-law or pure disk emission without hot dust contribution. These two quasars also have the smallest black hole (BH) masses and highest Eddington ratios among z~6 quasars, indicative of short BH growth timescale. These observations suggest possible evolution in either dust torus structure or dust properties of quasars at the earliest epoch, constrained by both BH/AGN growth and timescale of dust formation in AGB envelops. In Cycle 4 we propose to carry out IRAC, IRS PUI 16 micron and MIPS 24 micron imaging of a sample of 9 new quasars at z>6 discovered in the last three years. The new observations will more than double the Spitzer sample size at z>6. All objects have excellent multiwavelength data, with BH mass estimates based on broad emission line width, and are GTO targets for Herschel at far-IR. With the combined Cycle 1/4 sample, we will (a) measure the fraction of quasars without hot dust emission at early epoch; (b) test the relation between hot dust properties and emission line properties, BH masses and accretion rates in quasars; (c) improve quasar IR SED measurements at z>6, and (d) probe the relation between hot and warm/cool dust traced by Herschel and sub/mm observations. In particular, three quasars in our new sample have similar emission line and BH properties to the two IR-weak quasars we found previously. We predict that they are likely candidates of new dust-deficient quasars at z>6.

Spitzer Space Telescope - General Observer Proposal #50681

Are Narrow-line Type-1 Quasars Deficient of Hot Dust?

Principal Investigator: Xiaohui Fan
Institution: The University of Arizona

Technical Contact: Linhua Jiang, University of Arizona

Co-Investigators:
Yue Shen, Princeton University
Michael Strauss, Princeton University
Marianne Vestergaard, University of Arizona
Linhua Jiang, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot IrsPeakupImage
Hours Approved: 14.2

Abstract:
One of the most surprising results from our previous Spitzer observations is the discovery of a class of quasars at z ~ 6 without detectable hot dust emission in the mid-IR. These objects have the narrowest emission lines at z ~ 6 with FWHM ~ 1600 km/s, but share all other characteristics of normal type-1 quasars in their broad-band SEDs from X-ray to radio. Based on virial mass estimates, they have relatively small black hole (BH) masses and high Eddington luminosity ratios. The existence of such objects may indicate strong evolution in dust properties at early epochs; alternatively, it could be an orientation effect and challenge the standard AGN unification model. No such narrow-line type-1 quasars without hot dust emission have been found at low redshift. However, these objects are very rare, counting for only one percent of the quasar population at z < 5, and none of them have been observed at the Spitzer sensitivity. Therefore, we propose to carry out four band Spitzer photometry of a sample of 15 luminous narrow-line type-1 quasars at z = 1 - 5 selected from the SDSS quasar catalog. All objects have excellent optical spectroscopy and BH mass measurements. The Spitzer photometry will be used to directly measure the mid-IR hot dust emission in these objects. Combined with Spitzer observations of broad-line quasars and low-redshift Narrow-line Seyfert 1 galaxis, the new Spitzer data will allow us to answer the following questions: (1) How does the fraction of hot-dust-free quasars evolve with redshift; do hot-dust-free quasars only exist at the earliest epochs, or are they common among mature quasars as well? (2) How is the hot dust emission in narrow-line type-1 quasars related to BH mass, accretion rate, luminosity, line of sight obscuration, and emission line wind? The proposed observations will provide crucial probes to the evolution of dust structures in quasars and its relation to BH growth in the early universe.

Spitzer Space Telescope - General Observer Proposal #30299

An intensive Spitzer survey of FeLoBAL QSOs

Principal Investigator: Duncan Farrah
Institution: Cornell University

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
Colin Borys, University of Toronto
Robert Priddey, University of Hertfordshire
Jose Afonso, University of Lisbon
Mark Lacy, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 9.9

Abstract:
We propose MIPS and IRS observations of eight 'FeLoBAL' quasars. These quasars are characterised by absorption from metastable excited states of iron in their UV spectra, and are currently thought to be extremely rare, with only 40 examples known over the whole sky. Very recent observations have however suggested that FeLoBALs are potentially quite common, and that they may represent a critical point in the lifetime of an IR-luminous galaxy when an obscured starburst is approaching its end, and a youthful quasar is starting to emerge from its dust cocoon. In this proposal, we aim to use Spitzer to test this hypothesis. We will use the MIPS data to see if FeLoBALs as a class are preferentially associated with heavily obscured starbursts, and use the IRS spectra to see if the mid-IR emission from FeLoBALs is consistent with an evolutionary sequence from ULIRG to FeLoBAL, through to optical QSO.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40374

Do FeLoBALs mark the transition between a ULIRG and a QSO?

Principal Investigator: Duncan Farrah
Institution: Cornell University

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
Colin Borys, University of Toronto
Robert Priddey, University of Hertfordshire
Jose Afonso, University of Lisbon
Mark Lacy, Spitzer Science Center
James Houck, Cornell University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 14.0

Abstract:
We propose deep IRS observations of six Spitzer/MIPS detected 'FeLoBAL' quasars. These quasars are characterised by iron absorption in their UV spectra. Once thought to be extremely rare, recent observations have however suggested that FeLoBALs may be common, and might represent a critical point in the lifetime of an IR-luminous galaxy when an obscured starburst is approaching its end, and a youthful quasar is starting to emerge from its dust cocoon. We have used Spitzer to observe seven FeLoBAL QSOs, and found that all seven are bright in the IR, and likely contain both luminous, dusty AGN and intense, obscured star formation. We here seek to use IRS to observe six of these QSOs, to determine whether or not FeLoBALs are a transition type object via direct comparison between their mid-IR spectra and those of ULIRGs and QSOs.

Spitzer Space Telescope - General Observer Proposal #50656

Are FeLoBAL QSOs a 'transition' population between ULIRGs and classical QSOs?

Principal Investigator: Duncan Farrah
Institution: Cornell University

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
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Robert Priddey, Hertfordshire
Colin Borys, Caltech
Jose Afonso, Lisbon Observatory

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 15.2

Abstract:
We propose to obtain MIPS photometry of 47 FeLoBAL QSOs. This class of QSO was, until recently, thought to be extremely rare, but recent work has shown that their strong reddening and heavy UV absorption systematically eliminates them from traditional QSO surveys, and that they may in fact be common objects. Furthermore, we recently observed a small sample of seven FeLoBAL QSOs with MIPS, and found evidence that a far higher fraction of the FeLoBAL QSO population may have FIR excesses, signifying active star formation, than the general QSO population, meaning that FeLoBAL QSOs may be the long sought population of 'youthful' QSOs that harbor both a rapidly accreting black hole and very high rates of star formation. Our sample size was however too small to demonstrate this reliably. Therefore, we here propose to observe a much larger sample of confirmed FeLoBAL QSOs in all three MIPS channels. Our goal is to determine the fraction of the FeLoBAL QSO population that contain heavily obscured star formation, and so provide a direct and robust test of the hypothesis that FeLoBAL QSOs are a 'transition' population between ULIRGs and classical QSOs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #111

Spitzer Spectroscopy of 8 micron bright, optically faint objects identified in the IRAC Shallow Survey

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Peter Eisenhardt, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 4.2

Abstract:
This program will obtain IRS short wavelength low resolution first and second order spectra of 5 objects identified in the IRAC Shallow Survey as having extremely large 8 micron to I band flux ratios (of order 1,000 or more). Four objects in the sample have 8um fluxes above 0.4mJy and I magnitudes fainter than 24, the fifth has an 8um flux of 0.35mJy and is not detected to I > 25. We hope that from 5.3 - 14.5 um spectroscopy will determine whether these objects are low redshift starburst galaxies, z ~ 1.5 ULIRGs, heavily reddened AGN, very high redshift quasars, or some new phenomenon.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #121

M81 Variability

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Center for Astrophysics

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 0.5

Abstract:
The pointlike nucleus of M81 has shown evidence of variability as referenced to earlier ground-based measurements, but uncertainties remain because of the different instruments' parameters. We will obtain three new epochs of observations to compare directly with previous Spitzer observations.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30291

IRS spectroscopy of a complete sample of Seyfert galaxies in the local universe

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Howard Smith, Harvard-CfA

Co-Investigators:
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Howard Smith, CfA
Matt Ashby, CfA
Matt Malkan, UCLA
Leslie Hunt, Arcetri, INAF
Paola Andreani, Trieste, INAF
Eduardo Gonzalez, Alcala

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 22.9

Abstract:
As AGNs are intimately related to dust, it is essential to study them at wavelengths which minimize the obscuring effects of dust extinction, while maximizing the dust emission diagnostics. IRS spectroscopy will be able to measure the fine structure lines from the ionized gas excited both from black hole accretion and from stellar ionization, and also lines from H2 as diagnostics of PDRs, shock excitation from starbursts, and hard X-ray heating from the AGN. By combining our proposed observations with similar ones in the ROC, we will assemble a complete database sample of active galaxies - the "12 Micron Sample" of 53 Seyfert 1s and 63 Seyfert 2's. We will address five goals. (i) Test the evolutionary scenario (of HII, Seyfert 2, Seyfert 1) by comparing over activity type observable physical quantities such as: the hardness of the ionizing continuum; the star formation rate and the dust extinction; (ii) establish what is the contribution to the total energy budget in each galaxy arising from black hole accretion and from star formation activity in the Local Universe. This will be done by separating spectroscopically through detailed modeling the AGN from the starburst component; (iii) characterize the star formation activity in Seyfert galaxies; (iv) derive the fraction of radiant energy in the local Universe produced by stars and that produced by accretion onto massive black holes, and derive the respective luminosity functions; (v) assess the importance of bolometric luminosity, ionizing radiation, and nuclear physical conditions to classification schemes. Our observations will enable us to produce accurate local templates for application to AGNs in the early epochs of the Universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30447

IRS spectroscopy of "type-3" quasars

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Mark Lacy, Spitzer Science Center
Pauline Barmby, CfA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 4.5

Abstract:
We wish to obtain IRS spectra of a sample of objects which have the mid-infrared colors of AGN and mid-infared luminosities of quasars, but which lack AGN indicators in their optical spectra. Three of these objects have low-ionization optical spectra, and two lack emission lines but are most likely at z~1-2. We wish to investigate the possibility that these ‘‘type-3’’ quasars are an early phase in the development of AGN, perhaps hidden by a starburst triggered by the same merger event which triggered their AGN activity. Other possibilities include unusual starbursts with large amounts of warm dust, or otherwise normal AGN which lack a narrow line region. IRS spectra will allow us to distinguish between these different scenarios.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40072

Spectral Energy Distributions of the High-Redshift 3CR Sources: Testing Unification

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Smithsonian Astrophysical Observatory

Co-Investigators:
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Mark Lacy, Spitzer Science Center
Daniel Stern, Jet Propulsion Lab
Gillian Wilson, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsPeakupImage MipsPhot
Hours Approved: 19.9

Abstract:
We propose IRAC, IRS peakup, and MIPS photometry of a complete sample of high-redshift (z>1) radio galaxies and quasars. The sample contains 63 massive and powerful radio galaxies and quasars from the 3CR catalog, selected strictly on the basis of flux density of the radio lobes. It should therefore be an orientation-independent sample, suitable for testing AGN unification models. The observations will consist of photometry of the radio source counterpart galaxies from 3.6 to 24 microns. In addition, we will map an approximately 4 arcmin region around the radio galaxy with IRAC to look for possible clusters around the radio sources. The galaxy spectral energy distributions will enable us to determine the stellar luminosity and mass of the host galaxies and the mid-infrared luminosity of AGN-related power law emission. In addition, the IRAC images will allow us to study the environment of these most massive 3CR sources. The maps will be large enough to cover the presumed galaxy clusters and deep enough to detect galaxiesat least ten times fainter than the 3CR sources.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40093

Spitzer Studies of High-Redshift Radio Galaxies

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Daniel Stern, Jet Propulsion Laboratory

Co-Investigators:
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Peter Eisenhardt, Jet Propulsion Laboratory
Audrey Galametz, European Southern Observatory (Germany)
Mark Lacy, Spitzer Science Center
Joel Vernet, European Southern Observatory (Germany)
Steve Willner, Center for Astrophysics

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsPeakupImage IrsStare MipsPhot
Hours Approved: 19.7

Abstract:
At every epoch, high-redshift radio galaxies (HzRGs) are associated with the most massive galaxies known, as evidenced by their tight observed-frame K-z relation which traces the bright envelope of field galaxies. Our Cycle 1 program entailed a comprehensive 3-camera Spitzer imaging survey of 70 HzRGs at 1<z<5.2. All 70 sources were observed with IRAC, but only subsets were observed with IRS and MIPS; in total, only 16 HzRGs have their entire mid-IR SED observed. Most observed sources are easily detected by Spitzer out to 24 microns. These Cycle 1 data have shown that at all cosmic epochs, the rest-frame H-band luminosity is consistent with the passive evolution of an approximately 3e11 M(sun) stellar population which formed at high redshift. In addition, tentalizing new trends have been uncovered: (1) a correlation between mid-IR flux and radio luminosity; (2) an evolution with redshift of the fraction of stellar light to AGN heated hot dust emission in the rest-frame NIR; (3) significant overdensities of 24 micron sources around radio galaxies at 1.5<z<2.5. We will test these tentative correlations and put them on a firm statistical ground by completing the initial survey with 16 and 24 micron photometry for the entire sample. We also propose 1 hr of IRS spectroscopy of 4C 23.56, one of the best-studied HzRGs at z~2.5.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40094

IRS spectroscopy of type-2 quasars: the relation of IR spectra to X-ray absorption

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Mark Lacy, Spitzer Science Center
Pauline Barmby, Smithsonian Astrophysical Observatory

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 3.0

Abstract:
We wish to compare the infrared spectra of three Compton thin and three Compton thick (or nearly Compton thick) type-2 quasars discovered using Spitzer color selection in the SWIRE-XMM field. All six quasars are in moderately-deep (>20ks) XMM pointings. Spitzer spectra of X-ray selected, Compton thin type-2 quasars are largely featureless, in contrast to those of type-2 quasars selected by Spitzer mid-infrared colors, which show a large range in silicate and PAH strengths. We wish to investigate whether the Compton thick type-2 quasars possess infrared spectra which show more signs of silicate absorption and/or PAH emission, consistent with the X-ray absorption arising outside of the accretion disk and inner torus.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40146

IRS Spectra of a Unique Infrared-Varying Galaxy in the IRAC-CF

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Matthew Ashby, Harvard-SAO

Co-Investigators:
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Joseph Hora, Harvard-Smithsonian Astrophysical Observatory
Jason Surace, Spitzer Science Center/CalTech
Jessica Krick, Spitzer Science Center/CalTech
Howard Smith, Harvard-Smithsonian Astrophysical Observatory

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 4.1

Abstract:
A detailed analysis of the 87 multi-epoch mosaics taken by Spitzer/IRAC of the IRAC Dark Calibration Field at 17:40, +69:00 has uncovered numerous objects exhibiting strong variability at 3.6 um -- to our knowledge, the only variable galaxies discovered by Spitzer to date. Happily, one of these is bright enough at 24 um (0.5 mJy) to be accessible with the IRS/LL1 and LL2 in a modest allocation of only 4.1 h facility time, (S/N ~ 7 on the continuum). This object is extremely unlikely to be a foreground star -- and if it is in fact AGN dominated, then its variability, which takes place on timescales of ~ 1 year, ought toprovide a new window on substructures within AGNs. In combination with the moderate-depth ground-based photometry we have in hand, recently-completed HST/F814W observations, Akari/11, 15, and 18 um imaging observations, and approved Palomar spectroscopy, the observations will allow us to unambiguously constrain the nature of this object.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40358

MIPS 24 micron photometry of high-redshift 4C radio sources

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Smithsonian Astrophysical Observatory

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Jiasheng Huang, Harvard-Smithsonian Center for Astrophysics
Mark Lacy, Spitzer Science Center
Daniel Stern, Jet Propulsion Lab
Gillian Wilson, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 2.0

Abstract:
We propose MIPS 24 micron photometry of 4C radio sources at high redshift (1.5 < z < 3.5). This redshift range exceeds that covered by the 3CR sources. The combination of 3CR and 4C samples will permit us to study the most powerful radio sources over the full redshift range encompassing the cosmic epoch, where the star formation activity peaks. The sample is largely complete consisting of radio galaxies and both extended and compact steep-spectrum quasars. The sources are selected by their isotropic 178 MHz emission from the radio lobes making the sample suitable for testing the unified scheme and for separating orientation-dependent effects from both lobe and starburst evolution. We plan to complement our Spitzer 24 micron photometry with sensitive Herschel observations at 70-490 micron. The combination of Spitzer and Herschel data will permit us to explore the entire rest frame Mid- to Far-IR SEDs and to assess the AGN and star forming luminosity output during this early active phase of the universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50040

Spectral Energy Distributions of the High-Redshift 4C Sources: Testing Unification

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Center for Astrophysics

Co-Investigators:
Martin Haas, Astronomisches Institut Universitat
Belinda Wilkes, Harvard-Smithsonian Center for Astrophysics
Jiasheng Huang, Harvard-Smithsonian Center for Astrophysics
Mark Lacy, Spitzer Science Center
Daniel Stern, Jet Propulsion Lab
Gillian Wilson, UC Riverside
Matthew Ashby, Harvard-Smithsonian Center for Astrophysics

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsPeakupImage
Hours Approved: 4.9

Abstract:
We propose IRAC and IRS peakup photometry of high-redshift (z>1.5) radio galaxies and quasars. This is a followup to previous proposals in cycle 4. It will add IRAC and 16-micron data for galaxies having only MIPS observations. The galaxy spectral energy distributions will enable us to determine the stellar luminosity and mass and will help separate AGN from starburst emission.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50143

J2310-437: Spitzer Resolution of a Conundrum

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Center for Astrophysics

Co-Investigators:
Mark Birkinshaw, Bristol University
Harvey Tananbaum, Harvard-Smithsonian Center for Astrophysics
Diana Worrall, Bristol University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot IrsPeakupImage
Hours Approved: 0.6

Abstract:
J2310-437 is an active galaxy with enormous X-ray luminosity but -- unlike other AGN of this type -- no optical emission lines or colors typical of an AGN. Spitzer photometry will distinguish between two possibilities: an unprecedented AGN type capable of generating only continuum radiation or a more normal AGN concealed behind an enormous amount of dust.

Spitzer Space Telescope - General Observer Proposal #50763

Testing the Unified Model with a Complete Sample of Hard X-ray Selected AGN

Principal Investigator: William Forman
Institution: Smithsonian Astrophysical Observatory

Technical Contact: William Forman, Harvard-SAO

Co-Investigators:
Christine Jones, SAO
Varoujan Gorjian, JPL
Andrew Fabian, IOA
Michael Werner, JPL
Ryan Hickox, SAO
Sergey Sazonov, MPA
Eugene Churazov, MPA/IKI
Steve Willner, SAO
Jiasheng Huang, SAO
Qiusheng Gu, Nanjing University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 13.0

Abstract:
The hard X-ray (17-60 keV) INTEGRAL survey provides, for the first time, a nearly unbiased, complete sample of 69 emission line AGN selected directly by their accretion luminosity almost unaffected by absorption. By combining the hard X-ray selection with infrared observations of the re-radiated emission that originates in the geometrically thick torus, we can probe the physics of the re-radiation and the structure of the torus by investigating the details of the correlation between X-ray and mid-IR luminosities. New IRS, IRAC, and MIPS observations, combined with Spitzer archival data, will yield a complete data set for all 69 INTEGRAL AGN. With this sample, we will test the unified model by comparing the 17-60 keV band luminosity with that of the mid-infrared (MIR), test the Spitzer IR color-color selection of AGN using an unbiased X-ray selected AGN sample, test the optical R-band -- MIR separation of absorbed and unabsorbed AGNs, study the relation between silicate emission/absorption and AGN X-ray properties including luminosity and absorption, and derive a ''representative'' SED (and dispersion) for AGN of modest luminosity suitable for use beyond the local universe. Because our sample has well-defined statistical properties, we will measure the total energy release by AGNs (except for the contribution of extremely Compton thick sources) and therefore the total growth rate of supermassive black holes in the local Universe.

Spitzer Space Telescope - Directors Discretionary Time Proposal #1097

Measuring the Far Infrared Spectral Energy Distributions of a Complete Sample of Broad Absorption Line Quasars

Principal Investigator: Sarah Gallagher
Institution: UCLA

Technical Contact: Sarah Gallagher, UCLA

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 12.8

Abstract:
Is the Broad Absorption Line (BAL) Quasar phenomenon an effect of evolution or orientation? The answer has significant implications for understanding the connection between the growth of supermassive black holes and their host galaxies; BAL outflows are likely to be an important mechanism for regulating black hole accretion. To address this issue, this program will measure the far infrared spectral energy distributions of a complete sample of BAL quasars drawn from the Large Bright Quasar Survey. These data, in conjunction with information from other wavelength regimes, are crucial for accurately constraining the star formation rates, bolometric luminosities, and accretion rates in BAL quasars. Comparing these fundamental physical properties to those of non-BAL quasars will enable a full investigation into the evolution versus orientation explanation for the BAL wind.

Spitzer Space Telescope - Theoretical Research Proposal #30086

Illuminating the Dusty Wind: 3D Modeling of Quasar Silicate Emission

Principal Investigator: Sarah Gallagher
Institution: UCLA

Technical Contact: Sarah Gallagher, UCLA

Co-Investigators:
John Everett, Canadian Institute for Theoretical Astrophysics
Dean Hines, Space Science Institute

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 70729.0

Abstract:
The so-called ‘dusty torus’, an obscuring medium surrounding the black hole accretion disk, is an essential component of the Unified Model for Active Galactic Nuclei (AGNs) invoked to explain the diversity of AGN phenomenology. One promising source for the dusty torus is a dynamical wind from the accretion disk driven by both magnetic and radiative forces. At large (> 1 pc) radii in the wind, dust is not sublimated by the central continuum and will survive in the outflow. Such a model can naturally account for the large covering factor of the obscuring medium, which is otherwise difficult to explain. We propose to explore and constrain the geometry and dynamics of obscuration in quasars (the most luminous AGNs) by building dynamical and 3D Monte Carlo radiative transfer models of such dusty outflows. By testing simulated spectra from our models directly against silicate emission features in Spitzer IRS data of quasars known to host outflows (those with broad absorption lines), we will investigate the physics of the obscuring medium in this population. We plan to explore the parameter space of inputs such as continuum luminosity, spectral energy distribution, column density, and grain properties to determine what drives the observed trends in silicate emission; a library of simulated spectra will be provided to the community. Finally, these models will enable us to measure the mass outflow rate in these winds, an essential parameter for determining the kinetic luminosities of quasar winds, and thus their impact on their host galaxies.

Spitzer Space Telescope - General Observer Proposal #3421

Dust in the Wind: Mid-Infrared Spectroscopy of Broad Absorption Line Quasars

Principal Investigator: Sarah Gallagher
Institution: UCLA

Technical Contact: Sarah Gallagher, UCLA

Co-Investigators:
Francisca Kemper, UCLA
Dean Hines, Space Science Institute
Michael Brotherton, University of Wyoming

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 7.6

Abstract:
We propose to obtain high signal-to-noise ratio spectra of an exploratory sample of mid-infrared bright Broad Absorption Line (BAL) quasars. Though small in number, our carefully selected sample of 8 BAL quasars includes objects covering a wide range of BAL properties including outflow velocities and absorption depths with examples of both high and low ionization absorption. Furthermore, the objects have a wide range of UV continuum slopes allowing us to more directly assess the correlation of mid-infrared properties with the intrinsic ionizing continuum. Our proposed observations will enable us to constrain the overall dust content and distribution around the nucleus as well as more detailed constraints on the dust content within and along the line-of-sight to the wind. In particular, the details of the 9.7 micron silicate feature will constrain the opacity, grain size, and crystalline fraction of the dust. Combined with the larger photometric surveys being conducted by the Spitzer GTO teams, our detailed investigation will provide the first comprehensive picture of the dusty structures in BAL quasars. These results can then be compared directly with similar structures inferred in non-BAL quasars, further elucidating the nature of quasars and accretion-driven power in general.

Spitzer Space Telescope - General Observer Proposal #41021

Lower Luminosity AGNs at Cosmologically Interesting Redshifts: SEDs and Accretion Rates of z~0.36 Seyferts

Principal Investigator: Sarah Gallagher
Institution: UCLA

Technical Contact: Sarah Gallager, UCLA

Co-Investigators:
Tommaso Treu, UC Santa Barbara
Matthew Malkan, UCLA
Jong-Hak Woo, UC Santa Barbara

Science Category: AGN/Quasars/Radio Galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 11.0

Abstract:
We propose a multiwavelength campaign to constrain the SEDs of Seyferts at z~0.36. This epoch, corresponding to a look back time of 4 Gyrs, is cosmologically interesting for studies of the coeval development of black holes and their host galaxy bulges. Our sample, comprising 24 Seyferts, has unprecedented high quality Keck spectroscopy and HST imaging already invested to extract host galaxy bulge properties, estimate black hole masses, and separate nuclear and host optical luminosities. To supplement and extend this successful program, we request 93 ks of Chandra time (to measure the shape and power of the AGN-only X-ray continuum),11 hrs each of Spitzer and Gemini (to constrain the dust temperature), and 7 orbits of HST (to determine the nuclear luminosity for the final 7 objects).

Spitzer Space Telescope - General Observer Proposal #50328

Seeing the Unseen: MIR Spectroscopic Constraints on Quasar Big Blue Bumps

Principal Investigator: Sarah Gallagher
Institution: UCLA

Technical Contact: Sarah Gallagher, UCLA

Co-Investigators:
Karen Leighly, University of Oklahoma
Gordon Richards, Drexel University
Dean Hines, Space Science Institute
Patrick Ogle, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare IrsPeakupImage
Hours Approved: 31.7

Abstract:
The IRS on Spitzer offers an exciting opportunity for detailed, mid-infrared spectroscopy of z~2 quasars for the first time. This epoch, sampling the peak of the quasar luminosity evolution, is particularly important for understanding the nature of quasar activity in the most massive galaxies. We aim to use this powerful tool to constrain the shape and power of the far-ultraviolet through soft-X-ray ionizing continuum of luminous quasars. Though these so-called ‘big blue bumps’ dominate the power of quasar spectral energy distributions, they are largely unobservable as a result of hydrogen opacity in the Universe. However, we can determine the properties of the big blue bump by studying emission lines from ions in the coronal line region that emit in the mid-infrared and are created by those same energetic and elusive photons. We propose deep, high quality IRS observations of 5 luminous quasars with a range of HeII emission properties to investigate the mid-infrared spectral region in depth and constrain the shape of the ionizing continuum in each quasar. In addition, these high S/N spectra will provide templates for interpreting lower resolution, lower S/N IRS spectra.

Spitzer Space Telescope - Directors Discretionary Time Proposal #283

Relationship Between Black Hole Mass and Their Infrared Brightness to Synchrotron Radio Emission Ratio

Principal Investigator: Varoujan Gorjian
Institution: JPL

Technical Contact: Varoujan Gorjian, JPL

Co-Investigators:
Mark Hofstadter, JPL
Michelle Thaller, SSC
Dave Maclaren, LCER

Science Category: AGN/Quasars/Radio Galaxies
Observing Modes: IracMap
Hours Approved: 1.2

Abstract:
The objective of this proposal is to see whether there is a correlation between the central black hole masses of nearby AGN and the ratio of their radio to infrared flux. Spitzer will image the AGN in the 3.6 to 8um range and that will be compared to data gathered by the GAVRT students in the S and X radio bands. Once the data is in hand a comparison can be made of the thermal processes generating the IR and the non-thermal processes generating the radio, and whether the ratio of the thermal to the non-thermal is related to the masses of the black holes.

Spitzer Space Telescope - General Observer Proposal #30572

Probing Parsec Scale Structure of Nearby Seyferts Using Variability

Principal Investigator: Varoujan Gorjian
Institution: JPL

Technical Contact: Varoujan Gorjian, JPL

Co-Investigators:
Michael Werner, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 19.9

Abstract:
Variability is one of the most powerful tools for studying the structure of unresolved objects. To search for mid-IR AGN variability, we propose to re-observe 42 nearby Seyfert galaxies with all IRS modules and MIPS at 24 microns. The sample was originally observed as part of a GTO program and covers a wide range of X-ray determined Hydrogen column density, and because the sources are so bright, very high signal to noise data was obtained in short exposures: 60s for the low resolution IRS mode, 120s for the high resolution IRS mode, and 92 seconds for the MIPS 24 micron imaging mode. This second epoch, which spans 1 to 3 years since the original observations, should allow for variability to be detected in the silicate emission features, the dust continuum, and the gas phase emission lines. Based on models of the dusty torus, the variable mid-IR emission should be occurring on parsec and sub-parsec scales, thus giving information about the dust distribution on those scales..

Spitzer Space Telescope - Directors Discretionary Time Proposal #484

IRAC Monitoring of NGC 4051 for Interday Variability

Principal Investigator: Varoujan Gorjian
Institution: Jet Propulsion Laboratory

Technical Contact: Varoujan Gorjian, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 1.0

Abstract:
We will be observing the Seyfert 1.5 NGC 4051 on a daily basis for approximately 10 days for signs of variability at 3.6 and 5.8 microns. NGC 4051 has previously shown variability on this timescale at 2.2 microns. Based on the difference in variability at 3.6 and 5.8 microns limits can be placed on the dust distribution at the nucleus of the AGN.

Spitzer Space Telescope - Directors Discretionary Time Proposal #526

Capturing the Rare Spectral Change in a Nearby Seyfert

Principal Investigator: Varoujan Gorjian
Institution: JPL

Technical Contact: Varoujan Gorjian, JPL

Co-Investigators:
Michael Werner, JPL
Kieran Cleary, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 0.3

Abstract:
Spitzer has for the first time detected thermal continuum variability in the spectrum of an Active Galactic Nucleus (AGN). The Seyfert 1 Fairall 9 was observed in 2003 and in 2007 and has shown a distinct change in its slope in the 5-11um range. What is needed with this DDT observation is a third epoch to show how the change in emission is progressing and hence what that progression can tell us about the parsec scale structure of the putative torus that plays such a large role in AGN unification schemes.

Spitzer Space Telescope - General Observer Proposal #50476

Piercing through the Dust: the AGN Obscured Growth Phase at High Redshift

Principal Investigator: Carlotta Gruppioni
Institution: INAF - Osservatorio Astronomico di Bologna

Technical Contact: Cristian Vignali, Universita' di Bologna

Co-Investigators:
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Cristian Vignali, University of Bologna
Francesca Pozzi, University of Bologna
Chiara Feruglio, CEA - Service d'Astrophysique - Saclay
Fabrizio Fiore, INAF - Osservatorio Astronomico di Roma
Jacopo Fritz, INAF - Osservatorio Astronomico di Padova
Fabio La Franca, Universita' di Roma Tre
Roberto Maiolino, INAF - Osservatorio Astronomico di Roma

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 39.4

Abstract:
The search for and the characterization of highly obscured Active Galactic Nuclei, witnessing the co-eval growth of the Super Massive Black Holes (SMBHs) and stellar mass assembly at high (z~1.5-2.5) redshift, is a fundamental step towards a better understanding of galaxy and AGN evolution. The main scientific driver of the present proposal is to obtain good-quality Spitzer IRS spectra of a large sample of 78 bright MIPS (24 micron) selected sources, most likely hosting the most extreme examples (in terms of luminosity and obscuration) of accreting SMBHs at the epoch (z~2) of the peak of quasar and star-formation activity. The proposed observations, combined with the multi-wavelength database already available, will allow us to measure robust spectroscopic redshifts and to evaluate the amount of dust obscuration and star-formation through the detection of silicate absorption and PAH emission features. The ultimate goal is to assess the relative contribution of accretion and star-formation driven processed and to test the current hypotheses on the (obscured) growth of SMBHs and their host galaxies at high redshifts.

Spitzer Space Telescope - General Observer Proposal #20090

Exploring the nature of Mid-IR selected buried AGN candidates

Principal Investigator: Martin Haas
Institution: Astronomisches Institut, Ruhr-Universitaet Bochum

Technical Contact: Martin Haas, Astronomisches Institut, Bochum

Co-Investigators:
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Christian Leipski, Ruhr-Universitaet Bochum, Germany
Belinda Wilkes, Harvard-Smithsonian CfA, Cambridge, USA
John P. Huchra, Harvard-Smithsonian CfA, Cambridge, USA
Rolf Chini, Ruhr-Universitaet Bochum, Germany
Sven A.H. Mueller, Ruhr-Universitaet Bochum, Germany
Stephan Ott, ESTEC, ESA, The Netherlands

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 10.7

Abstract:
Among 3000 sources detected by the ISOCAM Parallel Survey at 6.7 micron in an area of 8 square degrees at high galactic latitude we have discovered a population of extremely infrared unknown objects. With a typical 6.7 micron flux between 4 and 0.7 mJy they have red 2MASS and optical counterparts. The analysis of the ISO and 2MASS colours suggests that we have found AGN with a pronounced near- and mid-IR emission from nuclear dust. We performed optical spectroscopy for 55 of the 80 AGN candidates selected by their red near-mid-IR colors. We find 27% type 1 AGN (redshift range z=0.1-1), 13% type 2 AGN (z=0.1-0.5), and 60% extremely reddened emission line galaxies (ELGs) with LINER and HII type spectra (z=0.07-0.3). Our multi-wavelength examination of the ELGs indicates that they resemble a population different from known IR luminous starburst galaxies. The high MIR/NIR flux ratio and the rather low FIR upper flux limits on IRAS-ADDSCANs argue against a pure starburst nature, suggesting that the red ELGs contain a buried AGN. While new IR surveys from Spitzer will certainly detect new interesting objects of that type, we have already identified a promising IR sample which has been further focussed by optical spectroscopy. Therefore, we apply for 19-38 micron IRS low resolution spectroscopy of 10 red ELGs carefully selected from our sample (6.7 micron flux > 1 mJy). By focussing on really buried AGN candidates and the [Ne V]24.3um and [O IV]25.9um lines, this proposal substantially goes beyond our shallower cycle-1 IRS 5-40 micron observations of MIR selected (mainly type 1 and type 2) AGN.

Spitzer Space Telescope - General Observer Proposal #3231

Establishing the mid-infrared selection of AGN

Principal Investigator: Martin Haas
Institution: Astronomisches Institut, Ruhr-Universitaet Bochum

Technical Contact: Martin Haas, Astronomisches Institut, Bochum

Co-Investigators:
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Rolf Chini, Ruhr-Universitaet Bochum, Germany
Sven A.H. Mueller, Ruhr-Universitaet Bochum, Germany
Christian Leipski, Ruhr-Universitaet Bochum, Germany
Norbert Schartel, XMM-Newton SOC, VILSPA, ESA, Spain

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 10.1

Abstract:
Since a large fraction of AGN is missed in common UV-excess surveys, and even in radio, near-IR and X-ray surveys, we have searched for AGN via mid-IR emission from their nuclear dust at T>300 K. This is a new AGN selection technique, and one not affected by extinction. Among 3000 high galactic latitude sources randomly detected by ISO at 6.7 microns we have discovered a population of extremly infra-red, mostly unknown objects. This population is not detected on IRAS-ADDSCANs and very few of these sources show up in the NVSS and FIRST radio surveys. Various colour criteria from 2MASS and optical wavebands and the comparison with known object types show that the sources have a higher MIR excess than those seen in the ELAIS survey. Our analysis suggests that we have, in fact, found AGN with a pronounced MIR emission. We estimate that, if this is true, the number counts of AGN will have to be revised dramatically upwards. In order to verify our hypothesis on the AGN nature of the sources, we have selected MIR-excess AGN candidates with unknown classification from our ISO survey. First results from optical spectrocopy show some to be AGN, but also that many of the sources are extremely reddened. Therefore, we here apply for 5-40 micron IRS spectroscopy of 30 of the remaining unidentified sources to establish their nature as AGN, to determine the fraction of type 1 and 2 AGN among this MIR selected sample, and to constrain their additional starburst contribution. While new IR surveys from Spitzer are expected to find more such interesting objects, we have already identified a promising sample. The requested observations will make a significant contribution to the debate on the entire AGN population.

Spitzer Space Telescope - General Observer Proposal #40314

IRS 19-38 micron spectra of 3CRR radio galaxies and quasars at z>1: Testing AGN unification at the peak of cosmic activity

Principal Investigator: Martin Haas
Institution: Astronomisches Institut, Bochum, Germany

Technical Contact: Martin Haas, Astronomisches Institut, Bochum

Co-Investigators:
Giovanni Fazio, Harvard-Smithsonian CfA
Belinda Wilkes, Harvard-Smithsonian CfA
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Robert Antonucci, Univ. California Santa Barbara
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Pat Ogle, Caltech
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Ralf Siebenmorgen, ESO, Garching
Peter Barthel, Kapteyn Inst. Groningen, NL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 19.3

Abstract:
Pure orientation-dependent AGN unification predicts for unobscured isotropic observables that powerful FRII radio galaxies and steep-spectrum quasars show the same distribution of high-excitation lines to radio power and of high- to low- excitation lines. By means of IRS spectra we were able to provide a successful test of this prediction for radio sources at intermediate redshift up to z<1. But at high redshift z>1 submillimetre observations of quasars and radio galaxies found intriguing differences between the two AGN classes. The differences could be due to the higher intrinsic luminosity at z>1, to co-eval starbursts or to other evolutionary effects which are related to the higher activity at the earlier cosmic epoch. In order to test AGN unification at high redshift and luminosity, we propose to obtain IRS low-resolution spectra of a complete 3CRR sample at 1<z<1.4 consisting of 8 radio galaxies and 10 quasars matching in isotropic 178 MHz lobe power. The major advantages of this redshift range are: 1) it is sufficiently high to include the epoch when cosmic star formation activity peaked, and 2) it is low enough that the essentially unobscured low- and high-excitation emission lines [NeII] and [NeV] (at rest frame wavelengths 12.8 and 14.3 micron) can properly be measured in the IRS 19-38 micron spectral window. Our proposed test will, for the first time, extend previous successful IRS studies of z<1 radio sources into the highest luminosity range and the epoch of peak star formation, as far as possible while still using IRS efficiently. The IRS spectra allow a clean test of whether or not unification of these two AGN classes is possible. For all 63 3CR radio sources at z>1 detailed 3.6-24 micron SEDs will be observed in 6 Spitzer bands using GTO. Then in a first step the spectroscopic results from the proposed 18 sources can be compared with broad-band SED features constraining models of the nuclear regions, and in a second step we may expand conclusions to the entire larger sample.

Spitzer Space Telescope - General Observer Proposal #20741

The mid-IR spectroscopy of the SDSS AGN

Principal Investigator: Lei Hao
Institution: Cornell University

Technical Contact: Lei Hao, Cornell University

Co-Investigators:
Michael Strauss, Princeton University
Vassilis Charmandaris, University of Crete
Lee Armus, Spitzer Science Center
Henrik Spoon, Cornell University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 31.7

Abstract:
We propose to observe the IRS low-resolution spectroscopy for a well defined sample of 74 AGN. The targets are drawn from the AGN catalogue spectroscopically selected from the Sloan Digital Sky Survey. We carefully sample both broad-line and narrow-line AGN over the entire [OIII]$\\lambda5007$ luminosity range, so that we can investigate the AGN dust properties as measured by the IRS low-res spectra as a function of luminosity. In the mean time, by comparing the dust properties of narrow-line and broad-line AGN of similar nuclear luminosities, we will be in a much better position to justify and improve our understandings of the unification scheme.

Spitzer Space Telescope - General Observer Proposal #40330

Are Starbursts the Progenitors of Supermassive Black Holes?

Principal Investigator: Tim Heckman
Institution: Johns Hopkins University

Technical Contact: Tim Heckman, Johns Hopkins University

Co-Investigators:
Vivienne Wild, Max-Planck Institut fuer Astrophysik
Paule Sonnentrucker, Johns Hopkins University
Brent Groves, Leiden Observatory
Lee Armus, Spitzer Science Center
Guinevere Kauffmann, Max-Planck Institut fuer Astrophysik

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 8.0

Abstract:
A popular model for the coevolution of bulges and supermassive black holes is one in which a galaxy merger leads to the inflow of gas which fuels a strong burst of star formation, followed by an AGN phase in which the black hole grows significantly. In this proposal we describe how mid-IR spectroscopy with Spitzer can directly test this model. Using the Sloan Digital Sky Survey to undertake a census of the growth of black holes in the local universe, we have found that a significant fraction of this growth seems to take place in a rare class of highly dust-obscured AGN hosted by morphologically disturbed galaxies whose optical spectra imply that they are in the post-starburst phase. Because of the high extinction in the optical, IRS data are required to: 1) Verify the presence of powerful AGN through measurements of the luminosity of the mid-IR [NeV] emission-lines, and 2) Verify that these are truly post-starbursts rather than dusty starbursts whose massive stars are invisible in the optical spectra. In this case, the discrimination will be primarily made using the equivalent widths of the PAH features. The combination of the robust statistics from the SDSS sample and the diagnostic power of the IRS will make this the best test to date of the significance of a starburst-to-AGN evolutionary pathway.

Spitzer Space Telescope - General Observer Proposal #20573

Signatures of Star Formation in Dusty High-Redshift QSOs

Principal Investigator: David Helfand
Institution: Columbia University

Technical Contact: Andreea Petric, Columbia University

Co-Investigators:
Andreea Petric, Columbia University
Rachel Mason, NOAO
Chris Carilli, NRAO

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 7.3

Abstract:
We propose a Spitzer/IRS search for aromatic hydrocarbon emission features to directly assess the energetic importance of star formation in QSOs. Comparison of the timescales of star formation activity with those of accretion have the potential to improve our understanding of the relation between the black holes in galaxy centers and the stellar content of galaxies, but to date, evidence of star formation in QSOs has been frustratingly indirect. As unambiguous signatures of star formation, and successfully used to estimate starburst luminosities in the local Universe, emission features of polyaromatic hydrocarbons (PAHs) represent a promising new tool to investigate star formation at high redshift; with the advent of Spitzer, searches for such features are now a realistic prospect. We therefore propose a pilot study of PAH features in a small sample of QSOs in which star formation is strongly suspected but not yet directly confirmed.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #14

IRS Standard Spectra for AGN, Starbursts and QSOs

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Daniel Weedman, National Science Foundation

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 23.6

Abstract:
A selection of AGN, Starburst Galaxies and QSOs will be observed with single pointings to determine high S/N spectra with all modules of the IRS. These spectra will be used to study the typical spectral signatures of these objects as well as the variations within each class. They will also be used as comparisons for other sources in the IRS program.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #15

Seeking Redshifts for Optically Unidentifiable Infrared Sources

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Daniel Weedman, National Science Foundation

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 129.4

Abstract:
Optically faint or unidentifiable sources from ISOCAM 15 micron, ISO FIRBACK, and SCUBA surveys are selected for MIPS and IRS lo res observations with the objective of determining spectroscopic redshifts. IRS observations will be obtained only for sources found to have MIPS 24 micron fluxes above about 0.7 mJy. Eventual IRS targets will also be chosen from the First Look Survey.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30272

IRS mapping of the 500 pc nuclear dust shell in Centaurus A

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Alice Quillen, University of Rochester

Co-Investigators:
Alice Quillen, University of Rochester
Joss Bland Hawthorne, Anglo Australian Observatory
Mairi Brookes, JPL
Charles Lawrence, JPL
J.D. Smith, University of Arizona
Kieran Cleary, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 7.1

Abstract:
We propose to map the central 1.5' of Centaurus A with IRS. This region covers a recently discovered 500pc bipolar shell. This shell, if confirmed, could be the only extragalactic nuclear shell with a mid-infrared counter part. Hence Centaurus A represents a unique laboratory to test scenarios and models of feedback from an AGN or/and circumnuclear star formation on the ISM near the nucleus. By comparing the IRS spectra of the shell component with the star forming parallelogram shaped region corresponding to the warped disk, we will seek confirmation that the shell is a separate and coherent structure, and better estimate its dust temperature and so mass. Derived constraints on its energetics will form the basis of subsequent models accounting for its formation. We will search for evidence of shocks in the shell due to its expansion and where the jets pass through it. As the shell covers all solid angles from the nuclear black hole, the IRS spectra will also be used to search for angular variations in the ambient UV radiation field.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30715

Mid-IR spectroscopy of Dwarf Seyfert 1s

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Lei Hao, Cornell University

Co-Investigators:
Lei Hao, Cornell University
Dan Weedman, Cornell University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 2.3

Abstract:
We propose to observe the low-resolution IRS spectra of a sample of 10 AGN with the smallest known BH mass: <10^6M_solar. The mid-IR observation of these intermediate BH mass AGN will provide critical information on AGN evolution, including the formation and evolution of the dusty torus. The dust mass of these AGN compare with that of high BH mass AGN could also give us clue on AGN fueling history. The total observation time is 8.3hrs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #74

Powerful Radio Sources

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Charles Lawrence, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 43.6

Abstract:
We will determine the mid- and far-infrared spectral energy distributions of powerful radio sources selected from the 3CRR sample in the redshift range 0.5 to 1.0. The total time for this program is 42.8 hours, of which 24.4 get accounted under Charles Lawrence General GTO time and 18.4 get accounted under the IRS GTO time.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #96

The mid-IR SED of nearby AGN

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Vassilis Charmandaris, Cornell University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare
Hours Approved: 2.8

Abstract:
We wish to examine the variations in form of the mid-IR spectral energy distribution in a few nearby active galactic nuclei. Of particular interest is the detection of high ionization lines as well as the the presence of the 5-8 hot continuum emission. Our small sample consists of galaxies with different Seyfert type and/or presence of a maser activity which could lead to further absorption of the nuclear spectrum.

Spitzer Space Telescope - General Observer Proposal #50469

Dust emission from BAL and non-BAL QSOs: probing the hot component with Spitzer

Principal Investigator: Damien Hutsemekers
Institution: University of Liege

Technical Contact: Damien Hutsemekers, University of Liege

Co-Investigators:
Theodoros Nakos, University of Ghent
Jean-Francois Claeskens, University of Liege
Klaus Meisenheimer, MPIA Heidelberg

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 9.0

Abstract:
About 20% of quasars show Broad Absorption Lines (BAL) in their spectra indicating high-velocity outflows with mass loss rates comparable to the quasar accretion rates. The BAL phenomenon can either affect all quasars, being only observed along peculiar lines of sight, or indicate a peculiar stage in the quasar evolution. Understanding BAL outflows is then necessary to improve our understanding of quasars in general, as well as for understanding the feedback effect of outflows on AGN hosts and on the intergalactic medium. Moreover, quasar outflows rather than winds from evolved stars could be an important source of dust. An accurate determination and comparison of the dust physical properties (temperature, luminosity, mass) for the various sub-types of BAL QSOs and for non-BAL QSOs may answer these questions. Determining the complete dust energy distribution (including the peak of emission) of z ~ 2 quasars is now possible using combined measurements from the Herschel and Spitzer observatories. We therefore propose to observe a sample of ~ 50 BAL and non-BAL QSOs carefully selected from the SDSS. MIPS and IRAC Spitzer photometric observations in the mid-infrared (4 - 24 micron) are proposed here to sample the hot dust emission. These data will complement far-infrared (75 - 490 micron) observations (characterizing the cold dust component) already foreseen with the Herschel PACS and SPIRE instruments as part of an accepted Herschel Guaranteed Time Key Programme.

Spitzer Space Telescope - General Observer Proposal #2306

Buried AGNs in ultraluminous infrared galaxies - A search for a strong dust temperature gradient -

Principal Investigator: Masatoshi Imanishi
Institution: National Astronomical Observatory of Japan

Technical Contact: Masatoshi Imanishi, NAOJ

Co-Investigators:
Philip R. Maloney, University of Colorado
Charles C. Dudley, Naval Research Labolatory
Roberto Maiolino, INAF-Osservatorio di Arcetri
Guido Risaliti, INAF-Osservatorio di Arcetri
Takao Nakagawa, ISAS, JAXA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 15.5

Abstract:
Ultraluminous infrared galaxies (ULIRGs) have been used extensively to trace the history of star formation in the early universe. However, the major issue of whether ULIRGs are powered primarily by starbursts or buried AGNs is poorly understood. We propose Spitzer IRS low-resolution spectroscopy of a complete sample of nearby non-Seyfert ULIRGs. By combining these data with ancillary ground-based 2.8-4.1 micron spectra, we will search for the signature of a strong dust temperature gradient, an excellent method to distinguish a buried AGN from a starburst, and quantitatively estimate the energetic importance of buried AGNs in ULIRGs. The wide wavelength coverage of Spitzer IRS is crucial for the success of this experiment.

Spitzer Space Telescope - General Observer Proposal #3377

To what extent does star formation precede the onset of AGN activity?

Principal Investigator: Katherine Inskip
Institution: Cavendish Astrophysics Group

Technical Contact: Katherine Inskip, University of Sheffield

Co-Investigators:
Paul Alexander, Cavendish Astrophysics
Garret Cotter, Oxford Astrophysics, University of Oxford
Malcolm Longair, Cavendish Astrophysics
Bojan Nikolic, Cavendish Astrophysics
Timothy Pearson, Caltech Astronomy
Anthony Readhead, Caltech Astronomy
Richard Savage, Sussex Astronomy Centre, University of Sussex

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 5.9

Abstract:
There is increasing evidence that the onset of radio-loud AGN activity now appears to be closely related to starbursts, possibly triggered by mergers. A commonly proposed evolutionary scenario has emerged in which an interaction/merger leads to infall of gas to the nuclear region, triggering a starburst. This is followed by a large increase in the amount of material being fed to the central black hole, thereby triggering the production of strong radio emission (e.g. Heckman et al. 1986). Here we propose observations of a small sample of radio loud AGN which are known to be young, i.e. their active phase has been triggered well within the last million years. Our aim is to search, using mid-IR spectroscopy, for signatures of ongoing star formation. Since we can date, with some confidence, the onset of significant AGN activity in these systems (i.e. the radio jet) such a detection would offer strong support to an evolutionary scenario in which significant star formation precedes the onset of AGN activity.

Spitzer Space Telescope - General Observer Proposal #30344

Decoupling luminosity, evolution and orientation effects in AGN

Principal Investigator: Matt Jarvis
Institution: University of Oxford

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Mark Lacy, IPAC
Mat Page, MSSL, UCL
Gordon Richards, Johns Hopkins
Bernhard Schulz, IPAC
Jason Stevens, Univ. of Hertfordshire
Stephen Serjeant, Open University
Alain Omont, IAP
Dave Clements, Imperial College London
James Dunlop, IfA, Edinburgh
Ross McLure, IfA, Edinburgh
Alejo Martinez-Sansigre, Oxford
Dimitra Rigopoulou, Oxford
Chris Simpson, Durham
Duncan Farrah, Cornell
Paul O'Brien, Leicester
Chris Willott, Herzberg Institute
Maarten Baes, Ghent
Gianfranco de Zotti, Padova
Alastair Edge, Durham
Eva Schinnerer, MPIA
Evanthia Hatziminaoglou, IAC, Tenerife
Paola Andreani, INAF
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Rob Ivison, UKATC, Edinburgh
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Paul ven der Werf, Leiden
Ian Waddington, Sussex
Aprajita Verma, MPE
Tim Waskett, Cardiff
Richard McMahon, IoA, Cambridge
Robert Priddey, Univ. of Hertfordshire
Colin Borys, Caltech
Eduardo Gonzalez-Solares, CASU, Cambridge

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 42.7

Abstract:
With this proposal we will decouple luminosity effects from evolutionary effects in matched samples of radio-loud and radio-quiet quasars, and determine the amount of radiation that is absorbed and reprocessed by the torus, and how this depends on luminosity and orientation. We have constructed a well-defined sample of radio-quiet quasars from the SDSS, spanning two decades in optical luminosity at a single cosmic epoch, to constrain luminosity dependent effects on the hot dust emission from the obscuring torus, without caveats of luminosity - redshift degeneracies, a fundamental problem in flux-density limited sample. Crucially, we have also defined a sample of radio-loud quasars selected in exactly the same way as the radio-quiet quasars, allowing us to address what effect radio emission may have on the dust properties of quasars. Finally, by selecting a sample of radio galaxies matched to have the same distribution in radio luminosity as the radio-loud quasars we will determine how orientation influences the near- and mid-IR SEDs, and in particular obtain a firm hold on

the geometry of the obscuring torus. Thus, this data will allow us to directly address all facets of AGN unification. Our sample will also be proposed for Herschel as an Open Time Key Project. Crucially, combining the data from Spitzer with far-infrared data from Herschel and SCUBA2 will allow us, for the first time, to measure the complete dust-sensitive SED for a statistically complete sample of AGN at a single cosmic epoch. Obtaining Spitzer observations of this sample is vital if we are to continue using large area surveys in a variety of wavebands to study AGN over the history of the Universe. It is both timely, and only recently possible to undertake this investigation. Thus, this proposal is the crucial first step in obtaining a benchmark sample with which to use in analysing future survey data across the wavebands to constrain the evolution in accretion and star-formation activity over the history of the Universe.

Spitzer Space Telescope - General Observer Proposal #20549

The Starburst-AGN Connection: A Search for AGNs in IR-Selected Starburst Galaxies

Principal Investigator: Robert Joseph
Institution: University of Hawaii

Technical Contact: Robert Joseph, University of Hawaii

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 8.8

Abstract:
We propose to address two long-standing astrophysical questions. The first is whether it is AGNs or starbursts that are the dominant energy generation process in luminous infrared galaxies. The second is whether there is evidence for a connection between starbursts and AGNs. Investigation of these ideas for the past 20 years has been pursued chiefly using optical spectroscopy, but since both these processes are deeply buried in dust, the results of such studies have never been conclusive. Mid-infrared IRS spectroscopy with the SST offers the opportunity to make a significant advance in addressing these two astrophysical issues by probing astrophysical processes much more deeply into the dust. We now have mid-infrared diagnostics which have been shown to clearly distinguish starbursts and AGNs. The SST and IRS provide the highest sensitivity that has ever been available for such measurements, thereby offering the opportunity to make a significant advance in addressing these two astrophysical issues.

Spitzer Space Telescope - General Observer Proposal #20631

Spitzer Observations of an Intensely Star Forming Quasar Host Galaxy

Principal Investigator: Kirsten Knudsen
Institution: Max-Planck-Institute for Astronomy

Technical Contact: Kirsten Knudsen, Max-Planck-Institute for Astronomy

Co-Investigators:
Fabian Walter, Max-Planck-Institute for Astronomy
Paul van der Werf, Leiden Observatory

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 4.2

Abstract:
The relation between starburst and AGN is an important topic in understanding galaxy formation and evolution. It has been shown that most spheroidal galaxies harbour an AGN, and that the mass of the black hole correlates with the velocity distribution of the stellar population, suggestive of a coeval formation. Here we propose to exploit the high sensitivity of MIPS to do mid- and far-infrared photometry of an unusual z=2.84 quasar. The quasar host galaxy is undergoing intense star formation (as witnessed through bright submm and CO detections), and is possibly one of the most massive starbursts observed in a high redshift quasar so far. The mid- and far-IR photometry will allow us to constrain the SED, and thereby both accurately determine the IR luminosity, separate the cold and the host dust components, and to determine the evolutionary stage. The MIPS data will be supplemented with IRAC data from another already approved program.

Spitzer Space Telescope - General Observer Proposal #3374

Spitzer/IRS Observations of Seyfert 1.8 and 1.9 Galaxies: Probing the Dusty Torus at Intermediate Viewing Angles

Principal Investigator: Steven Kraemer
Institution: Catholic University of America

Technical Contact: Steven Kraemer, Catholic University of America

Co-Investigators:
Michael Crenshaw, Georgia State University
Moshe Elitzur, University of Kentucky
Harry Teplitz, Cal Tech
Matthias Dietrich, Georgia State University
Theodore Gull, NASA's GSFC
Jane Turner, UMBC

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 7.0

Abstract:
According to the unified model for AGN, Seyfert 1.8 and 1.9 galaxies are viewed at inclinations between those of Seyfert 1s (face-on) and Seyfert 2s (edge-on) with respect to the source of obscuration, typically envisioned as a dusty torus. This view is supported by the weak broad emission-line components of the Balmer lines, with ratios that are consistent with significant (E(B-V} ~ 1 mag) reddening of the broad-line region. Mid-IR spectra are the only means with which to probe the circumnuclear gas in these intermediate Seyferts and constrain the physical structure of the torus, such as its size, scale height, and clumpiness. Seyfert 1.8s and 1.9s also tend to possess relatively weak high ionization narrow lines (e.g. [Fe~VII] 6087 A) compared to Seyfert 1s, suggesting that the dusty circumnuclear gas may also obscure the inner narrow line region. We request Spitzer IRS spectra of 12 Seyfert 1.8s and 1.9s in order to 1) determine the temperature of the dust, and hence its radial distance from the central engine, to test for a torus origin, 2) determine the scale height and clumpiness of the torus atmosphere via the silicate 10 feature and comparisons with clumpy torus models, and 3) penetrate the obscuring gas via mid-IR emission lines, such as [Ne~V] 14.3 microns and [O~IV] 25.9 microns, to reveal the hidden high-ionization inner narrow line region. We have selected targets with host galaxies that are close to face-on, to minimize contamination of the mid-IR spectra by dust in their galactic planes. Among the more than 60 Seyferts in the Spitzer/IRS reserved target catalog, there are only a handful of true Seyfert 1.8s and 1.9s, and all of these have inclined (b/a < 0.5) host galaxies.

Spitzer Space Telescope - Archive Research Proposal #40296

Measuring the Fraction of Obscured Quasars by the Infrared Luminosity of Unobscured Quasars

Principal Investigator: Julian Krolik
Institution: Johns Hopkins University

Technical Contact: Julian Krolik, Johns Hopkins University

Co-Investigators:
Ezequiel Treister, European Southern Observatory, Chile

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 37926.0

Abstract:
Recent work has suggested that the ratio of obscured to unobscured AGN declines with increasing luminosity, but it has been difficult to quantify this trend. We propose to measure this ratio as a function of luminosity in a new way: by studying the ratio of mid-infrared luminosity to intrinsic nuclear bolometric luminosity in unobscured AGN. Because the mid-infrared is created by dust reprocessing of shorter wavelength nuclear light, this ratio is a diagnostic of the solid angle around the nucleus covered by obscuring matter. In order to eliminate possible redshift-dependences while also achieving a large dynamic range in luminosity, we will collect archival 24 micron MIPS photometry from objects with redshifts near 1 in three surveys: SDSS, GOODS, and COSMOS. There is already data in the Spitzer archive for ~1000 SDSS quasars and ~10 lower luminosity GOODS AGN; observations are accumulating for ~150 COSMOS AGN with luminosity similar to the GOODS objects. To measure the bolometric luminosity for each object, we will use archival optical data from these surveys, supplemented by the GALEX data that are available for many of the objects in our sample. The resulting catalogs and data products will be made public on a friendly-access webpage as soon as they are ready. This database will be updated regularly as more data becomes publicly available in the Spitzer archive. We believe that such a database will be highly beneficial for the whole community.

Spitzer Space Telescope - General Observer Proposal #20757

Spectroscopy of Dusty Quasar Absorption Line Systems

Principal Investigator: Varsha Kulkarni
Institution: Univ. of South Carolina

Technical Contact: Varsha Kulkarni, Univ. of South Carolina

Co-Investigators:
Donald York, University of Chicago
Bruce Woodgate, NASA Goddard Space Flight Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 1.4

Abstract:
Damped Lyman-alpha absorbers (DLAs) in quasar spectra contain a large fraction of the neutral gas in galaxies and offer the most comprehensive information about chemical composition of distant galaxies. Recent observations, including our HST and MMT spectroscopy, are suggesting that the global mean metallicity of DLAs is relatively low at all redshifts, contrary to the predictions of cosmic chemical evolution models. Furthermore, imaging observations of most DLAs are suggesting star formation rates (SFRs) far below the global mean SFR. These "missing-metals" and "missing-stars" problems could be dust selection effects, since the more metal-rich and more star-forming DLAs may obscure background quasars more. As a first step toward characterizing the properties and distribution of dust in DLAs and their environments, here we propose a search for the IR emission and absorption signatures of the dust in a pilot sample of 5 DLAs at $0.3 < z < 2.8$. All of these DLAs show signs of large amounts of dust, (e.g., detections of the 2175 A dust feature or H2 or large depletions). Furthermore, each field shows several spectroscopically identified galaxies with Ly-alpha, H-alpha, [O II] or [O III] emission. We propose to obtain IRAC and MIPS images to detect the dust emission from the DLAs and their companion galaxies. We also propose to obtain IRS spectra of one of the background quasars to search for the redshifted 9.7 micron silicate absorption feature in this dusty DLA. The proposed observations will constrain (a) the rest-frame IR luminosities, (b) the nature of the stellar populations, (c) the extinction curve and dust composition, and (d) the unattenuated SFRs in the DLAs and their environments. These observations will provide the first detailed IR look at DLAs, and will help to quantify the role of dust in observations of DLAs and high-z galaxies in general. Spitzer is essential because it is the only existing facility with the necessary wavelength coverage and sensitivity.

Spitzer Space Telescope - General Observer Proposal #20083

A direct comparison of the infared SEDs of type-1 and type-2 quasars

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Lee Armus, Spitzer Science Center, Caltech
Gabriela Canalizo, University of California, Riverside
Susan Ridgway, Johns Hopkins University
Anna Sajina, University of British Columbia
Lisa Storrie-Lombardi, Spitzer Science Center, Caltech

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 21.9

Abstract:
We have used the Spitzer First Look Survey, in conjunction with the Sloan Digital Sky Survey, to select the first sample of type-1 (unobscured) and type-2 (obscured) quasars matched in mid-infrared luminosity. We wish to study the infrared SEDs of these objects using low resolution IRS spectroscopy and MIPS photometry. The results of this study will help us understand the relationship between the well-studied type-1 and the much less well-studied type-2 quasar populations. We will search for evidence of higher star formation activity in the type-2 objects though enhanced PAH and far-IR emission which may indicate that type-2 quasars evolve into type-1s. If, on the other hand, the only difference between type-1 and type-2 quasars is orientation, we expect the PAH emission and far-infrared SEDs to be similar. We will also compare our mid-infrared SEDs to models of emission from the dusty torus around the quasars, and use our observations of the SED shape and depth of the silicate absorption feature to constrain the clumpiness and optical depth of the dust.

Spitzer Space Telescope - General Observer Proposal #20705

The environments of high redshift type-2 quasars

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Alejo Martinez-Sansigre, U. Oxford
Dario Fadda, SSC
Myungshin Im, Seoul National U.
Steve Rawlings, U. Oxford
Francine Marleau, SSC
Tiffany Glassman, SSC
Chris Simpson, U. Durham
Chris Willott, Hertzberg Inst. of Astrophysics

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 15.9

Abstract:
We wish to study the environments of five 2.02<z<4.17 type-2 quasars that we have discovered in the Spitzer First Look Survey. We will use IRAC to image the fields at rest wavelengths well above the 4000A/Balmer break. Ancillary optical/near-infrared imaging data will be used in conjunction with the IRAC colors to obtain photometric redshifts for galaxies in the fields of our high redshift type-2 quasars. We will compare the environments we find to those of luminous radio galaxies at similar redshifts, a large fraction of which are in rich protocluster environments. Our type-2 quasars have much higher space densities than luminous radio galaxies, and we will thus be able to better explore the links between AGN and cluster formation and evolution.

Spitzer Space Telescope - General Observer Proposal #40143

A Spitzer study of the hosts of young, dust-reddened quasars

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Robert Becker, UC Davis/LLNL
Michael Gregg, UC Davis/LLNL
Eilat Glikman, Caltech
Gabriela Canalizo, UC Riverside
Tanya Urrutia, UC Davis/LLNL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 9.7

Abstract:
The black hole mass - bulge mass correlation in seen local galaxies tells us that quasar black holes and their host galaxies grow in concert. Yet only a minority of normal quasar hosts show evidence for star formation activity at a high enough rate to keep galaxy and black hole masses in step. We used HST/ACS to target a sample of dust-reddened type-1 quasars selected using FIRST and 2MASS, and found a very high fraction (85%) of merging and interacting host galaxies. This suggests that the starforming stages of quasar hosts may be correlated with dust reddening, which explains why so few starforming quasar hosts are seen in samples of X-ray or optically-selected quasars. To prove that our hosts are forming stars at high rates (~100 solar masses/year), however, we need infrared spectroscopy and photometry. IRS spectra and photometry will allow us to estimate star formation rates from the PAH and far-infrared excess to compare with those estimated from optical diagnostics, and thus estimate the amount of obscured star formation in the hosts. Spectra will also allow us to obtain an estimate of the obscuration to the quasar via the silicate feature.

Spitzer Space Telescope - General Observer Proposal #50375

An IRS spectral search for clumps in AGN tori

Principal Investigator: Mark Lacy
Institution: Spitzer Science Center

Technical Contact: Mark Lacy, Spitzer Science Center

Co-Investigators:
Duncan Farrah, Cornell
Margrethe Wold, University of Oslo
Andreea Petric, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 1.5

Abstract:
The dusty torus which is thought to hide the AGN in Seyfert-2 galaxies from our view has long been thought to be clumpy. Some objects show appearance and disappearance of broad lines in the optical, and nearly all Compton thin Seyfert-2s that have been studied show variable X-ray columns. We wish to investigate whether this variability extends to the column density of dust in the mid-infrared. In particular, the silicate and ice features in the spectra of Seyfert-2 galaxies should show measurable variability if the variable gas columns seen in the X-ray also contain dust. We wish to search for infrared spectral variability in a sample of eight nearby Seyfert 1.8-2 galaxies which are known to have highly-variable X-ray columns on timescales of months. These objects have all been observed previously with Spitzer, giving us a temporal baseline of 3-5 years. If variability is seen, we will be able to constrain the size of the clumps, and place them in the outer torus. If no variability is seen, it would suggest that the X-ray absorbing gas is in the inner torus or broad-line region.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #101

Infrared Imaging and Spectroscopy of Cen A and its Central Disk

Principal Investigator: Charles Lawrence
Institution: JPL

Technical Contact: Jocelyn Keene, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsMap IrsStare MipsScan
Hours Approved: 6.7

Abstract:
This project attempts to create a comprehensive infrared picture of Cen A, the closest active galaxy. It will produce large-scale images of the galaxy in all the IRAC and MIPS bands. Particular attention will be paid to the dust lane and embedded disk. Here we will use MIPS 70 micron super-resolution and SED modes for high-resolution and spectral imaging. IRS will be used in high-resolution mode to obtain a few spectra of the disk and in low-resolution mode to make a complete spectral image of it.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #108

Search for Obscured Supernovae in Ultraluminous Galaxies

Principal Investigator: Charles Lawrence
Institution: JPL

Technical Contact: Nick Gautier, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 5.5

Abstract:
Four ultraluminous galaxies will be monitored for supernova activity with oderately deep IRAC imaging at 4.5 and 8.0 microns. Arp 220, NGC 3690, NGC 7469 and NGC 1614 will be imaged with the 4.5 and 8.0 um IRAC arrays to a sensitivity of about 5 uJy, 1 sigma, approximately every 3 months for 2.5 years. A single 5.1 x 5.1 arcminute IRAC field will be used for each observation, no mapping will be done.

Spitzer Space Telescope - General Observer Proposal #30426

Spiter Observations of the Second Brightest Quasar, PHL 1811

Principal Investigator: Karen Leighly
Institution: The University of Oklahoma

Technical Contact: Karen Leighly, The University of Oklahoma

Co-Investigators:
Darrin Casebeer, The University of Oklahoma

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 0.9

Abstract:
Discovered in the FIRST radio survey, PHL 1811 (m_B=14.4, z=0.192) is the second brightest quasar beyond z=0.1 after 3C 273. PHL 1811, optically classified as a Narrow-line QSO, is a very unusual object. Undetected in the ROSAT All Sky Survey, five subsequent X-ray observations find it to be consistently X-ray weak, yet the X-ray spectra and variability indicate that the X-rays are neither absorbed nor scattered. It is the most convincing case of an intrinsically X-ray weak quasar, and its UV and optical spectra, dominated by low-ionization line emission, are consistent with an X-ray weak spectral energy distribution (SED). X-rays destroy small dust grains. Since PHL 1811 is intrinsically X-ray weak, it may have a very unusual IR spectrum. It should have a strong near-IR excess due to small dust grains. It may have PAH features that would be unusual in such a luminous object, and it may show emission from amorphous and possibly crystalline silicates. We propose high- and low-resolution Spitzer IRS spectroscopic observations of PHL 1811 to test the IR spectral dependence on the illuminating SED. PHL 1811 is sufficiently bright that this 0.9 hour program will provide high signal-to-noise spectra allowing sensitive detection and measurement of broadband and localized emission and absorption features. Like its unusual X-ray, UV and optical spectra, PHL 1811's IR spectrum is likely to challenge AGN models. To test SED dependence, we will compare PHL 1811's IR properties with those of three carefully-chosen comparison samples: 1.) a luminosity-matched quasar sample; 2.) a NLS1 sample; 3.) a BALQSO sample.

Spitzer Space Telescope - General Observer Proposal #3674

Discovering the Nature of LINERS: A Mutiwavelength Investigation

Principal Investigator: Claus Leitherer
Institution: Space Telescope Science Institute

Technical Contact: Claus Leitherer, Space Telescope Science Institute

Co-Investigators:
Lucimara Martins, Space Telescope Science Institute
Tim Heckman, John Hopkings University
Lee Armus, California Institute of Technology
Andrew Ptak, John Hopkings University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare
Hours Approved: 8.9

Abstract:
LINERs (Low Ionization Emission Line Regions) are the most common form of activity in the nearby universe, yet the ionization mechanism responsible for the line ratios observed in these objects is still controversial. Many of these galaxies have obscured nuclei, which complicates studies based on optical observations. Previous studies which combined different wavelength regions (Satyapal et al. 2003, Filho et al. 2004) found puzzling results and were not able to construct a consistent picture of what powers the emission lines. We propose IRS spectroscopy of a representative sample of LINERs in the mid-IR, for which we have high-resolution Chandra X-ray data, as well as high-resolution optical data. The X-ray data can reveal the presence of an AGN core, while the optical observations constrain the stellar population that may also be contributing to the gas ionization. The mid-IR penetrates dust, and will give a homogeneous set of strategic emission lines. Combining the X-ray and optical data with the mid-IR, we will be able to constrain photoionization models in a very efficient way, allowing us to understand the nature of LINERs and their significance in the global AGN/starburst context.

Spitzer Space Telescope - General Observer Proposal #50094

Disentangling the Starburst-AGN Connection

Principal Investigator: Nancy Levenson
Institution: University of Kentucky

Technical Contact: Nancy Levenson, University of Kentucky

Co-Investigators:
S. A. Uddin, University of Kentucky
G. D. Thompson, University of Kentucky

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 3.3

Abstract:
We propose to obtain IRS spectra of a complete sample of nearby optically-identified Seyfert 2 galaxies. Multiwavelength observations already provide detailed measurements of both the active galactic nuclei (AGN) and nuclear starburst properties of the sample, including luminosity and star formation rate. We will accomplish four specific science goals with this program: * We will separate the effects of AGN alone from the significant fraction (nearly 50%) of composite nuclei, which contain both an AGN and a starburst. * We will measure the geometry of the distribution of the dusty material responsible for the MIR emission, comparing with numerical models we have developed and identifying relationships with stellar and AGN properties. * We will determine whether obscuration is significantly correlated with AGN luminosity or stellar luminosity. * We will test the reliability of common star formation diagnostics, such as the strength of polycyclic aromatic hydrocarbon emission, in the presence of an AGN. The results of these investigations will be directly applicable to unobscured AGN, where comparable short-wavelength probes of star formation are ineffective against the bright AGN. Moreover, these results will help to answer the central question of luminous and ultra-luminous infrared galaxies, namely whether these energetic galaxies are powered by star formation, AGN, or a combination of the two.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #49

The Nature of Infrared-Selected QSOs

Principal Investigator: Frank Low
Institution: University of Arizona

Technical Contact: Paul Smith, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 40.2

Abstract:
Near-infrared surveys are currently uncovering a large population of previously unidentified radio-quiet active galactic nuclei (AGN). The large IR-to-optical flux ratios of many of these objects suggest that their optical emission is largely obscured from our view. Optical spectropolarimetry of some of the most luminous examples of IR-selected AGN indicates that the optical radiation is not emitted isotropically, and that these objects would be indistinguishable from UV/optically-selected AGN if the nuclei were viewed from a different vantage point. The existence of a population of obscured AGN may increase the space density of AGN by a factor of two or more, and this has major implications for theories of the origin and evolution of these accretion-powered objects. The space density of AGN also has important implications for our understanding of the history of star formation in the early universe. This program will obtain MIPS observations of a large sample of confirmed AGN discovered by the Two-Micron All Sky Survey. These measurements will place infrared-selected AGN in context with traditional UV/optical and radio AGN samples.

Spitzer Space Telescope - General Observer Proposal #20241

Feeding the greedy: Spitzer spectroscopy of Narrow Line Seyfert 1 galaxies

Principal Investigator: Dieter Lutz
Institution: MPE

Technical Contact: Dieter Lutz, MPE

Co-Investigators:
Luigi Gallo, MPE
Thomas Boller, MPE
Eckhard Sturm, MPE
Hagai Netzer, Tel Aviv University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 12.0

Abstract:
Narrow Line Seyfert 1 galaxies (NLS1) are a class holding unique clues as to the nature and evolution of AGN. Their extreme optical and X-ray spectral properties are generally believed to be due to rapid accretion at high L/L_Edd onto the nuclear black hole. NLS1 are tracing phases of active black hole growth, which are suggested to be connected to intense circumnuclear star formation events. We have assembled a team with expertise in X-ray and optical studies of NLS1, and in mid-infrared spectroscopy of galaxies, with the purpose of a detailed low and high resolution IRS spectroscopic study of 20 of the best observed local NLS1. We will study both aspects of feeding the AGN and of AGN feedback, in a project that has three main elements: (1) Rely on the high sensitivity and spatial resolution of IRS low-resolution spectra to use the aromatic 'PAH' features to detect and spatially locate star formation, testing the suggestion that NLS1 are connected to intense circumnuclear starbursts. (2) Obtain a full characterization of the nuclear mid-infrared emission line spectrum from Narrow Line Region and X-ray Dominated Regions, to better determine excitation and physical conditions in the near-nuclear regions, already known to differ from the conditions in other AGN. (3) Support the analysis of the first two questions by performing a detailed comparison of the NLS1 properties to IRS spectra of other active and inactive local galaxies, already being obtained by us and other teams in earlier Spitzer projects.

Spitzer Space Telescope - General Observer Proposal #30314

Star formation in QSOs at the peak of cosmic quasar activity

Principal Investigator: Dieter Lutz
Institution: MPE

Technical Contact: Dieter Lutz, MPE

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Paola Andreani, MPE
Linda Tacconi, MPE
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Roberto Maiolino, INAF Arcetri
Ohad Shemmer, Penn State University
Sylvain Veilleux, University of Maryland

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 46.5

Abstract:
Co-evolution of luminous AGN and powerful starbursts is a key aspect of galaxy evolution, indicated by the similar evolution with number densities peaking at z~2-3 for both quasars and submillimeter galaxies. It likely implies coexistence of significant accretion and star formation in the same objects, luminous high redshift quasars. While variously suspected from models and indirect arguments, this coexistence has not yet been reliably demonstrated due to the difficulty of detecting star formation tracers in the presence of the bright central AGN. We propose to use IRS spectroscopy of aromatic 'PAH' emission features to investigate whether extremely powerful L ~ 10^13 LSun starbursts are indeed present in luminous radio-quiet QSOs near the z~2 peak of cosmic quasar activity. We will test the idea that the rest frame far-infrared/submm emission of these objects arises largely from star formation. Our targets all have robust mm or submm detections, maximizing chances for IRS detections. This study builds on our previous use of IRS, where we have demonstrated for submillimeter galaxies that PAH emission from L ~ 10^13 LSun star formation at z~2.5 is detectable with IRS, and shown for a sample of lower luminosity local PG QSOs that AGN activity and star formation are connected, the latter producing most of the far-infrared emission.

Spitzer Space Telescope - General Observer Proposal #20493

A population of young starbursting QSOs at high redshift?

Principal Investigator: Roberto Maiolino
Institution: INAF

Technical Contact: Roberto Maiolino, INAF

Co-Investigators:
Hagai Netzer, Tel Aviv University
Ohad Shemmer, Pennsylvania State University
Masatoshi Imanishi, National Astronomical Observatory of Japan
Ernesto Oliva, INAF - Centro Galileo Galilei

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 8.3

Abstract:
In low redshift QSOs the Narrow Line Region (NLR) tends to disappear at high luminosities. This effect has been interpreted as a consequence of the NLR size extending beyond the size of the host galaxy. At high redshift, many luminous QSOs are also characterized by the total absence of the NLR, in keeping with the findings at low redshift. However, we have also found a large population of QSOs, emerging at z>2, characterized by an extremely strong [OIII]5007 Narrow Line. The inferred densities of the Narrow Line Region in these peculiar QSOs are orders of magnitude higher than in "classical" NLRs of low redshift AGNs. A possible explanation is that the hosts of QSOs with strong [OIII] emission are experiencing powerful starburst activity and that the large amount of dense gas associated with the starburst enhances the [OIII] emissivity. If this interpretation is correct, then high-z QSOs with strong [OIII] are tracing episodes of vigorous star formation associated to the Black Hole accretion. We propose to test this scenario by means of IRS low resolution spectra of a sample of QSOs z>2 with strong [OIII] emission. We expect that such mid-IR spectra should reveal PAH features tracing the putative starburst activity (at variance with low-z and [OIII]-weak QSOs), and also enhanced mid-IR emission due to a larger covering factor of the dust associated with the dense clouds emitting [OIII]. We also include a control smaple of QSOs with weak/absent [OIII], at the same redshifts. Due to the overwhelming AGN light dominating at essentially all wavelengths, PAH emission features is probably the only tool to unambiguosly test the stabursting scenario for the [OIII]-luminous QSOs at z>2.

Spitzer Space Telescope - Archive Research Proposal #3326

Far-IR Measurement of AGN and Starburst Activity in the First Look Survey

Principal Investigator: Matthew Malkan
Institution: UCLA

Technical Contact: Matthew Malkan, UCLA

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 59000.0

Abstract:
The infrared fluxes of nearly every galaxy observed so far can be fitted with a combination of these D, B, and S components, which have an underlying physical basis: the strength of B gives a measure of the recent rate of star formation, while the strength of S (in those minority of galaxies where it is present) is associated with Seyfert activity. We will use the flux ratios of the sources detected in all three MIPS bands to quantify how much of their emission comes from a quiescent disk, a starburst, or a Seyfert nucleus. The MIPS color differences between the D, B and S SEDs are so large (about an order of magnitude difference in flux ratios), that high precision photometry is not even essential. Since the MIPS classification is somewhat z-dependent, we will use the IRAC and R-band photometry of our MIPS sources to sort them approximately by redshift. We will compare estimates of the luminosity functions of starburst power and accretion power from z of 0 to above 1 In the First Look Survey field, our galaxy evolution models predict that we will have over 600 sources with a 5$\\sigma$ or better detection in {\\it all} 3 MIPS bands. We have measured photometry of all the IRAC, MIPS and R-band sources within the early release field of FLS. These measurements of source counts, magnitudes and multiwavelength colors fully confirm the feasibility of our program.

Spitzer Space Telescope - General Observer Proposal #50253

IR Observations of a Complete Unbiased Sample of Bright Seyfert Galaxies

Principal Investigator: Matthew Malkan
Institution: UCLA

Technical Contact: Matthew Malkan, UCLA

Co-Investigators:
Luigi Spinoglio, IFSI-INAF
Howard Smith, Smithsonian Center for Astrophysics
Silvia Tommasin, IFSI-INAF
Vassilis Charmandaris, University of Crete
George Bendo, Imperial College London

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 15.6

Abstract:
IR spectra will measure the 2 main energy-generating processes by which galactic nuclei shine: black hole accretion and star formation. Both of these play roles in galaxy evolution, and they appear connected. To obtain a complete sample of AGN, covering the range of luminosities and column-densities, we will combine 2 complete all-sky samples with complementary selections, minimally biased by dust obscuration: the 116 IRAS 12um AGN and the 41 Swift/BAT hard Xray AGN. These galaxies have been extensively studied across the entire EM spectrum. Herschel observations have been requested and will be synergistic with the Spitzer database. IRAC and MIPS imaging will allow us to separate the nuclear and galactic continua. We are completing full IR observations of the local AGN population, most of which have already been done. The only remaining observations we request are 10 IRS/HIRES, 57 MIPS-24 and 30 IRAC pointings. These high-quality observations of bright AGN in the bolometric-flux-limited samples should be completed, for the high legacy value of complete uniform datasets. We will measure quantitatively the emission at each wavelength arising from stars and from accretion in each galactic center. Since our complete samples come from flux-limited all-sky surveys in the IR and HX, we will calculate the bi-variate AGN and star formation Luminosity Functions for the local population of active galaxies, for comparison with higher redshifts.Our second aim is to understand the physical differences between AGN classes. This requires statistical comparisons of full multiwavelength observations of complete representative samples. If the difference between Sy1s and Sy2s is caused by orientation, their isotropic properties, including those of the surrounding galactic centers, should be similar. In contrast, if they are different evolutionary stages following a galaxy encounter, then we may find observational evidence that the circumnuclear ISM of Sy2s is relatively younger.

Spitzer Space Telescope - General Observer Proposal #30779

Contribution of Dust Emission to the Spectral Energy Distribution of Gamma-Ray Bright Blazars

Principal Investigator: Alan Marscher
Institution: Institute for Astrophysical Research

Technical Contact: Alan Marscher, Institute for Astrophysical Research

Co-Investigators:
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Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 12.3

Abstract:
A number of blazars have very high gamma-ray to IR apparent luminosity ratios, in some cases exceeding 100. While this might be the result of extreme relativistic beaming of inverse-Compton scattered radiation, the success of this model relies on the presence of a compact torus of hot dust surrounding the central engine. We propose to observe four gamma-ray bright blazars with MIPS, IRS, and IRAC in order to measure the spectral energy distribution in an effort to reveal thermal emission components from dust tori. Because the IR continuum is variable, we need two complete sets of SST observations, one in each of two visibility periods, in order to measure and subtract the time-variable, nonthermal component using an established procedure. Further subtraction of a quasi-steady synchrotron component, if present, will reveal the presence of graybody humps or silicate emission features corresponding to hot or cool dust.

Spitzer Space Telescope - Archive Research Proposal #3205

Resolution-Enhanced (HiRes) Imaging of the FLS Galactic and Extragalactic Components

Principal Investigator: Kenneth Marsh
Institution: Jet Propulsion Laboratory

Technical Contact: Kenneth Marsh, Jet Propulsion Laboratory

Co-Investigators:
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Chas Beichman, Jet Propulsion Laboratory
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Daniel Stern, Jet Propulsion Laboratory

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 115000.0

Abstract:
We propose to process all of the galactic and extragalactic images of the First Look Survey (FLS) using the ‘‘HiRes" resolution-enhancement procedure, which will increase the spatial resolution of Spizer data by a factor of between two and three over that obtainable in a standard mosaiced image. The product of this effort will be a catalog of mosaiced and resolution-enhanced images, to be released to the astronomical community at the earliest possible date. The release will include the HiRes software tool itself. As an additional task, we will undertake an analysis of the resolution-enhanced image set in order to evaluate statistically the spatial and spectral properties of the confusion in the various representative regions, and extract physical information from spatially resolved sources which will include circumstellar disks and prestellar cores. The value of HiRes for optimizing the resolution of survey data has been proven in the case of IRAS, as a result of which the scientific return of that survey was greatly increased. Similar rewards will result from its application to Spitzer data, and in particular, it will strengthen the stated goals of the FLS. We request $125K for this effort.

Spitzer Space Telescope - General Observer Proposal #30634

Two Types of Type-2?

Principal Investigator: Alejo Martinez-Sansigre
Institution: Oxford University

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Co-Investigators:
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Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 22.8

Abstract:
We propose to use the Spitzer IRS instrument to test the hypothesis that there are two distinct types of Type-2 (obscured) QSO: the first in which the nucleus is obscured at optical wavelengths by an organized torus; and the second, in which the nucleus is obscured by more distributed dust in an associated starburst. We will target a complete sample of Type-2 QSOs at z = 1.4-2 from the Spitzer First-Look Survey which, from optical spectroscopy, split into objects with high excitation, narrow-emission lines (torus-obscured QSOs?) and objects with totally blank optical spectra (starburst-obscured QSOs?). The IRS spectra will be sensitive to the the 'Silicate Break' (and PAH features) and therefore identify and provide redshifts for any starburst-obscured QSOs, whereas QSOs in which there is a clear view of hot dust in the torus, will have relatively featureless mid-IR spectra, except for the silicate absorption feature.

Spitzer Space Telescope - General Observer Proposal #40517

Infrared SEDs and dust emission from z > 5 quasars. Part I. Probing the hottest dust with Spitzer.

Principal Investigator: Klaus Meisenheimer
Institution: Max-Planck-Institut fuer Astronomie

Technical Contact: Helmut Dannerbauer, Max-Planck-Institut fuer Astronomie

Co-Investigators:
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Fabian Walter, MPIA
Xiaohui Fan, University of Arizona
Linhua Jiang, University of Arizona
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Ulrich Klaas, MPIA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 71.1

Abstract:
As part of a comprehensive multi-wavelength project to determine the Spectral Energy Distributions (SEDs) of all known quasars at z > 5, we propose Spitzer photometry in the four IRAC bands and the MIPS 24 um band. These observations are the necessary short wavelengths complement to our Herschel guaranteed time Key Project, which will measure the Far-IR SED of 77 quasars at z > 5 in the range 70 to 170 um (PACS) and 240 to 520 um (SPIRE). In addition, our target list contains 17 radio-loud quasars and galaxies at z > 3.5. The combined Spitzer plus Herschel photometry will characterize the overall Mid- to Far-infrared SEDs of a large sample of quasars at the highest redshifts in great detail and thus provide a data base of huge legacy value. We selected all those targets for this Spitzer proposal for which IRAC and MIPS photometry are neither observed nor scheduled. The proposed observations will cover rest-frame wavelengths between 0.5 and 4 um which will allow us to detect the hottest dust as an excess of the measured 24 um flux (above the UV-optical continuum as derived from the IRAC bands and NIR photometry). Our observations will enlarge the present samples of z > 5 quasars with Mid-IR photometry by a factor of 4. This will allow us to determine the frequency of peculiar (dust-free ?) objects detected in previous studies and to carry out statistical investigations of the relation between UV-optical spectrum from the accretion disk and the emission from the hottest part of the dust torus.

Spitzer Space Telescope - General Observer Proposal #3726

The symbiosis of AGN activity and galaxy formation

Principal Investigator: Jonathan Mittaz
Institution: University of Alabama at Huntsville

Technical Contact: Jonathan Mittaz, University of Alabama at Huntsville

Co-Investigators:
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Jason Stevens, Astronomy Technology Centre, ROE
Francisco Carrera, IFCA, University of Cantabria, Spain
Rob Ivison, Astronomy Technology Centre, ROE
Ian Smail, Institute for Computational Cosmology, University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 6.0

Abstract:
According to galaxy formation models, cluster ellipticals formed in high density regions through hierarchical merging of gas rich sub-components. In local ellipticals, the strong correlation observed between black hole and bulge mass implies that galaxy formation is inextricably linked to the build up of supermassive black holes. We have found 6 high redshift, X-ray luminous, but heavily absorbed AGN, embedded in strong bursts of star formation revealed in the submillimetre. Our SCUBA survey shows that the immediate vicinities of these objects contain large overdensities of ultraluminous star-forming galaxies which will evolve to form clusters. Here we propose to use SPITZER to measure the stellar masses of the companion galaxies, search for buried AGN, and thereby determine the sequence in which the cluster ellipticals are assembled, form their stars, and grow their massive black holes.

Spitzer Space Telescope - General Observer Proposal #41023

The Evolution of Faint AGN at High Redshift

Principal Investigator: Kirpal Nandra
Institution: Imperial College London

Technical Contact: Kirpal Nandra, Imperial College London

Co-Investigators:
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Pauline Barmby, SAO
Mark Davis, UC Berkeley
Mark Dickinson, NOAO
Sandra Faber, UC Santa Cruz
Giovanni Fazio, Harvard University
Antonis Georgakakis, Imperial College London
Puragra Guhathakurta, UC Santa Cruz
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Rob Ivison, University of Edinburgh
David Koo, UC Santa Cruz
Shinae Park, SAO
Ranga Ram-Chary, Caltech
David Frayer, IPAC/Caltech

Science Category: AGN/Quasars/Radio Galaxies
Observing Modes: IracMap
Hours Approved: 46.0

Abstract:
We propose a very deep (total 800ks/field) Chandra survey of 0.25 deg2 covering 3 contiguous fields in the Extended Groth Strip, which have exceptional multiwaveband coverage obtained by the AEGIS project. These data, in combination with the CDF North and South, will provide a definitive measurement of the evolution of faint, X-ray selected AGN from z=3-4, where the optical number counts start to drop dramatically. In combination with ultradeep Spitzer data in the same region, this survey will also provide a crucial step forward towards a more complete census of AGN activity and the importance of Compton thick AGN at high z, with associated implications for the total accretion budget of the universe.

Spitzer Space Telescope - General Observer Proposal #20142

Spectroscopy of the Dusty Torus in PG Quasars

Principal Investigator: Patrick Ogle
Institution: Caltech

Technical Contact: Patrick Ogle, Caltech

Co-Investigators:
Robert Antonucci, University of California, Santa Barbara
David Whysong, University of California, Santa Barbara

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 30.5

Abstract:
We propose IRS SL+LL spectroscopic observations of the dusty tori in the complete sample of UV-color selected PG quasars with redshift z<0.5. We will model each torus emission spectrum to determine torus covering fraction, temperature distribution, and dust composition. The torus covering fraction may be a function of quasar age, determined from host galaxy merger stage. We will also compare the torus and broad emission line properties of the PG quasars to determine if covering fraction is the key parameter determining Fe II and [O III] emission strengths. Additionally, we will search for a connection between torus covering fraction and black hole accretion rate relative to the Eddington limit. In this way, we hope to illuminate the connections between the properties of the torus as a fuel reservoir, the broad line region, and the accretion flow powering the quasar.

Spitzer Space Telescope - General Observer Proposal #50683

Evolution of Compact Quasars and Radio Galaxies

Principal Investigator: Patrick Ogle
Institution: Caltech

Technical Contact: Patrick Ogle, Caltech

Co-Investigators:
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Christian Leipski, University of California, Santa Barbara
Christopher O'Dea, Rochester Institute of Technology
Stefi Baum, Rochester Institute of Technology
Alvaro Labiano, Instituto de Estructura de la Materia (CSIC)
Makoto Kishimoto, MpIfR, Bonn
Gerardo Vazquez, Johns Hopkins University
David Whysong, NRAO VLA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 36.0

Abstract:
Compact (CSS/GPS) quasars and radio galaxies have small sizes (<20 kpc) and young expansion ages (<10^6 yr). They may be the progenitors of the larger (100 kpc), older "classical" (FRII) radio galaxies and quasars. We propose to take IRS spectra of a large sample of compact radio sources with sizes of 0.03-20 kpc at redshift z=0.4-1.0 to study AGN feedback and galaxy evolution. We will study the evolution of the star formation rate with radio source size by measuring PAH feature strengths with IRS and far-IR emission with MIPS. The radio jet may have a large impact on the host galaxy interstellar medium, via shock heating, shock-induced star formation, and by driving outflows. We will search for jet shock-heated molecular hydrogen and ionized gas, and study the dependence of silicate absorption depth on radio jet size. Together with our previous Spitzer observations of FR I and FR II radio galaxies, which have sizes of 20kpc-1Mpc, we will have a complete view of radio galaxies and quasars and their hosts over a large range of sizes, luminosities, and ages.

Spitzer Space Telescope - General Observer Proposal #50309

Investigating the Physics of ISM in Type 2 QSOs

Principal Investigator: Andreea Petric
Institution: Spitzer Science Center

Technical Contact: Andreea Petric, Spitzer Science Center

Co-Investigators:
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Nick Seymour, Spitzer Science Center
Anna Sajina, Haveford College
Lisa Storrie-Lombardi, Spitzer Science Center
Lee Armus, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 45.5

Abstract:
One of Spitzer's major contributions to the study of galaxy formation and evolution has been the detection of large numbers of obscured AGN. Spitzer found a large number of bigger and bolometrically brighter versions of Seyfert 2's, known as type 2 QSOs, whose existence had, until recently, only been theorized. Here, we propose to use IRS high resolution capabilities to perform a detailed analysis of the emission lines in a sample of six 0.3<z<0.8 type 2 quasars, with existing HST images and lo-res spectra. HST images, spectral energy distributions from optical to infrared wavelengths and low resolution IRS spectra allowed us for the first time to present a coherent picture of the nature of star formation in the host galaxies of type 2 quasars, though several questions remain. We intend to address those here: Specifically our goals are to: (1) reveal the excitation conditions of MIR lines, and the importance of the buried AGN and starbursts by studying the relation of high-ionization fine structure lines to the equivalent widths of 6.2 micron PAHs emission lines (2) determine the mass and temperature of warm molecular gas in type 2 QSOs by searching for H2 emission in at least two transitions (3) determine the types of silicates present in the most absorbed AGN in our sample to reveal their origin by investigating the structure of the silicate absorptions profiles and look for crystalline structures as found in some heavily absorbed ULIRGs . Any picture of how galaxies evolve, must account for the properties of all the classes of active objects from luminous opitically selected quasars, to submm galaxies and luminous infrared galaxies, local and high redshift sources. The proposed high resolution observations are imperative if we are to be able to compare these type 2 QSOs to local active objects such as LIRGs ULIRGs and to meaningfully interpret our findings from low resolution observations

Spitzer Space Telescope - General Observer Proposal #40398

The obscuring dust in the Compton-thick type 2 QSO SW104409

Principal Investigator: Mari Polletta
Institution: University of California, San Diego

Technical Contact: Mari Polletta, UCSD

Co-Investigators:
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Duncan Farrah, Cornell University
Belinda Wilkes, SAO
Carol Lonsdale, UCSD, IPAC/Caltech
Frazer Owen, NRAO

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 3.1

Abstract:
SW104409 is a remarkable and peculiar type 2 QSO. It is extremely luminous and absorbed by Compton-thick gas in the X-rays, shows a deep silicate feature in absorption in the mid-infrared, and narrow emission lines in the optical, and it falls in the category of Extremely Red Object. On the other hand, its optical spectrum shows a blue continuum, faint broad and asymmetric emission lines and its near-infrared spectrum is dominated by extremely hot dust emission. In order to explain these apparently contradicting properties, we suggest a scenario in which the inner walls of the obscuring torus are visible, an external dust component in the host galaxy produces the observed absorption signatures, and the optical continuum and broad lines are from scattered light. The probe that the observed absorption signatures are produced by dust in the host, will imply that there are even less real type 2 AGNs than it appears and the fraction of type 2 AGNs at high luminosities is even smaller as originally inferred, supporting the 'receding torus' scenario. In order to test this scenario, we propose to obtain a high (>30) S/N IRS low-resolution spectrum of SW1044009. Such a high quality spectrum will allow us to better characterize the near-infrared continuum and spectral features. The most recent clumpy torus models for highly obscured systems will be tested by comparing their predictions with the observed spectrum. There are few known sources in the literature with similar mid-infrared properties, but SW104409 is the brightest among all of them and benefits from a much richer multi-wavelength data set, from X-ray to radio. SW104409 is the only source of this kind to be bright enough to study in detail with a reasonable request of time (3 hours).

Spitzer Space Telescope - General Observer Proposal #50388

Obscuration in luminous AGNs

Principal Investigator: Mari Polletta
Institution: Institut d'Astrophysique de Paris

Technical Contact: Mari Polletta, Institut d'Astrophysique de Paris

Co-Investigators:
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Frazer Owen, NRAO
Dan Weedman, Cornell

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 37.5

Abstract:
Spitzer has unveiled a population of obscured QSOs whose fraction among all mid-infrared selected AGNs is higher than the fraction of obscured AGNs found at optical and X-ray wavelengths. Multi-wavelength observations of these mid-infrared selected obscured QSOs indicate that a sizable fraction of them are not obscured by the putative torus, but by cold dust outside the torus, and that the torus opening angle increases at higher luminosities, supporting the receding torus scenario. We propose to study the MIR spectra of a complete sample of obscured QSOs at 1.3<z<3 with large mid-infrared luminosities to 1) constrain the true (not-wavelength-dependent) fraction of obscured AGNs at high luminosities, 2) obtain the first unbiased luminosity function of obscured QSOs, 3) investigate the properties of the obscuring matter across the multi-wavelength spectrum, and 4) investigate whether star-formation activity affects obscuration in QSOs. The sample contains 29 sources of which 15 have already been observed with the IRS by previous programs. We thus require IRS observations for the remaining 14 sources, necessary to reach completeness in redshift-luminosity space, and cover >1 dex in luminosity.

Spitzer Space Telescope - General Observer Proposal #30294

IRS mapping of the 500 pc nuclear dust shell in Centaurus A

Principal Investigator: Alice Quillen
Institution: University of Rochester

Technical Contact: Alice Quillen, University of Rochester

Co-Investigators:
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Mairi Brookes, JPL
Charles Lawrence, JPL
J.D. Smith, University of Arizona
Kieran Cleary, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsMap
Hours Approved: 15.8

Abstract:
We propose to map the central 1.5' of Centaurus A with IRS. This region covers a recently discovered 500pc bipolar shell. This shell, if confirmed, could be the only extragalactic nuclear shell with a mid-infrared counter part. Hence Centaurus A represents a unique laboratory to test scenarios and models of feedback from an AGN or/and circumnuclear star formation on the ISM near the nucleus. By comparing the IRS spectra of the shell component with the star forming parallelogram shaped region corresponding to the warped disk, we will seek confirmation that the shell is a separate and coherent structure, and better estimate its dust temperature and so mass. Derived constraints on its energetics will form the basis of subsequent models accounting for its formation. We will search for evidence of shocks in the shell due to its formation and where the jets pass through it. As the shell covers all solid angles from the nuclear black hole, the IRS spectra will also be used to search for angular variations in the ambient UV radiation field.

Spitzer Space Telescope - Archive Research Proposal #30347

9-D Bayesian Quasar Classification in the Mid-IR/Optical

Principal Investigator: Gordon Richards
Institution: Johns Hopkins University

Technical Contact: Gordon Richards, Johns Hopkins University

Co-Investigators:
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Alex Gray, Georgia Tech
Robert Nichol, Portsmouth
Alex Szalay, Johns Hopkins University

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 49297.0

Abstract:
One of the hottest topics in extragalactic astronomy is the identification and census of type 2 quasars. Type 2 selection benefits enormously from the high quality imaging data afforded by the Spitzer Space Telescope since these objects are generally too obscured in the optical for efficient selection in that bandpass. We propose to develop a novel classification algorithm to aid in this endeavor. Bayesian quasar classification based on Kernel Density Estimation (Richards et al. 2004) and photometric redshift estimation (Weinstein et al. 2004) has already been shown to be very efficient in the optical using only the 5 SDSS bandpasses. Additional bandpasses, such as afforded by Spitzer-IRAC imaging, can be used to further improve this selection method and photometric redshift estimation. With appropriate tuning of our algorithms, we can meet two key goals. First is to construct a catalog of type 1 quasars in the roughly 50 square degrees of sky that currently have (or will have by the end of 2006), public data from both SDSS and Spitzer-IRAC. Such a catalog (including accurate photometric redshifts) will enable a second goal, namely more efficient type 2 quasar searches. We will improve the efficiency of type 2 quasar discovery by removing those mid-IR luminous type 1 quasars from the sample of objects that are currently being followed-up with multi-object spectroscopy on larger telescopes, and also by better isolating the type 2 quasar parameter space. We request $49927 of support to adapt our classification and photometric redshift algorithms to make use of the Spitzer-IRAC data and to publish a catalog of quasars identified by these algorithms.

Spitzer Space Telescope - Archive Research Proposal #3284

Optical-IR SEDs of SDSS Quasars in the Archival Spitzer-FLS Data

Principal Investigator: Gordon Richards
Institution: Princeton University

Technical Contact: Gordon Richards, Johns Hopkins University

Co-Investigators:
Patrick Hall, Princeton University
Sarah Gallagher, UCLA
Dean Hines, Space Science Institute
Mark Lacy, SSC
Lisa Storrie-Lombardi, SSC
Daniel Vanden Berk, Pittsburgh
Sebastian Jester, Fermilab
Scott Anderson, University of Washington
Xiaohui Fan, University of Arizona
Michael Strauss, Princeton University
Donald Schneider, Penn State
Donald York, University of Chicago

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 49894.0

Abstract:
We propose to study the relationship between the optical/UV and mid- to far-IR for normal quasars, dust reddened quasars, and broad absorption line quasars. This project builds on earlier quasar spectral energy distribution (SED) work, mostly using the PG sample of quasars, by extending our knowledge of the IR properties of quasars to higher redshifts and lower luminosities. Our sample will consist of ~40 spectroscopically confirmed quasars (with ~2 Angstrom resolution optical spectra) and ~160 fainter photometrically selected quasars (with accurate photometric redshifts) from the Sloan Digital Sky Survey that are in the Spitzer First Look Survey area. We will extract the IRAC and MIPS photometry for all these spectroscopically confirmed and photometrically selected quasars. Such a sample will contribute significantly to our knowledge of the UV to far-IR SEDs of normal quasars, which will be useful as a basis for comparison with unusual or obscured quasars. In addition we will probe the nature of the reprocessed dust emission through the detailed shape of the IR bump and investigate the AGN-starburst connection with the aid of very long-wavelength data where the starburst contribution is expected to be greatest.

Spitzer Space Telescope - Archive Research Proposal #3433

The Far-Infrared Properties of A Large Radio Selected Sample in the SIRTF-FLS

Principal Investigator: Eric Richards
Institution: Talaldega College

Technical Contact: Eric Richards, Talaldega College

Co-Investigators:
Don Walters, South Carolina State University

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 37553.0

Abstract:
We propose to analyze the infrared properties of a large sample of 10,000 radio sources within the principal SIRTF-First Look Survey. Our focus primarily will be on the far infrared photometry at 24, 70, and 160 microns of these radio objects selected at 1.4 GHz above 80 muJy. This study will constitute the single largest microJy radio sample to date allowing for characterization of their optical identifications, and source of radio-FIR radiation as primarily star-forming and/or non-thermal via AGN activity. We will create the following data products for dissemination to the astronomical community: 1) a catalog of 6,000 radio objects identified in the SIRTF-FLS survey above 80 muJy complete with radio, optical, X-ray, near and far infrared photometry and redshifts (or limits) where possible. 2) An aggregate and bi-variate radio and far-infrared luminosity function constructed from the complete sample of 3565 radio sources between redshifts of 0.1 to 3 to an accuracy of 10% or better. 3) An angular correlation function and study of the clustering properties of radio and infrared selected galaxies over spatial distances of 1-100 Mpc. 4) A list of unusual objects based on extreme colors and radio/optical properties for follow-up.

Spitzer Space Telescope - General Observer Proposal #50087

Is the Structure of the Dusty Torus Related to the Physics of the Accretion Disk?

Principal Investigator: Gordon Richards
Institution: Johns Hopkins University

Technical Contact: Gordon Richards, Johns Hopkins University

Co-Investigators:
Moshe Elitzur, University of Kentucky
Sarah Gallagher, UCLA/UWO
Dean Hines, Space Science Institute
Zeljko Ivezic, University of Washington
Martin Elvis, SAO
Rajesh Deo, Drexel University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 19.3

Abstract:
We propose to investigate the question ''Is the structure of the dusty torus related to the physics of the accretion disk'?'' using low resolution IRS spectra of a sample of high-redshift quasars. We will observe a representative sample of 18 bright SDSS quasars with 1.6<z<2.2 with IRS in low resolution mode. This redshift range brings the most sensitive continuum and emission line diagnostics into the optical and mid-IR bandpasses. Using these data we will explore the ability of IR data to reveal physical quasar parameters by comparison with clumpy torus models which make predictions for IR spectra of quasars as a function of dust structure and composition, orientation, and optical/UV continuum shape. When coupled with other indicators of accretion rate, mass, and orientation from the optical/UV, these IR observations will allow more detailed exploration of the relationship between the physical parameters that drive quasars (e.g., mass, accretion rate, and orientation) and their observed properties. These data will also enable critical testing of the new clumpy torus modeling paradigm itself. A total of 19.3 hours of Spitzer-IRS time is requested on 18 targets. With these data and 4 archival IRS observations, we will construct a template quasar spectrum covering 1.6-12 microns, complementing the lower redshift (longer wavelength) templates from Buchanan et al. (2006) and providing a legacy data set for future IR missions.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #59

Starburst Activity in Nearby Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot MipsScan
Hours Approved: 45.3

Abstract:
This program combines MIPS and IRAC imaging and MIPS and IRS spectroscopy (where available) of a sample of nearby starburst galaxies, over a range of metallicity and luminosity that includes the lowest metallicity galaxies known. These galaxies are near enough that groundbased support data already exist for many of them and they are bright enough that observing them does not take much time (except for the lowest metallicity galaxies). These data will be combined with new groundbased data and data from the literature to constrain a suite of starburst models. The models will provide the age and intensity of the burst that is consistent with the observations over a broad range of wavelengths and could be used to predict the subsequent evolution of the galaxy properties. Furthermore, this extremely detailed study of a small sample of starburst galaxies would provide the insight required to interpret observations of more distant galaxies (such as in the cosmological surveys) where we may only have a few photometric data points.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #61

Intrinsic Spectra of Hyperluminous Infrared Galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Dean Hines, Space Science Institute

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 8.2

Abstract:
We will use the low and high spectral resolution capabilities of the IRS aboard SIRTF to obtain high signal-to-noise mid-infrared spectra of a small sample of the most luminous Active Galactic Nuclei, which are characterized by their "warm" far-infrared spectral energy distributions as obtained by IRAS (the so called Hyperluminous Infrared Galaxies or HIGs). The sample consists of both Type 2 and Type 1 AGNs. The Type 1 objects present a relatively unobscured view of the central engine, and also have a polarized (scattered) component that is completely unobscured. The Type 2 objects have Type 1 polarized spectra, but this scattered light is highly extinguished indicating some obscuration even along the line of sight to the scattering region. The sample will allow us to compare the properties of the Type 1s and Type 2s, thus providing a check on the orientation and providing strong constraints on the geometry and internal structure of all four objects.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #82

The Far-IR Spectral Energy Distributions of Luminous Active Galactic Nuclei

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Dean Hines, Space Science Institute

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot MipsSed
Hours Approved: 88.2

Abstract:
The Far-IR Spectral Energy Distributions of Luminous Active Galactic NucleiHines, G.Rieke, Neugebauer, LowBy obtaining accurate photometry in the three MIPS bands, we will address the relationship between different forms of luminous AGNs, the evolution of AGN properties with redshift, and which physical processes regulate the energy outputs. In particular, unification schemes posit that various types of AGN (e.g., QSO vs. Hyperluminous Infrared Galaxy) are fundamentally similar in nature, but appear to have diverse properties because they are viewed at different angles. These aspect angles accentuate or de-emphasize emission at various wavelengths and from various regions near the central engine. We concentrate on sub-sets of the most luminous 10-20 objects each drawn from complete catalogs with z <= 0.3 and selected on different bases e.g., x-ray brightness, high frequency radio brightness, etc.. Use of previously well defined samples and the z <= 0.3 redshift limit aids completeness and ensures access to large existing databases and high resolution imaging. We supplement the core sample with two small samples of AGNs at z ? 2 and z >= 4.5 to probe evolutionary trends. This comparison will be particularly important for evaluating the effectiveness of our low-z SEDs as templates for identifying very high redshift AGNs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30306

MIPS Imaging of the Unusually Hot Type 1 QSO PG1307+085

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Dean Hines, Space Science Institute

Co-Investigators:
Dean Hines, Space Science Institute
Paul Smith, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 0.1

Abstract:
We propose new MIPS 24 and 70 micron imaging of the remarkable QSO, PG1307+085. Our previous MIPS observations indicate that this object may have the hottest mid-to-far infrared spectral energy distribution of any known QSO. There are reported ISO results that seem to contradict our MIPS measurements, and although we can find no obvious anomalies in either data set, we take the conservative approach to reobserve the object with MIPS.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30337

MIPS Imaging of the Hot Spots in Pictor A

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Dean Hines, Space Science Institute

Co-Investigators:
Dean Hines, Space Science Institute

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 0.3

Abstract:
We propose to obtain 24 and 70 micron images of the western hot spot in the classical double-lobed radio galaxy, Pictor A. We will also obtain a 70 micron image of the eastern hot spot to accompany our existing 24 micron image. When supersonic jets launched by an active galactic nucleus encounter the intergalactic medium, they form bow shocks. Relativistic electrons within this region are re-accelerated by compressed magnetic fields, which produces strong synchrotron emission. These hot spots represent important laboratories for high-energy physics, and considerable effort has been made to understand their structures and energy distributions. Changes in slope of the hot spot spectral energy distribution (SED) are directly related to the particle energy distribution and the magnetic field strength, and typically a hot spot SED appears to have a single break in slope. Based on extrapolations from the radio and optical wavelengths, the break appears to occur in the mid-infrared, but to date there are no mid-to-far infrared measurements of hot spots in radio lobes. We seek to remedy this situation by observing one of the rare radio galaxies where the angular extent of the lobes allows the hot spots to be imaged at both 24 and 70 microns. The MIPS observations will enable the tightest constraints yet available to be placed upon the electron energy distributions within the hot spots of Pictor A. Our results will also help inform studies of other hot spots that cannot be measured at 70 microns.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30419

IRS Observations of IR-Selected Obscured QSOs in Deep X-ray Fields

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Jennifer Donley, University of Arizona

Co-Investigators:
Jennifer Donley, University of Arizona
Dave Alexander, University of Cambridge
Jane Rigby, University of Arizona
Dean Hines, Space Science Institute
Yong Shi, University of Arizona
Pablo Perez-Gonzalez, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 26.2

Abstract:
Because of their optically-faint nature, obscured AGN have historically been difficult to detect. The dust that obscures the optical, UV, and soft X-ray emission, however, re-radiates in the mid-infrared, making Spitzer the ideal tool for studying these elusive objects. We propose low-resolution Spitzer IRS spectroscopy of 10 optically faint, mid-infrared bright sources identified in the Extended-Chandra Deep Field-South (E-CDF-S) and Extended Groth Strip (EGS). The IRS spectra of the majority of such sources observed thus far (~75%) are dominated by silicate absorption features or are featureless, and as such, are best-fit by obscured AGN templates. Infrared spectra by themselves, however, do not provide an unambiguous distinction between obscured AGN and obscured starburst activity. The most direct way to distinguish between these two scenarios is with deep X-ray observations, observations not available in the fields in which these sources have previously been selected. Deep (>200 ks) Chandra X-ray observations are available in both the E-CDF-S and EGS. In combination with the X-ray data, we will use the IRS spectral properties (redshifts, silicate/PAH strengths) to characterize the quasar/AGN content of these sources. In addition, this study will allow us to compare properties of infrared and X-ray selected obscured AGN, and place stringent constraints on the space density of obscured quasar activity.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30443

How do Buried "Compton-thick" AGN Reprocess Their Energy?

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Jane Rigby, University of Arizona

Co-Investigators:
Jane Rigby, University of Arizona
Jenn Donley, University of Arizona
Dean Hines, Space Science Institute
Yong Shi, University of Arizona
Michael Werner, JPL
Varoujan Gorjian, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot MipsSed
Hours Approved: 7.9

Abstract:
Forty percent of local AGN are obscured by such thick columns of gas and dust that essentially no UV, optical, or <8 keV X-ray photons escape. Such "Compton--thick" AGN presumably reprocess this absorbed energy into infrared photons, but we know very little about how this works. At what wavelengths is the energy re-emitted? How much energy is re-emitted by very hot dust (radiating at 10-20 micron), and how much is re-emitted by cool dust (radiating longward of 160 micron)? What does that say about the circumnuclear structure? To answer these questions, we propose to obtain high--quality 3.5--160 micron spectral energy distributions (SEDs) of a sample of nine nearby Compton--thick AGN. In order to avoid the usual confusion over whether IR emission comes from star--formation or black hole accretion, we select only Compton--thick AGN whose host galaxies are morphologically earlier than Sa (and therefore unlikely to have much ongoing star formation.) Obtaining these SEDs will require multiple Spitzer modes: IRAC photometry, IRS spectroscopy, MIPS SED mode, and MIPS photometry. We will combine this data with near--infrared observations from the literature and new sub-mm measurements to create high--quality 0.4--850 micron SEDs. These SEDs, covering the entire infrared regime, will show how Compton--thick AGN reprocess the energy from their buried nuclei. These SEDs are also desperately needed to understand the higher--redshift universe. One of the major questions about deep MIPS surveys is what fraction of the 24 micron light may be coming from buried AGN rather than star--forming galaxies. By measuring the SEDs of nearby Compton--thick AGN, we will have templates to apply to the higher-redshift universe. This will provide much better constraints on the fraction of the infrared background light coming from AGN (rather than star formation.)

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40053

Mid-Infrared Variability of AGN

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Paul Smith, University of Arizona

Co-Investigators:
Paul Smith, University of Arizona
Yong Shi, University of Arizona
Jane Rigby, The Observatories of the Carnegie Institution of W
Dean Hines, Space Science Institute
Gerry Neugebauer, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 14.6

Abstract:
Several issues dealing with the nature of flux variations of active galactic nuclei (AGN) in the thermal infrared remain unresolved after decades of investigation. Resolving the existing ambiguities will yield invaluable information concerning the physical processes important in these objects and the size of the region responsible for the IR continuum. Two sources of emission can dominate in the mid-infrared and provide a large fraction of the bolometric luminosity of AGN: (1) Synchrotron light is important for radio-loud AGN, and is generally observed to be highly variable at other wavelengths. (2) Thermal radiation from warm dust close to the central engine produces an enormous IR signature in many AGN and is likely to be dominant for radio-quiet AGN. We propose to re-observe a large sample of AGN of various types that have been measured at 24 microns by Spitzer during earlier observing cycles to identify variable objects. The stability of the well-characterized MIPS 24-micron channel, allow for the detection of <2-3% variations in the flux relative to the earlier MIPS measurements over a time scale 1-4 yr. Detection of flux variations at 24 microns identify nonthermal sources of IR emission given that changes in thermal emission sources occur over much longer time scales. Sizable radio-loud and radio-quiet subsamples are selected for systematic comparison.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40385

An Unusual Type of AGN: A Challenge to the Unification Model

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Yong Shi, University of Arizona

Co-Investigators:
Jennifer Donley, University of Arizona
Dean Hines, Space Science Institute
Jane Rigby, Carnegie Observatories
Paul Smith, University of Arizona
Yong Shi, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 2.1

Abstract:
We propose to obtain the IR spectral energy distributions (SEDs) of a small sample of unusual AGN--optically type 1.8/2 objects with little X-ray obscuration. Their extreme properties relative to the current unification model of AGN are our best means to refine the model and may identify exceptions that would strongly modify our overall view of the subject. There are various possibilities for the origin of this type of AGN: (1) they do not harbor broad line regions, which also implies that the torus does not exist or does not obscure our direct view of the nucleus if it is present; (2) dust survives in the broad line regions of these objects to obscure the broad line regions but not the X-rays; (3) the torus is very clumpy, permitting X-rays to pass but blocking the broad line regions. Spitzer data will test the above possibilities and provide information to improve the standard unification model.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40936

A Complete Sample of Seyfert Galaxies in the Local Universe

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Aleks Diamond-Stanic, University of Arizona

Co-Investigators:
Yong Shi, University of Arizona
Jennifer Donley, University of Arizona
Jane Rigby, Carnegie Institute
Almudena Alonso-Herrero, CSIC, Spain

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 27.6

Abstract:
We propose new Spitzer observations that will establish the infrared properties of a complete sample of Seyfert galaxies in the nearby Universe. Our sample, which includes all known B < 13.0 Seyferts in the Revised Shapley-Ames catalog, reduces biases found in other samples selected at optical/X-ray/IR wavelengths against type 2 and low-luminosity nuclei, and against AGN in edge-on host galaxies. These new observations, combined with existing archival data, will complete IRS low resolution, MIPS imaging at 24 microns, and IRAC imaging for the nuclei of the 91 Seyferts in the sample. With this data set, we will quantify on a firm statistical basis the differences between the infrared properties of type 1 and type 2 AGNs. We will also constrain the nature of the dust surrounding the central engine and identify trends as a function of luminosity and star-forming activity. The majority of these galaxy nuclei are also detected by Chandra or XMM Newton, and we plan to propose to get images of the remainder. Together with the existing optical data, it will be possible to extend this study across the electromagnetic spectrum. The sample lets us study the Seyfert phenomenon where it can best be studied - in the nearby Universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50099

Mid-Infrared Variability of Radio-Loud AGN

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Paul Smith, University of Arizona

Co-Investigators:
Paul Smith, University of Arizona
Yong Shi, University of Arizona
Jane Rigby, OCIW
Dean Hines, Space Science Institute
Gerry Neugebauer, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 0.2

Abstract:
Initial results for our MIPS Cycle 4 GTO program to measure the flux variability of 142 low-redshift AGNs at 24 microns include the finding that radio-quiet objects are not variable at a level of >2% over a time scale of 1-3 years. Of the 30 radio-quiet objects observed so far at two epochs, none show evidence of variability despite the targets having being drawn from various optical, near-IR (2MASS), and IRAS samples. This result argues against nonthermal emission as a significant contributor to the IR flux for both types 1 and 2 radio-quiet AGN. In contrast, 11 of 27 radio-loud AGN varied by >5% in flux density at 24 microns. These objects include gamma-ray-detected flat-spectrum radio sources and Fanaroff-Riley types I and II radio galaxies. As expected, the gamma-ray detected AGN show the highest degree of variability (e.g., PKS 1510-089 was found to be more than a factor of 3 brighter two years after it was first observed with MIPS). Unexpectedly, however, little evidence for variability was found for the three X-ray selected BL Lac objects observed so far. We propose a third epoch of 24 micron flux density measurements for the radio-loud portion of the sample (57 objects). These observations will confirm marginal variability detections from the first two epochs and allow for a more robust comparison of the variability amplitudes for various classes of radio-loud AGN.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50138

X-ray Obscured Broad-Line AGN

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Jennifer Donley, University of Arizona

Co-Investigators:
Yong Shi, University of Arizona
Paul Smith, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot IrsPeakupImage
Hours Approved: 11.3

Abstract:
While the vast majority of Type I AGN show little or no X-ray obscuration, approximately 10% are heavily obscured with X-ray column densities of N_H > 10^22 cm^-2. In addition to providing a unique and necessary test of the unified model, the study of these AGN has significant consequences for our understanding of the cosmic X-ray and infrared backgrounds, and therefore for the cosmic accretion and star-formation histories of the universe. A number of explanations have been proposed to explain the seemingly contradictory behavior of these X-ray obscured, broad-line AGN, including (1) dust sublimation near the central engine, (2) dust coagulation, (3) obscuration by clouds in the broad-line region, (4) column density variability, and (5) scattering of the broad emission lines off a reflecting medium. We therefore propose for MIPS and IRAC observations of the 11 sources in our sample of 13 for which this data is not yet available. In addition, we propose low-resolution IRS spectroscopy for the brightest 5 sources as well as 1 faint source with an exceptionally high column density, and IRS Peak-Up imaging at 16 microns for the remaining 7 sources. The MIPS, IRAC, and IRS Peak-Up photometry will allow us to test for the presence of hot dust, which may be in the process of being destroyed through dust sublimation. IRS spectroscopy will allow us to test for the presence of the 9.7 micron silicate feature, which should not be present if the dust distribution is dominated by large grains as predicted in some models, or which may be seen in emission if the broad-line region clouds are themselves responsible for the odd behavior of these AGN. In combination with polarimetric data and high-quality optical spectra from the Bok 90" telescope, these observations will provide us with the ideal dataset to test concretely for the first time the many potential explanations for the strange behavior of these unexpected AGN.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50196

Cosmic Evolution of Star Formation in Quasar Hosts from z=1 to the Present

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Yong Shi, University of Arizona

Co-Investigators:
Yong Shi, University of Arizona
Patrick Ogle, California Institute of Technology
Sukanya Chakrabarti, Harvard University
Linhua Jiang, University of Arizona
Dean Hines, Space Science Institute
Paul Smith, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 25.1

Abstract:
We propose to obtain IRS spectroscopic observations of the 6.2 um aromatic features for 57 optically selected quasars at 0.8<z<1.0. The main goal is to construct the luminosity function of the star formation rate (SFR) in quasar hosts at this redshift range. The interplay between blackhole accretion and star formation is a fundamental physical process in regulating galaxy evolution and blackhole growth. Although various models have been proposed to explore this interaction, they are not well constrained because the SFR is difficult to measure during the quasar phase, when observations are contaminated severely by nuclear emission. We have employed the aromatic feature observed with Spitzer to investigate the star formation in the complete PG quasar sample at z<0.5. Our study has shown that the luminosity function of the SFR in PG quasars is much flatter than that of field galaxies. Combining this proposal with the result for PG quasars at z<0.5, we can probe the cosmic evolution of the SFR in optically bright quasar hosts from z=1 to the present. This study will: 1.) determine the star-forming environments of high-redshift quasars; 2.) characterize the ULIRG-quasar connections at z=1; 3.) study evolution of the dusty AGN torus and role of host galaxy star formation in AGN torus properties.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50499

Mid-Infrared Variability of Radio-Loud AGN

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Paul Smith, University of Arizona

Co-Investigators:
Paul Smith, University of Arizona
Yong Shi, University of Arizona
Jane Rigby, OCIW
Dean Hines, Space Science Institute
Gerry Neugebauer, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes:
Hours Approved: 6.2

Abstract:
Initial results for our MIPS Cycle 4 GTO program to measure the flux variability of 142 low-redshift AGNs at 24 microns include the finding that radio-quiet objects are not variable at a level of >2% over a time scale of 1-3 years. Of the 30 radio-quiet objects observed so far at two epochs, none show evidence of variability despite the targets having being drawn from various optical, near-IR (2MASS), and IRAS samples. This result argues against nonthermal emission as a significant contributor to the IR flux for both types 1 and 2 radio-quiet AGN. In contrast, 11 of 27 radio-loud AGN varied by >5% in flux density at 24 microns. These objects include gamma-ray-detected flat-spectrum radio sources and Fanaroff-Riley types I and II radio galaxies. As expected, the gamma-ray detected AGN show the highest degree of variability (e.g., PKS 1510-089 was found to be more than a factor of 3 brighter two years after it was first observed with MIPS). Unexpectedly, however, little evidence for variability was found for the three X-ray selected BL Lac objects observed so far. We propose a third epoch of 24 micron flux density measurements for the radio-loud portion of the sample (57 objects). These observations will confirm marginal variability detections from the first two epochs and allow for a more robust comparison of the variability amplitudes for various classes of radio-loud AGN. The is part 2 of program 50099.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50507

Quasar and ULIRG Evolution

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Yong Shi, University of Arizona

Co-Investigators:
Yong Shi, University of Arizona
Sukanya Chakrabarti, Harvard University
Aleks Diamond-Stanic, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 4.9

Abstract:
Possible links between ultra-luminous infrared galaxies (ULIRGs) and quasars are at the center of current research on galaxy and supermassive black hole (SMBH) evolution. It is hypothesized that feedback from star formation and accretion by black holes causes interactions that regulate the growth of galaxies and account for the relation between SMBH and stellar bulge masses. Theoretical simulations of these processes make specific predictions about the time evolution of the luminosities due to star formation and accretion by a central SMBH. These predictions can be tested by observing complete samples of ULIRGs and PG and 2MASS quasars with IRS and MIPS. Such data allow separation of the stellar luminosity (identified through aromatic and far infrared emission) from that arising around the SMBH. The current set of Spitzer observations, however, fall short of the necessary complete samples. We propose to fill in the missing data and use the results to test theoretical evolutionary simulations.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50508

Quasar and ULIRG Evolution

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Yong Shi, University of Arizona

Co-Investigators:
Yong Shi, University of Arizona
Sukanya Chakrabarti, Harvard University
Aleks Diamond-Stanic, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes:
Hours Approved: 9.3

Abstract:
Possible links between ultra-luminous infrared galaxies (ULIRGs) and quasars are at the center of current research on galaxy and supermassive black hole (SMBH) evolution. It is hypothesized that feedback from star formation and accretion by black holes causes interactions that regulate the growth of galaxies and account for the relation between SMBH and stellar bulge masses. Theoretical simulations of these processes make specific predictions about the time evolution of the luminosities due to star formation and accretion by a central SMBH. These predictions can be tested by observing complete samples of ULIRGs and PG and 2MASS quasars with IRS and MIPS. Such data allow separation of the stellar luminosity (identified through aromatic and far infrared emission) from that arising around the SMBH. The current set of Spitzer observations, however, fall short of the necessary complete samples. We propose to fill in the missing data and use the results to test theoretical evolutionary simulations. This is part 2 of program 50507.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50597

High-Resolution Spectroscopy of a Complete Seyfert Sample

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Aleks Diamond-Stanic, University of Arizona

Co-Investigators:
Yong Shi, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 7.2

Abstract:
We propose new IRS high-resolution spectroscopy that will finish a full suite of data for a complete sample of Seyfert galaxies in the nearby Universe. Our sample, which includes all known B < 13 Seyferts in the Revised Shapley-Ames catalog, reduces biases found in other samples selected at optical/X-ray/IR wavelengths against type 2 and low-luminosity nuclei, and against AGNs in edge-on host galaxies. The existing data set is complete for 3.6-24 micron imaging and 5-40 micron low-resolution spectroscopy, but the sample is currently biased against faint Seyfert 2 nuclei for high-resolution spectroscopy. With these new data, we will investigate how the ratios of fine-structure lines vary as a function of Seyfert type, AGN luminosity, and host galaxy star formation activity, and how ubiquitous high-ionization lines are in low luminosity and obscured sources.

Spitzer Space Telescope - General Observer Proposal #50314

The dark side of accretion: SMBH census and AGN feedback at z=1-3

Principal Investigator: Mara Salvato
Institution: California Institute of Technology

Technical Contact: Mara Salvato, California Institute of Technology

Co-Investigators:
Fabrizio Fiore, INAF Roma, Italy
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Nick Scoville, Caltech Pasadena, USA
Dave Sanders, IfA Hawaii, USA
Herve Aussel, CEA Saclay, France
Francesca Civano, CfA Harvard, USA
Roberto Maiolino, INAF, Roma, Italy
Adriano Fontana, INAF Roma, Italy

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 49.8

Abstract:
We propose IRS spectroscopy of a sample 23 i) luminous, ii) highly obscured, iii) high redshift (Z ~ 2) QSO in the COSMOS field. They are selected on the basis of very red mid-IR to optical colors and represent the first complete 24 micron flux limited (f(24>0.75mJ) sample at high redshift. Their high MIR luminosity, their hard X-ray stacked signal and the accurate photometric redshifts assure that the proposed targets are among the most luminous and most obscured (most likely Compton Thick) AGN at z~2. The observed radio luminosities suggest that vigourous star formation is on-going in most of the objects. Therefore, our proposed targets represent the best, homogenous and complete sample of sources catched in the golden epoch of their co-eval accretion and star formation phase. The proposed IRS observations represent an unique opportunity to quantify the relative contribution of two phenomena.

Spitzer Space Telescope - Directors Discretionary Time Proposal #483

The galaxy SDSSJ0952+21 is unique in showing a very intense optical emission-line light echo in response to an EUV-X-ray flare which we detected in the optical, NUV and NIR continuum. The flare was likely caused by the tidal disruption of a star by the supermassive black hole in SDSSJ0952+21. The optical spectrum of the galaxy is characterized by exceptionally strong, fading, high-ionization iron lines and a broad, redshifted very peculiar Balmer-line profile with two narrow horns. We propose Spitzer IRS observations with the high resolution modules in order to detect, for the first time, the IR emission-line light echo of a giant flare. The IR emission-line spectrum is expected to be very rich, with a wealth of possible new diagnostics.

Principal Investigator: Mara Salvato
Institution: Caltech

Technical Contact: Mara Salvato, Caltech

Co-Investigators:
Stefanie Komossa, MPE
Arne Rau, Caltech

Science Category: agn/quasars/radio galaxies
Observing Modes: f
Hours Approved: 1.9

Abstract:

Spitzer Space Telescope - General Observer Proposal #30606

The Spitzer view of the X-ray obscured Universe: the XMM-HBS sample

Principal Investigator: Paola Severgnini
Institution: INAF- Osservatorio Astronomico di Brera

Technical Contact: Paola Severgnini, INAF

Co-Investigators:
Alessandro Caccianiga, INAF - Osservatorio Astronomico di Brera
Filomena Cocchia, INAF - Osservatorio Astronomico di Brera
Roberto Della Ceca, INAF - Osservatorio Astronomico di Brera
Tommaso Maccacaro, INAF - Osservatorio Astronomico di Brera
Elisabetta Memola, INAF - Osservatorio Astronomico di Brera

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 22.6

Abstract:
We propose here to perform IRAC (3.6, 4.5, 5.8 and 8 micron) and 2-band MIPS (24, 70 micron) imaging photometric observations of a statistically complete sample of 17 type 2 AGN drawn from the XMM-Newton Hard (4.5-7.5 keV) Bright Sample (HBS). The XMM-HBS sample is the largest hard X-ray sample available so far with a complete spectroscopic identification. These observations will give us the possibility to derive, for the first time, the spectral energy distributions (SEDs) from X-rays to MID-IR for a representative sample of X-ray selected absorbed AGN. The Spitzer data, combined with good X-ray and optical spectroscopic information, will allow us: 1) to investigate the possible presence of Compton-thick AGN; 2) to constrain the models of circumnuclear obscuration used to explain the physical processes in the sub-parsec circumnuclear region of AGN; and 3) to build a representative average SED for obscured AGN which will be useful to estimate photometric redshifts of distant sources. The total number of requested AORs is 34 (17 with IRAC and 17 with MIPS) for a total exposure time of 22.6 hours.

Spitzer Space Telescope - General Observer Proposal #50379

Probing Coeval Star Formation and Black Hole Growth in the Most Massive Galaxies

Principal Investigator: Nick Seymour
Institution: Spitzer Science Center

Technical Contact: Nick Seymour, Spitzer Science Center

Co-Investigators:
Carlos De Breuck, ESO
Patrick Ogle, Spitzer Science Center
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Phil Appleton, IPAC
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Audrey Galametz, ESO/JPL
Mark Lacy, SSC
Emeric Le Floc'h, IFA, Hawaii
Ray Norris, CSIRO
Brigitte Rocca-Volmerange, IAP
Alessandro Rettura, Johns Hopkins
Daniel Stern, JPL
Wil van Breugel, UC-Merced/LLNL
Joel Vernet, ESO
Andrew Zirm, Johns Hopkins

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 39.3

Abstract:
At every epoch, powerful radio galaxies are associated with the most massive galaxies known as evidenced by their tight observed-frame K-z relation which traces the bright envolope of field galaxies. We have shown (Seymour et al. 2007) that the rest-frame H-band stellar luminosities of high-z radio galaxies (HzRGs) are uniformly consistent with stellar masses of ~5x10^11 Msun across 1<z<4. HzRGs also have high AGN accretion rates as evidenced by their high radio and mid-IR continuum luminosities. Sub-mm observations imply, although not conclusively, that many HzRGs have high star formation rates and hence are under-going a rapid phase of host galaxy growth coeval with the central black hole growth. Currently, the mid-IR is the only window to obtain a handle on star formation in these unique and rare systems. The strength of the PAHs provides an indication of the star formation rate of these sources whereas the strength of the nearby silicate absorption feature relates to dust obscuration of the central AGN and can indicate the geometry of the obscuring dust (close to the AGN or more spread out through the host galaxy). We propose here to obtain IRS spectra of a sample of 22 HzRGs with a range of radio powers and radio lobe sizes in order to more accurately study the physics underlying their mid-IR emission. We have selected our sample to be at the peak epoch of powerful AGN and starburst activity, 1.5<z<2.5, with radio luminosities spanning three orders of magnitude and a range of radio lobe sizes up to 200kpc. These sources are all bright at 24um and have stellar masses from IRAC imaging. The proposed observations are augmented by a few archival IRS spectra already obtained. The key aim of this proposal is to ascertain how the star formation and obscuration, as measured from mid-IR diagnostics, relates to both host galaxy proprties, measured from IRAC, and AGN properties, measured from radio and mid-IR imaging.

Spitzer Space Telescope - General Observer Proposal #50423

A Benchmark Sample of Obscured QSOs Selected in the Mid-infrared

Principal Investigator: Nick Seymour
Institution: Spitzer Science Center

Technical Contact: Nick Seymour, Spitzer Science Center

Co-Investigators:
Mark Lacy, SSC
Anna Sajina, Haverford
Andreea Petric, SSC
Minh Huynh, SSC

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 37.7

Abstract:
Spitzer has led the way in finding large numbers of previously undetected, obscured, type 2 QSOs. Such sources have long been theorised, but are only recently being discovered in significant numbers and we are finding that they out number classical, unobscured type 1 QSOs by a ratio of ~2:1. As the central black hole of a galaxy is closely related to the mass of the host galaxy it is clear that obscured AGN represent an important stage in the coeval growth of the AGN and the host galaxy. Most important is the question of how star formation in the host galaxy relates to the obscruration and growth of the AGN. Using the IRAC colour-colour selection technique we have put together a complete sample of luminous AGN selected on a method independent of obscuration or our line of sight to the core. We have found that ~2/3 of our sample of 77 objects are not pure classical unobscured type 1 AGN, but have varying degrees of obscuration. Star formation is very hard to measure in such obscured objects with powerful AGN and currently the best methods are to observe the PAH features in the mid-IR or to directly measure the luminosity of the cold dust fueling the starformation. Hence, we propose to observe the 33/58 obscured type 2 sources from our sample which still require either IRS spectroscopy or MIPS far-IR imaging or both. These observations would help us for the first time to compile a complete sample of obscured AGN with star formation rate measures which would act as a '3C' bench mark sample for future surveys of obscured AGN to lower luminosity and to higher redshifts.

Spitzer Space Telescope - General Observer Proposal #20084

Quasar Bolometric Luminosity and Spectral Energy Distributions from Radio to X-ray

Principal Investigator: Zhaohui Shang
Institution: University of Wyoming

Technical Contact: Zhaohui Shang, University of Wyoming

Co-Investigators:
Michael Brotherton, University of Wyoming
Dean Hines, Space Science Institute
Daniel Dale, University of Wyoming

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 8.4

Abstract:
We propose to build the best SED data set spanning from radio to X-ray wavelengths for 35 quasars. We will use new and archival mid-to-far IR data from Spitzer as well as other existing multi-wavelength data. We have unique quasi-simultaneous FUV/UV-optical spectra for our sample, greatly reducing the uncertainty due to quasar intrinsic time variability in the UV bump. We will derive accurate bolometric luminosities for the sample and seek to establish a more reliable and accurate way to obtain the bolometric luminosity of quasars from their partial SEDs and/or spectral properties. We will also apply multivariate analysis to the SEDs, study the quasar multi-wavelength spectral properties and their dependence on the overall SEDs, and thus better understand the physical processes quasars employ emitting across the entire electromagnetic spectrum.

Spitzer Space Telescope - General Observer Proposal #30075

Unveil the Nature of Post-Starburst Quasars

Principal Investigator: Zhaohui Shang
Institution: University of Wyoming

Technical Contact: Zhaohui Shang, University of Wyoming

Co-Investigators:
Michael Brotherton, University of Wyoming
Dean Hines, Space Science Institute
Daniel Dale, University of Wyoming
Gabriella Canalizo, University of California, Riverside
Rajib Ganguly, University of Wyoming
Sabrina Cales, University of Wyoming

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 16.1

Abstract:
We propose to obtain mid-IR spectra of 16 spectroscopically selected post-starburst quasars in order to fully characterize the properties of this new class. Post-starburst quasars are broad-lined AGN that also posses the spectral signatures of massive, moderate-aged stellar populations (in excess of ten billion solar masses and ages of hundreds of Myrs). This class represents several percent of the quasar population and may explicitly reveal how black hole/bulge correlations arise. We will compare their mid-IR SED and possible PAH features with other classes. The current project, which will also incorporate HST, SDSS, IRTF, KPNO and Keck data, will for the first time determine reliably for a sample of objects the properties of the massive starbursts (ages, masses), their black holes mass, accretion rate, morphologies, environments, and the relationships among these. Beyond just characterizing the properties of these populations, we plan to investigate the hypothesis that post-starburst quasars are an evolutionary phase in the lifetime of most quasars.

Spitzer Space Telescope - General Observer Proposal #30476

Lineless Quasars at High-Redshift: BL Lacs or A New Class of Unbeamed Quasars?

Principal Investigator: Ohad Shemmer
Institution: Pennsylvania State University

Technical Contact: Ohad Shemmer, Pennsylvania State University

Co-Investigators:
Xiaohui Fan, University of Arizona
Niel Brandt, Pennsylvania State University
Scott Anderson, University of Washington
Donald Schneider, Pennsylvania State University
Michael Strauss, Princeton University
Gordon Richards, Johns Hopkins University
Aleksandar Diamond-Stanic, University of Arizona

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 15.9

Abstract:
The Sloan Digital Sky Survey (SDSS) has recently discovered a class of high-redshift quasars with no or extremely weak optical emission lines. Their redshifts are determined by the presence of strong Lyman break and Lyman Limit Systems. Their nature remains unknown: they could be analogs of BL Lac objects at high redshift, a new type of unbeamed quasar whose broad emission-line region is very weak or absent, or a combination of both. Four members of this class were observed in the X-ray, radio, and recently in the IR by Spitzer, and the results are perplexing: two X-ray- and radio-weak sources exhibit BL Lac-like power-law SEDs, consistent with synchrotron emission, while two sources that are mildly X-ray and radio bright exhibit a hint of an IR 'bump' consistent with thermal dust emission in typical quasars. We propose to continue our successful Spitzer A0-1 program and obtain IRAC and MIPS 24 micron photometry of 14 additional lineless quasars at z~3-5. The Spitzer photometry will probe the spectral region where there is a dramatic contrast between beamed synchrotron emission in BL Lac objects and thermal dust emission in unbeamed quasars: we expect a factor of ~3-10 difference in Spitzer fluxes between the two cases. It will reveal the nature of the IR emission mechanism, and unambiguously determine whether these lineless quasars are beamed sources similar to BL Lac objects, or a new type of unbeamed quasar.

Spitzer Space Telescope - General Observer Proposal #20231

Exploring the nature of the 9-13 micron silicate emission discovered in quasars

Principal Investigator: Ralf Siebenmorgen
Institution: ESO

Technical Contact: Ralf Siebenmorgen, ESO

Co-Investigators:
Martin Haas, Astron. Inst. Ruhr-Univ. Bochum
Endrik Kruegel, Max-Planck Inst. f. Radio-Astronomie, Bonn
Bernhard Schulz, IPAC/Caltech

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 3.5

Abstract:
While for type-2 AGN the 9.7 micron absorption from amorphous silicates is well known, the silicate emission feature predicted for type-1 AGN has not been observed so far. Now, our low resolution IRS spectra of two ultra-luminous Palomar-Green quasars show a broad emission feature between 9 and 13 micron rest frame wavelength which contributes about 20% of the quasars total luminosity in this wavelength band. We strongly suggest that this feature is due to silicates in emission. If true, then this result is spectacular in that it provides excellent spectroscopic evidence for the torus-like distribution of dust around quasars, a crucial requirement for the AGN unified schemes. Also remarkable is the fact that the emission feature is not located at rest frame wavelength 9.7 micron typical for amorphous silicates, rather it lies red-shifted in the wavelength range of crystalline silicates. While amorphous silicates are formed in cold regions, crystalline silicates require hot environments. Furthermore, at high spectral resolution ISOSWS observations have shown that, for example in Herbig Ae-Be stars, the crystalline silicates exhibit a family of several sharp lines. At the low resolution of our IRS spectra this family of lines will be smeared out, probably resulting in the single broad feature we see in those two quasars yet observed. Resolving the family of crystalline silicate lines will provide best evidence for the silicate nature of the broad emission bump seen in our quasars. Therefore, we propose to perform high resolution IRS spectroscopy of the two bright quasars 3C249.1 (= PG 1100+772) and 3C351 (= PG 1704+608); at their redshift about z=0.3 the rest-frame 9-13 micron bump shifts to 12-18 micron, hence is ideally covered by the IRS Short-HiRes mode. These observations will establish the nature of the broad emission feature as crystalline silicates, thereby providing unique templates for dust features in luminous AGN.

Spitzer Space Telescope - General Observer Proposal #3349

IRS spectroscopy of 3CR radio galaxies and quasars: Probing the unified schemes and the starburst contribution.

Principal Investigator: Ralf Siebenmorgen
Institution: ESO

Technical Contact: Ralf Siebenmorgen, ESO

Co-Investigators:
Dr. Martin Haas, Astronomisches Institut Uni Bochum
Dr. Bernhard Schulz, IPAC / California Institute of Technology
Dr. Endrik Krugel, Max-Planck-Inst. f. Radioastronomie

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 6.6

Abstract:
We have recently shown that the FIR dust luminosity is similar for powerful FR2 radio galaxies and steep spectrum quasars. This finding is based on photometry with the ISO satellite of 105 sources of the 3CR catalog. Our results support the unified schemes in which the FR2 galaxies are quasars viewed at high inclination so that their nuclei are hidden behind a dust torus which intercepts the optical-ultraviolet AGN radiation and reemits it in the infrared. Interestingly, for most of the FR2 galaxies, the MIR/FIR luminosity ratio is considerably lower than for the quasars. So either the FR2 galaxies are intrinsically different, contrary to the unification theory, or the dust torus, if seen edge-on as presumed in the FR2 galaxies, is optically thick even at MIR wavelengths leading to a suppressed MIR continuum. We here propose to address this issue by MIR spectroscopy looking for the 9.7 and 18 micron silicate absorption features which should show up in the FR2 galaxies, and for AGN-typical high excitation MIR emission lines (like Ne[V] 14.3, 24.3 micron and O[IV] 25.9 micron). As the FIR emission may be powered not only by the AGN but additionally by a starburst, we also search for PAH bands (at 6.2, 7.7, 8.6, 11.3 and 12.7 micron) because their presence or absence provide clues on the hardness of the engine's spectrum and thus on the nature of the activity. We have selected a well balanced sample of 10 FR2 galaxies and 10 quasars from the 3CR catalogue with redshifts between z=0.05 and z=1.5. The sample members display luminous to hyperluminous dust emission as revealed by ISO. Only Spitzer's IRS is capable of obtaining sensitive low resolution (R~64-128) MIR spectra between 5 and 40 micron. The analysis of the requested observations will make a significant contribution to the debate about unification and the role which starbursts play in the powerful 3CR sources.

Spitzer Space Telescope - Archive Research Proposal #20746

Revealing the Unresolved Hard Cosmic X-ray Background Using Spitzer

Principal Investigator: Aaron Steffen
Institution: The Pennsylvania State University

Technical Contact: Aaron Steffen, The Pennsylvania State University

Co-Investigators:
Niel Brandt, The Pennsylvania State University
Sarah Gallagher, University of California, Los Angeles
David Alexander, Institute of Astronomy

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 74559.0

Abstract:
We propose to use archival Spitzer IRAC and MIPS GOODS Legacy data, combined with supporting multi-band HST ACS and Chandra ACIS-I data, to find the sources that comprise the unresolved hard (2-8 keV) Cosmic X-ray Background (CXB). Heavily obscured Active Galactic Nuclei (AGNs), which are thought to be responsible for the unresolved CXB, are powerful mid and far-infrared sources due to dust reprocessing of the absorbed near-infrared to soft-X-ray AGN light. This AGN heated dust is hotter than that heated by stellar processes and exhibits a bright 3-10 micron continuum. Using infrared color-color selection of the Spitzer IRAC and MIPS bands it is possible to select these obscured AGNs from the infrared source population. By combining the X-ray flux from the infrared- selected AGN population using X-ray stacking methods, it is possible to determine if this obscured AGN population is the source of the unresolved hard CXB. In addition, we propose to test recent luminosity-dependent AGN obscuration theories not addressed in the simple "unified" AGN model by calculating the bolometric luminosities of the infrared-selected AGNs. The unified AGN model predicts the existence of a population of heavily obscured, luminous AGNs that outnumber unobscured, luminous AGNs by a factor of 4:1. The luminosity- dependent, AGN obscuration theory predicts that these obscured AGN will predominately low-luminosity, obscured AGNs. We also propose to compile a comprehensive GOODS AGN catalog, which will contain AGN selected via many different techniques, including infrared and optical color selection and X-ray selection methods. We will develop AGN confidence methods that will be used to "grade" the sources based on the AGN candidates' multi-wavelength properties.

Spitzer Space Telescope - General Observer Proposal #20808

Spitzer Imaging of Spectroscopically-Confirmed, X-ray-Luminous, Obscured AGN

Principal Investigator: Daniel Stern
Institution: JPL/Caltech

Technical Contact: Daniel Stern, JPL/Caltech

Co-Investigators:
Megan Eckart, Caltech
Fiona Harrison, Caltech
David Helfand, Columbia

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 15.0

Abstract:
We request 18.2 hours of IRAC and MIPS imaging to investige the mid-IR properties of spectroscopically-confirmed hard X-ray sources from five moderately-deep (50 - 200 ks) Chandra fields. These sources, identified in the SEXSI (Serendipitous Extragalactic X-ray Source Identification) survey, include (1) 14 X-ray luminous, narrow-lined quasars, typical of the class of object which dominates the X-ray background beyond 5 keV, and yet remained largely unidentified prior to the launch of Chandra and XMM-Newton; (2) 31 X-ray bright, optically-normal galaxies, sources which appear inactive at optical wavelengths but reveal the presence of an active nucleus at X-ray energies; and (3) 44 optically-faint X-ray sources which lack spectroscopic classification currently and are likely to be either high-redshift, or heavily-obscured. We will investigate the mid-IR properties of these obscured AGN, comparing them to a control sample of 25 broad-lined X-ray luminous AGN in the same fields. This survey will also allow investigation of the X-ray properties of mid-IR-selected AGN.

Spitzer Space Telescope - General Observer Proposal #30515

Compact Symmetric Objects: A New Class of "Buried" AGN?

Principal Investigator: John Stocke
Institution: University of Colorado

Technical Contact: John Stocke, University of Colorado

Co-Investigators:
Jeremy Darling, University of Colorado
Eric Perlman, University of Maryland, Baltimore County
Fred Hearty, University of Colorado

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 7.8

Abstract:
We propose to obtain mid-IR spectra with Spitzer/IRS to search for highly obscured (a.k.a. "buried") AGN in an unusual type of powerful radio galaxy called "Compact Symmetric Objects" (CSOs). Evidence from VLBI radio imaging of CSOs strongly suggest that these sources are very young radio galaxies (500-3000 years old) which will eventually become large-scale powerful AGN. Thus, we are viewing the nuclear regions of these galaxies at the time of the "birth" of these AGN. While there is substantial multi-wavelength evidence for considerable nuclear gas in CSOs, near-IR images obtained by us using HST/NICMOS show no strong evidence for extremely large extinctions since the nuclear regions of these CSOs show normal elliptical galaxy profiles at H-band. But no AGN point source is seen. Either CSOs are "naked AGN" with no nuclear non-thermal continuum or reprocessed line emission or these AGN are so extincted as to be visible only in the mid-IR. We seek to test these two hypotheses and thus to determine whether gas accretion powers CSOs or whether CSOs (and all radio-loud AGN by extension) require a different type of energy source like Black Hole spin energy.

Spitzer Space Telescope - General Observer Proposal #50591

Witnessing the Birth of Radio Galaxies: Spitzer Spectroscopy of Nearby Compact Symmetric Objects

Principal Investigator: John Stocke
Institution: University of Colorado

Technical Contact: John Stocke, University of Colorado

Co-Investigators:
Kyle Willett, University of Colorado
Jeremy Darling, University of Colorado
Eric Perlman, Florida Institute of Technology

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare IrsPeakupImage
Hours Approved: 20.0

Abstract:
We propose to obtain mid-IR spectra with the IRS to search for highly obscured (a.k.a. "buried") AGN in an unusual type of powerful radio galaxies called "Compact Symmetric Objects" (CSOs) and to determine whether they show any evidence for accreting gas. Evidence from VLBI proper motion studies finds that CSOs are very young AGN (500-3000 years old) which will eventually become large-scale powerful radio galaxies (similar to "mini-Cygnus As"). Thus, we are viewing the nuclear regions of these galaxies at the time of the "birth" of these AGN. While there is substantial multi-wavelength evidence for modest amounts of nuclear gas and dust in CSOs, near-IR HST images and ground-based spectra show no evidence for extremely large dust extinction, on-going mergers, or reprocessed line and continuum emission indicative of an accretion disk. Rather, the nuclear regions of CSOs show normal elliptical galaxy profiles at H-band with no evidence for an AGN point source. It is thus probable that either CSOs are "naked AGN" with no nuclear non-thermal continuum or reprocessed line emission, or that the AGN are so heavily extincted that the accreting gas is visible only in the mid-infrared. Our Cycle 3 IRS observations of a small subsample of CSOs show considerable diversity in their mid-infrared spectra; some resemble modestly starbursting galaxies, while others are akin to PG quasars. Tellingly, NONE of the five low-redshift CSOs previously observed with the IRS show confirmed [NeV] detections, suggesting that CSOs as a class lack accreting nuclear gas (a 2.5 sigma result based upon 5 objects), despite their recent launch of luminous, non-thermal radio jets. We propose to observe the remaining four z < 0.1 CSOs to determine whether they are powered by gas accretion or whether CSOs (and by extension, all radio-loud AGN) require a different type of energy source such as black hole spin.

Spitzer Space Telescope - General Observer Proposal #20466

Galaxies with Old Stellar Populations in Radio Source Fields at z ~ 3.8

Principal Investigator: Alan Stockton
Institution: University of Hawaii

Technical Contact: Alan Stockton, University of Hawaii

Co-Investigators:
Elizabeth McGrath, Institute for Astronomy, University of Hawaii
Gabriela Canalizo, University of California at Riverside

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 15.7

Abstract:
There is persuasive evidence that powerful radio sources are signposts for strongly overdense regions in the early universe. It is in such regions that the processes of galaxy formation and evolution are expected to have proceeded most rapidly, and thus in which we will find the earliest massive galaxies to have formed in the universe. We have been identifying and determining morphologies for galaxies comprising essentially pure old stellar populations at redshifts of 1.5 and 2.5, with the surprising result that, for the three of these galaxies for which we have been able to obtain high-resolution images from adaptive-optics imaging, all are dominated by massive disks of old stars. In two of these, any bulge component accounts for <10% of the total light (and baryonic mass, since all of the stars in both components are old). The presence of these massive (~ 2 to 3 X 10^11 solar masses) disk galaxies at z~2.5 comprising stars that have ages of 1 to 2 Gyr, with no detectible contamination from younger stars, suggests that it would be worthwhile to search for their precursors at higher redshifts. The next optimum redshift range for such a search is z~3.8, for which one obtains maximum discrimation of the 4000 A break in the H-K color. It is necessary to obtain good photometry at longer wavelengths, not only to distinguish between old stellar populations and heavily reddened starbursts, but also to get a good hold on the slope of the spectral-energy distribution at long wavelengths in order to verify an old stellar population in the presence of small amounts of contamination by young stars, which are almost inevitable at these early epochs. We are proposing deep IRAC imaging in all 4 bands of all 7 fields from the Texas Radio Survey with 3.65 < z < 4.05 and extinction A_B < 0.3. Together with ground- based imaging in 4 shorter-wavelength bands, these observations will allow a complete photometric identification and characterization of L* and brighter galaxies associated with these radio sources.

Spitzer Space Telescope - General Observer Proposal #40001

The Origin of QSO Extended Emission Regions: Superwinds from Starbursts or QSO Ignition?

Principal Investigator: Alan Stockton
Institution: Institute for Astronomy, University of Hawaii

Technical Contact: Alan Stockton, IfA, University of Hawaii

Co-Investigators:
Hai Fu, Institute for Astronomy, University of Hawaii

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 12.4

Abstract:
Luminous, massive extended emission-line regions (EELRs) are found around a substantial fraction of low-redshift radio-loud QSOs. These EELRs typically extendfor several tens of kpc and are highly structured entities. In spite of their preference for radio-loud QSOs, they generally show no significant correlation with radio jets or lobes. They also show no tendancy to follow the morphology of the host galaxy. A number of lines of evidence indicate strongly that this gas has been ejected from the host galaxy by a powerful superwind, but whether this wind is due to a central starburst or to radiative coupling of the QSO's energy output to surrounding dust and gas is uncertain. We propose spectroscopy of the 8 micron PAH feature with the IRS Low Res 7.4-14.5 micron module and MIPS 24, 70, and 160 micron photometry to constrain the star-formation rates in carefully matched samples of steep-spectrum, radio-loud QSOs with and without luminous EELRs.

Spitzer Space Telescope - Archive Research Proposal #3117

The Spitzer First Look Survey Extragalactic SED Database

Principal Investigator: Lisa Storrie-Lombardi
Institution: Caltech

Technical Contact: Lisa Storrie-Lombardi, Caltech

Co-Investigators:
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Jason Surace, Spitzer Science Center
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Lin Yan, Spitzer Science Center
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Phil Appleton, Spitzer Science Center
Lee Armus, Spitzer Science Center
Dario Fadda, Spitzer Science Center
David Frayer, Spitzer Science Center
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George Helou, Spitzer Science Center
Francine Marleau, Spitzer Science Center
Dave Shupe, Spitzer Science Center
Mark Lacy, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 96741.0

Abstract:
The extragalactic component of the Spitzer First Look Survey (FLS) reaches the same depth as the deepest ISO surveys yet covers an area 1500 times as large. It opens up an enormous amount of discovery space given the increased depth, improved resolution, and areal coverage that Spitzer provides. The extragalactic FLS team at the Spitzer Science Center has been involved in the planning of the survey since its inception and we have gathered a substantial ancillary data set, from optical through radio wavelengths, to maximize the science return of the survey. We have several science programs underway and a common feature to most is the need for photometric redshifts for the thousands of galaxies detected in the survey. We are requesting one year of funding for a post-doc to focus on this effort and we will return to the community via NED a database with the multiwavelength SEDs and photometric redshifts for the survey galaxies.

Spitzer Space Telescope - General Observer Proposal #3163

Mid- and Far-Infrared Spectral Energy Distribution of Type II Quasars from the Sloan Digital Sky Survey

Principal Investigator: Michael Strauss
Institution: Princeton University

Technical Contact: Michael Strauss, Princeton University

Co-Investigators:
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Timothy Heckman, Johns Hopkins University
Iskra Strateva, Pennsylvania State University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 14.2

Abstract:
The success of unification models for Seyfert galaxies raises the question of whether these models can be extended to high luminosity AGNs. Do obscured (type II) quasars exist? If so, how many are there? To date, only a small number of candidates have been found. We recently published a sample of 150 type II quasar candidates at redshifts z<0.8 selected by their emission line properties from the spectroscopic database of the Sloan Digital Sky Survey. Here we propose to perform 4-band IRAC and 3-band MIPS imaging of the 25 most luminous objects in the sample to measure their spectral energy distributions and infrared luminosities; we estimate their infrared luminosities to be as high as 10^47 erg/sec. These data will constrain physical models of circumnuclear obscuration, and thus for the first time probe unification models of AGNs at high luminosities. The infrared luminosities of the sample will allow us to construct the luminosity function of type II AGNs and to estimate their fraction in the AGN population and the contribution of obscured AGNs to the census of supermassive black holes. The total time of this program is 14.2 hours, with 2.8 hours of IRAC time and 11.4 of MIPS time. Many of the objects in the sample have been observed with HST, Chandra, XMM and MMT.

Spitzer Space Telescope - General Observer Proposal #3223

X-ray selected Type-2 QSOs -- Their Mid-Infrared Properties and Physical Nature

Principal Investigator: Eckhard Sturm
Institution: Max-Planck-Institute for Extraterrestrial Physics

Technical Contact: Eckhard Sturm, MPE

Co-Investigators:
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Ingo Lehmann, MPE
Vincenzo Mainieri, MPE
Reinhard Genzel, MPE (and UCB)
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Linda Tacconi, MPE
Matt Lehnert, MPE

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 25.5

Abstract:
Our recent XMM-Newton observations have revealed the presence of a population of intrinsically luminous but highly obscured AGN, the long sought after Type-2 QSOs. Such sources were proposed to be a crucial component of AGN unification theories and of models for the extragalactic X-ray and infrared background. Here we propose low-resolution IRS spectroscopy of 8 of these type 2 QSOs, selected mostly from our deep XMM-Newton observations of the Lockman Hole. The IRS low resolution spectra will represent the first mid-infrared spectra ever taken of such objects. In combination with our corresponding X-ray data, the spectra will allow us to study the nature of these objects and of their host galaxies. We will determine (i) the relative contributions of star formation and AGNs to their energy output, (ii) the fraction of their contribution to the cosmic infrared-background that is due to accretion, and (iii) the relation of re-processed mid-infrared AGN continuum and intrinsic X-ray emission. By comparing this mid-IR/X-ray ratio to lower luminosity AGNs, we will iv) probe the role of variations in the covering factor for the luminosity dependence of the type-2/type-1 ratio of AGNs.

Spitzer Space Telescope - General Observer Proposal #3237

Mid-infrared properties, excitation mechanisms and AGN content of LINERs -- An IRS survey

Principal Investigator: Eckhard Sturm
Institution: Max-Planck-Institute for Extraterrestrial Physics

Technical Contact: Eckhard Sturm, MPE

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Steve Lord, IPAC
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Amiel Sternberg, TAU
Dan Maoz, TAU

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 37.9

Abstract:
Low-Ionization Nuclear Emission-Line Region galaxies (LINERs) are a constituent in a major fraction of large galaxies, but their nature and their relation to AGN is still a puzzle. We propose to perform low and high resolution IRS spectroscopy of a medium-sized sample (37 objects) of nearby LINERs. In recent years, we have developed and refined spectroscopic mid-IR diagnostic tools based on ISO data and analysis. We will apply these tools to a sample consisting of both classical nuclear LINERs and extended, non-nuclear LINERs, in order to study the roles played by star formation, AGN, and shocks (interaction-driven or wind-driven) in exciting the gas. This will provide new clues as to which LINERs are AGN powered, and how these AGN LINERs differ from more luminous Seyfert galaxies. The fraction of LINERs that is AGN-powered, and the accretion mode in these low-luminosity objects, are important for a number of major issues in extragalactic astronomy, including the contribution of AGNs to the cosmic infrared background, the growth history of central black holes, and the relation of central accreting black holes to galaxy formation and evolution. We will also search for differences in the mid-infrared spectra of nuclear and non-nuclear LINERs in nearby galaxies. In higher redshift galaxies, non-nuclear LINER emission may be more important than locally because of the greater frequency of galaxy interactions, but nuclear and non-nuclear LINERs will be difficult to distinguish, due to limitations in spatial resolution. Our project will therefore provide the community with a fundamental IR data set for future studies of the more distant LINER population.

Spitzer Space Telescope - General Observer Proposal #30222

70 Micron MIPS and Chandra ACIS-I Imaging of the IRAC Dark Field: Infrared AGN

Principal Investigator: Jason Surace
Institution: Spitzer Science Center

Technical Contact: Jason Surace, Spitzer Science Center

Co-Investigators:
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Mark Lacy, Spitzer Science Center/Caltech
Matthew Ashby, Harvard Smithsonian Center for Astrophysics
Lin Yan, Spitzer Science Center/Caltech

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 25.5

Abstract:
Using data taken for the calibration the Infrared Array Camera on-board Spitzer, we have been able to discover a population of objects with mid-infrared variability on months-timescales and whose colors are characteristic of active galactic nuclei (AGN) at significantly high redshift. We request 25.5 hours of imaging at 70 microns with MIPS and 100 ksec of x-ray imaging with ACIS of the IRAC Dark Field. The 70 micron data are needed to provide a photometric data point near the peak of the spectral energy distribution, allowing an accurate determination of the spectral shape and bolometric luminosity. These are known to correlate locally with the nature of the energy source and will help provide a discriminant between AGN-like and starburst-like systems. The x-ray imaging provides an additional measure of the strength of AGN activity and the degree of obscuration to the energy source. This is an extragalactic field 15 arcminutes in diameter near the north ecliptic pole, and is the dark current calibration target for IRAC. Because it is observed frequently as part of routine operations, the field is now similar in size and depth to the infrared component of the GOODS program, and is confusion-limited in the mid-infrared. More importantly, due to the periodicity of the observations, the Spitzer data are sensitive to variability on week timescales, ultimately spanning a baseline of five to seven years. This cannot be achieved with an ordinary science GO program, and this is the only mid-infrared dataset that will have this capability at this depth for the foreseeable future. In the past year we have acquired deep multiband optical and near-IR imaging from the ground, and will soon acquire deep high spatial resolution HST imaging. All HST/Spitzer data in the field is publicly available, and the requested MIPS and Chandra data will add to this unique dataset.

Spitzer Space Telescope - Archive Research Proposal #30390

Mid-Infrared Variability from AGN in the IRAC Dark Field: Photometric Refinement, Discovery, and Characterization

Principal Investigator: Jason Surace
Institution: Spitzer Science Center

Technical Contact: Jason Surace, Spitzer Science Center

Co-Investigators:
Varoujan Gorjian, JPL
Mark Lacy, Spitzer Science Center/Caltech
Lin Yan, Spitzer Science Center/Caltech

Science Category: AGN/quasars/radio galaxies
Dollars Approved: 46910.0

Abstract:
We request archival funding to support an investigation into the mid-infrared variability of AGN discovered in the IRAC Dark Field. The requested funding is needed to refine the photometric accuracy of the IRAC calibration as a function of both array position and time, allowing detection of much smaller effects than could be achieved from the SSC pipeline data products. As part of this we propose to use more sophisticated search techniques to expand the range of detectable variability to smaller amplitudes and timescales than we have already found. This may also uncover supernova signatures and other periodic variations. The field itself is an extragalactic field 15 arcminutes in diameter near the north ecliptic pole, and is the dark current calibration target for IRAC. Because it is observed frequently as part of routine operations, it is now similar in size and depth to the infrared component of the GOODS program, and is confusion-limited in the mid-infrared. More importantly, due to the periodicity of the observations, the Spitzer data are sensitive to variability on week timescales, ultimately spanning a baseline of five to seven years, and are the only mid-infrared dataset that will have this capability at this depth for the foreseeable future. This work will have a significant impact on other studies both by producing a comprehensive look at variability in deep mid-IR surveys, and also through the development of advanced data reduction techniques that can be applied to other programs for the purpose of refining IRAC's relative photometric accuracy.

Spitzer Space Telescope - General Observer Proposal #20233

The dominant heating mechanism for the cool dust in luminous AGN: deep MIPS photometry of a complete sample of 2Jy radio sources

Principal Investigator: Clive Tadhunter
Institution: University of Sheffield

Technical Contact: Clive Tadhunter, University of Sheffield

Co-Investigators:
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Peter Barthel, University of Groningen
Katherine Inskip, University of Sheffield
Ilse van Bemmel, ESA/ST-ScI
David Axon, Rochester Institute of Technology
Rosa Gonzalez-Delgado, Instituto d'Astrofisica d'Andalucia
Joanna Holt, University of Sheffield
Javier Rodriguez Zaurin, University of Sheffield

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 33.6

Abstract:
Given its general importance for studies of star formation at all redshifts, the issue of the heating mechanism for the warm/cool dust in luminous AGN is one of the key problems in extragalactic astrophysics. We propose to address this issue by using the unique high sensitivity capability of the Spitzer to make a mid- to far-IR (MFIR) photometric survey of a complete sample of luminous 2Jy radio galaxies and radio-loud quasars at intermediate redshifts. Radio-loud AGN are ideal for a study of this type, because they have relatively clean selection criteria and it is possible to determine the luminosity, orientation and age of the AGN using the emission line and radio properties of the sources. Moreover, an important advantage of the 2Jy sample is that, unlike any other major sample of powerful radio sources, deep optical spectra exist for all the sample objects. These spectra provide both accurate emission line luminosities and information about the stellar populations -- crucial for investigating the link between starbursts and the MFIR properties. By correlating the MFIR, radio and optical properties of the objects in the sample we will determine: (a) the dominant heating mechanism for the dust at different MFIR wavelengths; (b) the extent to which the far-IR colours depend on orientation to the line of sight; and (c) the evolution of the far-IR properties with the ages of the radio sources. This will be the first deep MFIR survey of a substantial sample of luminous AGN for which complete information on the stellar populations, AGN and jet properties already exists.

Spitzer Space Telescope - General Observer Proposal #50558

The importance of starbursts in powerful radio galaxies

Principal Investigator: Clive Tadhunter
Institution: University of Sheffield

Technical Contact: Clive Tadhunter, University of Sheffield

Co-Investigators:
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Raffaella Morganti, ASTRON
David Axon, RIT
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Ilse van Bemmel, University of Leiden
Peter Barthel, University of Groningen
Katherine Inskip, University of Sheffield
Bjorn Emonts, Columbia University
Rosa Gonzalez Delgado, IAA, Granada

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 32.0

Abstract:
The heating mechanism for the warm/cool dust in active galaxies has long been a source of uncertainty that limits our ability to understand the links between the evolution of AGN and their host galaxies. In order to address this issue we have used deep Spitzer/MIPS observations for a complete sample of 2Jy radio galaxies to investigate the links between the mid- to far-IR (MFIR) continuum luminosities and the level of both the AGN and the optical starburst activity. In a major breakthrough we find strong correlations between the [OIII] emission line luminosities and both the 24 and 70 micron continuum luminosities, however, the objects in our sample with evidence for optical star formation activity show significantly enhanced 70 micron luminosities compared with the main correlation. On the basis of these results, we hypothesise that AGN illumination is the primary heating mechanism for the dust emitting at both 24 and 70 microns, but the 70 micron luminosity is substantially boosted by starburst heating in the 20 - 30% of objects with independent evidence for starburst activity. We now propose to test this hypothesis by using deep IRS spectroscopy to measure the strengths of the mid-IR PAH features in the 2Jy sample, which is unique in terms of its completness and availability of deep optical spectroscopy and MFIR photometry. If our hypothesis is correct we expect the objects with enhanced 70 micron luminosities to have PAH bands that are strong relative to their MFIR continuum and high ionization emission lines, whereas the objects falling on the main correlation will have weak or absent PAH emission. Combined with the existing MIPS and optical spectroscopic data, the IRS observations will for the first time enable us to definitively establish the significance of circum-nuclear starbursts in powerful radio galaxies. They will also allow a crucial comparison of the various methods used to quantify the starbursts associated with AGN at both low and high redshifts.

Spitzer Space Telescope - General Observer Proposal #20199

Radio Galaxies at Very High Redshift

Principal Investigator: David Thompson
Institution: California Institute of Technology

Technical Contact: David Thompson, California Institute of Technology

Co-Investigators:
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Carlos De Breuck, ESO
Wendy Lane Peters, Naval Research Laboratory
Aaron Cohen, Naval Research Laboratory
Tracy Clarke, Naval Research Laboratory
George Djorgovski, California Institute of Technology
Ashish Mahabal, California Institute of Technology

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 10.0

Abstract:
We have identified four faint (K>22 mag) and one exceptionally faint (K~23.5 mag) near-infrared counterparts to high-latitude, steep-spectrum, compact radio sources. They are likely to be radio galaxies at very high (z>5) redshift, placing them amongst the most powerful radio sources at any redshift. Deep IRAC imaging will be used to confirm the identifications and constrain the redshifts through their spectral energy distributions.

Spitzer Space Telescope - General Observer Proposal #30854

IRAC Survey of Large-scale Quasar Jets

Principal Investigator: Yasunobu Uchiyama
Institution: ISAS/JAXA

Technical Contact: Yasunobu Uchiyama, ISAS/JAXA

Co-Investigators:
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Meg Urry, Yale University
Paolo Coppi, Yale University
Jeffrey Van Duyne, Yale University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 20.8

Abstract:
Motivated by the success of our pilot Cycle-1 observations, we here propose a systematic IRAC imaging program of powerful quasar jets. Specifically, we propose to perform: (a) moderately deep [1 hr each] IRAC imaging of 10 powerful jets to make a complete set of infrared data for quasar jets detected by Chandra, and (b) very deep [7 hr] IRAC imaging of the 3C 273 jet as a follow-up to our Cycle-1 program. By exploring the mid-infrared properties of the extended jet emission from powerful quasars, this IRAC program will shed new light on the riddle of the Chandra-detected jets. Our scientific goals are: (1) determining the peak position of the synchrotron radiation component, which is connected directly with the maximum energy of the ultrarelativistic electrons in the jets and reflects from nature of the acceleration process, (2) measuring the spectral shape in the IRAC band to test whether the optical emission is belonging to the radio-infrared synchrotron component, and (3) searching for an infrared bump due to ''bulk Comptonization'', which if detected, gives strong confirmation of the beamed IC model. Together with extensive surveys with both HST and Chandra, our Spitzer survey will aid in the understanding of the physics of the extragalactic jets.

Spitzer Space Telescope - General Observer Proposal #20733

IRS Spectroscopy of Intermediate Redshift AGN in the GOODS Field: A study in AGN dust structure and evolution

Principal Investigator: Megan Urry
Institution: Yale University

Technical Contact: Jeffrey Van Duyne, Yale University

Co-Investigators:
Jeffrey Van Duyne, Yale University
Anton Koekemoer, STScI
Franz Bauer, Columbia University
Haojing Yan, CalTech/IPAC
Glenn Morrison, NOAO
Eleni Chatzichristou, U. of Athens

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 59.1

Abstract:
We propose Spitzer IRS low resolution spectroscopy of infrared-bright AGN from the GOODS North field. Using the broad wavelength coverage afforded by GOODS, we will examine the continuum emission of obscured AGN whose emission is dominated by dust re-radiation. Hard X-rays are excellent at detecting both obscured and unobscured AGN, as dust does not appreciably absorb such high energy radiation except when Compton-thick. Both hard X-ray and infrared emission is required to investigate the evolution of the surrounding dust torus geometry during the peak AGN epoch. These sources have been selected to be moderate luminosity AGN at redshifts $0.48<z<2.1$. The combination of X-ray hardness ratios, optical/NIR broadband coverage, optical spectroscopy, and IRS spectroscopy out to rest-frame ~24 micron wavelengths will result in the most complete spectral energy distributions of any AGN at these redshifts. We will estimate dust temperatures based on continuum and PAH/silicate feature strengths. The overall continuum shapes will be compared with recent dust torus reprocessing models to constrain the dust geometries of typical, high-redshift AGN.

Spitzer Space Telescope - General Observer Proposal #3586

On First Infrared Light from Large-scale Quasar Jets

Principal Investigator: Megan Urry
Institution: Yale University

Technical Contact: Yasunobu Uchiyama, ISAS/JAXA

Co-Investigators:
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Jeffrey Van Duyne, Yale University
Laura Maraschi, Osservatorio Astronomico di Brera
Fabrizio Tavecchio, Osservatorio Astronomico di Brera
Chi Cheung, Brandeis University
Rita Sambruna, George Mason University
Tadayuki Takahashi, JAXA/ISAS

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 2.5

Abstract:
We propose Spitzer IRAC imaging observations to detect, for the first time, infrared emissions from the hundred-kiloparsec-scale jets of powerful quasars. From reasonable extrapolation of the measured optical flux, the bright jets that we selected are indeed detectable with Spitzer's arcsecond imaging capability. The Spitzer observations, when combined with HST and Chandra, enable us to study simple but fundamental issues regarding the largely-unknown properties of the quasar jets.

Spitzer Space Telescope - General Observer Proposal #30745

Spitzer Observations of the First Unbiased AGN Sample of the Local Universe

Principal Investigator: Kimberly Weaver
Institution: NASA GSFC

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
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Jack Tueller, NASA GSFC
Eliot Malumuth, NASA GSFC
Craig Markwardt, NASA GSFC
Steve Kraemer, NASA GSFC
Lee Armus, IPAC

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 9.1

Abstract:
Many questions fundamental to AGN research remain unanswered because there still exists no large uniform AGN survey of the local universe. Such surveys are difficult because the majority of AGN are obscured by large amounts of dust and gas and prior astronomical samples suffer from severe selection effects. In the IR, the observed luminosities and spectral shapes are strongly affected by star formation and dust absorption and emission and there is in fact no clear consistency in IR AGN properties - Spitzer spectra show a large variety of signatures and a wide range of effective IR colors. The hard X-ray emission is the only radiation known that is both relatively unaffected by Compton-thin obscuration and is directly associated with the AGN. We propose here a "pilot study" of a new hard x-selected sample of AGN with the BAT on Swift with the goal of obtaining the first high quality IR spectral survey of an unbiased local AGN sample. These targets provide a means for insight into the IR/x-ray scatter and thus can determine the true distribution of IR properties of AGN. It is only by having an independent measure of AGN strength and total absorbing column density from a well-observed hard x-ray sample that one can untangle the complexity of the IR data. A hard x-ray survey will find all Compton thin AGN in a uniform fashion and determine their intrinsic luminosity. With these data we will search for the nonthermal continuum in the IR, constrain star formation in the galaxies, directly compare line-of-sight IR and x-ray column densities and construct non ad-hoc continuum models based on x-ray fluxes to predict the IR line ratios in gas photoionized by the AGN.

Spitzer Space Telescope - General Observer Proposal #50588

Spitzer Observations to Complete the First Unbiased AGN Sample of the Local Universe

Principal Investigator: Kimberly Weaver
Institution: NASA GSFC

Technical Contact: Kimberly Weaver, NASA GSFC

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Jack Tueller, NASA/GSFC
Steve Kraemer, NASA/GSFC
Craig Markwardt, NASA/GSFC
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Eliot Malumuth, NASA/GSFC
Ciprian Berghea, Catholic University
Kimberly Engle, NASA/GSFC
Lisa Winter, University of Maryland

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 26.8

Abstract:
Active galactic nuclei (AGNs) have been a major focus of extragalactic astronomy for decades, but because of obscuration effects, virtually all surveys for AGN based purely on optical, IR, UV or soft X-ray data have been highly biased in their selection (cf. Mushotzky 2004). Thus, to truly understand the intrinsic nature of AGN as a class, it is critical to start with an unbiased hard X-ray survey. This critical, unbiased hard X-ray survey is now available from the SWIFT Burst Alert Telescope (BAT). The BAT detects all bright AGN, whether they are obscured or not, and thus will find famous classical objects as well as previously unknown AGN. In fact, many of the BAT sources are newly discovered AGN, which have been poorly studied, if at all, at other wavelengths. We have found that these "new" AGN are under-luminous in their IR properties compared to classic AGN and thus IR-selected samples have not been representative. Our IR-weak AGN may be the most heavily obscured ones. Completing the BAT sample is critical to obtain a complete, unbiased sample of AGN properties based on hard X-ray data and to understand this new IR-under-luminous class. These data will become an invaluable addition to the Spitzer archive. Statistical conclusions drawn from classical objects are almost certain to be wrong due to inherent biases in their selection, which exclude this sample of severely absorbed, BAT-detected AGN.

Spitzer Space Telescope - Directors Discretionary Time Proposal #246

Flaring Quasar 3C454.3

Principal Investigator: Ann Wehrle
Institution: Caltech

Technical Contact: Patrick Ogle, Caltech

Co-Investigators:
Patrick Ogle, SSC

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 10.3

Abstract:
The quasar 3C454.3 is currently undergoing the largest optical flare in its recorded history: during the past three weeks it has exceeded even 3C273 in optical brightness. We propose to observe 3C454.3 with Spitzer IPAC, MIPS and IRS during each of their normally scheduled blocks in June, July and August 2005, and repeat observations daily. Supporting ground based data will be obtained from Palomar Mountain (approved observations on the 60" robotic telescope; A. Wehrle, PI), Colgate University, and other observatories of the international blazar monitoring teams. The Rossi X-ray Timing Explorer has already started observing as a Target of Opportunity.

Spitzer Space Telescope - General Observer Proposal #30785

Coordinated Spitzer/Chandra Observations of Gamma Ray Blazars

Principal Investigator: Ann Wehrle
Institution: Space Science Institute

Technical Contact: Ann Wehrle, Space Science Institute

Co-Investigators:
Patrick Ogle, Spitzer Science Center

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 6.3

Abstract:
We propose for coordinated Spitzer and Chandra observations of fourteen gamma-ray blazars. The blazars have two-peaked spectral energy distributions, where the infrared peak is synchtrotron emission produced by relativistic electrons, and the x-ray-gamma-ray peak is inverse-Compton scattered emission. The observations will map out the shape of the infrared synchrotron peak and its changes with two sets of independent observations about six months apart. All three Spitzer instruments will be used in normal, successive instrument campaigns, as we did during our 2005 observations of flaring blazar 3C454.3. The Chandra observations are used to obtain x-ray fluxes and spectral indices which will indicate relative contributions of synchrotron and inverse-Compton emission in the Chandra x-ray band. The Spitzer MIPS and Chandra observations need to be scheduled within a day of each other because the sources are highly variable.

Spitzer Space Telescope - General Observer Proposal #50231

Blazar Archetypes as Probes of Jet Physics

Principal Investigator: Ann Wehrle
Institution: Space Science Institute

Technical Contact: Ann Wehrle, Space Science Institute

Co-Investigators:
Benoit Lott, CENBG, France
Patrick Ogle, SSC/IPAC
Anita Reimer, Stanford University
Dayton Jones, JPL
Markus Boettcher, Ohio University
Gino Tosti, INFN, Perugia, Italy
Stefano Ciprini, INFN, Perugia, Italy
Andrea Tramacere, Stanford University and ASI-INAF

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 15.2

Abstract:
We propose to observe three archetypal blazars daily during intense 21-day global multiwavelength campaigns. The blazars 3C279, 3C454.3, and PKS 0528+134 are the brightest and most active observed with the EGRET instrument on the gamma ray telescope CGRO; we expect them to be detected at high SNR with GLAST. The Spitzer observations will be coordinated with daily Swift x-ray, ultraviolet and optical observations, with continuous GLAST sky-scanning observations., and with extensive groundbased observations. The resulting time-resolved spectral energy distributions, light curves and time lags between wavebands provide information on important aspects of the jet and its environment. These include breaking the degeneracy between the Doppler factor, the magnetic field, and the Lorentz factor at the break in the electron distribution. We will also model the composition of the jet (leptons or leptons and hadrons). Ultimately, the composition of the jets affects how much power is transmitted to the radio lobes, and thus how much power is dumped into the galaxy and environment. All three instruments will be used in standard instrument campaigns. The observations can be spaced flexibly every 24-48 hours depending on the length of the actual instrument cycles. GLAST will be launched in mid-2008 and will scan the full sky every three hours. We have identified optimal and backup windows which depend on the actual launch date. The coordinated observations are loosely constrained because Swift scheduling is very flexible: Swift can follow the Spitzer schedule. This is the second highest priority proposal of the GLAST LAT AGN Collaboration and is submitted on the Collaboration’s behalf.

Spitzer Space Telescope - General Observer Proposal #50753

Infrared Search for Hidden Active Galactic Nuclei

Principal Investigator: Michael Werner
Institution: JPL

Technical Contact: Varoujan Gorjian, JPL

Co-Investigators:
Daniel Stern, JPL
Kieran Cleary, JPL
Stephen Murray, Harvard Smithsonian Center for Astrophysics
Christine Jones, Harvard Smithsonian Center for Astrophysics
William Forman, Harvard Smithsonian Center for Astrophsyics
Ryan Hickox, Harvard Smithsonian Center for Astrophysics
Varoujan Gorjian, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 19.7

Abstract:
In 1982 Elvis et al called attention to a pair of galaxies with AGN-like x-ray emission but no AGN features in their visible spectra [referred to here as XBONGS]. Since then, deep x-ray surveys [Moran et al 2002] have revealed large numbers of galaxies with these characteristics: luminous in the x-ray but without the high excitation lines, specific line ratios, or broad emission lines which characterize Type I and/or Type II AGN. Thus understanding XBONGS is an important step towards defining the accretion history of the Universe. For brevity, we continue to refer to these objects as XBONGS, while recognizing that they are not a homogeneous group, and in fact a variety of explanations have been proposed. It has been suggested that XBONGs are powered by AGN which are hidden at visible wavelengths by (i) dilution by the bright emission from the galaxy, by (ii) extinction, or by (iii) the absence of visible and ultraviolet radiation due to modifications in the character of the accretion disk which surrounds the central black hole. These suggestions can be tested by infrared observations, so we propose here a program of IRS spectroscopy of 8 XBONGs carefully selected from 26 XBONGs identified in the XBootes survey of the NOAO Deep Wide-Field Survey. We will observe the [NeV] 14.3um and the [NeIII] 15.6um lines to identify and characterize the hidden AGN in these galaxies, drawing on our published Spitzer observations of these lines in AGN with known x-ray emission. We hope to distinguish among the competing models for the XBONG phenomenon and to make an assessment of this problem as part of the legacy of the cryogenic Spitzer mission.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #86

Imaging and Spectroscopy of X-ray Selected Seyfert Galaxies

Principal Investigator: Michael Werner
Institution: JPL

Technical Contact: Varoujan Gorjian, JPL

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare MipsPhot
Hours Approved: 23.5

Abstract:
In present unified schemes, dust plays a major role in determining Seyfert types, with Seyfert 1's being less obscured and Seyfert 2's being more obscured, but both with the same underlying energy generation mechanism, an accretion disk around a supermassive black hole. We have chosen to study a group of Seyferts at two wavelengths that are least affected by dust obscuration: x-rays and infrared. Our sample is a mix of Seyfert 1's and Seyfert 2's which have been observed in the x-rays, for which we will obtain IR spectra with all IRS modules, and photometry at 25 and 70 microns with MIPS. By comparing the characteristics of these two penetrating data sets we will be able to constrain better the role of dust in the nuclei of these active galaxies, especially the large column densities (>10^25 Hydrogen atoms per cm^2) derived from x-ray observations.

Spitzer Space Telescope - Directors Discretionary Time Proposal #242

IRS spectroscopy of type II quasars

Principal Investigator: Nadia Zakamska
Institution: Princeton University

Technical Contact: Nadia Zakamska, Princeton University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IrsStare
Hours Approved: 8.0

Abstract:
The success of unification models for Seyfert galaxies raises the question of whether these models can be extended to high luminosity AGNs. We recently published a sample of 150 type II (obscured) quasar candidates at redshifts z<0.8 selected by their emission line properties from the spectroscopic database of the Sloan Digital Sky Survey. We propose to conduct Spitzer mid-IR (7.4-21.3 micron) spectroscopy of the IR-brightest objects from the sample, as determined from our Cycle 1 imaging program with Spitzer. These data can be used to constrain the physical conditions of the obscuring material using radiative transfer models, as the shape of the spectral energy distributions at these wavelengths is sensitive to whether the dust is distributed homogeneously or is concentrated in clumps, to the exact viewing geometry and to the highest dust temperature present. For objects viewed edge-on, the 9.7 micron silicate feature in absorption can be u sed to calculate the line-of-sight optical depth of the dust. Additionally, if Polycyclic Aromatic Hydrocarbon emission features (6.2-16.4 micron) are detected, this would suggest the presence of strong starbursts possibly coupled to the AGN activity. Many of the objects in the sample have been observed with HST, Chandra, XMM and MMT.

Spitzer Space Telescope - General Observer Proposal #20749

Formation of Young Galaxies in the Vicinities of the Most Distant Radio Galaxy and Radio-Loud Quasar

Principal Investigator: Wei Zheng
Institution: Johns Hopkins University

Technical Contact: Wei Zheng, Johns Hopkins University

Co-Investigators:
Garth Illingworth, University of California, Santa Cruz
Rychard Bouwens, University of California, Santa Cruz
Roderik Overzier, Leiden Observatory
Richard White, Space Telescope Science Institute
George Miley, Leiden Observatory
Kuenley Chiu, Johns Hopkins University
Holland Ford, Johns Hopkins University

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 26.2

Abstract:
Our deep HST images have revealed a significant excess of associated galaxies in the fields of the most distant radio-loud objects known: a radio galaxy at z=5.2 and a radio-loud quasar at z=5.8. These objects are among the most distant protogalaxies known to date, and may be evidence for massive structures forming at very early times. We propose deep imaging with IRAC at 3.6 microns to probe their properties at restframe R-band. The Spitzer data will provide critical information on the spectral shape between (restframe) Ly-alpha and H-alpha. Due to the extreme richness of the two fields we expect to shed new light on the star-formation and assembly of mass in the very early univese, and its relation to the emergence of large-scale structure.

Spitzer Space Telescope - General Observer Proposal #50420

The AGN-starburst connection: How prominent is star formation in galaxies with very young AGN?

Principal Investigator: Nathan de Vries
Institution: Leiden University

Technical Contact: Nathan de Vries, Leiden University

Co-Investigators:
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Bernhard Brandl, Leiden University
Huub Rottgering, Leiden University
Richard Schilizzi, International SKA project office
Jacco Vink, Utrecht University
Karl-Heinz Mack, Istituto di Radioastronomia - INAF, Bologna
Daniele Dallacasa, Bologna University
Carla Fanti, Istituto di Radioastronomia - INAF, Bologna
Roberto Fanti, Istituto di Radioastronomia - INAF, Bologna
Carlo Stanghellini, Istituto di Radioastronomia - INAF, Bologna
Peter Barthel, Groningen University

Science Category: AGN/quasars/radio galaxies
Observing Modes: MipsPhot
Hours Approved: 5.5

Abstract:
Recently, Spitzer has been investigating the infrared properties of classical, powerful radio galaxies, and those of intermediate size radio sources. In this proposal we wish to extend these studies, and determine the infrared properties of the host galaxies of GPS sources, an enigmatic class of compact radio source that represents the youngest stage of radio source evolution. The AGN activity in GPS galaxies is still so recent (radio sources of typically 100-1000 years - as shown by VLBI monitoring), that there has been very little time for the AGN to influence the host galaxies, and they should be in the suggested transition phase between dominating starburst and AGN activity in major merger events. We will establish the dominant heating mechanisms for these unique objects, and determine the evolution of the dust properties as function of AGN life cycle. We propose to observe a sample of 15 young radio galaxies, matching in radio power and redshift with the extended radio galaxies, at 24 and 70 micron using MIPS.

Spitzer Space Telescope - General Observer Proposal #20727

High redshift, low luminosity radio galaxies in the NDWFS Bootes and Spitzer FLS fields

Principal Investigator: Wil van Breugel
Institution: UC Merced

Technical Contact: Wil van Breugel, UC Merced

Co-Investigators:
Steve Croft, LLNL-IGPP
Arjun Dey, NOAO
Wim de Vries, UCD-LLNL
Peter Eisenhardt, JPL
Adam Stanford, UCD-IGPP
Daniel Stern, JPL
Steve Willner, Harvard-CFA

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 22.6

Abstract:
The identification fraction of IRAC sources in the 'Shallow' surveys of the Bootes NDWFS and the First Look Survey field of moderately bright, 1 - 10 mJy level, radio sources drops significantly for 92 cm - 21 cm steep spectrum sources. Keck K-band observations of a handful of such sources show that 2/3 have K ~ 21 - 22, 'classic', fuzzy high redshift radio galaxy (HzRG) morphologies. We propose to obain deep IRAC identifications of a sample of such steep spectrum selected HzRG candidates which are marginally or un-detected at 3.6 micron. We expect that perhaps as many as half of these will be HzRGs at z > 3, with luminosities 10 - 100 lower and co-moving volume densities more than 1000 larger than the extremely luminous HzRGs known to date. This will make it possible, for the first time, to get a complete census of the radio source population (galaxies, starbursts, and quasars) in well studied fields that also includes high redshift radio galaxies. This will not only help us better understand the formation and evoution of these galaxies and their AGN, but also may allow us to search for proto-cluster overdensities, and study their galaxy populations, selected at less extreme radio luminosities than has been possible before.

Spitzer Space Telescope - Legacy General Observer Proposal #20708

A Public Deep IRAC Survey in the Extended CDF-South

Principal Investigator: Pieter van Dokkum
Institution: Yale

Technical Contact: Pieter van Dokkum, Yale

Co-Investigators:
Pat McCarthy, Carnegie, Pasadena
Megan Urry, Yale
Hans-Walter Rix, MPIA, Heidelberg
Ivo Labbe, Carnegie, Pasadena
Marijn Franx, Leiden
Eric Gawiser, Yale
Jiasheng Huang, CfA
Niel Brandt, Penn State
Mark Dickinson, NOAO
Garth Illingworth, UC Santa Cruz
Casey Papovich, U of Arizona
Eric Bell, MPIA, Heidelberg
Paulina Lira, U de Chile
Sukyoung Yi, Oxford
Rychard Bouwens, UC Santa Cruz
Ned Taylor, Leiden
Danilo Marchesini, Yale

Science Category: AGN/quasars/radio galaxies
Observing Modes: IracMap
Hours Approved: 122.9

Abstract:
The 0.5 x 0.5 deg area surrounding the CDF-South is the only cosmological survey field that has multi-wavelength coverage from X-rays to the thermal infrared and whose size exceeds the correlation length of massive galaxies at 1<z<4. More than 10,000 redshifts are known, ~800 AGN have been detected, and two-band HST ACS imaging exists over the whole field. While the GALEX, Chandra, HST, and MIPS data in this field are all very deep, the existing IRAC data are not. Deep IRAC data have been shown to be pivotal in a) identifying massive high redshift objects, b) estimating galaxy masses, and c) completing the census of AGN and their host galaxies. Hence we propose deep public IRAC imaging across the whole Extended CDF-South to enable such analyses over a large enough area where the evolution of cosmic average properties can be well measured. The full set of Great Observatories data in this 900 square arcmin low-background field offers unparalleled archival value for future studies with ALMA and 20m-30m telescopes.

Spitzer Space Telescope - General Observer Proposal #3294

Environmental drivers of galaxy evolution: IR-derived star formation rates in the Abell 901/902 supercluster

Principal Investigator: Eric Bell
Institution: Max-Planck-Institute fuer Astronomie

Technical Contact: Eric Bell, Max-Planck-Institute fuer Astronomie

Co-Investigators:
Christian Wolf, University of Oxford, UK
Klaus Meisenheimer, Max-Planck-Institute fuer Astronomie
Hans-Walter Rix, Max-Planck-Institut fuer Astronomie
Casey Papovich, University of Arizona
Meghan Gray, University of Nottingham, UK
Michael Balogh, University of Durham/ University of Waterloo
Rachel Somerville, STScI

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsScan
Hours Approved: 39.0

Abstract:
The environment in which a galaxy resides shapes its star formation (SF) history and present-day SF rates. Huge efforts have addressed this critical issue, primarily using optical emission-lines; these efforts find that SF is suppressed in dense environments. However, limited radio and IR data tentatively suggest that mergers, tidal interactions and ram-pressure effects can drive intense bursts of obscured SF, which are overlooked by optical observations. We propose deep MIPS and IRAC observations of a 0.5x0.5 degree field encompassing the Abell 901/902 supercluster region in order to explore the amount, distribution, and physical drivers of obscured SF in a wide range of environments. From our ultra-precise delta z=0.02 COMBO-17 photometric redshift catalog (1200 cluster members and >10000 background galaxies), we know that the Abell 901/902 supercluster has three dense sub-clusters connected by a low-density filamentary network, allowing characterization of obscured SF over a wide range of densities in a single field. From deep X-ray and weak lensing data, we also know that the X-ray luminosity to dark-matter density ratio varies from sub-cluster to sub-cluster, giving powerful leverage to differentiate between ram-pressure and tidal influences on obscured SF. In this 39hr proposal, we will study obscured SF down to roughly LMC luminosities (likely reaching 95 per cent of total cluster SF) in A901/902 using near-confusion-limited MIPS 24um data (where 70 and 160 data will help constrain SED shape for brighter galaxies). IRAC data is requested to pin down precise positions to attach redshifts to MIPS detections. Using these data we will address: Is SF always suppressed by dense environments, or is there a moderate density regime where SF is acutally enhanced? In which environments is the bulk of SF at the current epoch? How much SF in dense environments is heavily obscured? Do ram-pressure or tidal effects lead to obscured SF?

Spitzer Space Telescope - General Observer Proposal #20606

The evolution of early-type galaxies in nearby clusters: breaking the age-metallicity degeneracy with Spitzer IRS Blue Peak-Up Imaging

Principal Investigator: Alessandro Bressan
Institution: INAF Padova Astronomical Observatory

Technical Contact: Alessandro Bressan, INAF Padova Astronomical Observatory

Co-Investigators:
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Marcel Clemens, INAF Padova
Jose Ramon Valdes, INAOE
Gian Luigi Granato, INAF Padova
Laura Silva, INAF Trieste
Luigi Danese, SISSA

Science Category: galaxy clusters and groups
Observing Modes: IracMap IrsPeakupImage
Hours Approved: 48.9

Abstract:
We have shown with Cycle 1 observations that Spitzer has the capability of disentangling age and metallicity in old stellar populations. By looking to the broad emission feature left by dust enshrouded asymptotic giant branch stars above 9.7 microns, Spitzer IRS can provide direct evidence that the colour-magnitude relation of Virgo ellipticals is mainly driven by metallicity. However, with the IRS spectrograph we can only probe the bright tail of the colour-magnitude relation, and only in the nearest cluster. We propose to use IRS Blue Peak-Up, the only Spitzer band that looks directly in the core of that spectral feature, to reach fainter galaxies. We will perform a thorough investigation of early type galaxies along the colour-magnitude relation in Virgo and in Coma clusters. These observations, when coupled with already existing IRAC and Optical-NIR observations, will allow a) an unbiased census of the stellar populations in cluster early type galaxies; b) an estimate of the AGB material recycled into the ISM in these systems; c) a direct check of the universality of the colour- magnitude relation on a wide range of magnitudes; d) a spatial study of the stellar populations within the galaxies, e.g. investigating differences between bulge and disk populations within S0; e) the most secure reference frame with which to compare the evolution of early type galaxies in other environments (groups and field).

Spitzer Space Telescope - Archive Research Proposal #50416

Star Formation and AGN Feedback in Brightest Cluster Galaxies

Principal Investigator: Megan Donahue
Institution: Michigan State University

Technical Contact: Megan Donahue, Michigan State University

Co-Investigators:
G. Mark Voit, Michigan State University
Kenneth Cavagnolo, Michigan State University
Robert O'Connell, University of Virginia

Science Category: galaxy clusters and groups(low-z)
Dollars Approved: 100000.0

Abstract:
Feedback from active galactic nuclei at the centers of galaxies clusters has become crucial to our understanding of star formation in brightest cluster galaxies (BGCs). X-ray observations have long suggested that intracluster gas should be condensing and forming stars at the centers of galaxy clusters. However, observed levels of star formation in these systems are only 1%-10% of the cooling rate expected from early X-ray imaging. Now Chandra observations are showing clear signs of AGN feedback in the form of cavities in the X-ray gas, indicating that AGNs somehow act to limit star formation in BCGs. Yet, in many BGCs star formation still continues at a reduced level, and there are now abundant observations in the Spitzer archive that can help us study it. We are therefore proposing a Spitzer archival program to compare the IR signatures of star formation in BCGs with X-ray observations of those same systems that provide information about the history of AGN feedback, in order to clarify the relationship between star formation and feedback in the universe's largest galaxies.

Spitzer Space Telescope - Directors Discretionary Time Proposal #488

Infrared Properties of a Control Sample of Brightest Cluster Galaxies

Principal Investigator: Megan Donahue
Institution: Michigan State University

Technical Contact: Megan Donahue, Michigan State University

Co-Investigators:
Christopher O'Dea, Rochester Institute of Technology
G. Mark Voit, Michigan State Univeristy
Kenneth Cavagnolo, Michigan State University

Science Category: galaxy clusters and groups
Observing Modes: MipsPhot
Hours Approved: 1.7

Abstract:
Many cluster cores have been observed by Spitzer. However, most of these cores host Brightest Cluster Galaxies (BCGs) with unusual properties, such as large H-alpha luminosities, significant radio sources, or on-going interactions and mergers. We have identified a control sample of six BCGs lacking any of these signatures, in clusters of similarly high mass and X-ray luminosity. Our previous X-ray studies of clusters of galaxies have found that the central gas entropy, an observable quantity from the X-ray data corresponding to kT/n_elec^(2/3), is a direct indicator of gas with short cooling times.The presence of low-entropy X-ray gas in the cores of clusters of galaxies is strongly correlated with the presence of BCGs with star formation or radio sources. Toward the aim of establishing a scientifically solid control sample of BCGs, we are proposing observations of these six BCGs, in clusters whose central gas entropy ranges from low (~10 keV cm^2) to quite high(~300 keV cm^2), at z=0.03-0.09 and L_x>1E44 erg/s. This control sample will allow us to make specific tests of the effects of central entropy and direct comparisons between BCGs which harbor active AGN and star formation and those that do not.

Spitzer Space Telescope - General Observer Proposal #40387

Unmasking the Strong Evolution of Cluster Starbursts

Principal Investigator: Alan Dressler
Institution: Carnegie Institution of Washington

Technical Contact: Alan Dressler, Carnegie Institution of Washington

Co-Investigators:
Augustus Oemler, OCIW
Jane Rigby, OCIW
Lei Bai, Steward Observatory, Univ of Arizona
George Rieke, Steward Observatory, Univ of Arizona

Science Category: galaxy clusters and groups(high-z)
Observing Modes: MipsPhot
Hours Approved: 27.5

Abstract:
We propose 24 um observations of galaxies in 3 rich clusters at 0.33 < z < 0.43. We target large volumes in these clusters --- out to 5 Mpc from the cluster center -- in order to study the star formation history of the infalling galaxies that are building the clusters. Intermediate-redshift clusters are known to include a large population of star-forming galaxies, unlike the passive galaxies of today's clusters. More remarkably, these starforming galaxies are typically star-bursting rather than continuously-star-forming, a behavior driven by either the cluster environment, or by cosmic evolution, or both. The Spitzer MIPS observations are essential for measuring how much star formation is hidden by dust from our optical spectral diagnostics, and especially for identifying true post-starburst galaxies. For the two principal clusters of our proposal, we bring near-complete spectroscopic samples from IMACS/Magellan that provide ~2000 spectra with redshifts per field, ~250 of which are cluster or supercluster members -- the infalling population. The complete sample allows us to compare the cluster/supercluster population with similar ''field'' galaxies -- both isolated and in groups. For these two cluster fields, ~1300 foreground and background galaxies are in the redshift range of interest. These are targets for 24 um measurements as much as the cluster galaxies, since a comparison of similar environments, in the outskirts of clusters and in the true field, will test what effect, if any, the cluster is exerting on star forming history of these galaxies.

Spitzer Space Telescope - General Observer Proposal #50492

Constraining the power output of central galaxies into cluster cores

Principal Investigator: Alastair Edge
Institution: Durham University

Technical Contact: Alastair Edge, Durham University

Co-Investigators:
Richard Wilman, University of Oxford
Andrew Fabian, University of Cambridge
Hans Bohringer, MPE
Christopher O'Dea, Rochester
Mark Swinbank, Durham University
Stefi Baum, Rochester
Alice Quillen, Rochester
Jaehong Park, Rochester
Carolin Crawford, University of Cambridge
Roderick Johnstone, University of Cambridge
Philippe Salome, IRAM, Gernoble
George Privon, Rochester
Eiichi Egami, University of Arizona

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IracMap
Hours Approved: 8.1

Abstract:
The cores of clusters of galaxies are now recognised to be amongst the most dynamic environments known. The high pressure and density of the intracluster medium in the centre of the most massive clusters of galaxies provides a number of astrophysical puzzles. Can AGN provide all of the energy required to prevent large-scale cooling of gas in a cluster core? How long to AGN exist in their active phase? Do all brightest galaxies in cluster cores have an active phase? This proposal draws on results from two programmes that are about to complete data collection. The first is the ESO X-ray Cluster Elliptical Spectral Survey, EXCESS, which is a VLT programme of 446 spectra of every brightest cluster galaxy in the REFLEX X-ray cluster sample. This investment of 192 hours of VLT time has revealed the largest sample of optically line luminous objects known to date. The second program is P30659 (PI O'Dea) that has targeted 63 optically line luminous BCGs in the northern hemisphere and has clearly identified that the most extreme objects show evidence for strong star-formation and/or active galaxy. We propose to observe the 21 optically line luminous EXCESS BCGs with IRAC to provide a definitive sample of these rare objects. These data will inform future HST, APEX, VLT, ALMA and JWST observations of these enigmatic objects. We have already made 12 new CO detections from newly identified EXCESS BCGs with the IRAM 30m telescope and ancipate that this optical spectral library will be the basis of many multi-wavelength studies in the next decade. We request IRAC and MIPS 24um observations as the observations of the O'Dea sample clearly show an excess at 8 and 24um that correlates well with the fluxes at longer wavelengths.

Spitzer Space Telescope - General Observer Proposal #50251

IRS Spectroscopic Follow-up of Spitzer Brightest Cluster Galaxy Surveys

Principal Investigator: Eiichi Egami
Institution: Steward Observatory, University of Arizona

Technical Contact: Eiichi Egami, Steward Observatory, University of Arizona

Co-Investigators:
Christopher O'Dea, Rochester Institute of Technology
Alastair Edge, University of Durham
Alice Quillen, University of Rochester
Stefi Baum, Rochester Institute of Technology

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IrsStare
Hours Approved: 35.1

Abstract:
Infrared properties of brightest cluster galaxies (BCGs) are of great interest since they may be related to the intracluster gas cooling process in cluster cores (e.g., cooling flows). Spitzer's great sensitivity has made it possible for the first time to study the infrared properties of a large number of cluster BCGs systematically. Some interesting results have already emerged from our surveys: (1) infrared-luminous BCGs are only found in the cluster cores with extremely short gas cooling times (<1 Gyr); (2) the source of infrared luminosity can be star formation or AGN depending on the BCG; (3) a few of the infrared-luminous BCGs show exceptionally strong molecular hydrogen emission lines, which are a factor of 50 overluminous compared with those of typical LIRGs/ULIRGs in one case. Here, we propose to conduct a more extensive and definitive IRS spectroscopic follow-up of 22 infrared-luminous BCGs selected from our large Cycle 3 and 4 BCG surveys. This proposed observation will allow us to define the common characteristics of this class of galaxies, which may have some important implications for the process of galaxy formation in general (i.e., cooling gas flows accreting onto a seed mass).

Spitzer Space Telescope - General Observer Proposal #20439

Ultra-Deep IRAC Imaging of Massive Lensing Galaxy Clusters: Probing the Reionization Era with Spitzer

Principal Investigator: Eiichi Egami
Institution: Steward Observatory, University of Arizona

Technical Contact: Eiichi Egami, U. Arizona

Co-Investigators:
Jean-Paul Kneib, Observatoire de Marseille
Graham Smith, California Institute of Technology
Richard Ellis, California Institute of Technology
Michael Santos, University of Cambridge
Daniel Stark, California Institute of Technology
Jiasheng Huang, Center for Astrophysics

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 44.5

Abstract:
Locating and characterizing the first subgalactic sources that may have been responsible for completing cosmic reionization and ending the ''Dark Ages'' represents the latest frontier in observational cosmology. The remarkable potential of Spitzer to probe the reionzation era was demonstrated dramatically by the IRAC detection of a gravitationally-lensed z~7 galaxy at 3.6 and 4.5 um made by our group. The results have provided a number of significant constraints on the physical properties of this galaxy. Here, we propose to conduct ultra-deep IRAC imaging (10 hrs per band) of two of the most well-studied lensing clusters, Abell 1689 and Abell 2218, in our sample. Our goal is to detect more examples of lensed galaxies at z=6-8 and to explore for systems at higher redshift.

Spitzer Space Telescope - General Observer Proposal #30950

A Census of LIRGs in Clusters of Galaxies in the First Half of the Universe from the IRAC Shallow Survey

Principal Investigator: Peter Eisenhardt
Institution: JPL

Technical Contact: Peter Eisenhardt, JPL

Co-Investigators:
Adam Stanford, UC Davis
Mark Brodwin, JPL/Caltech
Anthony Gonzalez, U. Florida
Ranga-Ram Chary, SSC
Leonidas Moustakas, JPL/Caltech
Edward Wright, UCLA
Daniel Stern, JPL/Caltech
Roberto DePropris, CTIO

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 19.8

Abstract:
The incidence of LIRGs and ULIRGs is roughly two orders of magnitude higher in the field at redshift z > 1, and at these redshifts such objects dominate the global star formation activity. Mergers which fuel such activity might be expected to enhance the frequency of LIRGs in dense environments. We propose to use MIPS to obtain a census of LIRGs in z > 1 galaxy clusters from a well defined sample found in the IRAC Shallow Survey. Supporting IRAC and HST ACS data are also requested.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30

IRAC Shallow Survey

Principal Investigator: Peter Eisenhardt
Institution: JPL

Technical Contact: Peter Eisenhardt, JPL

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 61.8

Abstract:
The NOAO deep survey is presently surveying a 9 - 10 square degree region in Bootes to K=19.5 and R=26. Data in Bw, I, J and H is also being obtained. The MIPS and IRS GTO teams are planning to survey this region with MIPS. The primary objectives for the IRAC survey of this region are to identify galaxy clusters with redshifts greater than one, and to find field brown dwarfs. If the luminosity evolution observed in clusters to redshift one continues to hold, we expect to detect L*+1 (evolving) cluster galaxies to z=2.

Spitzer Space Telescope - General Observer Proposal #30940

Tracing Star Formation History in RCS Galaxy Clusters

Principal Investigator: Erica Ellingson
Institution: University of Colorado

Technical Contact: Erica Ellingson, University of Colorado

Co-Investigators:
Jessica Jones, U. Colorado
Howard Yee, University of Toronto
Tracy Webb, McGill University
Mike Gladders, U. Chicago
Yeong Loh, U. Colorado
Amy Bender, U. Colorado

Science Category: Galaxy Clusters and Groups
Observing Modes: MipsPhot
Hours Approved: 63.7

Abstract:
We propose to obtain MIPS 24micron images for 48 clusters selected from the Red-Sequence Cluster Survey to study the evolution of star formation history and AGN fraction and their dependence on galaxy environment. The cluster sample contains relatively rich clusters (50% with estimated richness richer than mid-Abell class 1), and covers a large redshift range (0.3 to 1.1) uniformly. Current studies of star formation in mid-redshift suggest that a significant fraction of star formation in clusters may be hidden by dust. A statistically robust census using a well-defined cluster sample will greatly improve our understanding of galaxy evolution clusters and the role the environment plays. We will be able to measure star formation rate to 30 Msun/yr, for the overall sample, and to ~10-15Msun/yr for a subsample of z~1 clusters. The combination of the MIPS data and allocated IRAC imaging of the same sample will allow us to disentangle starburst/AGN sources. We will derive the excess 24micron sources in clusters as a function of redshift, study the spatial distribution of dusty starbursts and AGN in clusters, and the dependence of these activities on the properties of the clusters. Furthermore, these clusters have extensive ancillary follow-up data, including deep 4-color optical photometry, H or K band NIR imaging, multi-object spectroscopy, HST-ACS images, and SCUBA and deep radio imaging, allowing us to carry out detailed studies of the properties of 24micron luminous galaxies in clusters.

Spitzer Space Telescope - General Observer Proposal #20754

The Stellar Mass of High Redshift RCS Galaxy Clusters

Principal Investigator: Erica Ellingson
Institution: University of Colorado

Technical Contact: Erica Ellingson, University of Colorado

Co-Investigators:
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Michael Gladders, Carnegie Observatories
Kris Blindert, University of Toronto
Adam Muzzin, University of Toronto
Tracy Webb, Leiden Observatory
Henk Hoekstra, University of Victoria
David Gilbank, University of Toronto

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 15.3

Abstract:
We propose IRAC observations of a sample of 42 galaxy clusters at z>0.5 drawn from the Red-Sequence Cluster Survey (RCS). These observations will be used to calibrate the optical richness of clutsters in the RCS surveys to stellar mass. Extensive multiwavelength observations of the sample will then allow us to calculate the cluster mass function to z~1, providing important constraints on the nature of dark energy and its effect on the formation on large scale structure. We will also use these observations to form a stellar-mass limited sample of cluster galaxies which will allow us to address outstanding questions about the evolution of galaxies in dense cluster environments. In particular, we will identify whether the well-known Butcher-Oemler effect is caused primarily by normal star forming galaxies falling into the cluster, or by dwarf galaxies undergoing strong starbursts within the cluster environment.

Spitzer Space Telescope - General Observer Proposal #20343

IRS Spectroscopy of Cluster Core Filaments

Principal Investigator: Andrew Fabian
Institution: University of Cambridge

Technical Contact: Roderick Johnstone, University of Cambridge

Co-Investigators:
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Carolin Crawford, University of Cambridge
Gary Ferland, University of Kentucky
David Alexander, University of Cambridge
Richard Wilman, University of Durham
Nina Hatch, University of Cambridge

Science Category: galaxy clusters and groups
Observing Modes: IrsStare
Hours Approved: 9.7

Abstract:
We propose to make IRS observations, using the high-resolution spectrographs, of optical emission line filaments in regions ~20 kpc (~1 arcmin) from the nucleus of NGC 1275, the central galaxy in the Perseus Cluster. These observations will help us to diagnose the heating mechanism of these filaments, which has been a long-standing problem, and understand the relation of this gas to the X-ray emitting intracluster medium. We have detected 2-micron ro-vibrational molecular hydrodgen lines from these regions with UKIRT. We expect to detect low excitation members of the H2 0-0 pure rotational line series and will also cover fine structure lines due to NeII, SI, SIII and Si II. These lines will be diagnostic of the presence of warm gas (few hundred degrees excitation temperature) intermediate between the cold CO emitting phase and the much hotter near infra-red and optically emitting phase. We also propose to cover the extended emission-line filament to the south of Abell 1795 which shows detailed correspondence with X-ray emission, and the peculiar dusty H-alpha nebula at the core of the Centaurus cluster.

Spitzer Space Telescope - General Observer Proposal #40161

VIRGOFIR: a far-infrared shallow survey of the Virgo cluster

Principal Investigator: Dario Fadda
Institution: California Institute of Technology

Technical Contact: Dario Fadda, California Institute of Technology

Co-Investigators:
Andrea Biviano, INAF - Italy

Science Category: galaxy clusters and groups(low-z)
Observing Modes: MipsScan
Hours Approved: 49.9

Abstract:
We propose to survey approximately 30 sq. deg. of the Virgo cluster at 24 and 70 micron. The proposed observations will cover more than 800 member galaxies brighter than B=18 and will allow a multi-wavelength study of cluster galaxies already surveyed by SDSS, GALEX, and ROSAT. We will in particular compute the infrared luminosity function of the cluster down to 10^41 erg/s, studying in this way the slope of the faint end of the luminosity function. The contribution of different type of galaxies to the luminosity function will be investigated. We will also explore the association between star-formation and subclustering in Virgo, by computing the luminosity function in the several subclusters observed. Since this will be the first local cluster (z<0.02) observed with Spitzer, it will serve as a reference for any comparison with more distant clusters, as well as with other environments.

Spitzer Space Telescope - General Observer Proposal #20512

A Reference Sample of Local Rich Galaxy Clusters: Infrared Emission from Infalling Galaxies and DIffuse Intra-Cluster Dust

Principal Investigator: Dario Fadda
Institution: Spitzer Science Center, Caltech

Technical Contact: Dario Fadda, Spitzer Science Center, Caltech

Co-Investigators:
Francine Marleau, Spitzer Science Center
Lisa Storrie-Lombardi, Spitzer Science Center
Andrea Biviano, INAF - Italy

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsScan
Hours Approved: 30.4

Abstract:
Violent episodes of star formation occur in galaxies infalling into clusters when they first encounter the intra-cluster medium (ICM). Most of this star formation is dust-absorbed and therefore only observable through mid- and far-IR observations. In the long term, ram pressure and tidal interactions in the densest central region of the cluster strip gas and dust from these galaxies suppressing star-formation and enriching the ICM. A concentration of cold diffuse dust is thus expected in cluster cores and its emission can be only observed in the far-IR. We propose to map three rich clusters at redshift z=0.2 with MIPS and IRAC up to two virial radii. These clusters have been selected in regions of exceptionally low Galactic absorption to study faint mid-IR sources and put stringent limits on the far-IR diffuse emission from cold dust. The observations will be deep enough to detect star forming galaxies down to a star-formation rate of one solar mass per year, to compute the global star formation in clusters and compare the average star formation with that of coeval field galaxies. Rich clusters are commonly found at high redshift in wide-field Spitzer surveys. However, locally, they are extremely rare. These observation will provide a reference sample for studying evolutionary effects with the same class of objects.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40033

Star Formation and Mass Assembly in Three 1.2 < z < 1.4 Clusters of Galaxies

Principal Investigator: Giovanni Fazio
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Gillian Wilson, Spitzer Science Center

Co-Investigators:
Jiasheng Huang, Smithsonian Astrophysical Observatory
Mark Lacy, Spitzer Science Center
Jason Surace, Spitzer Science Center
Adam Muzzin, University of Toronto
Gillian Wilson, Spitzer Science Center

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 25.9

Abstract:
We propose deep and wide-field IRAC and MIPS imaging of three galaxy clusters at 1.2 < z< 1.4. The IRAC data will be used to measure the faint-end of the infrared luminosity function, four magnitudes fainter than M*. We will combine the deep Spitzer data with existing optical data to make the first measurement of the stellar mass function in high-redshift cluster galaxies. The MIPS 24 micron data will be used for quantifying the dusty star formation rate and AGN activity as a function of radius from the cluster center. A key component of this proposal is the 10 x 10 arcminute field of view (5 x 5 Mpc at the clusters' redshift). By extending into the cluster "infall" region, we will probe the region where the majority of 24 micron sources are expected to lie.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50050

The Origin of Massive Galaxies in High Redshift Clusters

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Mark Brodwin, NOAO

Co-Investigators:
Mark Brodwin, NOAO
Peter Eisenhardt, JPL
Ranga-Ram Chary, SSC
Leonidas Moustakas, JPL
Audrey Galametz, ESO
Anthony Gonzalez, U Florida
Adam Stanford, UC Davis
Daniel Stern, JPL
Alexandra Pope, NOAO
Arjun Dey, NOAO
Buell Jannuzi, NOAO
Harry Teplitz, SSC

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IrsPeakupImage
Hours Approved: 28.2

Abstract:
We propose to obtain IRS 16 um peak-up imaging of 15 well-studied, Spitzer-selected, massive galaxy clusters at 1.1 < z < 1.4. These observations will provide mid-IR photometry for 200-300 cluster members, including a minimum of 40 spectroscopically confirmed cluster members. In combination with 24 um data awarded in cycle GO-3, these data will allow us to identify and study those IR luminous cluster galaxies powered primarily by star formation. Together with extensive, ongoing z > 1 spectroscopy and ground- and space-based multiwavelength imaging, these 16 um data will allow us to measure the contribution of cluster ULIRGs and LIRGs to the buildup of stellar mass in the Universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50161

Cluster Formation at 1.5 < z < 2

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Gillian Wilson, University of California Riverside

Co-Investigators:
Gillian Wilson, University of California Riverside
Mark Lacy, Spitzer Science Center/Caltech
Jason Surace, Spitzer Science Center/Caltech
Adam Muzzin, Yale University
Jiasheng Huang, Harvard Smithsonian Center for Astrophysics

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 12.0

Abstract:
We propose deep and wide-field IRAC and MIPS imaging of two galaxy clusters at 1.5 < z < 1.6. The IRAC data will be used to measure the faint-end of the infrared luminosity function. We will combine the deep Spitzer data with existing optical data to make the first measurement of the stellar mass function in very high redshift cluster galaxies. The MIPS 24 micron data will be used for quantifying the dusty star formation rate and AGN activity as a function of radius from the cluster center. A key component of this proposal is the 10 x 10 arcminute field of view (5 x 5 Mpc at the clusters' redshift). By extending into the cluster "infall" region, we will probe the region where the majority of 24 micron sources are expected to lie.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50333

The Highest Redshift Galaxy Cluster

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Peter Eisenhardt, JPL

Co-Investigators:
Adam Stanford, UC-Davis/LLNL
Daniel Stern, JPL

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 1.6

Abstract:
We propose to obtain IRAC four band and MIPS 24 micron imaging of XCS 2215-1738, the highest redshift galaxy cluster currently known, with z = 1.46. Optical spectroscopy at Keck and the VLT has identified 21 galaxies as having concurrent redshifts at z=1.46 and a velocity dispersion of 680 km/s. The approximate X-ray temperature, based on XMM archival data, is kT = 6.5 +/- 2.1 keV, also indicating that 2215-1738 is a massive cluster. The proposed IRAC data will reach to a depth of 2 magnitudes below L*. The MIPS data will detect starburst galaxies with IR luminosities above 3E11 Lsun. We will use the new data, in conjunction with existing optical and near-IR photometry, to estimate the stellar masses of the cluster galaxies, and to test for the presence of any dusty, star-forming cluster members.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #17

Distant X-ray Galaxy Clusters

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Peter Eisenhardt, JPL

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 31.4

Abstract:
We will measure the rest-frame 1.6um luminosity function of galaxies in x-ray selected clusters with z > 0.6. We expect to reach a depth of L*+4 at z=1. The sample consists of about 40 clusters with redshifts of up to 2.2, primarily selected from the Rosat Deep Cluster Survey, augmented by other clusters with z > 0.6 and known to have x-ray emission, and a few z > 1 clusters around radio galaxies for which the velocity dispersion or Faraday rotation implies a massive cluster is present. Locally, rest 1.6um emission correlates linearly with a galaxy's dynamical mass. X-ray emission arises from the intracluster medium, which dominates the baryonic mass in local galaxy clusters. Hence the 1.6um luminosity function in x-ray selected clusters as a function of redshift can be usefully compared to models for the growth of structure.

Spitzer Space Telescope - General Observer Proposal #50456

Probing Gas Stripping in Low-Redshift Groups and Clusters using Wide-Area 24-micron Imaging

Principal Investigator: Rose Finn
Institution: Siena College

Technical Contact: Rose Finn, Siena College

Co-Investigators:
Michael Balogh, University of Waterloo
Vandana Desai, Caltech
Rebecca Koopmann, Union College
Kenneth Rines, Harvard-Smithsonian Center for Astrophysics
Gregory Rudnick, NOAO
Dennis Zaritsky, University of Arizona
Joannah Hinz, University of Arizona
Bianca Poggianti, Padua Observatory

Science Category: galaxy clusters and groups(low-z)
Observing Modes: MipsScan
Hours Approved: 35.5

Abstract:
We propose to image a 1.42 degree by 2 degree (3.06Mpc x 4.33Mpc) region around 6 low-redshift galaxy groups and clusters using MIPS in scan mode. The primary goal of this proposal is to map the spatial distribution of star-formation within star-forming cluster galaxies as a function of the X-ray luminosity of their environments. By combining these new Spitzer observations with existing Spitzer archive observations of more massive local clusters, we will probe star-formation in environments that span the full range of X-ray luminosities. These observations will help determine the relative importance of galaxy-galaxy interactions, starvation, and ram-pressure stripping in driving the evolution of galaxies from blue to red. All clusters have extensive ancillary data including: multi-band photometry for all members and spectroscopy for 90% of cluster members from the Sloan Digital Sky Survey; HI observations covering the entire extent of the MIPS scan maps, giving a more detailed picture of the gas; and Chandra observations, which will help characterize the hot intra-cluster gas. Secondary science goals of these observations include: measuring the IR luminosity function for local clusters; providing a low-redshift baseline for the Spitzer observations of 0.4 < z < 1 clusters; and determining the bias in star-formation studies based on SDSS and 2dF spectroscopy.

Spitzer Space Telescope - General Observer Proposal #20009

Integrated H-alpha and Far Infrared Star Formation Rates of High Redshift Galaxy Clusters

Principal Investigator: Rose Finn
Institution: Siena College

Technical Contact: Rose Finn, Siena College

Co-Investigators:
Joannah Hinz, University of Arizona
Dennis Zaritsky, University of Arizona
Vandana Desai, IPAC
Bianca Poggianti, University of Padova, Italy
Claire Halliday, Max Planck
Nicole Homeier, Johns Hopkins University
Marc Postman, Space Telescope Science Institute
Ken Rines, Yale University

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 14.6

Abstract:
We propose to study the evolution of star formation in galaxy cluster environments by pushing back measurements to the earliest epoch at which large samples of confirmed clusters exist, $z \\simeq 0.8$. We will measure the integrated star-formation rates (SFRs) for 12 $z \\simeq 0.8$ galaxy clusters using (1) MIPS 24 and 70 um photometry and (2) ground-based H-alpha imaging. Most importantly, the 12 $z \\simeq 0.8$ clusters span the full range in mass, from near-group environment to the most massive cluster. The 6 highest mass clusters in the sample are targets of Spitzer GTO cluster programs (PIs: Rieke, Fazio). We request 18.6 hours to complete matching MIPS and IRAC imaging of 6 optically-selected, lower-mass clusters to provide an essential complement to the ongoing Spitzer GTO observations of massive clusters at this redshift. We have found that H-alpha-derived star-formation rates depend on both cluster mass and redshift. Therefore, one must sample the full range of cluster masses to reach robust conclusions regarding evolution. By observing 6 lower mass clusters, we will provide the key systematic test of any results obtained using the GTO targets. Our H-alpha imaging has better spatial resolution and is 3 times more sensitive in terms of SFRs than our proposed MIPS observations, which will detect galaxies with SFRs of 1 M$_odot$/yr. However, H-alpha imaging alone will miss heavily obscured star-forming galaxies that are commonly associated with interactions, and the interaction rate in clusters is expected to increase with redshift. The IRAC imaging will assist in source identification in the MIPS data and will provide robust stellar masses to quantify the total past star formation. All the lower mass clusters have extensive ancillary data, including HST imaging and ground-based imaging and spectroscopy. These data will allow us to study the morphology-density-SFR relation as well as compare [OII]/H-alpha/far-IR SFRs for several hundred cluster galaxies.

Spitzer Space Telescope - General Observer Proposal #30102

Star-Formation Rates of 9 Intermediate-Redshift Galaxy Clusters

Principal Investigator: Rose Finn
Institution: Siena College

Technical Contact: Rose Finn, Siena College

Co-Investigators:
Gregory Rudnick, NOAO
Dennis Zaritsky, University of Arizona
Bianca Poggianti, University of Padova
Bo Milvang-Jensen, Max-Planck Institut fur Extraterrestrische Physik
Kenneth Rines, Yale University

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 20.6

Abstract:
In dense environments in the local universe, very few galaxies are currently forming stars, while galaxies in less dense environments are undergoing significant star formation. We are studying the star-formation properties of local and distant galaxy clusters in order to understand what causes the environmental variations in galaxy star-formation properties. This proposal targets 9 low-mass clusters at z = 0.5 in order to fill two significant gaps in current Spitzer studies of galaxy clusters. First, we will double the sample of clusters at z = 0.5. Second, our sample contains optically-selected, low-mass clusters, and current Spitzer programs target only the most massive, X-ray selected clusters at this redshift. Cluster star formation properties depend on both cluster mass and redshift. Therefore, one must sample the full range of cluster masses to reach robust conclusions regarding evolution. We request 20.6 hours to complete MIPS and IRAC imaging of the 9 clusters. We will measure star-formation rates of one solar mass per year from MIPS 24 and 70 um photometry. We will measure stellar mass and identify AGN using the IRAC data. All 9 clusters have extensive ground-based imaging and spectroscopy, and these additional data will maximize the scientific return of the Spitzer observations.

Spitzer Space Telescope - General Observer Proposal #3228

Effects of Cooling Gas, Star Formation, Active Nuclei, and Mergers in Clusters of Galaxies

Principal Investigator: William Forman
Institution: Smithsonian Astrophysical Observatory

Technical Contact: William Forman, Smithsonian Astrophysical Observatory

Co-Investigators:
Christine Jones, SAO
Michael Pahre, SAO
Jan Vrtilek, SAO
Eugene Churazov, MPA

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 2.9

Abstract:
Spitzer IRAC imaging observations of the two brightest extragalactic X-ray sources, the clusters Virgo/M87 and Perseus/NGC1275 provide an opportunity to sensitively inventory the mass content in cluster cores and to determine the distribution of cool material. While the mass cooling from the hot gas phase has been shown to be smaller than the simple ''cooling flow'' model, significant amounts of gas are cooling. Many clusters show extended emission line regions, excess blue light from young stars, and dust. Combining images of the X-ray emitting gas, HST and ground-based imaging of the emission line gas, and sensitive radio observations with the high angular resolution of Spitzer IRAC observations will address the perplexing properties found in the central galaxies of rich clusters. Resolved images of cool material around the central galaxies M87/Virgo and NGC1275/Perseus promise new insights in understanding 1) the relationship between galaxy mergers, the matter that they inject into the central regions of clusters, and the onset of activity in the central galaxy, 2) the mass deposition rate in ''cooling flows'' 3) the origin of the dust associated with the emission line structures and 4) the effects of relativistic plasma, ejected by the central black hole, on the cooling gas and on star formation from this gas.

Spitzer Space Telescope - General Observer Proposal #50608

The nature of LIRGs in rich clusters at z~0.5

Principal Investigator: James Geach
Institution: Durham University

Technical Contact: James Geach, Durham University

Co-Investigators:
Ian Smail, Durham
Sean Moran, Caltech
Tommaso Treu, UCSB
Richard Ellis, Caltech
Alastair Edge, Durham

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IrsMap
Hours Approved: 14.0

Abstract:
We propose low resolution mid-IR spectroscopy of members of the rich cluster MS0451-03 at z=0.55 which are bright at 24um, and fall in the luminous infrared galaxy class (LIRG). This cluster is not as rich in active galaxies as others we have studied at this redshift, and we postulate that this cluster-to-cluster scatter could be partially due to the varying efficiency of processes related to global cluster properties on quenching star formation in infalling field spirals. We will test whether the LIRGs in MS0451-03 are powered by starbursts or active galactic nuclei (AGN), and whether their properties differ from an identically selected sample in the cluster CL0024+16, containing a larger population of LIRGs. If the hot ICM of MS0451-03 is more effective at switching off star formation (e.g. via ram pressure stripping), then these LIRGs may be the most gas-rich or intensely star forming galaxies that have survived cluster infall. We may also expect a higher fraction of AGN, since these are likely to be more difficult to 'switch-off' via pressure stripping. Understanding the nature of LIRGs in distant clusters is important, because these galaxies are a potential progenitor population of S0 galaxies, abundant in the cores of local rich clusters.

Spitzer Space Telescope - General Observer Proposal #30718

Spitzer Observations of a GRB-Selected Galaxy Cluster at z=1.8

Principal Investigator: Michael Gladders
Institution: Carnegie Observatories

Technical Contact: Edo Berger, Carnegie Observatories

Co-Investigators:
Edo Berger, Carnegie Observatories
Ivo Labbe, Carnegie Observatories

Science Category: Galaxy Clusters and Groups
Observing Modes: IracMap MipsPhot
Hours Approved: 5.1

Abstract:
We propose IRAC 3.8-8 micron and MIPS 24 micron imaging of a z~1.8 galaxy cluster discovered in association with the short gamma ray burst GRB 050813. This apparent cluster, nominally the highest redshift (by far!) bona-fide cluster known to date, appears as a spatial/color overdensity of ultra-red EROs which is overdense compared to the field by a factor of 40. This unique cluster sits at a redshift which bridges the actively star-forming proto-clusters seen around AGN at higher redshift, and lower redshift collapsed clusters, and we expect to see this transformation in action. The Spitzer will allow us to confirm the reality of this cluster, refine the photometric redshifts, and examine in detail the cluster galaxy population with respect to stellar populations, dust and AGN content, and correlate these to morphology (via in-hand HST-ACS imaging). Detailed modeling of the stellar population of the GRB host galaxy itself (a cluster member) will also set the strictest possible current limits on GRB progenitor lifetimes.

Spitzer Space Telescope - General Observer Proposal #40593

Quenched Star Formation in the Bullet Cluster

Principal Investigator: Anthony Gonzalez
Institution: University of Florida

Technical Contact: Anthony Gonzalez, University of Florida

Co-Investigators:
Sun Chung, University of Florida
Christine Jones, Harvard-Smithsonian Center for Astrophysics
Doug Clowe, Ohio University

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 5.4

Abstract:
We propose to obtain MIPS and IRAC imaging out to the virial radius for the bullet cluster, 1E0657-56, to quantify the impact of a supersonic cluster merger upon star formation in cluser galaxies. Using existing Cycle 2 IRAC observations of the cluster core, we have identified a strong correlation between PAH emission and the projected location of galaxies relative to the shock front. The proposed observations will enable us to both extend this analysis to a wider area, improving the statistics, and establish a more direct link to star formation using 24 micron emission. This data set will be used in conjunction with our extensive multiwavelength data sets, including H-alpha equivalent widths from optical spectroscopy, to provide a complete view of star formation in this unique system.

Spitzer Space Telescope - General Observer Proposal #20626

Search for Infrared Emission from the Leo Extragalactic HI Cloud

Principal Investigator: George Helou
Institution: Caltech

Technical Contact: George Helou, Caltech

Co-Investigators:
Yervant Terzian, Cornell University
William Latter, SSC/Caltech
Stephen Schneider, University of Massachussets

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsScan
Hours Approved: 24.2

Abstract:
We propose to map at 8, 24, 70 and 160um the one intergalactic HI cloud that has remained undetected at any wavelength other than the 21-cm HI line. The Leo Cloud was discovered serendipitously, and mapped subsequently in detail at both Arecibo and the VLA. The radio data reveal kinematic and spatial structure that rules out an origin as a recent tidal tail, leaving most likely the scenario that this is primordial, relatively pristine material. A detection of the dust emission from the Cloud would provide the only radiative manifestation other than HI, and would allow us to estimate the dust content of the Cloud, and therefore its metallicity. Even an upper limit would help constrain its origin and history.

Spitzer Space Telescope - General Observer Proposal #20740

Life on the Edges: Morphological Transformation of Galaxies in Clusters of Galaxies at z=1

Principal Investigator: Bradford Holden
Institution: University of California Observatories/Lick Observ

Technical Contact: Bradford Holden, UCO/Lick

Co-Investigators:
Daniel Kelson, Observatories of the Carnegie Institution of Washi
John Blakeslee, The Johns Hopkins University
Marijn Franx, Leiden Observatory
Garth Illingworth, University of California, Santa Cruz
Marc Postman, Space Telescope Science Institute
Kim-Vy Tran, ETH

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 29.3

Abstract:
Between a redshift of one and today, the mix of morphologies inside clusters of galaxies has changed. Both galaxy-galaxy mergers and passive processes have been proposed to explain this evolution. However, there is ample evidence that at z=1, clusters are still being formed out of infalling groups of galaxies. Therefore, these infalling groups are a likely location for the processes that drive morphological evolution. We propose for 15 by 15 arcminute mosaics using IRAC and MIPS in the vicinity of three z=0.8-0.9 clusters of galaxies. For each cluster, we have some or all of the HST ACS imaging required to measure the distribution of galaxy types and identify merger candidates. Our ongoing program of spectra and ground based imaging will determine the rest-frame optical properties and cluster membership. Spitzer's unique window into the rest-frame near and mid-infrared will allow us to determine accurate stellar mass estimates and star formation rates, even for red galaxies with little optical evidence of any activity. With these data, we will answer the questions: (1) do the infalling galaxies have a sufficient stellar mass to become a typical z=0 cluster galaxy, (2) are the mergers we observe among the infalling galaxies "dry" or are they undergoing massive amounts of star formation, and (3) are the star formation histories of these infalling galaxies consistent with them becoming the massive systems dominated by old stellar populations that we see in clusters of galaxies today?

Spitzer Space Telescope - General Observer Proposal #3521

Uncovering Galaxies and Star Formation in the Outskirts of Coma

Principal Investigator: Ann Hornschemeier
Institution: Johns Hopkins University

Technical Contact: Ann Hornschemeier, Johns Hopkins University

Co-Investigators:
Bahram Mobasher, Space Telescope Science Institute
David Alexander, Institute of Astronomy, Cambridge
Timothy Heckman, Johns Hopkins University

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 6.9

Abstract:
Clusters of galaxies provide ideal environments for studies of galaxies due to the overdensities of all types of galaxies in a variety of environments. At a redshift of z=0.0228, Coma is the nearest rich cluster, a unique laboratory for studying evolution of galaxies. We select a 30 arcminute by 50 arcminute field located approximately one degree from the the center of Coma for moderate-depth IRAC imaging; the total requested AOR time is 6.9 hours. The Spitzer observations, combined with the available optical photometric and spectroscopic data as well as Chandra X-ray data will be used to uncover the galaxies missed in optical surveys, constructing a MIR luminosity function down to very low mass dwarf galaxies. We will also explore the infall regime and the effect of dust in forming different types of galaxies, and compare the star-formation rates estimated from X-ray and infrared data for a well calibrated sample. The IRAC exposure time is 108~seconds per field of view; we will detect very low luminosity dwarf galaxies. This dataset complements the Guaranteed Time programs of the Spitzer instrument teams, which focus on the center of Coma.

Spitzer Space Telescope - General Observer Proposal #20253

Dusty Starbursts or Old, Red Galaxies in a Proto-Cluster at z ~ 2.4?

Principal Investigator: Myungshin Im
Institution: Seoul National University

Technical Contact: Myungshin Im, Seoul National University

Co-Investigators:
Philip Choi, Spitzer Science Center
James Colbert, Spitzer Science Center
Dario Fadda, Spitzer Science Center
Francine Marleau, Spitzer Science Center
Matt Malkan, University of California, Los Angeles
Giovanni Fazio, SAO/Center for Astrophysics
Howard Smith, SAO/Center for Astrophysics
Steve Willner, SAO/Center for Astrophysics
Michael Pahre, SAO/Center for Astrophysics

Science Category: galaxy clusters and groups
Observing Modes: MipsPhot
Hours Approved: 6.0

Abstract:
We propose deep MIPS 24 micron imaging of galaxies near the z=2.39 radio galaxy 53W002. Recently, we have uncovered an unusually large number of very red galaxies with J-K > 2.7 mag in this field. This is the expected color for old, passively evolving galaxies near the same redshift as the radio galaxy. Our Keck spectroscopic data identify several galaxies near this redshift, including one of red ones. Evidently we are seeing a proto-cluster of galaxies formed at high redshift in an overdense region. Our Spitzer IRAC observations of the red galaxies show that their spectral energy distributions can be fit by old (>1 Gyr), early-type galaxies. According to hierarchical galaxy formation models, the formation of massive cluster galaxies occurs around z ~ 2 - 3, preceding the formation epoch of early-types in low density environment. Finding massive galaxies in an already evolved stage would challenge the hierarchical galaxy formation scenario. However, there is an alternate explanation for the observed SEDs: very dusty young galaxies, where the dust entirely hides the young stars. This scenario would support the hierarchical model. In order to answer the critical question of whether these red galaxies are old (zf > 4) or are dusty, we will obtain a deep 24 micron image of the field. If dust is not seen, it will rule out hidden star formation and pose a severe challenge to the hierarchical model. Our observation will also provide limits or measurements of the IR flux of other z ~ 2.4 galaxies in the field, such as submm galaxies and Lyman-alpha emitters, offering us a more complete view of the star formation history in an overdense region.

Spitzer Space Telescope - General Observer Proposal #40508

Cooling the cores of protoclusters: Molecular Hydrogen as a diagnostic of feedback physics in the early Universe.

Principal Investigator: Walter Jaffe
Institution: University of Leiden

Technical Contact: Walter Jaffe, University of Leiden

Co-Investigators:
George Miley, University of Leiden
Malcolm Bremer, University of Bristol
Nina Hatch, University of Leiden
Raymond Oonk, Observatory

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IrsStare
Hours Approved: 15.8

Abstract:
We propose to observe massive galaxies forming at the centers of two z>2 protoclusters at z>2 with the IRS/SL2 spectrometer. Our aim is to detect the 1-0S lines (restframe K-band) that are markers of gas cooling and feedback reheating processes. These processes, which we have shown to be present in low-z "cooling flow" clusters, are required during galaxy formation in the early Universe to produce present-day galaxy populations. The ratio of the 1-0S lines to the nearby Paschen alpha line is a clear indicator of whether feedback is taking place. The targets were chosen on the basis of their large IR luminosities, the associated giant ionized gas halos, high H-alpha brightnesses and extreme star formation rates. They are the typical progenitors of the galaxies that dominate present day clusters. In addition to indicating the presence of feedback, the Spitzer spectra. when compared to groundbased Halpha will allow an accurate estimate of the currently unknown dust extinction in the clusters.

Spitzer Space Telescope - General Observer Proposal #30117

The missing energy in cooling flow clusters: dust and EUV radiation

Principal Investigator: Walter Jaffe
Institution: Leiden Observatory

Technical Contact: Walter Jaffe, Leiden Observatory

Co-Investigators:
Malcolm Bremer, Bristol University
Mark Birkenshaw, Bristol University
Joop Schaye, Leiden Observatory

Science Category: galaxy clusters and groups
Observing Modes: IrsStare MipsPhot
Hours Approved: 13.3

Abstract:
We propose observations of the the mid-IR continuum and line emission from the warm gas and dust at the centers of cooling flow clusters, in order to investigate the energetics of the cool gas and dust phases in these regions. The observations will allow us to characterise the shape of the UV spectrum that excites the gas and heats the dust, and provide clues to which mechanisms stop the cooling flow processes at about 10^7 K. For the first time in cooling flows, we will detect emission from the dust, measuring its temperature (or range of temperatures) and identify silicate and PAH features crucial for determining the relationship between the dust and the source that is heating it. These are key measurements as dust should play an important role in the energetics of the cool phase. As the cooling process in these clusters is analogous to the cooling that occurs during galaxy formation, the results of this programme will be applicable beyond the continuing controversy on cooling flows. The three clusters to be observed are already known to have IR emission features from ground-based and Spitzer observations made under AO-1. The complete suite of follow-up observations proposed here will allow us to draw far stronger inferences about the physics involved than can be gained from the earlier data alone.

Spitzer Space Telescope - General Observer Proposal #3161

Cool Molecular Gas in Cooling Flow Clusters

Principal Investigator: Walter Jaffe
Institution: Leiden Observatory

Technical Contact: Walter Jaffe, Leiden Observatory

Co-Investigators:
Malcolm Bremer, University of Bristol
Paul van der Werf, Leiden Observatory

Science Category: galaxy clusters and groups
Observing Modes: IrsStare
Hours Approved: 4.2

Abstract:
As part of a large ongoing multiwavelength study into the nature and energetics of the cool and cold phases of the intra cluster medium of clusters of galaxies, we propose to search for rotational H$_2$ lines from 100-200 Kelvin gas at the centres of these clusters. The cool gas has several possible origins, including having cooled from the hot phase of the intra cluster medium. In any event, a full understanding of its nature is key to our understanding of galaxy formation and evolution.

Spitzer Space Telescope - General Observer Proposal #40802

Unveiling the Hidden Heart of the Great Attractor

Principal Investigator: Thomas Jarrett
Institution: Spitzer Science Center

Technical Contact: Thomas Jarrett, Spitzer Science Center

Co-Investigators:
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Tony Fairall, UCT
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Takahiro Nagayama, Kyoto

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IracMap MipsScan
Hours Approved: 27.0

Abstract:
The southern Milky Way shrouds one of the most important dynamical structures in the local universe, the Great Attractor, whose discovery some two decades ago has sparked intensive research into the large scale mass distribution of galaxies over the entire sky. And yet the Great Attractor itself -- its size, density and total mass -- remains largely a mystery as it is cut in half by the gas and dust mask of the foreground Galactic Plane. Without a complete picture of the local galaxy distribution, the reconstructed density field and cosmological density and biasing parameters will like-wise remain uncertain. Here we propose to use IRAC & MIPS to map the most heavily extinguished region of the Great Attractor, the "heart" of the Norma Wall of galaxies that stretches across the plane of the Milky Way. Our preliminary investigation of this region using the shallow GLIMPSE survey resulted in detecting luminous galaxies that trace a more massive underlying population. We will identify and extract galaxies, follow them up with spectroscopic measurements to create a 3-D catalog of infrared galaxies in the region. Such a catalog will reveal the hidden large scale structure, completing the remaining gap that divides the southern and northern extragalactic sky after dedicated efforts in the optical, near-IR, X-ray and radio in mapping the galaxy distribution in the Great Attractor region. A complete view of the galaxy density field will enable comparison of the Great Attractor with the more distant Shapley Concentration to resolve the ongoing debate on their relative importance in generating the peculiar velocity field of the local universe. Spitzer is ideally suited to addressing the most difficult challenge associated with understanding the Great Attractor -- Spitzer is capable of simultaneously detecting all types of galaxies and penetrating the thick dust lanes of the Milky Way.

Spitzer Space Telescope - General Observer Proposal #3596

Where is the Dust and Star Formation in Compact Groups of Galaxies?

Principal Investigator: Kelsey Johnson
Institution: University of Wisconsin - Madison

Technical Contact: Kelsey Johnson, University of Virginia

Co-Investigators:
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Ann Hornschemeier, Johns Hopkins University
John Hibbard, NRAO

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 17.5

Abstract:
Compact groups of galaxies provide a unique environment to study the mechanisms by which star formation occurs amid continuous gravitational encounters. These dense groups host a variety of modes of star formation, and they can provide insight into the role of gas in galaxy evolution. As part of a multi-wavelength effort to study compact groups of galaxies (spanning X-ray to radio wavelengths), we propose Spitzer IRAC and MIPS imaging for a sample of twelve Hickson Compact Groups. The Spitzer observations will provide powerful diagnostics to study the recent and ongoing star formation in these groups, as well as the affect of galaxy interactions on the location of dust in these systems. We will investigate the role of environment in the formation of stars and massive star clusters, the properties of the embedded regions of star formation, the timescales involved in the triggering and propagation of star formation, the relationship between dust and gas, and the transition/relationship between starbursts and AGNs in these dense groups of interacting galaxies. The sample of giant galaxies, starbursts, LINERs, and AGNs is comparable in size and surface brightness sensitivity to the SINGS Legacy Program, which covers a wide range of environments, but does not include compact groups. These observations will ultimately have an impact on our understanding of the assembly of galaxies at high redshift, and on galaxy evolution throughout the universe.

Spitzer Space Telescope - General Observer Proposal #30945

Spitzer Observations of Environomental Effects on Virgo Cluster Galaxies

Principal Investigator: Jeffrey Kenney
Institution: Yale University

Technical Contact: Eric Murphy, Yale University

Co-Investigators:
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Jacqueline van Gorkom, Columbia University
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Curtis Struck, Iowa State University
Ranier Beck, Max Planck Institute-- Bonn
David Schiminovich, Columbia University
Eric Murphy, Yale University
Alberto Noriega-Crespo, Spitzer Science Center
David Makovoz, Spitzer Science Center

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsScan
Hours Approved: 102.9

Abstract:
We propose Spitzer MIPS and IRAC observations for a carefully selected sample of 36 Virgo cluster spiral and peculiar galaxies. The detailed information that Spitzer provides on the interstellar medium, star formation, and stellar populations, when combined with our considerable data base and simulations, will greatly improve our understanding of interactions in clusters and the consequences for galaxy evolution. For this sample, we already have VLA HI and radio continuum images from the VIVA survey, optical BVRH-alpha imaging, GALEX UV images, and optical spectroscopy. Mapping the unobscured distributions of star formation at 24um will reveal the effects of interactions, such as tidally triggered central starbursts, and ram-pressure induced star formation at the outer edges of stripped gas disks. We will compare the observed distributions of star formation with predictions from simulations which are already tightly constrained by the optical and HI data. The Spitzer 8um PAH images show outer galaxy ISM with a combination of sensitivity and resolution better than optical and HI images. This outer galaxy dust is a powerful tracer of the types of interactions and their timescales. Comparisons with B-I ‘‘dust extinction’’ maps will constrain interaction models by clarifying the ISM geometry. The near-IR data from IRAC, together with GALEX UV, H-alpha, and optical spectroscopy, will provide spatially-resolved star formation histories. Analyzing the expected variations in the radio-to-FIR ratio in extraplanar regions will also provide strong constraints on the physical processes which generally link these two emissions so tightly in star-forming galaxies. These galaxies are different from galaxies outside of clusters, since most of them have been significantly modified by their environment. The science goals are distinct from SINGS, although complementary, and would use the SINGS data as a benchmark for comparison with non-cluster galaxies.

Spitzer Space Telescope - General Observer Proposal #30507

Far-infrared Emission from the Coma Cluster of Galaxies

Principal Investigator: Tetsu Kitayama
Institution: Toho University

Technical Contact: Tetsu Kitayama, Toho University

Co-Investigators:
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Yuka Yoshikawa Tajiri, The University of Tokyo
Takashi Onaka, The University of Tokyo
Itsuki Sakon, The University of Tokyo
Naomi Ota, RIKEN
Hirohisa Nagata, National Astronomical Observatory of Japan
Kenkichi Yamada, Toho University

Science Category: galaxy clusters and groups
Observing Modes: MipsScan
Hours Approved: 11.4

Abstract:
We propose MIPS observations of the Coma cluster of galaxies (A1656), aiming at the first firm detection of intergalactic dust grains. Clusters of galaxies provide a unique environment of dust-gas interactions; the X-ray emitting plasma can heat the dust to 10-20 K via collisions, as well as destroy small grains via sputtering. Recent claim of detecting collisionally heated dust grains in Coma by ISOPHOT (Stickel et al. 2002), however, has been much debated owing to insufficient quality of the data. With MIPS, we can test their result unambiguously for the first time. In addition, multi-wavelength detections enable us to determine both the amount and the mean temperature of the grains. Combined with X-ray and optical data, they further provide powerful clues to understanding the dust-gas interaction and the ejection history of dust from galaxies. In case of no detection, we are still able to place severe constraints on its amount, which is a meaningful step forward in the long-standing argument regarding the intergalactic dust. Our observation will therefore provide a unique opportunity of probing the nature of dust grains in relation to the ambient hot gas and host galaxies.

Spitzer Space Telescope - General Observer Proposal #40652

Galaxy Evolution in the Cluster/Filament Environment

Principal Investigator: Dale Kocevski
Institution: University of California, Davis

Technical Contact: Dale Kocevski, University of California, Davis

Co-Investigators:
Harald Ebeling, University of Hawaii
Cheng-Jiun Ma, University of Hawaii

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsScan
Hours Approved: 16.0

Abstract:
Recent studies have found that the outskirts of galaxy clusters, such as the filament networks which feed them, play a pivotal role in driving galaxy evolution well before galaxies reach the cluster environment. Several processes have been proposed that would transform galaxies in the low-density regime, some of which directly suppress star formation activity and others that would instead trigger a burst of star formation that consumes most of the galaxy's gas supply. We can directly test for this latter class of mechanisms by searching for a starbursting population of galaxies in and around clusters. Furthermore since many of the proposed processes are most effective at different galaxy and gas densities, the properties of the local environment in which starburst galaxies are found can help constrain the mechanisms which trigger them. We propose 3.6-8 micron IRAC and 24 micron MIPS observations of a well defined and highly studied large-scale filament feeding the massive cluster MACS J0717.5+3745 at z=0.55. The filament is a highly coherent, spectroscopically confirmed structure detected in our galaxy surface density maps, weak lensing analysis and X-ray observations. We have compiled an extensive multi-wavelength dataset to aid in this study, including an 18-pointing, high-resolution HST ACS mosaic of the field. The environment around MACS J0717.5+3745 is well suited to investigate the mechanisms which trigger starburst activity and drive galaxy evolution in clusters as it provides a full range of environments to probe, from the cluster core to the filament-cluster interface and out to the low density regime of the filament proper. By examining the properties of the local environment in which starburst galaxies are activated, along with their morphological and spectroscopic attributes we can place strong constraints on the physical processes which trigger such activity and ultimately transform field galaxies into the passively evolving population of galaxies predominately found in clusters.

Spitzer Space Telescope - General Observer Proposal #50393

Investigating the Triggers of Starburst Activity in Galaxy Clusters

Principal Investigator: Dale Kocevski
Institution: University of California, Davis

Technical Contact: Dale Kocevski, University of California, Davis

Co-Investigators:
Harald Ebeling, University of Hawaii
Cheng-Jiun Ma, University of Hawaii

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsScan
Hours Approved: 16.0

Abstract:
The physical processes responsible for driving the transformation of star-forming field galaxies to passively evolving cluster members are still poorly understood. Several mechanisms have been proposed, some of which would directly suppress star formation activity, while others would instead trigger a burst of star formation that subsequently consumes most of a galaxy's gas supply. We can directly test for this latter class of mechanisms by searching for a starburst population of galaxies in and around clusters. Furthermore since many of the proposed processes are most effective at different galaxy and gas densities, the location and properties of the local environments in which these galaxies are found will help constrain the mechanism which trigger their activity. We propose 3.6-8 micron IRAC and 24 micron MIPS observations of the massive, relaxed cluster MACS J1423.8+2404 at z=0.54 in order to carry out a comparative study with our pending observations of the morphologically disturbed cluster MACS J0717.5+3745 at z=0.55. While the two systems have nearly identical global properties, there is ongoing galaxy accretion into MACS J0717.5+3745 through a large-scale filament connected to the system, whereas no such activity or signs of significant substructure are detected in MACS J1423.8+2404. We intend to use the observations to map the distribution of any galaxies undergoing a starburst phase from the cluster core out to the field population. The distinct environments offered by the two clusters, one with actively infalling galaxies and the other with a more virialized population, will allow us to better isolate the effects that these conditions have on triggering starburst activity. Furthermore, similarities in the global properties of the two clusters, such as system redshift and mass, will enable us to disentangle the role of large-scale versus local environment in driving galaxy evolution in these systems.

Spitzer Space Telescope - General Observer Proposal #20277

The Unique Cluster Lens SDSS1004+4112

Principal Investigator: Christopher Kochanek
Institution: The Ohio State University

Technical Contact: Christopher Kochanek, The Ohio State University

Co-Investigators:
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Xinyu Dai, The Ohio State University
Thomas Broadhurst, Tel Aviv University
Masamune Oguri, Department of Astrophysical Sciences, Princeton Un

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 6.8

Abstract:
SDSS1004+4112 is a unique example of a cluster lens because of its relatively high lens redshift (zlens=0.68), the existence of multiply imaged quasars for which time delays are measured, the presence of a significant number of multiply imaged background galaxies, and a quasar host galaxy that is so magnified that it can be observed in the mid-IR. By combining a deep 4-channel IRAC image with a NICMOS mosaic of the central, multiply-imaged region of the cluster, we will study the quasar host galaxy, search for low-mass substructure in the cluster, obtain accurate photometric redshifts for lensed arcs, discover very red lensed arcs and develop an accurate mass model for the cluster. Then we will combine all the data to obtain a competitive constraint on the cosmological model.

Spitzer Space Telescope - General Observer Proposal #20451

A Mid-Infrared Survey of Gravitational Lenses

Principal Investigator: Christopher Kochanek
Institution: The Ohio State University

Technical Contact: Christopher Kochanek, The Ohio State University

Co-Investigators:
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Xinyu Dai, The Ohio State University
Emilio Falco, Smithsonian Astrophysical Observatory

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 8.7

Abstract:
We will use mid-IR IRAC images of six gravitational lenses to understand a basic problem of gravitational lenses -- why simple lens models explain the image positions but not the image fluxes. We know from models of lensed quasar host galaxies observed by HST that the problem does not lie in our models for the gravitational potential of the main lens galaxy. For optical and near-IR data, the explanation can be propagation effects (dust), microlensing by stars in the lens galaxy, or what is known as cold dark matter (CDM) substructure (satellites) of the lens galaxy. The mid-IR fluxes are immune to both dust and microlensing -- the wavelength is to long to be bothered by dust and the emission region is to large to be bothered by microlensing. If the mid-IR flux ratios are still unexplained by simple lens models, the cause must be the predicted (and much debated) CDM substructure. Thus, the SST/IRAC observations will provide a simple test of a basic prediction of cold dark matter models for the formation of galaxies.

Spitzer Space Telescope - General Observer Proposal #50342

Exploring the Web : Galaxy Evolution in High-Redshift Superclusters

Principal Investigator: Lori Lubin
Institution: University of California

Technical Contact: Lori Lubin, University of California

Co-Investigators:
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Dale Kocevski, UC Davis
Christopher Fassnacht, UC Davis
Roy Gal, Institute for Astronomy
Neal Miller, JHU
Gordon Squires, SSC/Caltech
Mark Lacy, SSC/Caltech
Jason Surace, SSC/Caltech

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsScan
Hours Approved: 32.8

Abstract:
We propose deep IRAC and MIPS mapping of the Cl 1324 supercluster at z = 0.7 which contains 7+ clusters and extends 22 Mpc x 100 Mpc. The supercluster is already the subject of a multi-faceted program including (1) deep r'i'z'JK imaging from the Palomar 5-m and UKIRT 3.8-m to measure optical/near-IR colors, (2) spectroscopy with DEIMOS on the Keck 10-m to measure stellar content and [OII] emission for over 400 supercluster members, and (3) high-angular-resolution Chandra and VLA observations to study the starburst and AGN populations. Based on comparisons with our well-studied (in the optical, mid-IR, radio, and X-ray) and similarly-sized Cl 1604 supercluster at z = 0.9, we find significant evolution over only ~1 Gyr, with substantially smaller contributions from [OII]-emitting and starburst galaxies in the Cl 1324 supercluster. Because dust will severely bias measurements made in the optical, we require 3.6-24 micron observations to measure accurately stellar mass, star formation rate, and nuclear/starburst activity in the member galaxies and determine the true extent of evolution over this timescale. With the combined observations of the Cl 1324 and Cl 1604 superclusters, we have the unique opportunity to constrain the effect of large scale environment on galaxy evolution, the physical mechanisms responsible for fueling starburst and nuclear activity, and the timescales of gas quenching and black-hole accretion.

Spitzer Space Telescope - General Observer Proposal #30455

Mixing It Up : Gas, Stars, Starbirth, and AGN in a Supercluster at z = 0.9

Principal Investigator: Lori Lubin
Institution: University of California

Technical Contact: Lori Lubin, University of California

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Roy Gal, University of Virginia
Gordon Squires, SSC/Caltech
Mark Lacy, SSC/Caltech
Lin Yan, SSC/Caltech
John McKean, Max Planck Institut fuer Radioastronomie Bonn

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsScan
Hours Approved: 29.6

Abstract:
We propose a joint Spitzer/HST program to map the best-studied large scale structure at high redshift -- a massive twelve-cluster supercluster at z = 0.9 which extends 15 Mpc x 100 Mpc. Because clusters are actively forming at this redshift, and significant evolution has already been observed in their galaxy populations, this survey will provide the crucial link between large scale structure and galaxy-scale physics. The supercluster is already the subject of a multi-faceted program including (1) deep r'i'z'K imaging from the Palomar 5-m to measure optical/near-IR colors, (2) spectroscopy with DEIMOS on the Keck 10-m to measure stellar content, [OII] equivalent widths, and internal velocities for over 330 supercluster members, (3) high-angular-resolution Chandra and VLA observations to study the starburst and AGN populations, and (4) an 80 ksec XMM observation to quantify the cluster gas properties and the amount of diffuse emission from the low-density filaments. The proposed 3.6-24 micron mapping is an essential complement to this program because it provides more accurate measures of stellar mass, star formation rate, and nuclear/starburst activity across the entire structure. The ACS observations will provide equal detail on galaxy structural properties and morphology. Together, the deep mid-infrared observations and the high-angular-resolution HST imagery (along with our coordinated ground and space-based data) will allow us to measure the stellar mass function, stellar population ages, and star formation rates over the full range of environmental densities; use galaxy morphology to determine what type of galaxies host AGN and which physical processes are responsible for gas-fueling events; quantify the IR/radio/X-ray correlations at z = 0.9; and determine the effect of large scale structure on the stellar and gas content of galaxies in the high-redshift Universe.

Spitzer Space Telescope - General Observer Proposal #50096

Unveiling a Population of Hidden AGN in Clusters of Galaxies

Principal Investigator: Paul Martini
Institution: Ohio State University

Technical Contact: Paul Martini, Ohio State University

Co-Investigators:
John Mulchaey, OCIW
Daniel Kelson, OCIW

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 18.0

Abstract:
We have conducted an X-ray and visible-wavelength study of eight clusters of galaxies and measured an unexpectedly high AGN fraction of 5 percent, or approximately five times higher than previous estimates. However, these AGN classifications remain uncertain because all but four are based on X-ray luminosity and flux ratios as the galaxies lack the classical, visible-wavelength emission-lines characteristic of AGN. We propose Spitzer IRAC and 24micron MIPS photometry of our AGN candidates to determine if they are genuine AGN based on evidence for hot dust emission in the infrared. We will also use these observations to determine if these AGN lack visible-wavelength emission lines because they are intrinsically optically dull, or if they are heavily obscured. A previously hidden AGN population in clusters of galaxies has many interesting implications for AGN fueling, feedback, and black hole growth in rich environments, while the nature of these X-ray bright but optically normal galaxies make them cluster analogs of the faint field AGN uncovered with Spitzer and Chandra.

Spitzer Space Telescope - General Observer Proposal #20345

Starbursts and Supercavities in Clusters of Galaxies

Principal Investigator: Brian McNamara
Institution: Ohio University

Technical Contact: Brian McNamara, Ohio University

Co-Investigators:
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Michael Wise, MIT
Megan Donahue, Michigan State University
Mark Voit, Michigan State University
Paul Nulsen, CfA

Science Category: galaxy clusters and groups
Observing Modes: IrsStare
Hours Approved: 25.7

Abstract:
Evidence is mounting that AGN feedback injects significant energy into the massive hot atmospheres of large elliptical galaxies, groups, and clusters of galaxies. This inhibits accretion and limits the star formation that would otherwise occur in cooling flows. We propose to investigate this feedback process using Spitzer/IRS mid-IR spectral maps of six well studied cooling flow clusters. The maps will be used to obtain accurate measures of the star formation rate, dust distribution and AGN activity. These will be compared to measures of feedback power from shocks and relativistic-jet cavities in the X-ray emitting gas and the state of the hot gas in the vicinity of the AGN. Our prime target, MS0735.6+7421, has a pair of supergiant cavities and shocks that have deposited 6e61 erg into the surrounding gas. The central supermassive black hole grew in mass by roughly 1/3 during this outburst. The basic mechanisms of cooling and energy feedback which can be studied in the mid-IR in these systems are relevant to a wide range of galaxy astrophysics.

Spitzer Space Telescope - General Observer Proposal #50292

A Complete Census of Star-formation/AGN Activity in a z=0.14 ''Proto-cluster''

Principal Investigator: Glenn Morrison
Institution: University of Hawaii

Technical Contact: Glenn Morrison, University of Hawaii

Co-Investigators:
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Min Yun, UMass
Frazer Owen, NRAO
David Frayer, NHSC-Caltech
Stephane Arnouts, CFHT
Mark Dickinson, NOAO
William Keel, UAlabama
Chris Miller, CTIO

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IracMap MipsScan
Hours Approved: 24.8

Abstract:
We propose deep, wide-field IRAC/MIPS 24um and 70um observations of one of the richest, developing filamentary-type clusters in the nearby universe for the purpose for measuring galaxy activity (AGN/star-formation;SF) down to M*+3 with SF rates >1M_solar/yr. Given the rapid progression of ''downsizing'' since z<1, one would expect to see most of the activity in the lower mass population. Abell 1882 at z~0.14 has one of the most diverse environments of any filament-type cluster previously studied and is made up of high density groups which are interconnected via X-ray filaments. This cluster is a system in formation undergoing a phase of mass accretion and has a large and active radio population (45 with measured z's - with photo-z 100) whose radio power source is unknown. The region of interest is matched by our coverage at other wavelengths (radio, optical, NIR, UV). Past Spitzer 24um studies have demonstrated the prevalence of dust-obscured active populations in higher redshift structures (clusters, superclusters). Their 24um data along with other wavelengths have pointed to obscured activity which was assumed to be SF. The potential error in translating 24um to SFR is huge if one does not know the MIR/FIR SED or even whether the sources might be AGN! We will use 24 and 70um to calculate the best fitting SED (hence derive accurate FIR, 5x better) which will then allow us to calculate the q=log(FIR/radio) value, taking into account the cold dust temperature. A factor of 5x improvement in FIR is well-matched to q studies. It is the difference between a q=1.60 and q=2.30 galaxy, where q=1.60 is used as a dividing line between an AGN & SF. The key questions we will answer are: Is there a correlation between SB and AGN activity and the galaxy density, and if so on what spatial scales? Is there a systematic difference between the SB and AGN activity, as a function of local galaxy density and X-ray brightness?

Spitzer Space Telescope - General Observer Proposal #40044

A MIPS Survey of a Representative Sample of Galaxy Groups

Principal Investigator: John Mulchaey
Institution: Carnegie Institution of Washington

Technical Contact: John Mulchaey, Carnegie Institution of Washington

Co-Investigators:
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Somak Raychaudhury, University of Birmingham
Jesper Rasmussen, University of Birmingham
Chandreyee Sengupta, RRI
Frazer Pearce, University of Nottingham

Science Category: galaxy clusters and groups(low-z)
Observing Modes: MipsScan
Hours Approved: 36.6

Abstract:
Most galaxies in the universe are members of groups. Groups are, therefore, an important laboratory for studying the processes associated with galaxy formation and evolution. To better understand the group environment and its role on galaxy evolution, we are carrying out the first detailed optical, X-ray and HI study of an unbiased sample of nearby groups. Each group in our sample is being observed with the IMACS wide-field multi-object spectrograph on the Magellan I telescope, XMM-Newton and the GMRT. Our existing data suggests that a large fraction of group galaxies are undergoing active star formation and that the level of star formation is linked to the evolutionary stage of the group itself. However, our current star formation estimates may be significantly underestimated due to dust obscuration and the fact that our spectroscopic slits cover only the central regions of each galaxy. To obtain more robust estimates of the star formation properties, we propose a MIPS 24 and 70 micron imaging survey of our group sample. The proposed MIPS observations will probe to very low star formation rates (0.1 solar mass per year) allowing for an accurate census of the star formation activity in each system. The combination of our existing IMACS, XMM and GMRT data with the proposed MIPS observations will allow us to address the following questions:1) How do the star formation rates of galaxies in groups vary with the evolutionary state of the group?, 2) Are dusty starbursts common in galaxy groups?, 3) How have the galaxy populations in groups evolved over time? and 4) What mechanisms drive galaxy evolution in groups?

Spitzer Space Telescope - General Observer Proposal #50475

A Spitzer Survey of the NGC 2563 Group of Galaxies

Principal Investigator: John Mulchaey
Institution: Carnegie Institution of Washington

Technical Contact: John Mulchaey, Carnegie Institution of Washington

Co-Investigators:
Jacqueline van Gorkom, Columbia University
Ann Zabludoff, University of Arizona
Eric Wilcots, University of Wisconsin
Paul Martini, Ohio State University
Jesper Rasmussen, Carnegie Institution of Washington

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IracMap MipsScan
Hours Approved: 18.1

Abstract:
We propose an IRAC and MIPS imaging survey of the NGC 2563 group of galaxies. As one of the nearest X-ray groups, this system is an ideal target to study the role of galaxy-intragroup medium interactions in galaxy evolution. We have been awarded a large program with Chandra to trace the hot baryons in this group and have used the VLA to measure the HI properties of the group members down to very low gas masses. The proposed Spitzer observations will be used to map out the dusty ISM, study the old stellar populations and quantify the star formation properties of the group members. Combined with our extensive optical, HI and X-ray data, the Spitzer data will provide a complete census of the major baryonic components in this group. A key element of our program is that we are studying the group population out to the virial radius of the system. Our program has been designed to provide the first comprehensive study of the galaxies in an X-ray group and in many ways is the group equivalent to the extensive studies of richer systems like the Virgo and Coma clusters.

Spitzer Space Telescope - General Observer Proposal #20760

IRAC Imaging of the Most Distant X-ray Massive Galaxy Cluster at z=1.4

Principal Investigator: Christopher Mullis
Institution: University of Michigan

Technical Contact: Christopher Mullis, University of Michigan

Co-Investigators:
Piero Rosati, European Southern Observatory
Hans Boehringer, Max-Planck Institut fur extraterrestrische Physik
Axel Schwope, Astrophysikalisches Institut Potsdam
Georg Lamer, Astrophysikalisches Institut Potsdam
Rene Fassbender, Max-Planck Institut fur extraterrestrische Physik
Peter Schuecker, Max-Planck Institut fur extraterrestrische Physik
Veronica Strazzullo, European Southern Observatory

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 4.0

Abstract:
We propose to obtain deep IRAC imaging of the most distant X-ray-luminous cluster of galaxies found to date. XMMU J2235.3-2557 was first detected as an extended XMM-Newton X-ray source and then spectroscopically confirmed at z=1.393 with the VLT-FORS2. Based on its high X-ray luminosity, ICM gas temperature, and optical/NIR richness, this galaxy cluster is very likely the most distant and most massive (z>1) structure yet identified. The proposed IRAC observations will measure the rest-frame near-IR flux of the z=1.4 cluster galaxies. This flux is known to be strongly correlated with the underlying stellar mass. We will construct the rest-frame near-IR luminosity function, derive the stellar mass function, and perform SED fitting to constrain galaxy ages and masses at the largest look-back times ever probed with clusters. With these diagnostics extracted from the high-density cluster environment, combined with complementary measures in the field population, we will directly test the predictions of competing models of galaxy formation.

Spitzer Space Telescope - General Observer Proposal #30659

A Census of Star Formation in Brightest Cluster Galaxies: Is Star Formation the Ultimate Fate of the Cooling Gas?

Principal Investigator: Christopher O'Dea
Institution: Rochester Institute of Technology

Technical Contact: Christopher O'Dea, Rochester Institute of Technology

Co-Investigators:
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Andy Fabian, University of Cambridge
Brian McNamara, Ohio University
Steven Allen, Stanford
Alice Quillen, University of Rochester
Mark Voit, Michigan State University
Stefi Baum, Rochester Institute of Technology
Richard Wilman, University of Durham
William Sparks, STScI
Paul Goudfrooij, STScI
Duccio Macchetto, STScI
Carolin Crawford, University of Cambridge
Roderick Johnstone, University of Cambridge
David Frayer, IPAC
Craig Sarazin, University of Virginia
Joel Bregman, University of Michigan
George Rieke, University of Arizona
Eiichi Egami, University of Arizona

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 33.2

Abstract:
We propose a comprehensive IRAC and MIPS survey of a sample of X-ray selected low redshift brightest cluster galaxies with high H-alpha luminosities to determine the star formation properties of the key class of galaxy. The giant ellipticals in cluster cores have long been regarded as old, quiescent galaxies free of dust and star-formation. However, recent optical, sub-mm, and Spitzer mir-far IR observations have shown that this is not the case in the cores of cooling flows. Instead, substantial masses of both molecular gas (1E9-11 solar masses) and dust (1E7-8 solar masses) are found. Spitzer IRAC and MIPS observations of a few clusters have suggested that the BCGs with high X-ray luminosity and short cooling times or equivalently high H-alpha luminosities exhibit IR luminosities consistent with dust heated by star formation at rates of tens of solar masses per year (Egami et al 2006). These star formation rates are now consistent with the revised X-ray derived mass deposition rates offering the exciting possibility of a solution to the conundrum of cooling flows. These observations also revealed that the one source in their sample which hosted a powerful radio source had a star formation rate much lower than the inferred mass deposition rate, consistent with feedback from the central AGN lowering the mass inflow rate. These results are based on observationsof only a few clusters. With the observations proposed here we will be able to explore the relationship between the ICM, cooling flows, star formation, and AGN activity in BCGs and put these tentative results on firm statistical footing. We will obtain constraints on the fate of cooling gas, heating and cooling processes in the ICM, the nature of star formation in the central galaxies, and the activity of the central massive black hole. We anticipate that for this data set will be of great interest to a large number of researchers and will reduce our proprietary period.

Spitzer Space Telescope - General Observer Proposal #3384

Mid-Infrared Spectroscopy of Massive Cluster Cooling Flows

Principal Investigator: Robert O'Connell
Institution: University of Virginia

Technical Contact: Robert O'Connell, University of Virginia

Co-Investigators:
Brian McNamara, Ohio University
Michael Wise, MIT
Megan Donahue, Michigan State University
Mark Voit, Michigan State University
Paul Nulsen, Center for Astrophysics

Science Category: galaxy clusters and groups
Observing Modes: IrsMap IrsStare
Hours Approved: 14.5

Abstract:
Cooling flows in X-ray bright clusters of galaxies can deposit large amounts of cooled intracluster gas on the galaxies at their centers. A wide variety of UV/optical/IR signatures of deposition have been found, including evidence for cooled gas and dust and for star formation at rates of ~10-300 M_sun/yr. Recent Chandra and XMM-Newton soft X-ray spectroscopy shows that the energy balance of the intracluster gas is strongly affected by heating from a highly efficient feedback mechanism, which is not yet identified. We propose to obtain Spitzer/IRS mid-IR spectral maps to explore the deposition process in five archetypal cluster cooling flows. Our specific interests include assessing the relation of the dust to the cooling flow and obtaining greatly improved estimates of the star formation rates for comparison to the deposition rates. The basic mechanisms of cooling and energy feedback which can be studied in the mid-IR in these systems are relevant to a wide range of galaxy astrophysics.

Spitzer Space Telescope - General Observer Proposal #40460

Shocked Baryons and Star Formation in a High-Redshift Protocluster

Principal Investigator: Patrick Ogle
Institution: Spitzer Science Center

Technical Contact: Patrick Ogle, Spitzer Science Center

Co-Investigators:
Phil Appleton, NHSC-Caltech
Dario Fadda, NHSC-Caltech
Nick Seymour, Spitzer Science Center

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IrsMap
Hours Approved: 42.8

Abstract:
The origin of hot baryons in the massive intracluster media of galaxy clusters is an unsolved mystery. We will map the potential sources of hot baryons in a high-redshift, radio-selected galaxy protocluster. We propose a very deep (6 hr/pixel), 2 square arcminute spectral map of the redshift z=2.156 protocluster surrounding the MRC 1138-262 radio galaxy. Spitzer IRS LL observations will map star formation, AGN activity, and shocked molecular hydrogen in a large number of cluster galaxies. The recent Spitzer discovery of massive, high luminosity molecular hydrogen emission in galaxy clusters and radio galaxies motivates our search. High-velocity galaxy collisions, starburst super-winds, relativistic radio jets, and cluster accretion shocks are all potential mechanisms for shocking, disrupting, and removing the cool baryons in galaxy potential wells and ejecting them into the intracluster medium. Spitzer is sensitive to all of these processes through detection of the pure-rotational lines of molecular hydrogen and PAH emission from luminous, star-forming infrared galaxies and AGNs.

Spitzer Space Telescope - General Observer Proposal #3475

A MIPS Investigation of Cold Dust Surrounding Gas-Rich Dwarf Galaxies in the Virgo Cluster

Principal Investigator: Cristina C. Popescu
Institution: Max Planck Institut fuer Kernphysik

Technical Contact: Cristina Popescu, University of Central Lancashire

Co-Investigators:
Richard J. Tuffs, Max Planck Institut fuer Kernphysik, Astrophysics
Barry F. Madore, Observatories of the Carnegie Institution of Washi
Armando Gil de Paz, Observatories of the Carnegie Institution of Washi
Heinrich J. Voelk, Max Planck Institut fuer Kernphysik

Science Category: galaxy clusters and groups
Observing Modes: MipsPhot
Hours Approved: 11.4

Abstract:
We propose deep MIPS raster maps of extended fields centered on 11 gas-rich dwarf galaxies in the Virgo Cluster. The MIPS maps will elucidate the nature of the very cold dust outside the optical extent of these galaxies, as discovered by us with ISOPHOT. The 11 targets were selected either because they exhibit 170 micron emission from cold dust extending beyond the optical body of the galaxies (by factors of up to more than 3.5), and/or because they have extremely high 170/100 flux density ratios. The superior sensitivity and improved angular resolution of MIPS will allow us to obtain the first 2D maps of the extended 160 micron cold dust emission with detailed morphological information. The same large fields will also be mapped at 70 micron to obtain a spatial template of the cirrus emission which is the dominant source of confusion at 160 micron. The resulting deep MIPS maps at 160 micron will constitute a unique probe for distinguishing between the different scenarios for the wider existence, origin and heating mechanisms of the extended cold dust. We propose to exploit the excellent sensitivity of MIPS at 24 and 70 micron to measure the expected warm dust emission from the HII regions within these galaxies. This will probe the link - if any - between the dust powered within the optical disk and dust external to this disk. Comparison with CO, submm and optical broad/narrow band maps (all data already obtained and reduced by us) of the optical body of the dwarfs will be used to completely characterize the dust and gas content as well as the star formation properties and stellar mass of the central galaxy. Our observations will throw light on the relation of the dwarf galaxies to their ambient medium. They will also be important in a cosmological context, since gas-rich dwarf galaxies may prevail at the earliest epochs, making a higher contribution to the total FIR output of the early Universe than previously expected. The total AOR time for the proposed MIPS observations is 11.4 h.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50589

Unveiling the Effects of Environment on Star Formation in Galaxy Groups

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Krystal Tyler, University of Arizona

Co-Investigators:
Ivelina Momcheva, University of Arizona
Krystal Tyler, University of Arizona
Lei Bai, University of Arizona
Marcia Rieke, University of Arizona
Ann Zabludoff, University of Arizona
Delphine Marcillac, University of Arizona
John Mulchaey, Carnegie Institution of Washington

Science Category: galaxy clusters and groups(high-z)
Observing Modes: MipsPhot
Hours Approved: 22.3

Abstract:
As galaxies evolve, they are subject to a menagerie of violent events that can disrupt or entirely subdue ongoing star formation. Nowhere is this more apparent than in high-density environments. Clustering due to hierarchical formation results in interactions between galaxies and the intracluster medium, leading to the demise of star formation and the rise of red sequence galaxies. However, correlations between local density and galaxy properties like morphology, star formation rate, and color exist from the largest clusters down to the poorest groups. It is likely, since the majority of galaxies lie in groups, that global trends in fundamental properties are driven by this environment. That is, the strong observed decline in star formation rate from z ~ 1 is likely to be directly related to processes affecting group galaxies. Despite this, groups are rarely studied, especially compared to the massive amounts of data available for clusters. Indeed, if we wish to study the effect of density on galaxy evolution, we need to focus on all densities. We propose to observe 48 groups of galaxies at intermediate redshifts (0.12 < z < 0.82), the era where strong evolution and transformation are expected for groups, with MIPS at 24-microns. This waveband is ideal for studying obscured star formation in galaxies, which is especially useful for our intermediate redshift range, where other star formation indicators, such as H-alpha and [OII] emission lines, become difficult to acquire and/or correct for obscuration. We will combine our groups with additional data for nearby groups and those at z ~ 1, as well as data for clusters at similar redshifts, to study the effects of a wide variety of densities on galaxy evolution from z ~ 1 to the present.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40562

Star Formation in X-ray Underluminous Clusters

Principal Investigator: George Rieke
Institution: Steward Observatory, U. Arizona

Technical Contact: George Rieke, Steward Observatory, U. Arizona

Co-Investigators:
Lei Bai, Steward Observatory, Univ. of Arizona
Delphine Marcillac, Steward Observatory, Univ. of Arizona

Science Category: galaxy clusters and groups(low-z)
Observing Modes: MipsPhot MipsScan
Hours Approved: 7.0

Abstract:
X-ray underluminous clusters compose about half of the known cluster population, but their star formation is rarely studied. Their lower X-ray luminosities, compared with expectations from the scaling relation between X-ray luminosity and virial mass traced by the X-ray-selected clusters, are probably a result of the intracluster gas still being in the process of infalling and suggest they may be nascent clusters. The particular forming stage of the X-ray underluminous clusters may result in very different star formation properties when compared with well relaxed, X-ray luminous clusters. We have found some tentative evidence showing there is more star formation in these clusters. In this proposal, we will study star formation in 4 X-ray underluminous clustersat 24 microns and compare it with that in X-ray luminous clusters. This comparison will help us determine the mechanisms that suppress the star formation in the X-ray luminous clusters.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40602

IRS Spectroscopy of Infrared-Luminous Brightest Cluster Galaxies

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Eiichi Egami, University of Arizona

Co-Investigators:
Eiichi Egami, University of Arizona
Christopher O'Dea, Rochester Institute of Technology
Jaehong Park, University of Rochester
Alastair Edge, University of Durham
Alice Quillen, University of Rochester
Stefi Baum, Rochester Institute of Technology

Science Category: galaxy clusters and groups(low-z)
Observing Modes: IrsStare
Hours Approved: 5.0

Abstract:
Infrared properties of brightest cluster galaxies (BCGs) are of great interest since they may be related to the intracluster gas cooling process in cluster cores (e.g., cooling flows). Spitzer's great sensitivity has made it possible for the first time to study the infrared properties of a large number of cluster BCGs systematically. Some interesting results have already emerged from our GTO massive cluster survey: (1) infrared-luminous BCGs are only found in the cluster cores with extremely short gas cooling times (<1 Gyr); (2) the source of infrared luminosity seems star formation; (3) one infrared-luminous BCG shows exceptionally strong molecular hydrogen emission lines, which are a factor of 50 overluminous compared with those of typical LIRGs/ULIRGs. Here, we propose to conduct a more extensive IRS spectroscopic follow-up of 6 newly discovered infrared-luminous BCGs in our GO-3 survey. This proposed observation will allow us to define the common characteristics of this class of galaxies, which may have some important implications for the process of galaxy formation in general (i.e., cooling gas flows accreting onto a seed mass).

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50547

Star Formation in X-ray Underluminous Clusters

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: George Rieke, The University of Arizona

Co-Investigators:
Lei Bai, Steward Observatory, Univ. of Arizona
Krystal Tyler, Steward Observatory, Univ. of Arizona

Science Category: galaxy clusters and groups(low-z)
Observing Modes: MipsPhot MipsScan
Hours Approved: 7.5

Abstract:
X-ray underluminous clusters compose about half of the known cluster population, but their star formation is rarely studied. Their lower X-ray luminosities, compared with expectations from the scaling relation between X-ray luminosity and virial mass traced by the X-ray-selected clusters, are probably a result of the intracluster gas still being in the process of infalling and suggest they may be nascent clusters. The deficiency of the hot X-ray gas and the particular forming stage of the X-ray underluminous clusters may result in very different star formation properties when compared with well relaxed, X-ray luminous clusters. In the last Spitzer cycle, we proposed to observe four X-ray underluminous clusters with MIPS to study their star formation properties. Although we do not have MIPS data yet, the spectroscopic data we have obtained for these clusters already show evidence of surprisingly high star formation activities. However, with only four clusters in the sample, it is difficult to draw a statistically significant result. To further confirm this tentative result and to increase the statistical sample, we propose to observe four more X-ray underluminous clusters. This proposal will help us determine the mechanisms that suppress the star formation in the X-ray luminous clusters.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30827

Illuminating the evolution of CNOC2 group galaxies with MIPS at 24microns

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: George Rieke, The University of Arizona

Co-Investigators:
David Wilman, Max Planck Institute for Extraterrestrial Physics
John Mulchaey, Carnegie Observatories
Marcia Rieke, University of Arizona
Lei Bai, University of Arizona
Michael Balogh, The University of Waterloo
Daniele Pierini, Max Planck Institute for Extraterrestrial Physics
Richard Bower, University of Durham
Augustus Oemler Jnr, Carnegie Observatories
George Hau, University of Durham
Ray Carlberg, University of Toronto
Delphine Marcillac, University of Arizona

Science Category: galaxy clusters and groups
Observing Modes: MipsPhot
Hours Approved: 24.7

Abstract:
Groups of galaxies play a critical role in the global evolution of galaxies, as their dynamics make them the ideal environment to foster galaxy-galaxy interactions and mergers, generating infrared-bright dusty starbursts and leading to a dramatic transformation of the galaxy properties. As groups today contain ~60% of the galaxy population, and are the first super-galactic step in the hierarchical growth tree which dominates structure formation, these environments must have a critical influence on the evolution of star formation in the Universe as a whole. To study the evolution of star formation in groups requires highly complete, targetted, deep spectroscopic surveys; the only such survey is our sample of 26 groups at 0.3<z<0.55, selected from the CNOC2 redshift survey. This unique sample has: a) complete kinematic data to ~M*+3; b) high resolution HST ACS imaging; c)GALEX UV imaging; and d) X-ray data from both Chandra and XMM. We propose to obtain 24 micron MIPS observations of this sample, to uncover the signature of dust-obscured star formation that is probably the dominant mode in the gas-rich, frequently merging galaxies found in groups. With a sample of ~350 group and ~450 spectroscopically identified field galaxies at 0.3<z<0.55, our combined dataset will help to distentangle the roles of environment, epoch and stellar mass in controlling the evolutionary fate of a galaxy.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30889

Detecting extended intracluster dust emission in Abell 2029

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: George Rieke, The University of Arizona

Co-Investigators:
Lei Bai, University of Arizona

Science Category: galaxy clusters and groups
Observing Modes: MipsScan
Hours Approved: 11.6

Abstract:
Detecting dust in the hot intracluster gas has been a goal for a number of infrared missions. There are a number of tentative detections, but they are generally not confirmed with further observation. If interpreted as upper limits, the non-detection or the weak detection of this dust component by IRAS and ISO in many clusters suggests a strongly dust-depleted intracluster plasma, which is believed arises due to sputtering. Using MIPS 24 micron data for Abell 2029, we have detected a weak signal of this extended emission in the cluster core, coincident with the X-ray peak. Unlike previous studies, the resolution of MIPS allows us to remove the contributions of the cluster galaxies. Also, the instrument stability and the long baseline observation mode we used minimize the systematic error of the signal. Nonetheless, the detection is not solidly established. Therefore, we are asking for three times longer exposure time to achieve a secure detection of this extended dust emission.

Spitzer Space Telescope - General Observer Proposal #40058

Evolution of Star Formation in the 400 Square Degree Galaxy Cluster Survey

Principal Investigator: Kenneth Rines
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Kenneth Rines, Smithsonian Astrophysical Observatory

Co-Investigators:
Rose Finn, Siena College
Alexey Vikhlinin, Harvard-Smithsonian CfA
Rodion Burenin, Space Research Institute (IKI), Moscow, Russia
Thomas Reiprich, Institute for Astrophysics, Bonn University, Germa
Allan Hornstrup, Danish National Space Center, Copenhagen, Denmark
Harald Ebeling, Institute for Astronomy, Hawaii
Hernan Quintana, P.U.C., Chile

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 25.1

Abstract:
We propose to study the evolution of star formation in cluster galaxies using a sample that will be arguably the largest and best-studied representative sample of moderate-redshift X-ray clusters for the next decade. The star formation properties of cluster galaxies differ dramatically from field galaxies, but the reasons why remain unclear. Observations of individual clusters suggest that total cluster star formation rates depend on both redshift and cluster mass, but cluster-to-cluster variations are large. To overcome these variations, we propose a survey of clusters from one of the largest area deep X-ray cluster surveys, the 400 square degree survey. We will observe a mass-selected sample of moderate redshift clusters which are being observed in a large (1.8 Msec) Chandra project to probe dark energy. Spitzer observations are critical for measuring optically-obscured star formation, which can be a factor of 10-100 larger than total [OII] SFRs in moderate redshift cluster galaxies. Because clusters are effective gravitational lenses, the IRAC observations can also be used to probe high-redshift galaxies. These Spitzer observations will (1) provide a complete census of SFR in a large X-ray cluster sample, (2) determine the dependence of SFR on both redshift and cluster mass, (3) measure the size of cluster-to-cluster variations in SFR, (4) test the correlations between different tracers of SFR and their evolution, (5) provide important clues to the environmental dependence of star formation in galaxies, and (6) determine the potential impact of cluster galaxy evolution in using clusters as probes of dark energy. Part of this sample was approved in GO2; we propose to complete the sample.

Spitzer Space Telescope - General Observer Proposal #20225

Evolution of Star Formation in the 400 Square Degree Galaxy Cluster Survey

Principal Investigator: Kenneth Rines
Institution: Yale University

Technical Contact: Kenneth Rines, Harvard University

Co-Investigators:
Rose Finn, Siena College
Alexy Vikhlinin, Harvard-CfA
Rodion Burenin, Space Research Institute, Russia
Thomas Reiprich, IfA, Bonn U.
Allan Hornstrup, Danish National Space Center, Copenhagen
Harald Ebeling, IfA, Hawaii
Hernan Quintana, P.U.C. Chile

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 25.3

Abstract:
We propose to study the evolution of star formation in cluster galaxies using a sample that will be arguably the largest and best-studied sample of moderate-redshift X-ray clusters for the next decade. The star formation properties of cluster galaxies differ dramatically from field galaxies, but the reasons why are still unclear. Observations of individual clusters suggest that total cluster star formation rates depend on both redshift and cluster mass, but the cluster-to-cluster variations are large. To overcome these variations, we propose a survey of clusters from one of the largest area deep X-ray cluster surveys, the 400 square degree survey. We will observe a mass-selected sample of moderate redshift clusters which are being observed in a large (1 Msec) Chandra project to probe dark energy. Spitzer observations are critical for measuring optically-obscured star formation, which can be a factor of 10-100 larger than total [OII] SFRs in moderate redshift cluster galaxies. Because clusters are effective gravitational lenses, the IRAC observations can also be used to probe high-redshift galaxies. These Spitzer observations will (1) provide a complete census of SFR in a large X-ray cluster sample, (2) determine the dependence of SFR on both redshift and cluster mass, (3) test the correlations between different tracers of SFR and their evolution, (4) provide important clues to the environmental dependence of star formation in galaxies, and (5) determine the impact of cluster galaxy evolution in using clusters as probes of dark energy.

Spitzer Space Telescope - General Observer Proposal #50733

Star formation in the Infall Regions of Intermediate Redshift Clusters

Principal Investigator: Gregory Rudnick
Institution: NOAO

Technical Contact: Gregory Rudnick, NOAO

Co-Investigators:
Rose Finn, Siena College, USA
Vandana Desai, Spitzer Science Center, USA
Alfonso Aragon-Salamanca, Nottingham University, UK
Bianca Poggianti, Padova Observatory, Italy
Gabriella De Lucia, Max-Planck-Institute for Astrophysics, Germany
Claire Halliday, Osservatorio Astrofisico di Arcetri, Italy
Bo Milvang-Jensen, Niels Bohr Institute, Denmark
Dennis Zaritsky, University of Arizona,USA
Douglas Clowe, Ohio University, USA
Pascale Jablonka, Geneva Observatory, Switzerland
Steven Bamford, University of Portsmouth, UK

Science Category: galaxy clusters and groups(high-z)
Observing Modes: MipsScan
Hours Approved: 28.3

Abstract:
There are well known correlations between star formation and environment such that clusters have a much lower fraction of star forming galaxies than groups or the field. Clusters may therefore play an important role in supressing star formation in galaxies. Local studies have supported this scenario but have not been able to isolate the mechanisms that suppress star formation since the majority of galaxies in clusters have already ceased forming stars. To determine how clusters transform galaxies en masse it is necessary to catch the transformation "in the act". We propose panoramic MIPS 24 micron imaging of 7 well studied galaxy clusters at 0.55 < z < 0.8 drawn from the ESO Distant Cluster Survey (EDisCS). We will measure how the fraction of star forming galaxies depends on local galaxy density and on clustercentric distance, probing with one data set from the cluster cores, through the infall regions, and into the field. The requirements of this survey are influenced by our experience from EDisCS. It must have 1) observations at large lookback times when the galaxy population in clusters was rapidly evolving, 2) a large sample of clusters with a large range in velocity dispersion to determine the dependence of star forming galaxy fraction on cluster mass, 3) measurements to large clustercentric radii to probe local densities comparable to groups but in the vicinity of clusters, and 4) data at MIR wavelengths to measure SFR unbiased by dust obscuration. Our EDisCS clusters are the best studied systems at these redshifts, with optical and near infrared ground-based imaging, HST imaging, extensive deep VLT spectropscopy, XMM-Newton data, and deep IRAC and MIPS data, all on the central ~2.5 x 2.5 Mpc of each cluster. Most importantly, they are part of an extensive wide--field spectroscopy program covering ~12Mpc x 12Mpc, which will yield unambiguous cluster membership and determinations of the local environment.

Spitzer Space Telescope - General Observer Proposal #50210

Obscured starbursts in galaxy clusters: a MIPS survey of z=0.5 clusters

Principal Investigator: Ian Smail
Institution: Insitute for Computational Cosmology

Technical Contact: Ian Smail, Insitute for Computational Cosmology

Co-Investigators:
Julie Wardlow, Durham University
Jim Geach, Durham University
Harald Ebeling, IfA, Hawaii
Cheng-Jiun Ma, IfA, Hawaii
Alastair Edge, Durham University

Science Category: galaxy clusters and groups(high-z)
Observing Modes: MipsScan
Hours Approved: 35.2

Abstract:
We propose panoramic MIPS 24um imaging of four intermediate redshift (z~0.5) clusters selected from the MACS X-ray Survey. We will combine these with observations of four clusters at the same epoch from our pilot study (which span a broader range in mass) to parameterize the evolutionary sequence of infalling field galaxies in terms of the cluster global structure. This analysis will distinguish between the role of global and local environment in determining the star formation histories of starburst galaxies entering the cluster potential from the low-density field. Our previous successful MIPS project has yielded some exciting results - in particular the existence of large populations of starburst galaxies in z~0.5 clusters with strong PAH emission - which have been completely overlooked by previous optical/near-IR surveys of these well-studied systems. These are potentially the missing link between distant spirals and the local passive S0 galaxies which are the dominant population in local clusters. Our initial results point to a strong dependence of star formation on specific cluster properties - either the dynamical state or the cluster mass (or equivalently temperature of the ICM). By specifically targeting four clusters with a narrow range in mass, but a wide range of structures, we aim to determine the key drivers of the variation in the starburst population within clusters. This will provide vital clues as to the physics of environmental transformations of galaxies: an important ingredient of current galaxy evolution models.

Spitzer Space Telescope - General Observer Proposal #30263

Obscured activity and environment: a 24um survey of two well-studied clusters at z~0.5

Principal Investigator: Ian Smail
Institution: Insitute for Computational Cosmology

Technical Contact: Ian Smail, Insitute for Computational Cosmology

Co-Investigators:
James Geach, Durham University
Alastair Edge, Durham University
Richard Ellis, Caltech
Tommaso Treu, UCSB
Tadayuki Kodama, NAOJ
Masayuki Tanaka, University of Tokyo

Science Category: galaxy clusters and groups
Observing Modes: MipsPhot
Hours Approved: 15.6

Abstract:
We propose to use MIPS to obtain high quality panoramic 24um mid-infrared imaging of galaxies within two rich clusters at z~0.5 which are part of an panoramic photometric survey using Subaru. Our survey traces the galaxy properties within the large scale structure around these massive clusters. In the outer regions of galaxy clusters critical processes take place which transform the properties of in-falling, star-forming spiral field galaxies and convert these to the passive, early-type galaxies which dominate the cluster population. In our optical survey of rich clusters at z=0.4-0.5 we have discovered a sharp dependence with local galaxy density in the apparent star formation activity within galaxies. This critical density threshold is characteristic of groups and filaments. We now propose to extend ourinvestigation of this behaviour using sensitive mid-infrared observations to trace the variation of obscured activity within the large-scale structure around these clusters. This will allow us to construct the evolutionary cycle for galaxies as they are accreted onto a cluster, by tracing the variation in their activity as a function of their environment. The results of our analysis will provide a clearer view of the physical processes responsible for creating the strong environmental variations in galaxy properties which underpin the local morphology-density relation.

Spitzer Space Telescope - General Observer Proposal #40872

A Joint Spitzer/Lensing Survey - Exploring the Connection Between Hierarchical Assembly and Starburst Activity in Galaxy Clusters at z=0.2

Principal Investigator: Graham Smith
Institution: University of Birmingham

Technical Contact: Graham Smith, University of Birmingham

Co-Investigators:
Eiichi Egami, Steward Observatory
Richard Ellis, California Institute of Technology
Masahiro Takada, Tohoku University
Toshifumi Futamase, Tohoku University
James Taylor, University of Waterloo
Arif Babul, University of Victoria
Jean-Paul Kneib, OAMP, Marseilles
Phil Marshall, UCSB
John Carlstrom, University of Chicago
Gus Evrard, University of Michigan
Alexis Finoguenov, UMBC
Pasquale Mazzotta, CfA
Trevor Ponman, University of Birmingham

Science Category: galaxy clusters and groups(low-z)
Observing Modes: MipsPhot
Hours Approved: 34.6

Abstract:
We propose to conduct a wide-field Spitzer/MIPS 24um survey of 32 X-ray luminous galaxy clusters at z~0.2. These 32 are drawn from the 100 clusters under intense multi-wavelength study as part of the Local Cluster Substructure Survey (LoCuSS). All 32 have high quality wide-field weak lensing data from Subaru, supplemented by HST imaging of the cluster cores. Our primary science goal is to achieve a definitive survey of starburst activity in local clusters and to correlate the amount of obscured activity with dynamical state of the clusters. The combination of the proposed 25'x25' MIPS 24um maps and our detailed lensing-based mass maps will be uniquely powerful for that purpose. The superb sensitivity of MIPS will allow us to detect LIRGs in the virialised region of each cluster in just ~1.2 hours per cluster; the structural analysis of the lensing mass maps will diagnose the amount and location of recent hierarchical infall into the clusters. We will therefore be able to quantify precisely the amount of obscured star formation in local clusters and to delineate how that activity relates to hierarchical assembly. Our results will therefore have a major impact on efforts to understand whether infalling spiral galaxies transform into S0 galaxies by gradual fading or via an intense starburst phase. For this huge statistical survey (several orders of magnitude larger than the state of the art), we request a modest 36 hours of observing time.

Spitzer Space Telescope - General Observer Proposal #3506

Hot Dust in Cool Cores

Principal Investigator: William Sparks
Institution: Space Telescope Science Institute

Technical Contact: William Sparks, Space Telescope Science Institute

Co-Investigators:
Megan Donahue, Michigan State University
Chris O'Dea, Space Telescope Science Institute
Duccio Macchetto, Space Telescope Science Institute
Stefi Baum, Space Telescope Science Institute
Paul Goudfrooij, Space Telescope Science Institute
James Rhoads, Space Telescope Science Institute
Sangeeta Malhotra, Space Telescope Science Institute
Laura Ferrarese, Rutgers University
Patrick Cote, Rutgers University
Andres Jordan, Rutgers University
James Pringle, University of Cambridge

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 5.2

Abstract:
With IRAC primarily, and MIPS to complement, we propose to obtain sensitive thermal imaging of hot dust in two archetypal, powerful X-ray clusters (cool-core clusters, aka cooling-flows). Dust is pivotal in connecting the diverse environments of these clusters. It provides a window for us to study the physics of interfaces between hot and cold ISM and the transport processes that may be absolutely fundamental in dictating the dominant physical process at work. In these clusters, hot, thermal plasma produces strong X-ray emission, gas a thousand times cooler radiates intense optical emission lines, while molecular and neutral gas are also known to be present, along with ultra-relativistic plasma associated with AGN, radio sources and jets. Recent dramatic observations have shown that all of these disparate aspects of cluster physics may be fundamentally connected, with transport processes and feedback mechanisms potentially critical in developing a consistent and coherent understanding of cluster physics.

Spitzer Space Telescope - General Observer Proposal #20694

IRAC and MIPS Mapping of Galaxy Populations in a Supercluster at z=1.27

Principal Investigator: Spencer Stanford
Institution: University of California, Davis

Technical Contact: Spencer Stanford, University of California, Davis

Co-Investigators:
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Simona Mei, JPL
Ranga-ram Chary, JPL/SSC
Peter Eisenhardt, JPL
Mark Brodwin, JPL
Fumiaki Nakata, NAOJ
Blakeslee John, JHU
Bradford Holden, UCSC

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 8.2

Abstract:
We propose to complete the mapping of the Lynx supercluster at z=1.27 in the mid-infrared, to cover a large range of environments that will include newly discovered galaxy groups. The proposed observations would obtain IRAC data on the 7 recently discovered groups, and MIPS 24 micron imaging of all the groups and the two central clusters. The two short wavelength IRAC bands sample the rest-frame near-IR, where the SED of old stellar populations peaks, so these data are useful for constraining estimates of stellar masses. Knowledge of the way that the stellar mass function varies with local galaxy density at z > 1 would be valuable for comparisons with the results for the low z universe derived from SDSS. We will combine the four IRAC bands with our optical and NIR data to measure accurate spectral energy distributions, to which evolutionary spectral synthesis models can be fit in order to estimate the stellar population ages and masses, as well as refined photometric redshifts. We will use the MIPS 24 micron observations to measure star-formation activity as a function of local environment in the supercluster to investigate the location of star formation during the transitions of field galaxies through groups and into clusters.

Spitzer Space Telescope - General Observer Proposal #30642

Star-Forming Galaxies in MS 2053-04, An Unusually Active Cluster at z=0.6

Principal Investigator: Kim-Vy Tran
Institution: Leiden Observatory

Technical Contact: Kim-Vy Tran, Leiden Observatory

Co-Investigators:
Tracy Webb, McGill University
Garth Illingworth, UC Santa Cruz

Science Category: galaxy clusters and groups
Observing Modes: IracMap MipsPhot
Hours Approved: 8.0

Abstract:
We request imaging with both IRAC and MIPS of a contiguous 6'x10' region centered on MS 2053-04, a massive galaxy cluster at z=0.59 (1.2e15 Msun). MS2053 is one in only a handful of clusters at z>0.5 with more than 150 spectroscopically confirmed members. It is a classic Butcher-Oemler cluster that is in the process of accreting a significant fraction of new members (~25%) and subsequently has an unusually high fraction of emission line members (44%). MS2053 also lenses a galaxy at z=3.15 into two giant gravitational arcs. The multi-band mid-IR imaging is needed to measure total star formation rates in the 157 confirmed members and identify those with active galactic nuclei. In combination with our wide-field X-ray, optical, and near-IR imaging and extensive spectroscopic survey, the mid-IR observations will enable us to (1) determine whether star formation and/or nuclear activity is enhanced in newly accreted members; (2) trace how quickly the progenitors of S0 members build up their stellar masses; and (3) search for dusty, star-forming galaxies that are lensed by the cluster.

Spitzer Space Telescope - General Observer Proposal #30958

The Duty Cycle of Supermassive Black Holes: X-raying Virgo

Principal Investigator: Tommaso Treu
Institution: University of California, Santa Barbara

Technical Contact: Tommaso Treu, University of California, Santa Barbara

Co-Investigators:
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Robert Antonucci, University of California, Santa Barbara
Jong-Hak Woo, University of California, Santa Barbara

Science Category: Galaxy Clusters and Groups
Observing Modes: MipsPhot
Hours Approved: 9.5

Abstract:
Nuclear accretion on to super-massive black holes (SMBHs) plays a key role in the evolution of their host galaxies, as inferred from the ubiquity of SMBHs and the correlations between BH mass, and host mass and velocity dispersion. A fundamental unadressed issue is the actual distribution of accretion rates; we propose snapshot observations of an unbiased sample of 84 early-type galaxies in the Virgo cluster. Together with joint Spitzer 24 um observations, and publicly available HST-ACS and UV data, this survey will probe low-level nuclear activity over four orders of magnitude in black hole mass, thereby delivering the first unbiased census of the duty cycle of local SMBHs.

Spitzer Space Telescope - General Observer Proposal #30957

Observations of a Distant X-ray Luminous Cluster of Galaxies

Principal Investigator: Melville Ulmer
Institution: Northwestern University

Technical Contact: Melville Ulmer, Northwestern University

Co-Investigators:
Christophe Adami, LAM
Florence Durret, IAP
William Mahoney, CalTech
Eduardo Cyprinao, CTIO
Gastao Lima Neto, IAG, San Palo

Science Category: Galaxy Clusters and Groups
Observing Modes: IracMap MipsPhot
Hours Approved: 4.0

Abstract:
A key to understanding cluster evolution is to study distant clusters of galaxies in X-rays. We propose to observe with Chandra, XMM-Newton, and Spitzer Cl J1257+4738 (CL1257). CL1257 is the most distant (z=0.866) cluster found in the SHARC survey and the second most X-ray luminous cluster above z=0.85. The data will help to determine the global physical properties of CL1257 and its global dynamical state. With recent Gemini data we found 4 out of 6 cluster member galaxies to have [OII] 3727 emission lines, implying recent starburst activity. A compilation of luminosity versus redshift of known clusters above z=0.85 suggests that clusters do not reach their peak X-ray luminosity until z=0.9.

Spitzer Space Telescope - General Observer Proposal #50720

Mid-Infrared Imaging of the z=0.9 Super-Cluster RCS2319

Principal Investigator: Tracy Webb
Institution: McGill University

Technical Contact: Tracy Webb, McGill University

Co-Investigators:
Mike Gladders, University of Chicago
Erica Ellingson, University of Colorado, Boulder
Howard Yee, Univesity of Toronto
Adam Muzzin, Yale University
David Gilbank, University of Waterloo
Amelia Hicks, University of Virgina

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 9.8

Abstract:
The Red-Sequence Cluster Survey (RCS) has recently discovered a rare grouping of three massive (~5x10^14 M) galaxy clusters, at a spectroscopically confirmed redshift of z = 0.9. With separations of ~5 Mpc, this structure is a clear example of the ancestors of today's most massive galaxy clusters. The richest cluster of the three was observed with Spitzer in Cycles 3 and 4 as part of a large program (40 clusters), designed to study the evolution of clusters and cluster galaxies; here we request time to obtain similar data on the second two clusters within the super-structure. Infrared imaging with Spitzer IRAC and MIPS will facilitate a comprehensive study of the galaxy population within this structure by (1) tracing stellar mass; (2) quantifying the dust-enshrouded activity; (3) separating star-forming systems from dusty AGN; and (4) constraining star formation rates and total luminosities of cluster galaxies. Key to the success of this program is the wealth of data we have obtained at other wavelengths including 1000's of spectra in the supercluster field, and deep X-ray and radio imaging with Chandra and the VLA over the entire area. Together, these data afford the unique opportunity to fully characterize the galaxy population within the unambiguous progenitor of the massive local clusters.

Spitzer Space Telescope - General Observer Proposal #3440

Dust Emission in the Intra-Group Medium (IGM) of Stephan's Quintet

Principal Investigator: C. Kevin Xu
Institution: California Institute of Technology

Technical Contact: C. Kevin Xu, California Institute of Technology

Co-Investigators:
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Michael Dopita, Australian National University
Gao Yu, UMASS
Nanyao Y. Lu, Caltech, SSC/IPAC
Cristina Popescu, MPIK, Germany
Jack Sulentic, University of Alabama
Richard Tuffs, MPIK, Germany
Min Yun, UMASS

Science Category: galaxy clusters and groups
Observing Modes: IrsStare MipsPhot
Hours Approved: 7.0

Abstract:
Stephan's Quintet (SQ) is the best studied example of the compact group phenomenon and provides the first solid evidence for diffuse IGM dust emission. We propose MIPS 70um and 160um observations in the raster mapping mode, and IRS observations with SH, LH, SL 1st-order and SL 2nd-order modules in the staring mode. The observations will search for clues to the origin of diffuse IGM dust emission that we detected with ISO. They will also set constraints to physical models for IGM dust destruction in the large scale shock that was triggered by a high speed collision (~ 1000 km/sec) between an intruder galaxy and the IGM. A 6' x 6' area will be mapped with MIPS to study the spatial distribution and heating mechanism of the diffuse dust. In addition two positions in the shock front will be observed with IRS to probe PAH destruction and the physical conditions in the ionized medium of the shock. The observations will shed new light on the so-called 'feedback' processes governing the exchange of mass, metals and energy between galaxies and their external environment.

Spitzer Space Telescope - General Observer Proposal #50610

Charting Cluster Mass Build-up using Luminous IR Galaxies

Principal Investigator: Min Yun
Institution: University of Massachusetts

Technical Contact: Min Yun, University of Massachusetts

Co-Investigators:
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Giovanni Fazio, CfA
Jiasheng Huang, CfA
Matthew Ashby, CfA
David Hughes, INAOE, Mexico
Itziar Aretxaga, INAOE, Mexico
James Lowenthal, Smith College
Thushara Perera, University of Massachusetts
Kimberly Scott, University of Massachusetts
Jason Austermann, University of Massachusetts
Josh Younger, Harvard University

Science Category: galaxy clusters and groups(high-z)
Observing Modes: IracMap MipsPhot
Hours Approved: 94.6

Abstract:
An important legacy of Spitzer telescope is that it has established the increasing importance of IR luminous (LIRG) and ultraluminous IR galaxies (ULIRGs) in the cosmic star formation and mass assembly history to z>1. Hierarchical models of galaxy formation and evolution and the popular notion of ‘‘downsizing’’ suggest that so-called "submillimeter galaxies" (SMGs) with $L(IR)=10^{12-13}L_\odot$ likely play an important role in the mass assembly history at z>1-2, particularly in high density environments. Using the AzTEC instrument on James Clerk Maxwell Telescope (JCMT) and Atacama Submillimeter Telescope Experiment (ASTE) telescope in Chile, we have constructed a new data base that includes 1000 SMGs (>2 times larger than all previous SMG surveys combined) covering both ‘‘blank’’ and biased/overdensity fields. The main aim of this Spitzer proposal is to map the process by which clusters build up their mass using luminous IR galaxies identified using MIPS 24 micron and AzTEC 1100 micron surveys and to put the SMG phenomenon in the broader context of galaxy and large scale structure evolution.

Spitzer Space Telescope - General Observer Proposal #3482

IRAC Imaging of a Proto Galaxy Cluster at z~3

Principal Investigator: Wil van Breugel
Institution: UC Merced

Technical Contact: Spencer Stanford, University of California, Davis

Co-Investigators:
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George Miley, Leiden University
Bram Venemans, Leiden University
Andrew Zirm, Leiden University
Huub Rottgering, Leiden University
Jaron Kurk, Arcetri Observatory
Steve Croft, Lawrence Livermore National Laboratory

Science Category: galaxy clusters and groups
Observing Modes: IracMap
Hours Approved: 28.1

Abstract:
We propose to obtain deep IRAC images in all four bands of a z~3 proto galaxy cluster. We have spectroscopically identified 31 star forming galaxies at the redshift of a z=3.16 radio galaxy, MRC0316-257. The IRAC data will sample the rest frame near-IR in the member galaxies, allowing an estimate to be made of the stellar masses. Combined with our existing optical and near-IR photometry, the IRAC data will allow us to search for non-star-forming galaxies in the protocluster, which should be easily detectable if their stellar populations formed at z ~ 5 or greater. Our target lies in the redshift gap between the z ~ 2 and z ~ 4 protoclusters targetted by GTO programs in Cycle 1. So by combining our data with those in the archive, we will be able to determine the formation history of massive galaxies in clusters as they virialize from z ~ 4 to 2, and test the predictions of the hierarchical vs monolithic collapse scenarios.

Spitzer Space Telescope - General Observer Proposal #20375

Of Starbursts and Monsters: An IRS High-resolution Spectroscopic Study of Ultraluminous Infrared Galaxies

Principal Investigator: Lee Armus
Institution: IPAC

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
Vassilis Charmandaris, University of Crete
Vandana Desai, Caltech
Henrik Spoon, Cornell University
Lei Hao, Cornell University
Berhard Brandl, Leiden University
Jeronimo Bernard-Salas, Cornell University

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 23.6

Abstract:
Ultraluminous infrared galaxies (ULIRGs) generate the power output of quasars, but nearly all of this energy emerges in the mid and far-infrared part of the spectrum. While rare at low-redshift, ULIRGs are resposible for the strong evolution in the mid-IR number counts to z~1, and may dominate the star formation rate density and far-infrared background at z~2-3. The GTO ULIRG program is observing a sample of 110 ULIRGs in the local universe with the IRS. Less than half of these have observations with the high-resolution IRS modules. We propose to observe a sample of 34 ULIRGs from this program in SH and/or LH in order to search for unambiguous proof of buried AGN (via the [NeV] emission line), as well as characterize the warm molecular gas content, the small grain characterisitics and the starburst mass functions, via the H2, PAH, and [NeII], [NeIII], [OIV], [SIV], and [SIII] line flux ratios in the SH and LH IRS spectra. These observations will double the number of ULIRGs will high quality, high-resolution IRS spectra in the archive, and significantly increase the number of ULIRGs observed at z > 0.3, where most of the evolution in the counts of IR-bright galaxies is occuring.

Spitzer Space Telescope - Legacy General Observer Proposal #30323

A Spitzer Spectroscopic Survey of a Complete Sample of Luminous Infrared Galaxies in the Local Universe

Principal Investigator: Lee Armus
Institution: IPAC

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
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Ben Chan, IPAC
Vassilis Charmandaris, University of Crete
Aaron Evans, Stony Broook
David Frayer, SSC
Justin Howell, IPAC
Lisa Kewley, University of Hawaii
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David Sanders, University of Hawaii
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Henrik Spoon, Cornell University
Eckhard Sturm, MPE
Jason Surace, SSC
Sylvain Veilleux, University of Maryland

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 160.0

Abstract:
The IRAS Revised Bright Galaxy Sample (RBGS) is a complete sample of extragalactic objects with IRAS 60-micron flux densities above 5.24 Jy, covering the full sky above abs(b) > 5 degrees. The RBGS objects are the brightest 60-micron sources in the extragalactic sky. The 21 ULIRGs and 182 LIRGs in the RBGS form a complete sample of 203 infrared luminous, local galaxies which are excellent analogs for comparisons with infrared and sub-mm selected galaxies at high redshift. We propose to obtain IRS low and high-resolution spectra of 158 LIRGs in the RBGS which, when taken to gether with the existing or planned GO and GTO observations of the remaining LIRGs and ULIRGs in the RBGS, will provide an unprecedented spectroscopic database of a complete sample of luminous infrared galaxies in the local Universe. The total requested time for this program, including all overheads, is 160 hrs. The primary goals of this proposal are to use the low and high-resolution IRS spectra to (1) search for buried AGN and determine their contribution to the bolometric luminosity, (2) determine the star-formation rates and ages, (3) characterize the state of the ionized and molecular gas, and (4) study the properties of the small and large dust grains and determine if all of these properties are a function of luminosity and/or merger stage. By observing a large sample of LIRGs with the IRS, we can build a unique spectral library that will be invaluable long after the helium on Spitzer runs out. This library will be an essential tool for understanding the galactic merger process, and the genesis of the bulk of the infrared activity at all epochs. The IRS spectra will stand on their own merits, however, when coupled with the IRAC and MIPS images, the ground-based near-infrared data, and the HST ACS and GALEX images, the spectra we request here will form a critical component of a comprehensive, multi-wavelength dataset that will serve as a lasting resource in the true spirit of the Spitzer Legacy program.

Spitzer Space Telescope - General Observer Proposal #50702

Mapping GOALS: IRS Spectral Mapping of a Complete Sample of LIRGs in the Local Universe

Principal Investigator: Lee Armus
Institution: Spitzer Science Center

Technical Contact: Lee Armus, Spitzer Science Center

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Eckhard Sturm, MPE
Jason Surace, Spitzer Science Center
Tatjana Vavilkin, SUNY Stony Brook
Sylvain Veilleux, University of Maryland

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap
Hours Approved: 56.0

Abstract:
The Great Observatory All-sky LIRG Survey (GOALS) targets a complete sample of 203 LIRGS in the local Universe, selected from the IRAS Revised Bright Galaxy Sample (RBGS). The RBGS is a complete sample of 629 galaxies with IRAS 60-micron flux densities above 5.24 Jy, covering the full sky above Galactic latitudes abs(b) > 5 degrees. The RBGS objects are the brightest 60-micron sources in the extragalactic sky, and they span a wide range in morphologies from normal, isolated gas-rich spirals to full mergers. The sample includes numerous nuclear starbursts, Type 1 and 2 Seyfert nuclei, and LINERS. These systems are the best local analogs for comparisons with infrared and sub-mm selected galaxies at high redshift. In Cycles 1 and 3 we were awarded time to image the GOALS sample with IRAC and MIPS, and to obtain nuclear spectra with the IRS. The cycle-3 observations formed the core of a Spitzer Legacy program to obtain and make available IRS nuclear spectra of the GOALS targets. Here we propose to extend and enhance the Spitzer observations of the GOALS sample by obtaining IRS maps in the low-resolution SL and LL slits of 81 LIRGs (in 61 systems) which are close, bright, and highly resolved with IRAC. The primary goals of this proposal are to construct IRS spectral maps which will enable us to (1) explore the ionization state, small and large grain dust properties, and warm molecular gas over the full extent of LIRGs covering a wide range in luminosity and interaction state, and (2) create globally integrated SEDs which, when combined with the existing Spitzer, HST, VLA, NIR, ground-based optical, and proposed Herschel imaging data, will allow us to extend the photometry and spectra from the UV through the radio on matched spatial scales. These spectral maps will complete an unprecedented mid-infrared spectroscopic and photometric survey of luminous infrared galaxies in the local Universe. The total requested time for this program, including all overheads, is 111 hrs.

Spitzer Space Telescope - General Observer Proposal #20216

A bridge between ultraluminous and normal galaxies at high redshifts: Spitzer imaging of a unique spectroscopic radio field

Principal Investigator: Andrew Blain
Institution: Caltech

Technical Contact: Andrew Blain, Caltech

Co-Investigators:
Scott Chapman, Caltech
Ian Smail, University of Durham
Lee Armus, Caltech/SSC
David Frayer, Caltech/SSC
David Alexander, University of Cambridge
Rob Ivison, UKATC

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IracMap MipsPhot
Hours Approved: 13.3

Abstract:
Ultradeep radio images and Spitzer maps both provide windows on the high-redshift Universe immune to the effects of dust extinction. The very deepest radio sources trace the evolution of star-formation activity at luminosities less than the confusion limit in submm and far-IR surveys, opening a bridge between the most extreme submm-selected galaxies and the optically-selected Lyman-break population: the galaxies at 100-1000 Giga solar luminosities that dominate the far-IR background. We are targeting a VLA image in the Lockman Hole that goes twice as deep as the GOODS-N radio map for complete spectroscopy of the 250 radio sources to build up a compact, densely-sampled 15-arcmin field. These spectra will yield an unparalleled view of both the rate of evolution and the large-scale structure traced by dust-obscured galaxies. Spitzer IRAC and MIPS imaging of this special field will allow an unprecedented census of the rate and spatial distribution of dust-enshrouded high-redshift star formation activity, with MIPS revealing details of the galaxy SEDs, and the relationship between radio and far-IR emission, while IRAC reveals the stellar masses built up in the dust-enshrouded galaxies that could provide the link between current optical and far-IR samples, and which make most of the stars in the Universe today.

Spitzer Space Telescope - General Observer Proposal #50305

Mid-IR spectroscopy of hot and dusty, luminous high-z star forming galaxies

Principal Investigator: Scott Chapman
Institution: Caltech

Technical Contact: Scott Chapman, Caltech

Co-Investigators:
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Karin Menendez-Delmestre, Caltech
Bruno Letarte, Caltech
George Helou, SSC
Ian Smail, Durham
Rob Ivison, ROE, Edinburgh
David Trethewey, Cambridge, IoA
Mark Swinbank, Durham

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare IrsPeakupImage
Hours Approved: 53.8

Abstract:
We have identified a population of high-redshift microJy radio sources which have rest-UV/optical spectra characteristic of dusty luminous starbursts, and whose radio emission implies ~1000M/yr star formation rates, but which have no detectable submm emission from cool dust. These galaxies have S(24um)=0.1-1mJy similar to submm galaxies, and typically have enormous molecular gas reservoirs (confirmed through CO3-2 detections). Resolved radio morphologies with 3kpc scale sizes completes the picture: we propose that these "optically faint radio galaxies" (OFRGs) are a new class of luminous dusty starburst with hotter dust temperatures than the similarly high-redshift ultraluminous submm galaxies. We propose Spitzer-IRS to observe the 10 confirmed star-forming OFRGs in our accepted molecular gas CO(3-2) study at the IRAM Plateau-de-Bure interferometer. We will probe the intense mid-IR emission from these galaxies for signatures of their power source, and to understand whether the aromatic features are sensitive to the more intense ionization fields in OFRGs compared with SMGs.

Spitzer Space Telescope - General Observer Proposal #20239

MIPS 70- & 160-micron Imaging of an IRS Sample of Ultra-luminous Infrared Galaxies at z~2

Principal Investigator: Philip Choi
Institution: Spitzer Science Center

Technical Contact: Philip Choi, Spitzer Science Center

Co-Investigators:
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David Frayer, Spitzer Science Center
Harry Teplitz, Spitzer Science Center
Lee Armus, Spitzer Science Center
Anna Sajina, University of British Columbia
George Helou, Spitzer Science Center
Jason Surace, Spitzer Science Center
Dario Fadda, Spitzer Science Center
Ranga Ram Chary, Spitzer Science Center

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: MipsPhot
Hours Approved: 40.4

Abstract:
We propose to obtain MIPS 70- and 160-micron imaging of a mid-IR selected sample of high redshift (z~2), ultra-luminous infrared galaxies (ULIRGS). This sample was first identified in the Extragalactic First Look Survey and has since been detected with follow-up IRS spectroscopy. In addition to the IRS spectroscopy, an extensive dataset that includes IRAC, MIPS 24-micron imaging, SCUBA and MAMBO photometry and Keck spectroscopy will soon be fully assembled. The proposed addition of FIR imaging to the current dataset will allow us to 1) Directly measure the total infrared luminosity of these systems; 2) Identify the AGN vs. Starburst energetic nature of these sources based on the mid-IR emission-to-bolometric luminosity and MIR slope diagnostics; 3) Combine with SCUBA and MAMBO observations to derive total cold dust temperatures and masses; and 4) Compare this population of distant MIR-selected ULIRGs to the known SCUBA populations.

Spitzer Space Telescope - Theoretical Research Proposal #50278

Polyatomic Molecule Synthesis on Dust Grain Analogues Using Superthermal Atoms

Principal Investigator: Ara Chutjian
Institution: Jet Propulsion Laboratory

Technical Contact: Ara Chutjian, Jet Propulsion Laboratory

Co-Investigators:
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John MacAskill, Jet Propulsion Laboratory
Stojan Madzunkov, Jet Propulsion Laboratory

Science Category: ULIRGS/LIRGS/HLIRGS
Dollars Approved: 75000.0

Abstract:
This proposal focuses on the physical and chemical processes catalyzed by dust grains that can lead to the formation of larger bio-forming polyatomic molecules through a new experimentally-accessible reaction channel involving fast, ground-state atoms. The fast-atom source at JPL will be used to study molecular formation with well-characterized beams of superthermal H, D, and O atoms (energies of 0.1 to 50 eV) colliding with species frozen (4.8 K) on interstellar dust grain analogues. At these atom-grain energies chemical reaction barriers are overcome and new reaction channels are opened. Simulated are conditions in prestellar cores, YSOs, circumstellar envelopes, cool dark clouds, and protoplanetary disks; from shock-heated regions to cooler and UV-shielded nebulae in the accretion phase. The results of this work will allow one to explain the presence, within these objects, of molecules such as CO2, CH3OH, and H2CO with abundances in excess of that predicted from gas-phase or thermal (closed-channel) gas-grain collisions alone. The laboratory-generated species will be compared to those detected by the Spitzer IRS. One can then correlate the superthermal-atom reactions in the laboratory to the presence of polyatomic species in those astrophysical objects that can harbor superthermal atoms. Predictions can be made, and heretofore undetected absorption/emission lines can be searched. Polyatomic formation has recently been demonstrated at JPL by creating abundant CO2 molecules via the reaction O(3P) + CO(adsorbed at 4.8 K) --> CO2, at O(3P) energies of 2, 5, 10, and 14 eV. The CO2 was detected using temperature-programmed desorption/mass spectrometry. This is the first observation anywhere of molecule production using superthermal atoms. Methanol (CH3OH) and ethanol (CH3CH2OH) have also been synthesized in the system O+CO/CH4 (mixed ice at 4.8 K). This work will be expanded to study formation of H2CO, HCOOH (formic acid), CH3NH2 (methyl amine) and the simplest amino acid CH2NH2COOH (glycine).

Spitzer Space Telescope - General Observer Proposal #40640

The most extreme starbursts in the local Universe

Principal Investigator: Steve Croft
Institution: University of California, Davis

Technical Contact: Steve Croft, University of California, Davis

Co-Investigators:
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Edward Laag, UC Riverside
Gabriela Canalizo, UC Riverside
Mark Lacy, SSC
Wil van Breugel, LLNL / UC Merced
Bob Becker, UC Davis

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: MipsPhot
Hours Approved: 31.4

Abstract:
We select galaxies with extreme star formation rates (SFR > 200 solar masses per year) in a volume-limited (0.1 < z < 0.3) sample from the Brinchmann et al. (2004) study of star-forming galaxies in the local Universe. Such galaxies are predicted to have infrared (IR) luminosities greater than 10^12 solar luminosities, and as such are the optically-selected counterparts to ultraluminous infrared galaxies (ULIRGs). We propose to obtain MIPS 24, 70 and 160 micron observations of this sample to study the luminosities, SEDs, and dust temperatures of the host galaxies, their merger companions, and other galaxies in their environs. We will look for evidence (from SEDs) of hidden "Type 2" AGN, and correlate merger fraction, merger stage (from optical images), and AGN fraction with other properties such as IR luminosity and color. Trends within the sample, as well as comparison with IR-selected ULIRGs, will shed light on the evolutionary processes linking extreme star formation, AGN fueling, and the fate of gas and dust in the mergers which are believed to lead to the formation of large elliptical galaxies. The extreme SFRs in our sample are more familiar from high-redshift systems such as sub-mm galaxies, Lyman break galaxies, and distant radio galaxies. This is an excellent opportunity to study with unprecedented detail and sensitivity the local analogs of these systems which were so important in the evolution of galaxies in the early Universe.

Spitzer Space Telescope - General Observer Proposal #30407

The Astrophysics of OH Megamasers in Merging Galaxies: the Role of Star Formation, Dust, Molecules, and AGN

Principal Investigator: Jeremy Darling
Institution: University of Colorado

Technical Contact: Jeremy Darling, University of Colorado

Co-Investigators:
Lee Armus, Spitzer Science Center
Vassilis Charmandaris, University of Crete
Ylva Pihlstrom, University of New Mexico
Henrik Spoon, Cornell University

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsPeakupImage IrsStare
Hours Approved: 25.5

Abstract:
OH megamasers (OHMs) are starburst-scale masers associated with merging galaxies that can trace star formation, the formation of binary massive black holes, and possibly the feedback process between starbursts and black hole accretion in nascent quasars. We lack a physical understanding of the mechanisms and conditions responsible for the OHM process, and the physical conditions distinguishing OHM hosts from non-masing (ultra)luminous infrared galaxies ([U]LIRGs) have not been identified. Understanding the astrophysics of OHMs is critical to employing them as tracers of black hole and galaxy evolution at high redshift. Spitzer IRS spectra provide a rich set of diagnostics of dust phases, AGN influence, and the molecular ISM, all at scales well matched to the regions responsible for maser activity. We propose to obtain both high and low resolution IRS spectra of a flux-limited sample of 28 OHM hosts and compare the physical properties derived from the spectra to a sample of (U)LIRGs in the Spitzer archive. Combined with ancillary high resolution optical and radio imaging and spectroscopy, we hope to place the OHMs into the evolutionary sequence of major mergers and address fundamental questions about the nature of OHMs such as the source of the maser pump, the importance of beaming, and whether OHMs require AGN activity or are simply coincident with it.

Spitzer Space Telescope - General Observer Proposal #20113

Probing the Moderate Redshift Galaxies Mid- and Far-Infrared Spectral Energy Distribution [ModzSED]

Principal Investigator: Herve Dole
Institution: Universite Paris Sud XI

Technical Contact: Herve Dole, Universite Paris Sud XI

Co-Investigators:
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Emeric Le Floc'h, University of Arizona
Casey Papovich, University of Arizona
Paul Smith, University of Arizona
Charles Engelbracht, University of Arizona
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Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare MipsSed
Hours Approved: 21.0

Abstract:
Observations of the Cosmic Infrared Background together with infrared cosmological surveys (e.g. at 24mu with MIPS) are showing that Luminous and Ultraluminous Infrared Galaxies (LIRG & ULIRG) play a critical role in the evolution of galaxies. Unfortunately, their spectral energy distributions (SED) are largely unconstrained in the far-infrared (FIR) part, which makes it difficult to derive accurate bolometric luminosities. Until now, extrapolations from mid-infrared (MIR) luminosities were used to derive the FIR and bolometric luminosities. Are these extrapolations accurate ? Are they valid at moderate and high redshift ? Given the critical contribution of SEDs to interpretations of the cosmological evolution of the luminosity functions, we need accurate measurements of SEDs in the FIR (and in the MIR to validate the extrapolations to longer wavelengths). The immediate objective of our program is to obtain low-resolution MIR spectra (with IRS) and FIR spectra (with MIPS SED) of a sample of about 17 moderate redshift galaxies ($0.02<z<0.55$) selected at 70 microns, for 21h of Spitzer time, to derive their complete IR SEDs. We plan characterize the SEDs in the (L_{bol}, z) plane, their evolution (if any), and compare them to existing models; then we will characterize the MIR to FIR extrapolation.

Spitzer Space Telescope - General Observer Proposal #20427

Accurate Far-Infrared Spectral Energy Distributions of 60-Micron-Selected Ultraluminous Infrared Galaxies at Redshifts from 0.2 to 1

Principal Investigator: Charles Dowell
Institution: Jet Propulsion Laboratory

Technical Contact: Charles Dowell, Jet Propulsion Laboratory

Co-Investigators:
Colin Borys, California Institute of Technology
Thomas Greve, California Institute of Technology
Min Yang, California Institute of Technology

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: MipsPhot
Hours Approved: 5.1

Abstract:
We propose MIPS 160 micron observations of Ultraluminous Infrared Galaxies (ULIRGs) at redshifts z = 0.2 to 1 selected from the Stanford et al. IRAS FSC/FIRST sample. The upper end of the galaxy luminosity function during the period z = 1 to the present day has been studied little, yet this is the redshift interval during which the number of ULIRGs changed by the greatest amount. Our approach is to compile and characterize the complete mid- and far-infrared spectral energy distributions of 21 ULIRGs from which we can derive luminosities and mean dust temperatures to 10% uncertainty and examine dust temperature distributions. The key new information regarding these sources will be MIPS 160 micron photometry (under this GO proposal) accurately defining the spectral peak and IRS spectra (under an independent GTO program) characterizing the warm dust and gas; these data will be combined with existing IRAS 60 and 100 micron photometry and a ground-based 350 micron survey which has already detected half of the sources. We will be able to separate the emission from AGN, starburst, and cirrus components and to study evolutionary trends and correlations between the mid-IR and far-IR spectra.

Spitzer Space Telescope - General Observer Proposal #20176

Spectral Energy Distributions of Star-Forming Galaxies, from Low Metallicity to Ultraluminous Infrared Galaxies

Principal Investigator: Chad Engelbracht
Institution: The University of Arizona

Technical Contact: Chad Engelbracht, The University of Arizona

Co-Investigators:
Karl Gordon, University of Arizona
Daniel Dale, University of Wyoming

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: MipsSed
Hours Approved: 5.2

Abstract:
We propose to use the MIPS spectral energy distribution (SED) mode to generate high-resolution SEDs for a sample of nearby, energetically star-forming galaxies. These data will be used to measure the luminosities, temperatures and dust masses of the galaxies, and to determine to what extent multiple dust components are required to fit the SED. We will combine the new data with photometric and spectroscopic data from Spitzer and from the literature to generate SED templates to aid in photometric redshift measurements or in interpretation of other galaxies for which only photometry is available. By observing starburst, ultraluminous, and low-metallicity galaxies we will fill a critical gap in the SED coverage of galaxies provided by existing Spitzer programs. The galaxies we will observe are the very ones that dominate the extragalactic infrared emission and dominate the number counts of distant galaxies. The MIPS SED mode provides unprecedented sensitivity and precision to measure the infrared emission peak in these galaxies, in particular allowing for the first time detailed far-infrared (FIR) measurements of faint, low-metallicity galaxies. The SED wavelength coverage (55 - 96 micron) is ideally positioned to measure the emission peak in these galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30139

Redshift of 350-micron Selected Galaxy

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Steven Willner, Center for Astrophysics

Co-Investigators:
Steven Willner, Smithsonian Astrophysical Observatory
Matt Ashby, Smithsonian Astrophysical Observatory
Sophia Khan, Blackett Laboratory, Imperial College London

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap
Hours Approved: 3.1

Abstract:
The first galaxy discovered by blank field surveys at 350 microns appears on the basis of its spectral energy distribution to be a starburst near z=1. An IRS spectrum from 14 to 35 microns should verify or refute this understanding of the object.

Spitzer Space Telescope - General Observer Proposal #30621

IRS spectroscopy of LIRGs in the cluster Cl0024+16 at z=0.4

Principal Investigator: James Geach
Institution: Durham University

Technical Contact: James Geach, Durham University

Co-Investigators:
Ian Smail, ICC, Durham
Alastair Edge, ICC, Durham
Richard Ellis, Caltech
Tommaso Treu, UCSB
Sean Moran, Caltech

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 26.0

Abstract:
We propose to use low-resolution IRS spectroscopy to obtain mid-infrared spectra of a representative sample of 13 spectroscopically confirmed members of the cluster Cl0024+16 at z=0.4. We have detected these galaxies at 24um with fluxes >0.6 mJy in a previous MIPS program, implying far-infrared luminosities putting them in the LIRG class. We have demonstrated that the luminous mid-infrared population in rich clusters evolves rapidly with look-back time, at a rate comparable to that in the surrounding field. Our aim is to use the IRS spectra to understand the origin of the mid-infrared emission - either from intense dust-enshrouded star-formation, an active galactic nucleus (AGN), or a combination of both. If we confirm that the mid-infrared emission is produced by star-formation, then these sources would be starbursts with implied star-formation rates of 10s-100 Solar masses per year. This population is missed in optical surveys due to dust obscuration, although such levels of obscured activity are needed to transform the bulge-weak spiral populations which are seen in distant clusters into the bulge-strong S0 populations which dominate such environments locally.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40991

An IRS Survey of Infrared Sources in the IRAS and SDSS

Principal Investigator: Lei Hao
Institution: Cornell University

Technical Contact: Lei Hao, Cornell University

Co-Investigators:
Daniel Weedman, Cornell University
Vassilis Charmandaris, University of Crete
Jim Houck, Cornell University
Henrik Spoon, Cornell University

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 24.4

Abstract:
We propose to conduct an IRS low-resolution survey of 98 sources in the IRAS and SDSS cross-matched catalogue. The sample covers representative 2/3 of all sources that are optically faint ($r_{petrosian}>16$ mag in the SDSS galaxy sample) and infrared bright ($f(25\mu m)>100$mJy). This criteria is similar to the one looking for high-redshift dusty sources in various surveys, therefore provide a comparable sample to study the distribution of the spectral properties such as the silicate strengths, PAH emissions, atomic and molecular emission lines, to compare with and understand the high-redshift dusty sources. This sample probes a much lower infrared luminosity than previous large samples on ULIRGs and LIRGs, and gives a different but complementary view on infrared sources in the local universe. The uniform optical spectra and image of the SDSS database is an important auxiliary tool and can be connected with the properties of the IR properties and environmental properties, and help to reveal the evolution of IR sources in the low-luminosity range. This IRS GTO proposal takes 25 hrs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #105

Spectroscopic Study of Distant ULIRGs II

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Lee Armus, Spitzer Science Center

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IracMap IrsStare
Hours Approved: 85.3

Abstract:
Ultraluminous Infrared Galaxies (ULIRGs) have bolometric luminosities of quasars but they outnumber the QSOs with same optical luminosities. Even though several of the nearby ULIRGs have been studied extensively many questions regarding their dust content and energetics remain, and little is known about the more distant ones. We propose to extend our knowledge of these objects and explore the potential evolution in their properties with redshift by obtaining full low-res spectra of a sample of ULIRGs with redshifts up to 0.5.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30073

IRS GTO ULIRG program: filling in the gaps

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Henrick Spoon, Cornell University

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 12.7

Abstract:
Ultraluminous infrared galaxies (ULIRGs) generate the power output of quasars, but nearly all of this energy emerges in the mid and far-infrared part of the spectrum. While rare at low redshifts, ULIRGs are responsible for the strong evolution in the mid-infrared number counts to z~1, and may dominate the star formation rate density and far-infrared background at z~2-3. The GTO ULIRG program is observing a sample of 110 ULIRGs in the local universe with IRS. Many of these sources do not have near-infrared photometry to supplement the IRS spectroscopy. Others, in particular the more redshifted ULIRGs, do not have a proper sampling of their rest frame far-infrared spectral energy distributions. We hence to propose to obtain IRAC 3.6 micron and MIPS 70 & 160 micron photometry for 1/3 of our ULIRGs, to extend their spectral energy distributions, required for proper modeling of their complex dust continuum spectra. In addition, we would like to re-observe the IRS SL2 spectra of two of our ULIRGs at higher signal-to-noise to obtain good profiles of the broad 4.6 micron CO absorption profiles in their spectra. So far, these features have been discovered in only a handful of ULIRGs. Their origin is not yet understood. We further propose to obtain IRS low-resolution spectroscopy of the distant ULIRG IRAS 23515-2917, which -- judging from previous ISO spectroscopy -- is likely deeply obscured and may show signatures for the presence of crystalline silicates in its spectrum.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #521

16um imaging of candidate ULIRGS at z 1-2

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Tom Soifer, Spitzer Science Center

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsPeakupImage
Hours Approved: 5.4

Abstract:
We will obtain 16um images of targets from the Bootes Field selected to have high 8um/24um flux ratios. These are candiate ULIRGS in the redshift range 1 to 2, where strong silicate absorption has depressed the 24um continuum. The 16um data will establish the validity of the silicate absorption in heavily dust enshrouded ULIRGS and provide targets for follow-on spectroscopy.

Spitzer Space Telescope - General Observer Proposal #50611

High Resolution Spectral Mapping of Starburst Rings in Nearby Seyfert Galaxies

Principal Investigator: Justin Howell
Institution: Spitzer Science Center

Technical Contact: Justin Howell, Spitzer Science Center

Co-Investigators:
Lee Armus, Spitzer Science Center
Steve Lord, NASA Herschel Science Center
Phil Appleton, NASA Herschel Science Center
Joe Mazzarella, IPAC
Andreea Petric, Spitzer Science Center

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap
Hours Approved: 14.3

Abstract:
Seyfert galaxies in the local universe provide a unique opportunity to map the transition and feedback between the active nucleus and starburst activity within the host galaxy. We propose to observe the nearby Seyfert galaxies NGC~1068 and NGC~1365 with high-resolution IRS spectra extending from the nucleus through their starburst rings, with spatial resolution of $\\sim200$~pc. The total time requested for this program is 14.3~hrs. The goals of this proposal are to map the zone of influence of the AGN and measure the conditions in the ISM from the nucleus throughout the inner disk and starburst rings. To what extent are star forming regions with bright PAH emission being illuminated by the AGNs? Where is shocked molecular gas observed? This program will provide the first comprehensive analysis of mid-infrared spectral diagnostics at high spatial and spectra resolution throughout the inner ~2 kpc regions in two Seyfert galaxies with circumnuclear starburst rings.

Spitzer Space Telescope - General Observer Proposal #50008

Luminous buried AGNs in ultraluminous infrared galaxies and the origin of galaxy downsizing

Principal Investigator: Masatoshi Imanishi
Institution: National Astronomical Observatory of Japan

Technical Contact: Masatoshi Imanishi, NAOJ

Co-Investigators:
Chris Dudley, George Mason University
Roberto Maiolino, Rome Observatory
Takao Nakagawa, Japan Aerospace Exploration Agency

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 11.5

Abstract:
Ultraluminous infrared galaxies (ULIRGs) have been used extensively to trace the history of star formation in the early universe. However, the major issue of whether ULIRGs are powered primarily by starbursts, or if AGNs hidden behind dust are energetically important, is poorly understood. Unlike optically detectable AGNs obscured by torus-shaped dust, most of putative AGNs in very dusty ULIRGs' nuclei may be deeply "buried" in all direction. It is fundamental to quantitatively determine the energetic importance of such elusive buried AGNs in ULIRGs, if we are to understand the true nature of the ULIRG population. Based on infrared 3-4 micron (Subaru) and 5-35 micron (Spitzer) low-resolution spectra of optically non-AGN ULIRGs at z < 0.15, we have investigated the equivalent widths of PAH emission features and geometry between energy sources and dust. We have succeeded in detecting luminous buried AGN signatures in half of the observed ULIRGs. With the advent of AKARI's 2.5-5 micron spectroscopic capability, it is now possible to extend this successful approach to ULIRGs at z = 0.15-0.3. We propose Spitzer IRS 5-35 micron low-resolution spectroscopy of optically non-AGN ULIRGs at z = 0.15-0.3. By including these more distant ULIRGs, we can for the first time make a meaningful investigation of the fraction of luminous buried AGN as a function of infrared luminosity. If we find that luminous buried AGNs are more common in galaxies with higher infrared luminosities, as our preliminary analysis of archival data suggests, then we may be able to provide the first observational evidence that the well-known galaxy downsizing phenomena are indeed due to stronger AGN feedbacks in currently more massive (= previously more infrared luminous) galaxies. Additionally, the proposed observations will be an important bridge for the comprehensive understanding of the ULIRG population from nearby (z < 0.15) to cosmologically distant (z = 0.3-4) universe.

Spitzer Space Telescope - General Observer Proposal #50119

IRS observations of a new population of massive high-z galaxies discovered by SWIRE and MAMBO

Principal Investigator: Guilaine Lagache
Institution: Institut d'Astrophysique Spatiale

Technical Contact: Guilaine Lagache, Institut d'Astrophysique Spatiale

Co-Investigators:
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Maria Polletta, IAP, France
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Francois Boulanger, IAS, France
Andrew Baker, Rutgers, US
Stefano Berta, MPE, Germany
Benjamin Bertincourt, IAS, France
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Carol Lonsdale, University of Virginia
Frazer Owen, NRAO, Socorro, US
David Shupe, IPAC, US
Lin Yan, SSC, US

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap
Hours Approved: 54.3

Abstract:
We propose to obtain low resolution mid-IR spectra of a sample of 16 SWIRE-selected massive star-forming ULIRGs at z~2, deeply observed at 1.2 mm with IRAM-MAMBO. This sample is complete, with a selection of all sources in 0.5 square degree whose IRAC photometry peaks at 5.8 microns, S(24)>500 microJy and r>23. More than 80% of the sources have S(1.2mm)>~ 1.5 mJy, and are thus submillimeter galaxies (SMGs) with far-IR luminosities greater than a few 10^12 Lo. The sample is thus representative of a rich, Spitzer-selected special subclass of SMGs (~2000 in all SWIRE fields). Compared to sub-mm selected SMGs, these sources are brighter at 24 microns (larger PAH/FIR ratio), and have larger stellar masses. They represent thus an important stage of the assembly of elliptical galaxies already massive at z~2, with a strong, close to 'maximal', starburst probably triggered by one of the last major gaseous mergers. The sample benefits from exceptionally rich complementary data, with one of the deepest VLA observations and deep 70-160 micron data. We expect that, in most of these objects, the emission is dominated by the starburst in mid-IR (PAHs) and far-IR (thermal dust), but the parallel growth of black holes is also known to be at work in such objects and the lack of AGN signatures in our sample is somehow surprising. The proposed IRS spectra will provide essential information about this important, but poorly studied, sub-class of high z starbursts by: 1) disentangling the mid-IR PAH and AGN contribution; 2) analyzing the detailed properties of their PAH spectrum, in relation with mm, radio and far-IR properties, and comparing with classical SMGs; 3) checking any evidence of silicate absorption; 4) inferring physical and spatial properties of the starburst from this spectral information together with complete multi-wavelength data.

Spitzer Space Telescope - General Observer Proposal #20589

The Role of Mergers and Interactions in Luminous and Ultra-Luminous Infra-Red Galaxies

Principal Investigator: Claus Leitherer
Institution: Space Telescope Science Institute

Technical Contact: Joao Leao, Space Telescope Science Institute

Co-Investigators:
Joao Rodrigo Souza Leao, STScI

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 13.5

Abstract:
We propose a study of Luminous and Ultra-Luminous Infrared galaxies (LIRGs and ULIRGs, respectively) to investigate their energy generating mechanisms and the role played by interactions and mergers in their evolution. These galaxies are gas-rich systems with infrared luminosities in the range log(L_IR) = 11- 12. These systems are mainly found in interacting pairs or groups and most of them have indications of a recent, past or ongoing merger or interaction. Despite the many advances in understanding these galaxies, many questions remain: (i) What is the relative frequency of AGNs and starburst in LIRGs and ULIRGs?, (ii) Is the number of AGN-ULIRGs a function of the infrared luminosity?; (iii) Is the nuclear separation in these galaxies a determinant factor in the appearance of an AGN? To answer these question we propose a IRS spectroscopic survey of 28 LIRGs and ULIRGs in different merger or interaction stages. The plan is to use the low resolution modes of IRS (SL and LL) to cover the 5.2 to 38 um wavelenght range. This wavelength region is rich in high ionization lines and PAH features which can be used as diagnostic indicators of the main energy source in these galaxies: AGN or massive star formation.

Spitzer Space Telescope - General Observer Proposal #20496

Comparison of Time-Variable IR and X-Ray Continuum Spectra in Four Blazars

Principal Investigator: Alan Marscher
Institution: Institute for Astrophysical Research

Technical Contact: Alan Marscher, Institute for Astrophysical Research

Co-Investigators:
Svetlana Jorstad, IAR BU USA

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: MipsPhot
Hours Approved: 9.7

Abstract:
We propose a series of far-IR photometric observations of 4 blazars with MIPS at three wavelengths from 24 to 160 microns. We are monitoring these objects in the X-ray with RXTE 2-3 times per week, as well as at optical, near-IR, and radio wavelengths with ground-based telescopes. The sample consists of two quasars with extremly relativistic jets (3C 279 and PKS 1510-089), a quasar with Seyfert-like optical and X-ray emission but blazar characteristics in the radio (3C~273), and BL Lac. For each object, this program will (1) fill the expansive IR gap in the time-variable spectral energy distribution, (2) determine the time scale and magnitude of far-IR flux and spectral index variability, (3) establish the relationship between the X-ray and far-IR spectral indices and how this changes with flux level and overall shape of the SED, and (4) sample the flux variability at far-IR wavelengths and measure time lags relative to fluctuations at other wavebands. This is critical information for testing models for the X-ray emission and for indicating the extent to which the IR emission is co-spatial with that in other spectral domains.

Spitzer Space Telescope - General Observer Proposal #50688

The Near and Far-IR SEDs of Spitzer GTO ULIRGs

Principal Investigator: Jason Marshall
Institution: California Institute of Technology

Technical Contact: Jason Marshall, California Institute of Technology

Co-Investigators:
Lee Armus, SSC
Henrik Spoon, Cornell University

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IracMap MipsPhot
Hours Approved: 7.3

Abstract:
Spectra of a sample of 109 ultraluminous infrared galaxies (ULIRGs) have been obtained as part of the Spitzer IRS GTO program, providing a dataset with which to study the underlying obscured energy source(s) (i.e., AGN and/or starburst activity) powering ULIRGs in the local universe, and providing insight into the high-redshift infrared-luminous galaxies responsible for the bulk of the star-formation energy density at z = 2-3. As part of this effort, we have developed the CAFE spectral energy distribution decomposition tool to analyze the UV to sub-mm SEDs of these galaxies (including their IRS spectra). Sufficient photometry for these decompositions exists for approximately half of the GTO ULIRGs. However, we lack crucial data for the other half of the sample in either or both the 2-5 micron gap between the near-IR passbands and the start of the IRS wavelength coverage and the far-IR beyond 100 microns. These spectral regions provide critical constraints on the amount of hot dust near the dust sublimation temperature (indicating the presence of an AGN) and the total luminosity and mass of dust in the galaxy (dominated by the coldest dust emitting at far-IR wavelengths). We therefore propose to obtain IRAC observations in all channels and MIPS observations at 70 and 160 microns for the 37 and 17 GTO ULIRGs lacking data in these wavelength ranges, respectively. Considering its very low cost of 7.3 total hours of observation, the scientific return from this program is enormous: nearly doubling the number of GTO ULIRGs with full spectral coverage, and completing a dataset that is sure to be an invaluable resource well beyond the lifetime of Spitzer.

Spitzer Space Telescope - General Observer Proposal #3672

Spitzer Observations of a Complete Sample of Luminous Infrared Galaxies in the Local Universe

Principal Investigator: Joseph Mazzarella
Institution: California Instiute of Technology

Technical Contact: Joseph Mazzarella, California Instiute of Technology

Co-Investigators:
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Lee Armus, Caltech, IPAC/SSC
Aaron Evans, SUNY, Stony Brook
David Frayer, Caltech, IPAC/SSC
Catherine Ishida, Subaru
Joseph Jensen, Gemini
Sophia Khan, GSFC
Dong-Chan Kim, University of Maryland
Steven Lord, Caltech, IPAC/NHSC
Barry Madore, OCIW & Caltech
David Sanders, IfA, University of Hawaii
Bernhard Schulz, IPAC, NHSC
Jason Surace, Caltech, IPAC/SSC
Sylvain Veilleux, University of Maryland
Kevin Xu, Caltech, IPAC/GALAX

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IracMap MipsPhot
Hours Approved: 90.1

Abstract:
We propose Spitzer Space Telescope observations of all ~200 luminous infrared galaxies (LIRGs, L_ir > 10^{11} L_sun) and ultraluminous infrared galaxies (ULIRGs, L_ir > 10^{12} L_sun) in the IRAS Revised Bright Galaxy Sample, a complete flux-limited survey of all extragalactic objects with total 60um flux density greater than 5.24 Jy, covering the entire sky surveyed by IRAS at Galactic latitudes abs(b) > 5 degrees. The superb sensitivity of Spitzer provides a unique opportunity to survey the physical properties of star formation and the interstellar medium in a large, statistically complete, flux-limited sample of nearby LIRGs and ULIRGs. IRAC and MIPS will be used to image the infrared emission in individual galaxies within interacting/merging systems that were not resolved by IRAS or ISO. Problems to be addressed include: 1) How do star formation rates and the spatial distribution of dust emitting regions vary with the stage of the interaction/merger, the mass ratio of the galaxies, the geometry of the encounter, and the properties of each galaxy known from optical, near-infrared, H I, CO, and radio continuum observations? 2) Which LIRGs most likely represent progenitors of ULIRGs and QSOs, and what characteristics of the galaxies and their merger geometries likely lead to dust heating dominated by AGNs rather than starbursts? 3) What are the relative amounts of cold (10 - 30 K), cool (30-50 K) and warm (T_d > 50 K) dust components in LIRGs and ULIRGs, and can this be used to age-date merger events? 4) Are there regions with very hot dust (600 - 1000 K) in some of these objects? This survey will also provide an important archive of data for establishing links between the global infrared properties of high redshift infrared/sub-mm galaxies and structural details that can be well resolved only in local LIRGs.

Spitzer Space Telescope - General Observer Proposal #40682

IRS Observation of Four Exceptionally Red 24 micron Sources

Principal Investigator: Sebastian Oliver
Institution: University of Sussex

Technical Contact: Sebastian Oliver, University of Sussex

Co-Investigators:
Matthew Thomson, University of Sussex
Duncan Farrah, Cornell
Carol Lonsdale, University of California, San Diego
Mari Polletta, University of California, San Diego
David Shupe, IPAC
Jason Surace, IPAC

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap
Hours Approved: 10.1

Abstract:
Four strong candidates for some of the most extreme objects observable with IRS have been identified using a technique for source extraction based on using the data from SWIRE 24 micron images taken at two epochs. These are highly reliable sources but which have no detection at IRAC wavebands. This suggests that they are the most extremely red sources. Our proposal is for an IRS observation of these four objects in order to apply various SED models to attempt to find the nature of these objects.

Spitzer Space Telescope - General Observer Proposal #3640

IRS observations of ultraluminous ELAIS galaxies

Principal Investigator: Ismael Perez-Fournon
Institution: Instituto de Astrofisica de Canarias

Technical Contact: Ismael Perez-Fournon, Inst. Astrofisica de Canarias

Co-Investigators:
Baltasar Vila-Vilaro, University of Arizona
Michael Rowan-Robinson, Imperial College of Science, Technology and Med
Dimitra Rigopoulou, Department of Astrophysics, Oxford University
Duncan Farrah, Jet Propulsion Laboratory
Sebastian Oliver, University of Sussex
Francesca Pozzi, University of Sussex
David Clements, Imperial College of Science, Technology and Medici
Eduardo A. Gonzalez-Solares, Institute of Astronomy, U. of Cambridge
Ivan Valtchanov, Imperial College of Science, Technology and Medici
Fabio La Franca, Dipartimento di Fisica, Universita' degli Studi "R
Steve Serjeant, University of Kent, Canterbury
Mattia Vaccari, Imperial College of Science, Technology and Medici
Thomas Babbedge, Imperial College of Science, Technology and Medici
Carlotta Gruppioni, University of Bologna
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Antonio Hernan-Caballero, Instituto de Astrofisica de Canarias
Francisco M. Montenegro Montes, Instituto de Astrofisica de Canarias
Alejandro Afonso-Luis, Instituto de Astrofisica de Canarias

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 65.9

Abstract:
We propose to use the low spectral resolution capabilities of IRS to obtain high signal-to-noise mid-infrared spectra of a sample of 70 Ultra- and Hyperluminous extragalactic objects at high redshift discovered in the ELAIS survey. The European Large Area ISO Survey (ELAIS) offers the largest complete mid-IR, high-z, high-L extragalactic sample prior to SPITZER. At any redshift ELAIS provides the most luminous objects easily observable with IRS, being complete to about S (15 um) = 1 mJy, well-matched to the sensitivity of IRS. For this proposal we have selected all those galaxies and AGN which have redshift (determined either spectroscopically or photometrically) larger than one. The sample includes objects confirmed to be type-1 quasars with optical spectroscopy as well as galaxies, fainter in the optical, which are probably dusty luminous starbursts. From the IRS observations we plan to investigate in detail: a) the source of the high bolometric luminosities of the most luminous objects in the distant Universe and compare them with nearby galaxies of similar luminosities, b) the physics of dust and gas in high-redshift objects using well-established mid-infrared spectral diagnostic tools, c) the role of the high-luminosity objects in current models of galaxy formation, and d) the AGN-starburst connection.

Spitzer Space Telescope - Directors Discretionary Time Proposal #288

The Evolution of Infrared-luminous Galaxies at High Redshift

Principal Investigator: Alexandra Pope
Institution: U. British Columbia

Technical Contact: Alexandra Pope, U. British Columbia

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 13.2

Abstract:
My primary goal is to understand how different populations of infrared-luminous galaxies are related to each other, and how they all fit into our picture of galaxy evolution. This goal will be addressed using upcoming deep, wide-field Spitzer and SCUBA-2 extragalactic surveys, along with multi-wavelength imaging and spectroscopic data. I will use these datasets to constrain the shape of the IR SED to obtain accurate estimates of the star formation rates and dust properties. I will use IRS observations to characterize the mid-IR SED as a function of redshift, luminosity and sample selection to separate AGN and starburst components.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40455

The clustering and environment of ULIRGs at 0.7<z<1.5

Principal Investigator: George Rieke
Institution: Steward Observatory, U. Arizona

Technical Contact: Benjamin Weiner, Steward Observatory, U. Arizona

Co-Investigators:
Benjamin Weiner, Steward Observatory
Alison Coil, Steward Observatory
Delphine Marcillac, Steward Observatory
Casey Papovich, Steward Observatory
Christopher Willmer, Steward Observatory
Emeric Le Floc'h, University of Hawaii

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: MipsScan
Hours Approved: 11.0

Abstract:
We propose to use MIPS scan mapping at 24 microns to map an 0.65 sq deg field with 6208 galaxy redshifts from the DEEP2 redshift survey, to a flux limit of 205 micro-Jy (5 sigma). This depth is sufficient to detect ultraluminous infrared galaxies (L_IR > 10^12 Lsolar) to z=1.5, the limit of the DEEP2 redshifts. There are only 35 ULIRGs with redshifts in the existing overlap field between DEEP2 + MIPS, the Extended Groth Strip; mapping this field will detect ~ 54 ULIRGs with redshifts, more than doubling the existing sample. ULIRGs are thought to be the sites of extreme starbursts and/or AGN produced in massive, gas-rich mergers. They may mark formation events for massive elliptical galaxies, in which case they should be highly clustered. We will use the MIPS 24 micron detections and the thousands of galaxy redshifts to measure ULIRG-galaxy clustering and the ULIRG environment, group membership, and pair fraction, to constrain the nature of ULIRGs, mechanisms for their triggering, and what types of galaxies they may evolve into. The key ingredients for this study are large area coverage and dense sampling of spectroscopic redshifts; because the 24 micron data does not have to be very deep, it is economical in observing time. Because ULIRGs are rare, especially at low z, most of the ULIRGs will be at z>1 where photometric redshifts are less reliable; the high-quality spectroscopic redshifts provided by the DEEP2 data are key to this project.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40534

IRS spectroscopy of Z~2 ULIRGs

Principal Investigator: George Rieke
Institution: University of Arizona

Technical Contact: Delphine Marcillac, University of Arizona

Co-Investigators:
Casey Papovich, Steward Observatory
Christopher willmer, Steward Observatory
Benjamin Weiner, Steward Observatory
Dario Fadda, NASA Herschel Science Center / CalTech

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap
Hours Approved: 31.2

Abstract:
Deep cosmological surveys at infrared and submillimeter wavelengths have revealed a population of sources with very high star formation rates (SFR ~ 2000 Msol/year) at z~2. These sources would form sim 10^{11} M$_{odot}$ in only sim 5$ imes$10^{7}years! If these sources are really dominated by star formation with a such a high SFR, they are an enigma for the coevolution of the mass spheroid and SMBH since no traces of AGNs have been found in them, even though they are forming a large amount of their mass into stars. One possibility is that an AGN is contributing significantly to their IR emission. Another possibility is that they exhibit different MIR-FIR properties than local sources, which could lead to an overestimation of their estimated SFR. We propose to take high quality Spitzer IRS spectra to probe the MIR properties of these sources. We have selected targets from fields with very deep FIR data so we can understand the nature of the sources across the infrared regime.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50323

IR spectra, star formation rates, and metallicities in submillimeter galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Benjamin Weiner, Steward Observatory, U. Arizona

Co-Investigators:
Benjamin Weiner, Steward Observatory
Eiichi Egami, Steward Observatory
Delphine Marcillac, Steward Observatory
Casey Papovich, Steward Observatory
Christopher Willmer, Steward Observatory
Jane Rigby, Carnegie Observatories
Almudena Alonso-Herrero, Instituto de Estructura de la Materia
Chad Engelbracht, Steward Observatory

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap MipsPhot
Hours Approved: 8.2

Abstract:
Sub-millimeter continuum observations probe the long-wavelength side of far-IR dust emission from distant galaxies, detecting cold dust and dusty galaxies at higher redshifts. This makes the sub-mm uniquely sensitive to types of dusty galaxies that are disfavored by shorter-wavelength selection, such as at 24 microns. However, for the same reason, only a relatively small number of sub-mm galaxies have high-quality Spitzer/IRS spectra. We propose to obtain IRS spectra of a carefully selected sample of 7 galaxies with sub-mm detections, firm radio and infrared cross-IDs and positions, sufficient 24 micron flux, and in several cases, detections at 70 and even 160 microns. These galaxies are in fields with deep IRAC and MIPS photometry and sensitive multiwavelength coverage from X-ray to radio. The IRS spectra will determine the restframe mid-IR PAH emission, silicate absorption, and continuum shape. These features along with far-IR dust temperatures and multiwavelength data will enable us to construct SEDs for cool, dusty galaxies at z ~ 0.5-2, and to determine whether the properties of such galaxies are similar to local unusually cool ULIRGs (e.g. Arp 220) or have evolved with redshift. We are also proposing to take deep IRS exposures to measure Brackett alpha, [Ne II] and [Ne III] mid-IR lines in 3 of the galaxies. These lines yield measurements of star formation rate and metallicity that are unaffected by extinction. We will test whether IR-luminous galaxies at z~1 are lower metallicity than local examples, and whether metallicity evolution is affecting far-IR estimates of star formation rate.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50324

IR spectra, star formation rates, and metallicities in submillimeter galaxies

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Benjamin Weiner, Steward Observatory, U. Arizona

Co-Investigators:
Benjamin Weiner, Steward Observatory
Eiichi Egami, Steward Observatory
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Casey Papovich, Steward Observatory
Christopher Willmer, Steward Observatory
Jane Rigby, Carnegie Observatories
Almudena Alonso-Herrero, Instituto de Estructura de la Materia
Chad Engelbracht, Steward Observatory

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes:
Hours Approved: 33.9

Abstract:
Sub-millimeter continuum observations probe the long-wavelength side of far-IR dust emission from distant galaxies, detecting cold dust and dusty galaxies at higher redshifts. This makes the sub-mm uniquely sensitive to types of dusty galaxies that are disfavored by shorter-wavelength selection, such as at 24 microns. However, for the same reason, only a relatively small number of sub-mm galaxies have high-quality Spitzer/IRS spectra. We propose to obtain IRS spectra of a carefully selected sample of 7 galaxies with sub-mm detections, firm radio and infrared cross-IDs and positions, sufficient 24 micron flux, and in several cases, detections at 70 and even 160 microns. These galaxies are in fields with deep IRAC and MIPS photometry and sensitive multiwavelength coverage from X-ray to radio. The IRS spectra will determine the restframe mid-IR PAH emission, silicate absorption, and continuum shape. These features along with far-IR dust temperatures and multiwavelength data will enable us to construct SEDs for cool, dusty galaxies at z ~ 0.5-2, and to determine whether the properties of such galaxies are similar to local unusually cool ULIRGs (e.g. Arp 220) or have evolved with redshift. We are also proposing to take deep IRS exposures to measure Brackett alpha, [Ne II] and [Ne III] mid-IR lines in 3 of the galaxies. These lines yield measurements of star formation rate and metallicity that are unaffected by extinction. We will test whether IR-luminous galaxies at z~1 are lower metallicity than local examples, and whether metallicity evolution is affecting far-IR estimates of star formation rate. This is part 2 of program 50323.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50586

Star Formation Rates and Metallities at z=1

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Jane Rigby, University of Arizona

Co-Investigators:
Jane Rigby, Carnegie Observatories
Benjamin Weiner, Steward Observatory
Delphine Marcillac, Steward Observatory
Almudena Alonso-Herrero, Instituto de Estructura de la Materia, Spain
Chad Engelbracht, Steward Observatory
Eiichi Egami, Steward Observatory

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsMap MipsPhot
Hours Approved: 19.9

Abstract:
We have two goals in this proposal. Deep 24 micron Spitzer surveys are widely used to study the evolution of star formation rate (SFR) with redshift. Such studies depend critically on the conversion from observed mid-IR flux density to total IR luminosity, and then to SFR. Our first goal is to test this conversion at z~1 on galaxies similar in luminosity to those that dominate the faint source counts. Our test is centered on measuring Brackett alpha line strengths in three z=1 galaxies whose fluxes have been strongly amplified by gravitational lensing. We have or will be obtaining 70 micron measurements of these same galaxies to constrain their far infrared spectral energy distributions. We will combine our sample with three unlensed, more luminous z=1 galaxies from a companion GTO proposal (50323). The two samples will test critically the IR to SFR conversions. Our second goal is to measure the metallicities for these three lensed galaxies. We already have measurements of the [Ne II] and [Ne III] lines in our LL1 spectra. By combining these results with the Br alpha and with measurements of Pa alpha, [Ne II], and [Ne III] in local LIRGs (from another of our GTO programs), we will determine the neon abundances. Neon should track the overall metallicities closely because it is synthesized in massive stars and does not deplete onto grains.

Spitzer Space Telescope - Directors Discretionary Time Proposal #1096

Dust in ULIRG environments

Principal Investigator: Henrick Spoon
Institution: Cornell University

Technical Contact: Henrick Spoon, Cornell University

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 10.0

Abstract:
ISO spectroscopy has revealed that the spectra of ULIRGs are not simply an ultra-luminous blend of AGN and starburst spectra. Instead, the 5-15 micron spectra show clear signs of ice and silicate absorption features, which distort their mid-infrared spectra. Especially puzzling are the 'modified' PAH emission features seen in the ISO-CAM-CVF spectra of the more luminous and distant ULIRGs. We propose to study the effects of ice and silicate absorption on the spectra of ULIRGs from the Tran et al. ISO ("ZZ-ULIRG") sample. This sample is supplemented with less luminous galaxies, which ISO has shown to be very dusty. Our goal is to obtain full low-res spectra for the complete sample and full high-res spectra for most of them.

Spitzer Space Telescope - General Observer Proposal #40244

Absorption line diagnostics of hidden star formation in ULIRGs

Principal Investigator: Henrik Spoon
Institution: Cornell University

Technical Contact: Henrik Spoon, Cornell University

Co-Investigators:
Fred Lahuis, Leiden Observatory
Alexander Tielens, NASA Ames Research Center
Lee Armus, Caltech/SSC
Marco Spaans, Groningen University
Masatoshi Imanishi, National Astronomical Observatory of Japan

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 14.9

Abstract:
Ultraluminous infrared galaxies (ULIRGs) have the power output of quasars, yet emit nearly all their energy in the mid and far-infrared part of the spectrum. Over the last 10 years, much effort has focussed on identifying tracers of AGN and star formation activity in the infrared in order to quantify the origin of the infrared luminosity in these systems. Recently, we discovered the presence of warm (200-600K) dense (~10^6 cm-3) molecular gas through acetylene, hydrogen cyanide, and carbon dioxide gas-phase absorption lines in the IRS spectra of (U)LIRGs. In the Galaxy these lines are characteristic for the 'Hot Core' phase of deeply embedded protostars. Consequently, we attribute these lines to a phase of deeply embedded star formation. While these features are most readily recognized in the spectra of highly dust enshrouded (U)LIRGs, they are also seen in ULIRGs with unambiguous evidence for an AGN. Hence, such deeply embedded star formation seems to be a general characteristic of (U)LIRG nuclei. Here we propose to use the IRS on Spitzer to search for these molecular absorption lines in a wider sample of ULIRG nuclei to determine the frequency and importance of this hitherto unrecognized phase of hidden star formation and characterize the physical conditions of the absorbing dense gas. These spectra, combined with existing high signal-to-noise observations of (U)LIRGs will allow us to place our observations of hidden star formation in ULIRGs in the context of evolution of infrared galaxies as a whole.

Spitzer Space Telescope - General Observer Proposal #3746

A spectroscopic study of local hyperluminous infrared galaxies

Principal Investigator: Aprajita Verma
Institution: Max-Planck-Institut fuer extraterrestrische Physik

Technical Contact: Aprajita Verma, MPE

Co-Investigators:
Matthias Tecza, University of Oxford
Matthew Lehnert, MPE
Lutz Dieter, MPE
Eckhard Sturm, MPE

Science Category: ULIRGS/LIRGS/HLIRGS
Observing Modes: IrsStare
Hours Approved: 15.4

Abstract:
While IRAS revealed a plethora of ultraluminous infrared galaxies (ULIGs L_IR > 10^10 L_solar), the high luminosity component (L_IR > 10^13 L_solar) is relatively rare in number. Often selected with techniques biased towards AGN, Hyperluminous infrared galaxies (HyLIGs) are intriguing sources displaying a variety of optical spectroscopic types, and too faint for any meaningful spectroscopic investigation with instruments to date. Their colossal infrared luminosities imply a highly obscured starburst and/or AGN power source where the majority of the4 UV/optical photons are absorbed and re-radiated by dust across the infrared wavelength range. The presence of dust means the galaxy's emission suffers extinction. This is particularly important as it implies optical spectroscopy probes only the unobscured components of these systems. With the advent of the SST, these rare sources are spectroscopically accessible for the first time at the wavelengths where they are bright and suffer from low extinction. Spectroscopic data from the Infrared Space Observatory (ISO) reveal that the mid-infrared is rich with spectral features: continuum and features from a range of dust grains residing in different phases of interstellar matter within a galaxy; subtle absorption features from silicates and water ice and hydrocarbons; and lines originating from ions, atoms and molecules. However HyLIGs were beyond the reach of ISOs sensitivity. With the Spitzer Space Telescope (SST) we may now probe into the constituent media and physical processes occurring within these luminous galaxies, for which our knowledge to date is broadly confined to coarsely sampled SEDs.

Spitzer Space Telescope - General Observer Proposal #20000

Gotcha! Using Swift GRBs to Pinpoint the Highest Redshift Galaxies

Principal Investigator: Edo Berger
Institution: Carnegie Observatories

Technical Contact: Ranga-Ram Chary, California Institute of Technology

Co-Investigators:
Lennox Cowie, U. Hawaii
Ranga-Ram Chary, Spitzer Science Center
Derek Fox, Caltech
Shirnivas Kulkarni, Caltech
Paul Price, U. Hawaii
Joshua Rich, Australian National University
Patrick McCarthy, Carnegie Institution of Washington
Michael Rauch, Carnegie Institution of Washington
Alicia Soderberg, Caltech
Bradley Cenko, Caltech
Michael Gladders, Carnegie Institution of Washington
Kurt Adelberger, Carnegie Institution of Washington
Amy Barger, U. Wisconson, Madison
Brian Schmidt, Australian National University
Bruce Peterson, Australian National University
George Djorgovski, Caltech

Science Category: GRBs
Observing Modes: IracMap
Hours Approved: 17.0

Abstract:
While there is convincing evidence that the Universe was re-ionized between redshifts of 6.5 and 15, the role of galaxies in this process is still not understood. Several star-forming galaxies at z~6 have been identified in recent deep, narrow-field surveys, but the expensive observations along with cosmic variance and contamination make it difficult to assess their contribution to re-ionization. Moreover, the detection of galaxies at z>7 is exceedingly difficult even with the Hubble UDF or cluster lensing. Significant progress can be made using gamma-ray bursts (GRBs) localized with the now-operational Swift satellite, which is capable of detecting bursts out to z>10. GRBs have the advantage of being an uncontaminated signpost for star-formation, and their afterglows are sufficiently bright even at z>6 to allow photometric selection (via the Ly-alpha drop out technique) with 2-5 meter telescopes. Using our approved TOO programs at an extensive range of facilities (from 1-m robotic telescopes to Keck/Magellan), we can rapidly find afterglows at z>6 and easily distinguish them from dusty low redshift bursts. This approach is highly efficient compared to current techniques, especially at z>7. Here we request imaging with NICMOS (z>6), ACS (z~6), and Spitzer/IRAC to characterize the properties (SFR, age, morphology) of up to five galaxies located in this manner, and begin to address their role in re-ionization. These observations are requested as >2 month TOOs, allowing flexibility of scheduling and at the same time taking a unique and timely advantage of the exquisite performance of three of NASA's premier missions.

Spitzer Space Telescope - General Observer Proposal #20419

Spitzer Observations of the Highest-Redshift Gamma-Ray Bursts

Principal Investigator: Derek Fox
Institution: Penn State University

Technical Contact: Derek Fox, Penn State University

Co-Investigators:
Avishay Gal-Yam, California Institute of Technology
Alicia Soderberg, California Institute of Technology
Shri Kulkarni, California Institute of Technology
Edo Berger, Observatories of the Carnegie Institution of Washi
S. Brad Cenko, California Institute of Technology
Dae-Sik Moon, California Institute of Technology
Fiona Harrison, California Institute of Technology
Dale Frail, National Radio Astronomy Observatory
Steven Shectman, Observatories of the Carnegie Institution of Washi
Eric Persson, Observatories of the Carnegie Institution of Washi
Mark Phillips, Observatories of the Carnegie Institution of Washi
Miguel Roth, Observatories of the Carnegie Institution of Washi
Patrick McCarthy, Observatories of the Carnegie Institution of Washi
Michael Rauch, Observatories of the Carnegie Institution of Washi
Paul Price, University of Hawaii
Brian Schmidt, Australia National University
Hye-Sook Park, Lawrence Livermore National Laboratory

Science Category: GRBs
Observing Modes: IracMap
Hours Approved: 38.9

Abstract:
We propose to use the Spitzer Space Telescope to study the infrared (3.6 to 8.0 micron) afterglow emission of GRBs from the ''dark ages'' of the universe, z>6. Current theories of the early universe predict the first star formation activity at z~20, and since GRBs are associated with the deaths of massive stars they may be expected at this epoch as well, before the formation of the first quasars. Our candidate high-redshift afterglows will be identified in ground-based near-infrared imaging as fading sources with red J-Ks and H-Ks colors, J-Ks > H-Ks > 3.0 mag. For these bursts, 4-band IRAC imaging can provide the crucial additional color information that will distinguish afterglows at z>12.7 (H-band drop-outs) from those within high-extinction environments at z>6 (rest-frame E_(B-V)>0.8). We request time to carry out two high-impact Spitzer TOO campaigns during the cycle. The confirmation of even a single z>6 burst will have immediate implications for theories of the early universe, formation of the first nonlinear structures, the nature of the earliest stars, and cosmology.

Spitzer Space Telescope - General Observer Proposal #3592

Spitzer Observations of the Highest-Redshift Gamma-Ray Bursts

Principal Investigator: Derek Fox
Institution: Penn State University

Technical Contact: Derek Fox, Penn State University

Co-Investigators:
Avishay Gal-Yam, California Institute of Technology
Alicia Soderberg, California Institute of Technology
Shri Kulkarni, California Institute of Technology
Edo Berger, California Institute of Technology
Brad Cenko, California Institute of Technology
Dae-Sik Moon, California Institute of Technology
Sarah Yost, California Institute of Technology
Fiona Harrison, California Institute of Technology
Dale Frail, National Radio Astronomy Observatory
Mario Hamuy, Observatories of the Carnegie Institution of Washi
Steve Shectman, Observatories of the Carnegie Institution of Washi
Eric Persson, Observatories of the Carnegie Institution of Washi
Mark Phillips, Observatories of the Carnegie Institution of Washi
Miguel Roth, Observatories of the Carnegie Institution of Washi
Patrick McCarthy, Observatories of the Carnegie Institution of Washi
Michael Rauch, Observatories of the Carnegie Institution of Washi

Science Category: GRBs
Observing Modes:
Hours Approved: 23.4

Abstract:
We propose to use the Spitzer Space Telescope to study the infrared (3.6 to 8.0 micron) afterglow emission of GRBs from the 'dark ages' of the universe, z>6. Current theories of the early universe predict the first star formation activity at z~20, and since GRBs are associated with the deaths of massive stars they may be expected at this epoch as well, before the formation of the first quasars. Our candidate high-redshift afterglows will be identified in ground-based near-infrared imaging as objects with red J-K and H-K colors, J-K > H-K > 3.0 mag. For these bursts, 4-band IRAC imaging can provide the crucial additional color information that will distinguish afterglows at z>13 (H-band drop-outs) from those within high-extinction environments at z>6 (rest-frame E_B-V>0.8). We request time to carry out two high-impact Spitzer TOO campaigns during the cycle. The confirmation of even a single z>6 burst will have immediate implications for theories of the early universe, formation of the first nonlinear structures, the nature of the earliest stars, and cosmology.

Spitzer Space Telescope - General Observer Proposal #3730

Isolating GRB Supernovae

Principal Investigator: Andrew Fruchter
Institution: Space Telescope Science Institute

Technical Contact: Andrew Fruchter, Space Telescope Science Institute

Co-Investigators:
David Bersier, Space Telescope Science Institute
Jose Maria Castro Ceron, Space Telescope Science Institute
Javier Gorosabel, Space Telescope Science Institute
Andrew Levan, University of Leicester
Peter Nugent, LBNL
James Rhoads, Space Telescope Science Institute
Nial Tanvir, University of Hertferdshire
Steve Thorsett, University of California, Santa Cruz

Science Category: GRBs
Observing Modes:
Hours Approved: 40.5

Abstract:
It is now thought likely that most, if not all, long-duration gamma-ray bursts (GRBs) harbor a supernova under their bright multi-wavelength afterglows. The supernovae, like the afterglows, however, can vary substantially in brightness, and in most cases are largely overwhelmed by the synchrotron radiation from the GRB fireball. Here we propose to observe nearby (z < 0.4) GRBs at one, two and three weeks after burst in the rest frame using IRAC. In the 3 -- 8 micron region of the spectrum the power-law afterglow of the GRB will be essentially uncontaminated by the supernova, permitting an accurate measurment of the magitude and spectral-slope of the afterglow. Late-time observations in the same spectral range will permit us to remove any effect of the host galaxy, as well as any confusing backround, from the early-time measurments. These observations will allow a relatively clean subtraction of the afterglow from the total light of the GRB, dramatically increasing the contrast between the afterglow and the supernova, and allowing a study of the physical properties of the progenitors of these most extraordinary bursts.

Spitzer Space Telescope - General Observer Proposal #20721

Gamma-Ray Burst Physics in the Spitzer/Swift Era

Principal Investigator: Peter Garnavich
Institution: University of Notre Dame

Technical Contact: Peter Garnavich, University of Notre Dame

Co-Investigators:
Kris Stanek, Harvard-Smithsonian Center for Astrophysics
Kevin Krisciunas, Notre Dame
Stephen Holland, Swift Science Center/NASA
Alberto Noriega-Crespo, Spitzer Science Center/IPAC
Michael Pahre, Harvard-Smithsonian Center for Astrophysics
David Bersier, STScI
Rosalba Perna, Princeton
Thomas Matheson, NOAO/Tucson

Science Category: GRBs
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 22.7

Abstract:
Gamma-Ray burst (GRB) afterglows are detected from the X-rays to the radio but the thermal infrared remains unexplored territory. The combination of Spitzer infrared space telescope and the Swift gamma-ray burst explorer provides a unique opportunity to map the spectral energy distribution of afterglows between 3 and 160 microns. The synchrotron model for afterglows predicts a steeply rising power-law spectrum over this range with specific spectral breaks due to the physics of the emission. These breaks have never been directly observed due to the limited spectral coverage available from the ground. Spitzer observations will provide a definitive test of the standard afterglow model. The nearly featureless power-law spectra of GRB afterglows will allow the study of dust properties in high redshift galaxies using the IRS spectrograph on Spitzer. And deep IRAC imaging of optically dark afterglows will differentiate between low-redshift bursts with significant dust extinction, and ultrahigh-redshift events predicted to be found by Swift to z~9. We propose to map the energy distribution of two normal, optically bright GRB afterglows identified by Swift and observed as targets-of- opportunity by Spitzer. And we propose to study two 'dark' bursts which may result from core collapse supernovae at the earliest epoch of star formation. Swift was successfully launched in November 2004 and has already found several GRB. Automated annocuncement of GRB localizations are expected to begin shortly. This is a resubmission of an approved Cycle 1 program (study two bright afterglows) as we await Swift targets.

Spitzer Space Telescope - General Observer Proposal #3653

Gamma-Ray Burst Physics in the Spitzer/Swift Era

Principal Investigator: Peter Garnavich
Institution: University of Notre Dame

Technical Contact: Peter Garnavich, University of Notre Dame

Co-Investigators:
Krzysztof Stanek, Harvard-Smithsonian Center for Astrophysics
David Bersier, Space Telescope Science Institute
Stephen Holland, Swift Science Center
Kevin Krisciunas, University of Notre Dame
Thomas Matheson, Harvard-Smithsonian Center for Astrophysics
Alberto Noriega-Crespo, Spitzer Science Center
Michael Pahre, Harvard-Smithsonian Center for Astrophysics
Rosalba Perna, Princeton University

Science Category: GRBs
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 73.8

Abstract:
Gamma-Ray burst (GRB) afterglows are detected from the X-rays to the radio but the thermal infrared remains unexplored territory. The combination of Spitzer infrared space telescope and the Swift gamma-ray burst explorer provides a unique opportunity to map the spectral energy distribution of afterglows between 3 and 160 microns. The synchrotron model for afterglows predicts a steeply rising power-law spectrum over this range with specific spectral breaks due to the physics of the emission. These breaks have never been directly observed due to the limited spectral coverage available from the ground. Spitzer observations will provide a definitive test of the standard afterglow model. The nearly featureless power-law spectra of GRB afterglows will allow the study of dust properties in high redshift galaxies using the IRS spectrograph on Spitzer. And deep IRAC imaging of optically dark afterglows will differentiate between low-redshift bursts with significant dust extinction, and ultrahigh-redshift events predicted to be found by Swift to z~9. We propose to map the energy distribution of two normal, optically bright GRB afterglows identified by Swift and observed as targets-of-opportunity by Spitzer. And we propose to study two 'dark' bursts which may result from core collapse supernovae at the earliest epoch of star formation.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #76

IR Study of Gamma-Ray Bursts

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Bill Forrest, University of Rochester

Science Category: GRBs
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 6.7

Abstract:
Gamma Ray Bursts are interesting and enigmatic phenomena. With the accurate positioning given by Beppo-Sax and the rapid followup in the visible and radio, several bursts have been found to be associated with distant galaxies at z~1 and greater. Recent studies have provided evidence for collimated outflows and shocks associated with GRB's strenghtening the connection between them and supernovae. If GRB's are associated with young star-forming regions, then there is likely to be strong infrared emission from the heated dust. Furthermore, there is likely to be considerable extinction at shorter wavelengths, rendering visible and near IR observations less than definitive. We use the infrared cameras to measure the 4.5 to 24 um energy distribution and morphology of the putative emitting regions. For regions sufficiently bright, the spectrometer will provide diagnostics of the emission mechanisms and the redshift. The redshift is especially crucial in the cases where no host galaxy has been detected (or the host galaxy is too faint for ground-based redshift determination).

Spitzer Space Telescope - General Observer Proposal #30421

Spitzer-Chandra ToO Observations of a Short/Hard GRB

Principal Investigator: Kevin Hurley
Institution: University of California, Berkeley

Technical Contact: William Mahoney, California Institute of Technology

Co-Investigators:
Katherine Alatalo, University of California, Berkeley
Joshua Bloom, University of California, Berkeley
Nathaniel Butler, University of California, Berkeley
Emilio Falco, Smithsonian Institute
Ryan Foley, University of California, Berkeley
Jonathan Granot, Stanford University
Daniel Kocevski, University of California, Berkeley
William Lee, Universidad Nacional Autonoma de Mexico
Weidong Li, University of California, Berkeley
William Mahoney, California Institute of Technology
Michael Pahre, Harvard University
Daniel Perley, University of California, Berkeley
David Pooley, University of California, Berkeley
Jason Prochaska, University of California, Santa Cruz
Enrico Ramirez-Ruiz, Institute for Advanced Study
Ian Smith, Rice University
Gordon Squires, California Institute of Technology
Alin Panaitescu, Los Alamos National Laboratory

Science Category: GRBs
Observing Modes: IracMap MipsPhot
Hours Approved: 33.3

Abstract:
While long gamma-ray bursts (GRBs) have been conclusively demonstrated over the past nine years to be distributed at great cosmological distances, the nature of short and hard GRBs has yet to be definitively determined. An understanding of the origin of mysterious short gamma-ray bursts remains an elusive and exciting pursuit. A great leap forward was made this past year with the first rapid localizations and afterglow detection of such events, but follow-up has yet to reveal a detailed understanding of the progenitors and the nature of the afterglow light. We propose an ambitious multiwavelenth approach to the problem, leveraging Spitzer with Chandra as well as numerous ground- based telescopes. By measuring the broad-band spectrum of the afterglow and any concurrent "mini-supernova" over a wide range of wavelengths at several epochs, we can distinguish between models proposed to explain this type of burst. We will constrain the energetics of the explosion, the short GRB bursting rate (an important number for gravitational wave observatories), and measure with unprecedented detail the stellar content of a short burst host galaxy. Given the high impact nature of these observations and the rarity of short bursts, we are requesting multiepoch Target of Opportunity observations on a single event in Cycle 3. The wavelengths observed by Spitzer, when used in coordination with these other instruments, can make a crucial contribution to understanding the nature of short/hard GRBs, particularly by removing the degeneracies among the models due to dust extinction.

Spitzer Space Telescope - General Observer Proposal #40152

Spitzer-Chandra ToO Observations of a Short Duration GRB

Principal Investigator: Kevin Hurley
Institution: University of California, Berkeley

Technical Contact: William Mahoney, California Institute of Technology

Co-Investigators:
Joshua Bloom, University of California, Berkeley
Nathaniel Butler, University of California, Berkeley
Emilio Falco, Smithsonian Institute
Ryan Foley, University of California, Berkeley
Jonathan Granot, Stanford University
Daniel Kocevski, University of California, Berkeley
William Lee, Universidad Nacional Autonoma de Mexico
Weidong Li, University of California, Berkeley
William Mahoney, California Institute of Technology
Michael Pahre, Harvard University
Daniel Perley, University of California, Berkeley
David Pooley, University of California, Berkeley
Jason Prochaska, University of California, Santa Cruz
Enrico Ramirez-Ruiz, Institute for Advanced Study
Ian Smith, Rice University
Gordon Squires, California Institute of Technology
Alin Panaitescu, Los Alamos National Laboratory

Science Category: GRBs
Observing Modes: IracMap MipsPhot
Hours Approved: 33.4

Abstract:
While long gamma-ray bursts (GRBs) have been conclusively demonstrated over the past ten years to be distributed at great cosmological distances, the nature of short duration (<~2 s) GRBs has yet to be definitively determined. An understanding of the origin of mysterious short gamma-ray bursts remains an elusive and exciting pursuit. A great leap forward has been made over the past two years with the first rapid localizations and afterglow detections of such events, but follow-up has yet to reveal a detailed understanding of the progenitors and the nature of the afterglow light. We propose an ambitious multiwavelenth approach to the problem, leveraging Spitzer with Chandra as well as numerous ground-based telescopes. By measuring the broad-band spectrum of the afterglow and any concurrent "mini-supernova" over a wide range of wavelengths at several epochs, we can distinguish between models proposed to explain this type of burst. We will constrain the energetics of the explosion and the short GRB bursting rate (an important number for gravitational wave observatories), and measure with unprecedented detail the stellar content of a short burst host galaxy. Given the high impact nature of these observations and the rarity of short bursts, we are requesting multiepoch Target of Opportunity observations on a single event in Cycle 4. The wavelengths observed by Spitzer, when used in coordination with these other instruments, can make a crucial contribution to understanding the nature of short duration GRBs, particularly by removing the degeneracies among the models due to dust extinction. This is a resubmission of our AO-3 ToO proposal, which has not been called yet. However, even if that observation is carried out, we are requesting an AO-4 observation, because so little is known about the short bursts that each new detection adds a very significant amount of information.

Spitzer Space Telescope - General Observer Proposal #50017

Spitzer ToO observations of a short gamma-ray burst

Principal Investigator: Kevin Hurley
Institution: University of California, Berkeley

Technical Contact: William Mahoney, California Institute of Technology

Co-Investigators:
Joshua Bloom, UC Berkeley
Nathaniel Butler, UC Berkeley
Emilio Falco, Smithsonian Institute
Ryan Foley, UC Berkeley
Jonathan Granot, Stanford University
Daniel Kocevski, UC Berkeley
William Lee, UNAM
Weidong Li, UC Berkeley
William Mahoney, California Institute of Technology
Michael Pahre, Harvard University
Daniel Perley, UC Berkeley
Jason Prochaska, UC Santa Cruz
Enrico Ramirez-Ruiz, Institute for Advanced Study
Ian Smith, Rice University
Gordon Squires, California Institute of Technology
Alin Panaitescu, Los Alamos National Laboratory

Science Category: GRBs
Observing Modes: IracMap MipsPhot
Hours Approved: 33.4

Abstract:
An understanding of the origin of the short gamma-ray bursts remains an elusive and exciting pursuit. A great leap forward has been made over the past three years with the first rapid localizations and afterglow detections of such events, but follow-up has yet to reveal a detailed understanding of the progenitors and the nature of the afterglow light. We propose an ambitious multiwavelength approach to the problem, leveraging Spitzer with Chandra as well as numerous ground-based telescopes. By measuring the broad-band spectrum of the afterglow and any concurrent "mini-supernova " over a wide range of wavelengths at several epochs, we can distinguish between models proposed to explain this type of burst. We will constrain the energetics of the explosion and the short GRB bursting rate (an important number for gravitational wave observatories), and measure with unprecedented detail the stellar content of a short burst host galaxy. Given the high impact nature of these observations and the rarity of short bursts, we are requesting multiepoch Target of Opportunity observations on a single event in Cycle 5. The wavelengths observed by Spitzer, when used in coordination with these other instruments, can make a crucial contribution to understanding the nature of short duration GRBs, particularly by removing the degeneracies among the models due to dust extinction. This is a resubmission of our AO-4 ToO proposal, which has not been called yet. However, even if that observation is carried out, we are requesting an AO-5 observation, because so little is known about the short bursts that each new detection adds a very significant amount of information. Harvey Tananbaum has agreed to grant us Chandra ToO time through November 2008 (the end of Chandra AO-9) if Spitzer observations are carried out. Following that, we will submit a Chandra AO-10 proposal for ToO time; if warranted, we will request Chandra Director's Discretionary Time to support our Spitzer observations.

Spitzer Space Telescope - General Observer Proposal #40598

GRBs as Beacons of Star Formation at High Redshifts

Principal Investigator: Christine Jones
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Christine Jones, Smithsonian Astrophysical Observatory

Co-Investigators:
Guido Chincarini, University of Milano
Sergio Campana, Astronomical Observatory of Brera
Giampiero Tagliaferri, Astronomical Observatory of Brera
Giovanni Fazio, SAO
William Forman, SAO
Kamson Lai, Harvard University

Science Category: GRBs
Observing Modes: IracMap
Hours Approved: 18.4

Abstract:
We propose to observe two samples of high redshift GRB host galaxies The first is a sample of 18 GRB hosts at 2<z<3.5 chosen at the peak of cosmic star formation. The second sample of GRB host galaxies are likely at very high redshifts z>5. Our primary scientific goals are 1) to measure the stellar mass and star formation rates and epochs for these two samples of high redshift GRB host galaxies; 2) then to compare the distribution of galaxy masses and star formation rates for four samples of GRB hosts at redshifts from z=0 to z=6 with predictions of the cosmic star formation history and the results found from other galaxy samples. The four samples are the 18 GRB hosts at 2<z<3.5 (proposed here), the seven z>5 GRB hosts, the z~1 GRB host sample (Floc'h et al. 2006) and finally, the low redshift GRB hosts (mostly star forming dwarfs).

Spitzer Space Telescope - Directors Discretionary Time Proposal #478

Spitzer Observations of the Naked Eye GRB080319B

Principal Investigator: Shrinivas Kulkarni
Institution: Caltech

Technical Contact: Arne Rau, Caltech

Co-Investigators:
Stephen Cenko, Caltech
Arne Rau, Caltech
Eran Ofek, Caltech
Derek Fox, Penn State
Edo Berger, Princeton
Michael Werner, JPL

Science Category: GRBs
Observing Modes: IrsPeakupImage
Hours Approved: 1.6

Abstract:
We request a single epoch of IRS blue peak-up imaging of GRB080319B, the brightest optical counterpart to a gamma-ray burst ever detected. The peak optical magnitude observed from GRB080319B, R ~ 6 mag, implies the event was (briefly) visible to the naked eye and almost 3 magnitudes brighter than the previous record holder, GRB990123. Like GRB990123, GRB080319B shows a dramatic rise and fall at early times indicative that we are probing the shocked ejecta of the outflow via reverse shock emission. Spitzer infrared imaging, when coupled with our broadband optical, X-ray, and radio campaign, should help unravel what underlying properties distinguish events like GRB080319B and GRB990123 from the majority of GRB afterglows.

Spitzer Space Telescope - Directors Discretionary Time Proposal #272

Probing the Dark Side of the Cosmic Evolution Using Dark Gamma-Ray Bursts

Principal Investigator: Emeric Le Floc'h
Institution: University of Arizona

Technical Contact: Emeric Le Floc'h, U.Arizona

Science Category: GRBs
Observing Modes: IracMap MipsPhot
Hours Approved: 14.6

Abstract:
The signatures of supernovae detected in the X-ray and optical counterparts of long Gamma-Ray Bursts (GRBs) have led to the conventional wisdom that long GRBs originate from the death of short-lived massive stars and trace therefore the star formation history of the Universe. However, the GRB host galaxies that were studied so far barely overlap with the infrared-luminous sources responsible for the bulk of the star-forming activity at high redshift. These results may seriously question the idea that long GRBs are unbiased tracers of massive star formation, and it is therefore urgent to accurately place the GRB phenomena in their true star formation context. In fact, most GRB hosts were so far pinpointed with optically-bright afterglows, potentially leading to selection effects against dusty sources. To clarify the importance of this bias I propose to carry out a comprehensive study of GRB host galaxies and to focus more specifically on those identified from optically-dark GRBs selected with Swift. Thanks to the unprecedented sensitivity of the Spitzer Space Telescope I will constrain the fraction of bursts originating from massive star formation deeply enshrouded in dust. Comparing the properties of such dark GRB hosts with those of the other galaxies signposted with optically-bright GRB counterparts, I will assess to which extent dark bursts can be used to probe the dark side of the cosmic evolution.

Spitzer Space Telescope - General Observer Proposal #30251

Far-infrared dissection of the GRB980425/SN1998bw host galaxy : toward an understanding of the origin of Gamma-Ray Bursts

Principal Investigator: Emeric Le Floc'h
Institution: University of Arizona

Technical Contact: Emeric Le Floc'h, U. Arizona

Co-Investigators:
Bernhard Brandl, University of Leiden
Vassilis Charmandaris, University of Crete
Miroslava Dessauges, Observatoire de Geneve
Bill Forrest, University of Rochester
Karl Gordon, University of Arizona
Francois Hammer, Observatoire de Paris-Meudon
Daniel Schaerer, Observatoire de Geneve

Science Category: GRBs
Observing Modes: MipsPhot
Hours Approved: 1.0

Abstract:
As part of a previous survey of GRB host galaxies that we performed with Spitzer at 4.5, 8.0 and 24mic, we discovered in the host of GRB980425/1998bw (z=0.0085) a particularly luminous HII region contributing more than 75% to the total mid-IR emission of the underlying galaxy. This IR-luminous HII region is associated with a compact super star cluster recently proposed as the original environment where the precursor of the GRB was born. It exhibits indeed powerful massive star formation as well as signatures of the Wolf-Rayet stars now considered as the most likely progenitors of long GRBs. We propose to image this super star cluster at 70mic and 160mic with MIPS. The combination of these observations with our existing data at shorter wavelengths will lead to a thorough characterization of its properties and to the most detailed panchromatic view of a GRB host galaxy ever achieved so far. Comparisons with other well-studied dust-obscured HII regions of the local Universe will allow us to infer more stringent constraints on the physical conditions favoring the trigger of long GRBs in star-forming environments.

Spitzer Space Telescope - General Observer Proposal #20370

Are the hosts of Gamma-Ray Bursts representative of the high redshift starburst galaxies ?

Principal Investigator: Emeric Le Floc'h
Institution: University of Arizona

Technical Contact: Emeric Le Floc'h, U. Arizona

Co-Investigators:
Herve Aussel, CNRS, CEA-Saclay (France)
Francoise Combes, Observatoire de Paris-Meudon (France)
Pierre-Alain Duc, CNRS, CEA-Saclay (France)
Hector Flores, Observatoire de Paris-Meudon (France)
Bill Forrest, University of Rochester (USA)
Francois Hammer, Observatoire de Paris-Meudon (France)
Felix Mirabel, European Southern Observatory
Casey Papovich, University of Arizona (USA)
Dave Sanders, University of Hawaii (USA)

Science Category: GRBs
Observing Modes: IracMap MipsPhot
Hours Approved: 13.2

Abstract:
Although eight years have already passed since the discovery of the first Gamma-Ray Burst (GRB) optical counterparts and their host galaxies at cosmological distances, the true origin of these cataclismic events and the nature of their hosting environments is still a matter of strong debate. Recent results from optical data seem indeed to indicate that GRBs occur in rather faint, dust-free and low-mass blue galaxies, while it has also been suggested, from submillimeter and radio data, that GRB hosts could be powerful starbursts luminous in the infrared. Though GRBs are now considered as exciting probes of the very early Universe, such a disunited view clearly hampers the understanding of the cosmic site selection that they operate. Given the distance of the currently-known GRB hosts (median redshift ~1.1), studies performed so far strongly suffered from technical limitations (limited sensitivity in the submillimeter and radio; optical emission lines redshifted out of easily-accessible wavelength ranges). In this program, we propose to address the current controversy about these objects thanks to the unique capabilities of the Spitzer Space Telescope. To this purpose, we will measure the stellar mass and the instantaneous star formation rate of 20 GRB hosts respectively with IRAC and MIPS imaging. Our observations will shed a new light to better understand not only the nature of these galaxies but also how GRBs can be used to map the high redshift Universe.

Spitzer Space Telescope - General Observer Proposal #3641

The Enigmatic Supernova 2001em: Off-Axis GRB Afterglow?

Principal Investigator: Schuyler Van Dyk
Institution: Spitzer Science Center

Technical Contact: Schuyler Van Dyk, Spitzer Science Center

Co-Investigators:
Bohdan Paczynski, Princeton University
Jonathan Granot, Institute for Advanced Study
Enrico Ramirez-Ruiz, Institute for Advanced Study
Christopher Stockdale, Marquette University
Nino Panagia, ESA/Space Telescope Science Institute
Kurt Weiler, Naval Research Laboratory
Alexei Filippenko, UC Berkeley
Weidong Li, UC Berkeley
Walter Lewin, Massachusetts Institute of Technology
David Pooley, Massachusetts Institute of Technology

Science Category: GRBs
Observing Modes: IracMap IrsStare MipsPhot
Hours Approved: 2.9

Abstract:
Gamma-ray burst sources (GRBs) are among the most energetic events in the Universe. Long-duration GRBs originate from the collimated, relati- vistic jets in the collapsar scenario. Compelling evidence exists for the association of two Type Ib/c supernovae, thought to arise from very massive Wolf-Rayet star progenitors, with GRBs. Why are not most, or all, SNe Ib/c associated with GRBs? Possibly many GRBs do not have detectable gamma-ray emission, due to off-axis beaming, yet they will be detectable as SNe Ib/c, with late-time afterglows. Recently we have detected the puzzling SN Ic 2001em in the radio, two years after explo- sion. We make specific model predictions that, if this is a GRB afterglow, it should be a luminous mid-IR source, detectable with Spitzer. Observa- tions with Spitzer, in concert with nearly contemporaneous observations at a rich variety of wavelengths, will provide valuable insight into this event and its relationship to GRBs.

Spitzer Space Telescope - General Observer Proposal #20385

A detailed look at the host galaxy of GRB 031203

Principal Investigator: Darach Watson
Institution: University of Copenhagen

Technical Contact: Darach Watson, University of Copenhagen

Co-Investigators:
Jens Hjorth, University of Copenhagen
Johan Fynbo, University of Copenhagen
José María Castro Cerón, University of Copenhagen
Jesper Sollerman, Stockholm University
Goran Östlin, Stockholm University

Science Category: GRBs
Observing Modes: IrsStare MipsSed
Hours Approved: 4.3

Abstract:
GRB 031203 is the closest gamma-ray burst (GRB) known apart from the exceptional GRB 980425. Using the host galaxy of GRB 031203, we can make the first detailed investigation of the conditions of star formation in a GRB host galaxy in a way that is independent of extinction effects. In particular, for the first time, we will be able to determine the hardness of the intrinsic stellar radiation field, the metallicity, total extinction, the dust mass and the dust temperature in a GRB host.

Spitzer Space Telescope - General Observer Proposal #40388

The first extinction curve of a gamma-ray burst afterglow

Principal Investigator: Darach Watson
Institution: University of Copenhagen

Technical Contact: Darach Watson, University of Copenhagen

Co-Investigators:
Anja Andersen, University of Copenhagen
Jose Maria Castro Ceron, University of Copenhagen
Johan Fynbo, University of Copenhagen
Jens Hjorth, University of Copenhagen
Daniele Malesani, University of Copenhagen
Michal Michalowski, University of Copenhagen
Nial Tanvir, University of Hertfordshire
Paul Vreeswijk, European Southern Observatory

Science Category: GRBs
Observing Modes: IracMap MipsPhot
Hours Approved: 17.8

Abstract:
In this proposal we intend to derive for the first time the absolute extinction curve of a single star-forming region at high redshift using a GRB afterglow, using a target of opportunity IRAC and MIPS 24 micron photometric observation to fix the level of the extinction-free continuum in the mid-infrared. Since GRBs occur in actively star-forming regions, it was anticipated that there should be significant dust extinction of their optical afterglows. But the extinctions derived solely from the reddening in GRB optical/near IR spectra have been low. At the same time these reddening measurements disagreed strongly with extinctions inferred from metallicity measurements and led to the suggestion of a flat dust extinction curve, possibly because of dust destruction by the GRB. In spite of the large literature on grey dust and the alteration of the extinction curve by dust destruction, its existence has so far never been demonstrated. The dust properties of GRB environments are of interest not only for their value in studies of GRB and their formation, but also because GRBs occur in star-forming galaxies at very high redshifts (currently <z> = 2.8), and GRB afterglows give us a means to study dust and metallicity in the hearts of extremely distant star-forming regions that are accessible in no other way. These observations will be triggered on a burst where we have, (1) a good quality optical spectrum that shows a large damped Ly alpha absorption line, log N(HI) > 21.5, (2) a high signal-to-noise X-ray spectrum with a significant detection of extragalactic absorption and (3) multi-colour optical/near infrared (NIR) photometric follow-up of the afterglow near-simultaneous with the Spitzer observation.

Spitzer Space Telescope - Archive Research Proposal #40847

A Reanalysis of IR Background Fluctuations in Spitzer IRAC GOODS fields

Principal Investigator: Asantha Cooray
Institution: University of California Irvine

Technical Contact: Asantha Cooray, University of California Irvine

Co-Investigators:
Ranga Chary, SSC
Mark Dickinson, NOAO
James Davies, NOAO
Henry Ferguson, STScI
James Bock, Caltech/JPL
Ian Sullivan, Caltech
Daniel Stern, JPL/Caltech
Elizabeth Barton, UC Irvine
Alexandre Amblard, UC Irvine
Devdeep Sarkar, UC Irvine
Edward Wright, UCLA
Stefano Casertano, STScI

Science Category: cosmic infrared background
Dollars Approved: 66973.0

Abstract:
We propose a reanalysis of IRAC GOODS HDF-N and CDF-S data to measure clustering of the unresolved IR background (IRB) present in "empty" pixels. These clustering measurements will be used to study any indications for the presence of an unresolved, diffuse IR background from redshifts related to reionization and associated with redshifted UV emission from first-light galaxies. We will improve previous analyses by cross-correlating unresolved IR fluctuations between different IRAC channels to determine if the color of unresolved fluctuations are consistent with spectra expected for first-light galaxies containing Population III stars. The cross-correlation analysis will also allow us to separate various noise and systematic effects that are not common to IRAC passbands. A significiant effort in this proposed program will be to understand statistical errors and systematic uncertainties in fluctuation measurements. Given first-light galaxy fluctuations cluster at 10 arcminute angular scales and individual IRAC images are limited to 5 arcminutes, we will remosaic GOODS BCDs by inserting simulated patterns of first-light galaxies and measure clustering in new mosaics to see if we recover the input fluctuations and to establish the accuracy of diffuse backgrounds in the mosaic. For fluctuation measurements, we will also implement a likelihood analysis of IR images to measure the power spectrum of anisotropies in multipole space. These techniques are commonly used in CMB studies and are optimized to handle issues associated with complex mask and window functions that are applied to images. With such a technique we can directly address if our existing procedure based on Fourier transforms leads to biased estimates of clustering or not. Data products involving masked images, new mosaics of GOODS, and software to measure clustering will all be made publicly available, as we have done in the past in our similar studies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #64

Combined Program on Cosmic IR Background/Evolution of SFR/Lyman Break and SCUBA SED's

Principal Investigator: Giovanni Fazio
Institution: Harvard-Smithsonian Astrophysical Observatory

Technical Contact: Michael Pahre, Smithsonian Astrophysical Observatory

Science Category: Cosmic infrared background
Observing Modes: IracMap IrsStare MipsPhot MipsScan
Hours Approved: 88.9

Abstract:
This program combines three scientific programs: Detection of the Cosmic IR Background, evolution of the Cosmic star formation rate, and SED's of Lyman Break and SCUBA sources. Only the latter is described in detail here at this time. Over the past few years Steidel et al. have used the Lyman Break technique with great success to identify UV-bright star-forming galaxies at redshifts of 3 and 4. The expected corrections for extinction to the star formation rates are large, suggesting much of the luminosity will be reradiated in the mid and far infrared. Also in thelast few years, several high redshift galaxies have been detected at submm wavelengths, which again has been interpreted as due to high star formation rates reradiated by dust. The submm emission is generally on the (modified) Rayleigh-Jeans tail of the blackbody emission from the dust, and hence does not in itself significantly constrain basic properties such as dust temperature and bolometric luminosity. Lacking these constraints, estimates of star formation rates in these objects are wildly uncertain. We will use SIRTF observations to address these issues. IRAC measurements of redshifted near IR light provide a good estimate of the total stellar mass present. IRS measurements of the very strong 7.7um PAH feature are diagnostic of whether an AGN or starburst dominates the bolometric luminosity. And MIPS far IR photometry directly measures the dust temperature and luminosity. Adding these pieces to the puzzle will tell us the true total star formation rate in these objects.

Spitzer Space Telescope - Archive Research Proposal #3396

Cosmic Far-IR Background Fluctuation Studies of the FLS

Principal Investigator: Bruce Grossan
Institution: LBNL

Technical Contact: Bruce Grossan, LBNL

Co-Investigators:
George Smoot, U.C. Berkeley Space Sciences Laboratory

Science Category: Cosmic infrared background
Dollars Approved: 59500.0

Abstract:
We propose to make high-quality maps of the FLS extragalactic survey region, and to analyze the Cosmic Far-IR Background (CFIB) fluctuations in the maps to constrain galaxy density and evolution functions, and measure clustering. Deep survey Log N- Log S analysis is usually used to understand galaxy populations and evolution, but the analysis is confusion limited with MIPS at 70 and 160 um. Statistical fluctuations in the background, however, are from sources fainter than the confusion limit, and therefore carry information about the distribution of fainter, more distant objects than identified sources. Not only can we learn about the star formation history of the universe from these fluctuations, we can also learn about structure and galaxy formation, as source clustering would leave a strong signal on map power spectra undetectable with identified sources (due to insufficient statistics). Making large, sensitive, far-IR maps is challenging: detector drift and power law noise can imprint false structure. Though MIPS' calibration flashes remove most of these effects, our analysis of MIPS characterization array data shows that after flash correction, power law noise and drift remain (e.g. 8% median drift per scan at 70 um) that will affect large maps. We have therefore developed a novel application of the COBE matrix method (developed for microwave background analysis), our Clrmap software package, to produce statistically optimal MIPS maps. Maps reduced with our software show significant reduction in noise structure compared to co-added maps. We will use our map power spectrum analysis to evaluate models and measure galaxy distribution & evolution, and clustering parameters. In power spectra of 160 um simulated FLS maps, the predicted clustering signal is 5 times stronger than for random galaxies for k= 0.03-0.2 (1/arcmin). This signal is easily detected with our <30%/bin errors. This measurement will constrain galaxy formation models, one of the most outstanding problems in astrophysics.

Spitzer Space Telescope - General Observer Proposal #30231

Realizing Spitzer's Far-IR Background Science Potential

Principal Investigator: Bruce Grossan
Institution: LBNL

Technical Contact: Bruce Grossan, LBNL

Co-Investigators:
George Smoot, UC Space Science Laboratory

Science Category: cosmic infrared background
Observing Modes: MipsScan MipsTp
Hours Approved: 12.0

Abstract:
We propose a short program of MIPS scans of the Lockman Hole (LH) to provide the new data necessary to greatly improve the quality of the existing MIPS map of this region. The improved maps will permit us to make power spectrum measurements (P(k)) of the 160 μm IR background (CFIB) in order to measure IR galaxy clustering and differential evolution. Our simulations show that these dramatic improvements in results and map quality are possible using only an additional 10% of the original MIPS time on this field. Currently, scan-related structure, "stripes", limit the precision of P(k) measurements of the CFIB in the LH map. It is well-known that "cross- linking" scans are required to reduce stripes in such maps, however, only an insignificant number of these scans were made in the large MIPS surveys appropriate for CFIB analysis. We planned our observations to address this fundamental problem. Our simulations indicate that the striping contribution to P(k) is reduced by up to 77% on the scales where galaxy clustering and evolution are measured, greatly enhancing the science potential in the map. Our P(k) results thus far with this map apparently reject current galaxy distribution models -but only at weak significance. Reducing the systematic error as proposed will permit Spitzer to realize it's full potential in CFIB science, changing these weakly significant "hints" into significant measurements. We emphasize that these observations will not just reduce P(k) error but will also yield higher-quality, more robust maps; the better backgrounds and reduced striping will in turn yield better source fluxes, benefiting a wide range of Spitzer science, not just CFIB.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #12

MIPS Survey and IRS Spectroscopy of Sources in the KPNO Bootes Field

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Tom Soifer, Spitzer Science Center

Science Category: Cosmic infrared background
Observing Modes: IrsStare MipsScan
Hours Approved: 78.0

Abstract:
Surveys of high galactic latitude sky will be undertaken to learn the source of the cosmic infrared background. This project covers the shallow survey which has a dual purpose. It provides the modest-depth, large area survey descirbed below and provides an area from which to select targets for IRS spectroscopy by combining the MIPS data with groundbased optical imaging. First we will use MIPS primarily at 24um to survey the 14h+34d field of the NOAO Deep Wide-Field survey, identify targets from these observations that are bright enough to obtain spectra with IRS and meet selection criteria defined by the combined team, and obtain low resolution IRS spectra of these sources from 5.3-40um. A prime selection criterion for obtaining IRS spectra will be that they must be brighter than 1 mJy at 24um. Generally the main science goal of the IRS observation will be to determine redshifts from IR spectral features. The targets chosen for IRS observation will generally be faint enough so that optically determined redshifts will not be feasible even with 10m telescopes.

Spitzer Space Telescope - Archive Research Proposal #3253

Structure of cosmic infrared background from First Look Survey

Principal Investigator: Alexander Kashlinsky
Institution: SSAI

Technical Contact: Alexander Kashlinsky, SSAI

Co-Investigators:
Richard Arendt, SSAI, Goddard Space Flight Center
Jonathan Gardner, NASA Goddard Space Flight Center

Science Category: Cosmic infrared background
Dollars Approved: 72682.0

Abstract:
We propose to search for cosmic infrared background (CIB) anisotropies using data from the Spitzer First Look Survey (FLS). We expect that we will be able to measure the spatial fluctuation spectrum of the CIB using the longest wavelength MIPS channels and set new interesting upper limits on small scale CIB fluctuations at the IRAC bands. These will be new constraints on the CIB at wavelengths, spatial scales, and sensitivities that have not been previously available.

Spitzer Space Telescope - Theoretical Research Proposal #40197

Anisotropy in the Cosmic Near Infrared Background: Simulations vs Observations

Principal Investigator: Eiichiro Komatsu
Institution: University of Texas, Austin

Technical Contact: Eiichiro Komatsu, University of Texas, Austin

Co-Investigators:
Paul Shapiro, University of Texas at Austin
Elizabeth Fernandez, University of Texas at Austin

Science Category: cosmic infrared background
Dollars Approved: 74999.0

Abstract:
The goal of the proposed research is to make the most detailed and reliable theoretical prediction for the distribution of fluctuations in the cosmic near infrared background from unresolved high-z galaxies and ionized bubbles at z>7, taking into account the large scale structure as well as inhomogeneous distribution of ionized (HII) bubbles around sources. We shall use both analytical calculations (Fernandez & Komatsu 2006) and numerical simulations (Iliev et al. 2006) for completing this task. In particular we will be the first to use high-fidelity large-scale simulations of the cosmic reionization to calculate fluctuations in the cosmic near infrared background. The results from our research will be made publicly available in the form of simulated maps of the near infrared background as well as the angular power spectrum computed from the simulated maps. Our products should be immediately useful for interpreting the power spectrum of significant fluctuations (Kashlinsky et al. 2007; Cooray et al. 2007) detected in the Spitzer data from the GOODS Spitzer Legacy Program. The data from other Spitzer Legacy Programs, such as S-COSMOS, which do wide-field deep imaging surveys in the near infrared bands, should also benefit from our products.

Spitzer Space Telescope - General Observer Proposal #20174

Physics of the Hotspots and Jets in the Powerful Radio Galaxy Cygnus A

Principal Investigator: Daniel Harris
Institution: Smithsonian Astrophysical Observatory

Technical Contact: Daniel Harris, Smithsonian Astrophysical Observatory

Co-Investigators:
Lukasz Stawarz, Smithsonian Astrophysical Observatory
Michal Ostrowski, Jagiellonski University, Poland
Chi Teddy Cheung, NRAO and MIT

Science Category: extragalactic jets
Observing Modes: IracMap
Hours Approved: 3.9

Abstract:
We propose Spitzer imaging of the archetype powerful radio galaxy Cygnus A with IRAC at 4.5 and 8.0 microns. The main goal of our 3.6 hr observation is to detect and measure the high energy (infrared) portion of the synchrotron spectra of the well-known hotspots. These observations will be compared directly to expectations from different models for high-energy particle acceleration in non-relativistic shocks. Additionally, we aim to study possible manifestations of the propagation of the powerful radio jets which have been revealed tentatively in previous high resolution X-ray and radio spectral imaging.

Spitzer Space Telescope - General Observer Proposal #20501

Star Formation and Ionized Gas along the Centaurus A Jet

Principal Investigator: Rosina Iping
Institution: the Catholic University of America

Technical Contact: Rosina Iping, the Catholic University of America

Co-Investigators:
Susan Neff, NASA's GSFC
George Sonneborn, NASA's GSFC

Science Category: extragalactic jets
Observing Modes: IrsMap
Hours Approved: 1.9

Abstract:
We propose IRS spectral mapping of several distinct environments along the jet of NGC 5128 (Cen A) to determine the characteristics of star formation, dust properties, and shocked gas where the jet interacts with the outer regions of the galaxy. Powerful jets are common phenomena of AGN with massive black holes. The jets carry substantial energy out of AGN and may induce significant star formation along the way. Cen A is the nearest AGN with a powerful jet and a key object for understanding the jet-galaxy interactions. Recently, UV emission was detected by GALEX along the jet of Cen A at distances up to 40 kpc from the AGN. Some of the UV emission is associated young hot stars, whose formation was probably induced by jet-cloud interaction. However, significant amounts of UV emission are detected that are not clearly associated with star formation. Optical emission ([O III], Halpha) may arise from collisionally ionized gas associated with jet shocks, or from photoionization by young stars. IRS 5-15 um spectral mapping of key regions in Cen A, augmented by our GALEX and FUSE observations, will permit us to determine the origin of the hot plasma (shocks or stars) and the distribution of young stars as traced by dust in the star forming region.

Spitzer Space Telescope - General Observer Proposal #20455

Deep Imaging of Quasar Jets with IRAC

Principal Investigator: Svetlana Jorstad
Institution: Boston University

Technical Contact: Svetlana Jorstad, Boston University

Co-Investigators:
Alan Marscher, Boston U., USA
Jonathan Gelbord, MIT, USA
Herman Marshall, MIT, USA
Dan Schwartz, SAO, USA
Diana Worrall, SAO & U. of Bristol, UK
Mark Birkinshaw, SAO & U. of Bristol, UK
Eric Perlman, UMBC, USA

Science Category: extragalactic jets
Observing Modes: IracMap
Hours Approved: 11.9

Abstract:
We propose to obtain IRAC images of the jets of 6 quasars that have extended X-ray and radio emission, with bright knots on arcsecond scales. The resulting mid-IR images combined with existing X-Ray/optical/radio measurements will allow us to obtain the spectral energy distributions (SED) for each of roughly 30 knots from 10E9 to 10E18 Hz . This is crucial information to decide between two competing high-energy radiation processes - inverse Compton scattering and synchrotron radiation. The SEDs will be used to infer the values of the Doppler beaming factor, magnetic field, and density and cutoffs of the electron energy distribution for the knots. These parameters are needed to calculate the kinetic power of the most luminous quasar jets, which have been estimated to range from 1E46 to extreme values exceeding 1E49 erg/s. From this study, we will be able to determine the extent to which the jet decelerates significantly with distance from the nucleus and how the efficiency of ultra-high-energy particle acceleration depends on location and morphology.

Spitzer Space Telescope - General Observer Proposal #41022

Velocity Gradients in the Jets of BL Lac Objects

Principal Investigator: Alan Marscher
Institution: Boston U.

Technical Contact: Alan Marscher, Boston U.

Co-Investigators:
Svetlana Jorstad, Boston U.

Science Category: extragalactic jets
Observing Modes: IracMap
Hours Approved: 0.9

Abstract:
We propose to observe the arcsec-scale jets of 2 BL Lac objects with highly relativistic jets (bulk Lorentz factor of 16) on parsec scales in order to determine whether a velocity gradient exists between the axis and edge of the jet and along the length of the jet. Models both for the morphology of jets in BL Lac objects and for the launching of the jet predict such gradients. If radio-selected BL Lac objects are end-on FR 1 sources, there should be strong X-ray emission from inverse Compton scattering of CMB photons along the highly beamed fast spine of the jet. The imaging observations with Chandra, HST, SST, and the VLA will therefore verify whether such a spine exists and on what length scale it decelerates to nonrelativistic speeds.

Spitzer Space Telescope - Directors Discretionary Time Proposal #300

A Second Huge Flare in Blazar 3C454.3

Principal Investigator: Ann Wehrle
Institution: Space Science Institute

Technical Contact: Patrick Ogle, Caltech

Co-Investigators:
Patrick Ogle, SSC

Science Category: extragalactic jets
Observing Modes: IrsStare
Hours Approved: 3.2

Abstract:
A second huge flare in blazar 3C454.3 occurred in July 2007, with the optical brightness at R=12.8 as of 19 July 2007, within half a magnitude of its historical maximum in the 2005 flare. We propose 9 daily IRS observations of 40 minutes each, immediately following our scheduled IRS observation on July 28th, 2007 until the current visibility window closes. We initiated a multiwavelength observing campaign that involves Swift and possibly Integral TOO's and a dozen ground based observatories. The Spitzer observations will measure the changing location and shape of the infrared peak in the spectral energy distribution during the rise of the flare, which we will compare to our similar data obtained during the decay of the 2005 major flare.

Spitzer Space Telescope - General Observer Proposal #20016

Search for Very Thick Disks Around NGC 891 and NGC 5907 with the IRS PUI

Principal Investigator: Martin Burgdorf
Institution: John Moores University

Technical Contact: Martin Burgdorf, John Moores University

Co-Investigators:
Matthew Ashby, Harvard/Smithsonian Center for Astrophysics

Science Category: dark matter
Observing Modes: IrsPeakupImage
Hours Approved: 2.1

Abstract:
Flat galaxy rotation curves routinely observed out to large radii in HI and in optical emission lines are convincing evidence for the existence of dark matter. As yet, we know very little about the nature of this dark matter. An intriguing possibility is that a population of very cool objects - extreme brown dwarfs or "Jupiters'' - accounts for a significant part of its mass. Their intrinsic faintness at visible wavelengths would explain why they have not yet been clearly detected. IRAC GTO observations of two famous edge-on galaxies (NGC 891 and 5907) have yielded good evidence for such a very red, thick disk component that could comprise some of this "missing mass", but the mid-infrared colors as yet offer no clear discriminant of the thick disks' makeup. We propose to use the IRS PUI mode for follow-up observations of the thick disks seen in the two edge-on IRAC GTO program galaxies. By measuring the thick disk fluxes at 16 microns we can obtain crucial information for example about the temperature of the objects in these disks and hence get a better idea of their nature. As the expected signal is much smaller than the foreground emission from the zodiacal light, we propose to execute raster maps perpendicular to the midplanes of these galaxies without touching the regions of strong emission. The radiation from the thick disks will then appear as a surface brightness gradient measured as a function of distance on both sides of the galactic midplanes. Previous attempts to detect halo or thick disk material around edge-on galaxies concentrated on the near infrared; the observations proposed here would be the first ones at longer wavelengths which are aimed only at regions outside the visible disks. In addition to the proposed 16 micron images, we will obtain 22 micron images in parallel, from the other IRS peak-up array at similar positions relative to the galaxies. We request 2.1 hours to carry out this program.

Spitzer Space Telescope - General Observer Proposal #40125

Are LMC/SMC microlensing events due to dark matter?

Principal Investigator: Andrew Gould
Institution: Ohio State University

Technical Contact: William Reach, Spitzer Science Center

Co-Investigators:
William Reach, Spitzer Science Center, California Institute of Te
Andrzej Udalski, Warsaw University Observatory
Kim Griest, Department of Physics, University of California, Sa
Subo Dong, Department of Astronomy, Ohio State University
David Bennett, Department of Physics, Notre Dame University
Andrew Boden, Michelson Science Center, California Institute of

Science Category: dark matter
Observing Modes: IracMap
Hours Approved: 25.5

Abstract:
The outstanding question in the interpretation of microlensing events observed toward the Magellanic Clouds (MC) is the location and nature of the lens population. Because Earth-based photometric observations are ambiguous in inferring the lens distance, existing MC survey events can be explained by lenses in the Galactic halo, the Galactic disk, the clouds themselves, or a combination of all three. By virtue of its orbit, Spitzer offers a literally unique perspective on MC microlensing events. Here we propose to continue our program of target-of-opportunity Spitzer/IRAC photometric observations of MC microlensing events detected in an ongoing ground-based survey, and to combine the Spitzer and ground-based datasets to unambiguously determine the lens "microlens parallax", which strongly constrains the host population of individual lenses. The first such Spitzer observations constrained OGLE-2005-SMC-001 to lie in the Galactic halo at 95% conficence. A handful of additional determinations will unambiguously settle the lens location controversy and associated uncertainty in interpreting MC microlensing surveys,and allow the determination of whether the putative halo lenses comprise a significant component of Galactic dark matter.

Spitzer Space Telescope - General Observer Proposal #30542

Dust in the Wind: Mapping Galactic Superwinds with Spitzer

Principal Investigator: Lee Armus
Institution: IPAC

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
Bruce Draine, Princeton University
Chad Engelbracht, University of Arizona
Tim Heckman, Johns Hopkins University
David Hollenbach, NASA-Ames Research Center
Charles Hoopes, Johns Hopkins University
Kartik Sheth, Spitzer Science Center
Patrick Shopbell, California Institute of Technology
John David Smith, University of Arizona
Jason Surace, Spitzer Science Center
Fabian Walter, MPIA

Science Category: starburst galaxies
Observing Modes: IracMap IrsMap
Hours Approved: 36.2

Abstract:
Galactic-scale superwinds, driven by the collective effect of massive stars and supernovae, have been invoked as a source of heating and metallicty enrichment of both the intra-cluster and inter-galactic medium. There is abundant morphological, physical, and kinematic evidence for superwinds in nearby starburst and infrared-luminous galaxies. At high redshifts, superwinds have been seen in Lyman-break galaxies at z=2-3. M82 and NGC 253 are the nearest, brightest and best-studied starburst galaxies with multi-wavelength evidence for superwinds. GALEX UV images suggest that dust is present far out in the halos of both galaxies. Recent Spitzer IRAC imaging of M82 has revealed a spectacular, large-scale nebula along the outflow axis that is strongly emitting in the 7.7+8.6 micron PAH bands. While Spitzer IRS spectra of M82 have been taken, the superwind has never been mapped. Similarly, there exist no Spitzer IRAC images of NGC 253. We propose, therefore, to obtain an IRS spectral map of the M82 wind with the SL and LL modules of the IRS in order to measure the dust, ionized gas, and warm molecular gas in the outflow region. These spectral maps, covering the 5-38 micron range, will allow us to measure the properties (size and ionization state) of the small grains in the wind, the temperature and distribution of the warm molecular gas, and the physical parameters of the ionized gas (ionization state and density) in the superwind. In addition, we propose to obtain a deep IRAC map of NGC 253 in order to search for extended, extraplanar PAH emission. We will compare the IRAC data to existing optical, X-ray, and UV images, and use them to plan for future spectroscopic follow-up with the IRS. The total time for this proposal is 36.2 hrs.

Spitzer Space Telescope - General Observer Proposal #40444

IRS Observations of Local Lyman Break Analogs

Principal Investigator: Lee Armus
Institution: Spitzer Science Center

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
Tim Heckman, The Johns Hopkins University
Roderick Overzier, The Johns Hopkins University
Harry Teplitz, Spitzer Science Center
Ranga Chary, Spitzer Science Center
Brian Siana, Spitzer Science Center
Chris Martin, California Institute of Technology

Science Category: starburst galaxies
Observing Modes: IrsStare
Hours Approved: 33.9

Abstract:
UV-selected Lyman Break Galaxies (LBGs) provide one of the best probes of star formation in the early (z > 2) Universe. They represent a phase of intense star formation in the early stages of galaxy evolution. Since LBGs at high redshift are difficult to study, local starburst galaxies are often used as templates to understand the properties of the thousands of LBGs uncovered in deep surveys. However, these local starbursts generally have much smaller luminosities and UV surface brightnesses, or they are much dustier. We have used the UV all-sky imaging survey done with the Galaxy Evolution Explorer (GALEX) to identify for the first time a rare population of low-redshift starbursts with properties remarkably similar to high-redshift LBGs. These compact, UV Luminous Galaxies (UVLGs) resemble LBGs in terms of size, star formation rate, surface brightness, metallicity, kinematics, reddening, and color. In Spitzer cycle 3 we obtained IRAC and MIPS images of this UVLG sample. Here, we propose to obtain IRS spectra of 25 UVLGs in order to measure their dust properties (PAH emission, silicate absorption, MIR slope), search for buried AGN, measure the ionization state of the gas, and understand how the bolometric corrections relate to both the mid-infrared and UV properties. With these spectra we will build the only existing library of MIR spectral templates which can be used to understand the dust properties of high-redshift LBGs. The total time for this program is 33.9 hrs.

Spitzer Space Telescope - General Observer Proposal #50575

Dust in the Wind: Mapping the Nearest Galactic Superwind with the IRS on Spitzer

Principal Investigator: Lee Armus
Institution: Spitzer Science Center

Technical Contact: Lee Armus, Spitzer Science Center

Co-Investigators:
Francois Boulanger, IAS
Bruce Draine, Princeton University
Chad Engelbracht, University of Arizona
Pierre Guillard, IAS
Timothy Heckman, Johns Hopkins University
David Hollenbach, NASA-Ames Research Center
Charles Hoopes, Naval Research Lab
Matthew Lehnert, Observatoire de Paris
Kartik Sheth, Spitzer Science Center
Patrick Shopbell, California Institute of Technology
John David Smith, University of Arizona
Jason Surace, Spitzer Science Center
Fabian Walter, MPIA

Science Category: starburst galaxies
Observing Modes: IrsMap
Hours Approved: 35.7

Abstract:
Galactic-scale superwinds, driven by the collective effect of massive stars and supernovae, have been invoked as a source of heating and metallicty enrichment of both the intra-cluster and inter-galactic medium. There is abundant morphological, physical, and kinematic evidence for superwinds in nearby starburst and infrared-luminous galaxies. At high redshifts, superwinds are found in Lyman-break galaxies at z=2-3. M82 is the nearest, brightest and best-studied starburst galaxy with multi-wavelength (UV, X-ray, Halpha, CO, etc.) evidence for a superwind. Spitzer IRAC imaging of M82 has revealed a spectacular, large-scale nebula along the outflow axis that is strongly emitting in the 7.7+8.6 micron PAH bands. Spitzer IRS maps of the base of the wind reveal a complex structure of dust, ionized gas, and molecular gas, emitting strongly in PAH features and H2 lines. However, most of the wind and the dust halo in M82 remains unobserved with the IRS. Here, we propose to obtain IRS maps of the dust in the wind at larger radii, outside the X-ray/UV ionization cone, and in the outer parts of the wind. The IRS maps proposed here will triple the wind area mapped with the IRS above the plane, and reach out more than a factor of two in radius. M82 provides a unique opportunity to study a superwind in unprecedented detail. When combined with the existing maps, the data proposed here will provide us with the most complete physical picture of the interaction of a dusty wind with a galaxy halo that can be achieved with Spitzer.

Spitzer Space Telescope - General Observer Proposal #3477

Identifying the Earliest Massive Starbursts: Picking the Redshift-Temperature Lock

Principal Investigator: Frank Bertoldi
Institution: Max-Planck-Institut fuer Radioastronomie

Technical Contact: Hauke Voss, Max-Planck-Institut feur Radioastronomie

Co-Investigators:
Voss Hauke, Max-Planck-Institut fuer Radioastronomie
Karl M. Menten, Max-Planck-Institut fuer Radioastronomie
Chris L. Carilli, National Radio Astronomy Observatory
Frazer Owen, National Radio Astronomy Observatory
Steven Eales, Cardiff University
Dieter Lutz, Max-Planck-Institut fuer extraterrestrische Physik
Helmut Dannerbauer, Max-Planck-Institut fuer extraterrestrische Physik

Science Category: starburst galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 27.9

Abstract:
With IRAC at 3.6 micron and MIPS at 24 micron we like to image the largest region yet mapped deeply at mm or submm wavelengths, the Abell 2125 MAMBO Deep Field. Our aim is to identify at arcsec resolution the population of dusty mm galaxies that are particularly difficult to identify at any other waveband, presumably because they lie at redshifts well above 3. These Spitzer Space Telescope observations in combination with our millimeter, optical and radio photometry will resolve the distance--dust temperature degeneracy, thus providing good photometric redshifts which will allow us, for the first time, to obtain a solid measure of the number density of very massive starburst galaxies at redshifts above 3, and thereby to place the most stringent constraints on galaxy formation models. Spitzer observations will furthermore help identify the true counterparts of the mm galaxies undetected at radio wavelengths, allow realistic estimates of the infrared luminosities and dust masses, and permit a look at the environments of these early, massive starbursts. The highest redshift sources identified thereby (possibly producing the highest redshift object ever detected) will motivate follow-up optical, near-IR and mm spectroscopy to obtain accurate redshifts and to search for molecular (CO, HCN) and atomic (CI) emission, opening up detailed studies of the most distant dusty starburst galaxies, likely corresponding to forming massive spheroidal galaxies.

Spitzer Space Telescope - General Observer Proposal #20542

Selecting dusty starburst galaxies at z=1.5 using a silicate absorption feature

Principal Investigator: Colin Borys
Institution: Caltech

Technical Contact: Duncan Farrah, Cornell University

Co-Investigators:
Duncan Farrah, Infrared Processing and Analysis Center
Philip Choi, Spitzer Science Center
Dave Frayer, Spitzer Science Center

Science Category: starburst galaxies
Observing Modes: IrsStare
Hours Approved: 18.4

Abstract:
We propose Spitzer IRS spectroscopy of a sample of 15 high redshift dusty starburst galaxies. The sample, drawn from the SWIRE and FLS surveys, is based on a silicate absorption feature at 9.7 microns being redshifted into the MIPS 24 micron band. Thus, the objects should all be around a redshift of z=1.5. This is a traditionally difficult epoch to obtain optical spectra of galaxies, and is known as the "redshift desert". Our proposed observations will validate the selection technique and, if successful, allow us to draw samples of hundreds of z=1.5 dusty starburst galaxies contained in the rich spitzer Legacy data sets.

Spitzer Space Telescope - General Observer Proposal #20767

Mid-IR spectroscopy of suspected very hot dusty, high-z galaxies

Principal Investigator: Scott Chapman
Institution: Caltech

Technical Contact: Scott Chapman, Caltech

Co-Investigators:
Andrew Blain, Caltech
Ian Smail, U.Durham
Rob Ivison, U.Edinburgh

Science Category: starburst galaxies
Observing Modes: IrsStare
Hours Approved: 23.7

Abstract:
We have identified a population of high-redshift microJy radio sources which have optical and near-IR photometric and spectroscopic properties characteristic of dusty luminous starbursts, and whose radio emission is as intense as expected from this class of galaxy, but which have no detectable submm emission from cool dust. As these galaxies are detected with ~0.5mJy 24micron fluxes, we propose that they are a new class of luminous dusty starbursts with characteristic dust temperatures that are hotter than the similarly high-redshift ultraluminous submillimeter-selected galaxies (SMGs) identified in deep submm surveys. The radio emission from these submm-faint radio galaxies indicates far-IR luminosities that are comparable to those of the SMGs. We propose Spitzer IRS observations of 6 of these galaxies to to probe the intense mid-IR emission from these galaxies for signatures of their power source. We expect that large numbers of these galaxies will be detected in mid-IR Spitzer surveys, and we can rapidly and efficiently define their observational characteristics by exploiting our existing radio-selected spectroscopic sample.

Spitzer Space Telescope - General Observer Proposal #30510

NeV and OIV in Wolf-Rayet Galaxies

Principal Investigator: Daniel Devost
Institution: Cornell University

Technical Contact: Daniel Devost, Cornell University

Co-Investigators:
Claus Leitherer, Space Telescope Science Institute
David Whelan, Cornell University
Lei Hao, Cornell University

Science Category: starburst galaxies
Observing Modes: IrsStare
Hours Approved: 39.3

Abstract:
We propose to investigate the occurrence of the highly excited OIV and NeV lines in a small but well-defined sample of Wolf-Rayet (W-R) galaxies selected from their optical emission lines, starburst size, and abundances. Our observations will help shed more light on the long standing question of the excitation mechanism of OIV in star forming regions. At the same time, we will be able to perform quantitative tests of models predicting the strength of NeV emission in regions solely powered by stars.

Spitzer Space Telescope - General Observer Proposal #3269

Infrared SEDs of Seyfert Galaxies: Starbursts and the Nature of the Obscuring Medium

Principal Investigator: Jack Gallimore
Institution: Bucknell University

Technical Contact: Jack Gallimore, Bucknell University

Co-Investigators:
Moshe Elitzur, University of Kentucky
Christopher O'Dea, STScI
Stefi Baum, STScI
David Axon, RIT
Martin Elvis, CfA
Andrew Robinson, RIT

Science Category: starburst galaxies
Observing Modes: IracMap IrsMap MipsSed
Hours Approved: 46.3

Abstract:
The obscuring torus in Seyfert galaxies reprocesses the hard radiation from the active nucleus into the mid-infrared, and modeling the state and structure of the obscuring torus therefore depends on accurate measurements of the mid-infrared. Circumnuclear starbursts impact the evolution of both the host galaxy and the central engine and uniquely contributes to the far-infrared. Unfortunately, quality measurements of the nuclear mid-far infrared SED is available only for a handful of "famous" Seyferts, but most measurements are limited by poor spectral sampling (e.g., broadband photometry only) and large apertures (~ 100" ISO and IRAS beams). We propose IRAC, IRS spectral mapping, and MIPS SED measurements of a well-defined sample of Seyfert galaxies with the goal of providing a database suitable for detailed modeling and decomposition of the nuclear emission, including the torus and circumnuclear starburst contributions. The spectral database will allow a statistical study of the evolution of the starburst and active nucleus. Spectral mapping techniques will provide detailed SEDs over 3-99 m in a 20" aperture, which corresponds to the inner < 3 kpc for 75% of the sample.

Spitzer Space Telescope - Archive Research Proposal #20407

Gas, Dust, and Star Formation in Wolf-Rayet Galaxies

Principal Investigator: Roy Gal
Institution: University of California, Davis

Technical Contact: Roy Gal, University of California, Davis

Co-Investigators:
Iranderly Fernandes, Instituto Nacional de Pesquisas Espaciais, Divisao
Aurea Garcia-Rissmann, Laboratorio Nacional de Astrofisica/MCT
Reinaldo de Carvalho, Instituto Nacional de Pesquisas Espaciais, Divisao

Science Category: starburst galaxies
Dollars Approved: 66835.0

Abstract:
Starbursts, and particularly Wolf-Rayet galaxies, are objects with violent star formation that cannot be maintained for a Hubble time. They provide important clues to understanding galaxy formation and evolution mechanisms, since massive stars play an important role in the nucleosynthesis of heavier elements and the transfer of mechanical energy to the interstellar medium. Understanding how gas collapses to generate bursts of star formation in galaxies, and how star cluster evolution occurs to form the relation between central black hole mass and galaxy bulge properties is one of the key subjects in modern astrophysics. We propose to use existing high- and low- resolution IRS observations to investigate the gas properties and stellar populations of a sample of local Wolf Rayet galaxies, using mid-infrared diagnostic diagrams. The mid-IR has the advantage of not being subject to the huge extinction that affects UV and optical observations, especially in objects with strong star formation where the young clusters are embedded in a thick dust shorud. We will probe the star formation/AGN processes in these environments through the analysis of fine structure line ratios, PAH emission and the derivation of photo-ionization parameters. These results will be compared with those derived from spectra available in the SDSS database and targeted long-slit observations, revealing the limitations of traditional shorter wavelength observations. Realistic photoionization models will be used to analyze a broad range of physical parameters and peculiarities of the observed regions. Correlations between the massive stellar spectral signatures and gas abundance, or gas excitation, will enable estimation of the number of such stars in the observed regions. The heterogeneous character of the sample, including active and non-active galaxies, will allow us to test evolutionary scenarios proposed for AGN, an important test for the Unified Model of AGN.

Spitzer Space Telescope - General Observer Proposal #20390

Star Formation and Dust in Nearby Lyman Break Galaxy Analogs Discovered by GALEX

Principal Investigator: Charles Hoopes
Institution: Johns Hopkins University

Technical Contact: Charles Hoopes, Johns Hopkins University

Co-Investigators:
Timothy Heckman, Johns Hopkins University
David Schminovich, Columbia University
Stephane Charlot, Max-Plank-Institut fur Astrophysik
Guinevere Kauffmann, Max-Plank-Institut fur Astrophysik
D. Christopher Martin, California Institute of Technology
R. Michael Rich, University of California at Los Angeles
Samir Salim, University of California at Los Angeles
Mark Seibert, California Institute of Technology

Science Category: starburst galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 15.8

Abstract:
We have used the ultraviolet all-sky imaging survey currently being conducted by the Galaxy Evolution Explorer (GALEX) to identify for the first time a rare population of low-redshift starbursts with properties remarkably similar to high-redshift Lyman Break Galaxies. These compact UV-luminous galaxies (UVLGs) resemble Lyman Break Galaxies in terms of size, UV luminosity, surface brightness, mass, metallicity, kinematics, and color. They have characteristic "ages" (stellar mass/SFR) of only a few hundred Myr. This population of galaxies is thus worthy of study in its own right and as a sample of local analogs of Lyman Break Galaxies. We propose to obtain far-infrared and mid-infrared fluxes for a sample of the 31 nearest and brightest compact UVLGs using MIPS and IRAC. With these data we will 1) determine the total star formation rate using the far-IR+UV luminosity, 2) probe the dust content and the relation between UV reddening and IR flux in these galaxies, 3) explore the relationship between PAH emission features and star-formation rates in the extreme environment of UVLGs, 4) construct the IR to UV SED and compare with extensive spectral evolution models to determine the star formation history and total stellar mass, and 5) calibrate techniques to study the properties of high-redshift Lyman Break Galaxies. These data will provide important information on star formation in the present-day universe, and will shed new light on the earliest major episodes of star formation in high-redshift galaxies.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #30680

A Complete IRS Sample of PAH-rich Star Forming Dwarves in the SWIRE ELAIS N1 Field

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Sarah Higdon, Cornell University

Co-Investigators:
James Higdon, Cornell University
Duncan Farrah, Cornell University
Carol Lonsdale, UCSD
Jason Marshall, Cornell University
Thomas Nikola, Cornell University
Gordon Stacey, Cornell University

Science Category: starburst galaxies
Observing Modes: IrsStare
Hours Approved: 6.6

Abstract:
Understanding galaxy formation is at the foundation of extragalactic astronomy. Galaxies are thought to be assembled via mergers of small dwarf-like systems at high redshift. One of the best ways of providing observational constraints to the models is through a better understanding of local examples of these "building blocks", star forming dwarf galaxies. We have exploited the SWIRE legacy database to perform an unbiased search for extreme star forming PAH-rich dwarf galaxies. We wish to observe a complete and flux-limited 8 um selected sample of 27 PAH-rich dwarf galaxies in the ELAIS N1 field with the Infrared Spectrograph. This proposal is part of a much larger study of the PAH-rich dwarf galaxy population. However, the Spitzer observations are critical for our project as this is a mid-infrared selected sample and we need to compare the mid-infrared properties with Spitzer surveys of known galaxy type. Only Spitzer enables us to measure the PAH features; directly observe the low-J rotational molecular hydrogen lines; and the fine structure lines in a practically extinction-free wavelength range. These observations will characterize the physical properties of the star-forming regions, e.g., star formation rate, excitation, electron density, warm molecular gas mass. Please note that this is a COMPLETE SURVEY OF 27 PAH-RICH DWARVES. The SPITZER TIME request is SPLIT between this GTO proposal (SJH_PDGT), which has my total GTO time allocation of 6.6 hrs for 4 sources AND a GO proposal (SJH_PDGO) to observe the remaining 23 SOURCES in 37.9 hrs.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40038

Infrared Spectra of a Complete Bright Galaxy Sample Defined by Spitzer

Principal Investigator: James Houck
Institution: Cornell University

Technical Contact: Daniel Weedman, Cornell University

Co-Investigators:
Emeric Le Floc'h, University of Hawaii
Kate Brand, Space Telescope Science Institute

Science Category: starburst galaxies
Observing Modes: IrsStare
Hours Approved: 23.6

Abstract:
A complete, flux-limited sample needing IRS low-resolution observations has been defined for 121 sources chosen from the IRS GTO Bootes Survey and from the Spitzer First Look Survey. Samples are defined to 10 mJy and to 6 mJy at 24u. We have already obtained spectra for 26 galaxies having 24u fluxes > 10 mJy, and GO observations exist for 13 sources in the total sample of 121. Of these 26 sources, 15 show strong PAH emission features characteristic of starbursts, 3 show deep silicate absorption features, and 8 show AGN emission lines or featureless infrared spectra. Redshifts range from 0.017 to 2.41, and continuum luminosities at rest-frame 6u have 2x10^{41} ergs per s < vLv(6u) < 6.3x10^{46} ergs per s., indicating that such a sample covers the full range of infrared-luminous populations of extragalactic sources. New IRS GTO observations are proposed for 33 sources for a total of 23.6h GTO time. These GTO sources will complete the 10 mJy sample for both Bootes and the FLS and initiate a 6 mJy Bootes sample with 12 sources. A companion GO proposal for the remaining 49 sources in the 6 mJy Bootes sample will complete that sample. The proposed GTO and GO observations will assemble enough sources to study unbiased luminosity functions and evolution for infrared-luminous galaxies of various types.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40050

Abundance gradients in NGC 6052

Principal Investigator: Jim Houck
Institution: Cornell University

Technical Contact: Daniel Devost, Cornell University

Co-Investigators:
Bernhard Brandl, Leiden University
David Whelan, Cornell University
Vianney Lebouteiller, Cornell University
Jeronimo Bernard-Salas, Cornell University
Shannon Guiles, Cornell University

Science Category: starburst galaxies
Observing Modes: IrsMap
Hours Approved: 4.8

Abstract:
There are hints in IRS low resolution data of NGC 6052 (Whelan et al. 2007) of the presence of a metallicity gradient. We propose here to investigate this in more detail by observing this galaxy for 5 hours using the SH module in mapping mode. If confirmed, this gradient would be the first one detected inside a dwarf star forming system other than the LMC.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40101

Dust properties in the extremely metal-poor BCD: IZw18 - from IRS mapping

Principal Investigator: Jim Houck
Institution: Cornell University

Technical Contact: Yanling Wu, Cornell University

Co-Investigators:
Yanling Wu, Cornell University
Vassilis Charmandaris, University of Crete
Leslie Hunt, INAF
Jeronimo Bernard-Salas, Cornell University
Vianney Lebouteiller, Cornell University

Science Category: starburst galaxies
Observing Modes: IrsMap IrsPeakupImage IrsStare
Hours Approved: 8.4

Abstract:
We propose to use the short-low and short-high modules of the IRS to map the extremely low-metallcity blue compact dwarf galaxy, IZw18. Having just 1/30th the solar metallicity, IZw18 has been studied extensively at nearly all wavelengths and has been considered a local analogue to the formation of primordial galaxies in the early universe. We aim at obtaining deep mid-IR spectra of the NW and SE clusters of the galaxy, which are known to display a variation in their broadband infrared colors, and use those spectra to study the physics of dust and radiation field in the galaxy. How different are the spectral slopes in these regions and what causes this difference? Are the metallicities derived from the infrared for these two regions also different and how do they compare to the optical? We will be able to answer these questions with the new proposed observation.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #73

IRS and MIPS observations of Starburst galaxies

Principal Investigator: James R. Houck
Institution: Cornell University

Technical Contact: Daniel Devost, Cornell University

Science Category: starburst galaxies
Observing Modes: IrsMap
Hours Approved: 12.2

Abstract:
The observational properties of starburst galaxies are dominated by the light emitted by their young stellar population. Many starburst galaxies have high FIR fluxes which are the direct product of heating by the hot stars and re-emission in the 60-100 microns part of the spectrum. Starburst galaxies thus form an ideal laboratory to study star formation and its relationship to the physical properties of a galaxy and it's ISM. A sample of 7 starburst galaxies for which physical properties have been derived from optical spectroscopy will be observed with IRS and MIPS. First, observations at 24 microns with MIPS imaging are planned to estimate fluxes and source position for IRS spectroscopy. Then, low resolution IRS observations will allow studies of the dust, PAH and PDR properties while high resolution spectroscopy will be performed on two bright unresolved sources to study high excitation lines. MIPS imaging at 160 microns is also planned to allow the deepest probing possible of the dust. The properties derived with these observations will be compared with the physical properties derived from the optical observations.

Spitzer Space Telescope - Archive Research Proposal #30844

The Formation and Early Evolution of Star Clusters

Principal Investigator: Kelsey Johnson
Institution: University of Virginia

Technical Contact: Kelsey Johnson, University of Virginia

Co-Investigators:
Amy Reines, University of Virginia
William Vacca, NASA-Ames
Andrea Gilbert, IGPP/LLNL

Science Category: starburst galaxies
Dollars Approved: 75460.0

Abstract:
Super star clusters are one of the most extreme star forming environments in the universe, and an important mode of star formation during the cataclysmic events of galaxy merging and assembly. These clusters are also important agents of galactic evolution in the local universe, and can have violently disruptive effects on their host galaxies. Despite the importance of super star clusters throughout the universe, the physical conditions and environments required for their formation are almost completely unconstrained by existing observations. Based on a recently completed radio survey, we have identified a number of candidate extremely young (natal) super star clusters in a sample of nearby starburst galaxies. These sources are still embedded in their natal dust cocoons. We are proposing to add archival Spitzer data to our radio results in order to construct the SEDs of these thermal sources and determine their physical properties. By combining the radio, Spitzer mid-infrared, and near-IR data with 3-D radiation transfer codes, our proposed program will address critical issues related to the birth and early evolution of super star clusters. Using IRAC and MIPS imaging along with IRS spectroscopy, we will investigate the properties of the birth environments, the physical parameters of the embedded stellar clusters and their natal cocoons, and the timescales involved in their formation. The results from this project will ultimately provide insight into star formation and galactic evolution throughout the universe.

Spitzer Space Telescope - General Observer Proposal #30670

Evolution of Compact Extreme Starburst Galaxies

Principal Investigator: James Lowenthal
Institution: Smith College

Technical Contact: James Lowenthal, Smith College

Co-Investigators:
Matthew Bershady, University of Wisconsin
Jesus Gallego, Universidad Complutense de Madrid
Rafael Guzman, University of Florida
Salman Hameed, Hampshire College
David Koo, UCO/Lick Observatory

Science Category: starburst galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 45.8

Abstract:
The global SFR was tenfold greater at z=1 than at z=0, and "downsizing" scenarios of galaxy formation maintain that the strong evolution in SFR progresses from high- to low-mass systems with time. Meanwhile, large reservoirs of star formation previously hidden from the optical by obscuring dust are being uncovered in the IR and submm in diverse populations of galaxies over a wide range of redshift. We propose deep IRAC imaging and MIPS photometry of a unique sample of well-studied 26 extreme starburst galaxies, half of them nearby HII galaxies and the other half luminous compact blue galaxies (LCBGs) at redshift z~0.5. These intensely starforming but mostly low-mass systems, like their massive cousins the ultraluminous infrared galaxies (ULIRGs), apparently evolve significantly: they can account for as much as 40% of the increase in global SFR observed between z=0 and z=1. They may also include local analogs of Lyman break galaxies at z~3, and are probably the same class of UV-bright starbursts recently observed in the local universe with GALEX. Coverage of our sample has two significant advantages over other multiwavelength surveys: spatially resolved HST/STIS-UV and optical imaging and spectroscopy, and high spectral and spatial resolution 2D spectroscopy with Keck/HIRES. Thus we can measure important physical parameters that are unavailable with the FLS, EGSS, GOODS, and other surveys. Our main science goal is (1) to use the mid- and far-IR emission to measure optically obscured star formation from z~1 to z=0 as a function of dynamical mass and rest-UV size and morphology; this will directly address inconsistencies in our current downsizing picture of galaxy evolution and the role of compact extreme starbursts. We also plan (2) to compare the SEDs of our samples to those of LBGs, to test the hypothesis that LCBGs include local analogs of LBGs; and (3) to measure the starbursts' stellar masses in the rest-NIR, which is necessary for analysis of SFH, b parameter, and their cosmic evolution.

Spitzer Space Telescope - General Observer Proposal #20528

Exploring the Dust Content of Galactic Winds with MIPS

Principal Investigator: Crystal Martin
Institution: University of California Santa Barbara

Technical Contact: Crystal Martin, UCSB

Co-Investigators:
Karl Gordon, Steward Observatory
Charles Engelbracht, Steward Observatory

Science Category: starburst galaxies
Observing Modes: MipsPhot MipsScan
Hours Approved: 45.0

Abstract:
This program explores the dust content of galactic winds. Nearly half of all stars in the universe probably form in a starburst event, where high concentrations of supernova explosions drive galactic-scale gaseous outflows. In nearby starburst galaxies, winds have been mapped at radio, optical, and X-ray frequencies revealing bipolar lobes of hot gas laced with cooler filaments bubbling out of the host galaxy. Most of the outflowing material is entrained interstellar gas, so it will remain quite dusty unless the grains are destroyed. Dusty winds have significant implications for the circulation of heavy elements in galaxies, the dust content of the intergalactic medium, and the acceleration of gaseous outflows. GALEX images of scattered ultraviolet light from galactic winds now provide compelling evidence for the survival of some grains. MIPS photometry of starburst winds at 24, 70, and 160 microns can, in principle, measure the dust temperature providing accurate estimates of the amount of dust (e.g. Engelbracht et al. 2004). To date, however, most MIPS observations of starburst galaxies are far too shallow to detect thermal emission from halo dust. The requested observations would provide the most sensitive observations currently possible for a sample of starburst galaxies, selected to span the full range of starburst luminosity and spatial geometry in the local universe.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #50162

Tracing the History of Star Formation and Accretion with a Deep Spitzer/Radio Survey

Principal Investigator: George Rieke
Institution: The University of Arizona

Technical Contact: Jennifer Donley, University of Arizona

Co-Investigators:
Nick Seymouor, SSC
Tom Dwelly, University of Southampton
Ian McHardy, University of Southampton
Jennifer Donley, Steward Observatory
Mat Page, MSSL
Andrew Hopkins, University of Sydney
Nic Loaring, SALT

Science Category: starburst galaxies
Observing Modes: MipsScan
Hours Approved: 21.6

Abstract:
At the faint flux densities reached by the deepest radio surveys (<50uJy at 1.4GHz), thousands of sources are detected per square degree. Population models predict that most of the faintest radio sources should be star-forming galaxies (SFGs). Hence the deepest radio surveys offer an excellent method to examine star-formation out to z>2; a method that is free from many of the assumptions (e.g. dust attenuation) typically made when measuring star formation rates. However, a significant minority of the faint radio population is accretion powered (i.e. by AGN), and such objects must first be removed from the SFG sample before we can e.g. measure the cosmic star formation rate density. Determining the power source behind the faintest radio sources is difficult due to their typically low luminosities at optical/NIR wavelengths. We have explored a range of measures such as radio morphology, radio spectral index and radio-to-24um flux density ratio to determine the power source (AGN or SFG) for faint radio sources detected in our VLA/GMRT/MERLIN/Spitzer survey field. We find that the radio-to-24um flux density ratio discriminator is particularly effective at separating AGN and SFRG powered radio sources, but unfortunately our current 24um MIPS data are not sufficiently deep to allow secure classification of radio sources below ~100uJy - the flux range where SFGs are expected to become the dominant radio population. Therefore we request further deep MIPS observations of our field in order to apply the radio-to-24um discrimination method to our entire radio sample. With this Spitzer data we will be able to make an independent measure of the cosmic star-formation rate density, and determine the radio luminosity function of starforming galaxies to z~2.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #24

Studies of the broad 22-micron feature

Principal Investigator: Thomas Roellig
Institution: NASA Ames Research Center

Technical Contact: Thomas Roellig, NASA Ames Research Center

Science Category: starburst galaxies
Observing Modes: IrsMap IrsStare
Hours Approved: 28.4

Abstract:
Recently a broad 22 um feature has been observed in H II regions and starburst galaxies. We are planing further studies of this feature and its relationship with starburst galaxies. Supernovae are very likely the major production source of this broad 22 um dust feature and the strength of the feature can be used to trace the supernova rate in a galaxy. We plan to use the IRS to observe a sample of galaxies with different degree of starburst activities, with the goal of studying the strength of the 22 um feature strength and its relationship to starburst activity. In addition, we also plan to map the Carina Nebula where the 22 um feature was previously observed, with the goal of studying the excitation mechanism of this feature and the identification of its carrier. Finally, we will also observe the 22 micron feature in two supernova remnants.

Spitzer Space Telescope - General Observer Proposal #20577

Nascent starbursts: a missing link in galaxy evolution

Principal Investigator: Helene Roussel
Institution: California Institute of Technology

Technical Contact: Helene Roussel, Max-Planck-Institut fur Astronomie

Co-Investigators:
George Helou, IPAC/Caltech
Jim Condon, National Radio Astronomy Observatory
Rainer Beck, Max-Planck-Institut fur Radioastronomie
John-David Smith, University of Arizona

Science Category: starburst galaxies
Observing Modes: IracMap IrsMap MipsPhot
Hours Approved: 20.4

Abstract:
We have identified a rare category of galaxies characterized by an extreme deficiency in synchro- tron radiation, relative to dust emission, and very high dust temperatures. We studied in detail the most extreme such object, and concluded in favor of a starburst just breaking out, less than one megayear old, in a galaxy having undergone no major star formation episode in the last 100 Myr. Such systems offer a perfect setting to study the initial conditions and early dynamics of starbursts and understand better the regulation of the infrared-radio continuum correlation in galaxies. For the prototypical nascent starburst, the mid-infrared spectrum is quite peculiar, suggesting tran- sient dust species and high optical depth; tracers of dust and molecular gas are the only indicators of unusual activity, and the active regions are likely very compact and dust-bounded, suppressing ionization. Only Spitzer data can provide the needed physical diagnostics for such regions. A sample of 25 nascent starbursts was drawn from the cross-correlation of the IRAS Faint Source Catalog and the NVSS VLA radio survey, and carefully selected based on our multi-wavelength VLA maps to span a range of infrared to radio ratios and luminosities. This sample allows a first step beyond studying prototypes toward a statistical analysis addressing systematic physical pro- perties, classification and search for starburst development sequences. We propose imaging and spectroscopic observations from 3 to 160 microns to characterize the state of the interstellar medium and the gas and dust excitation origin. Our aim is to learn from these unique systems how a star formation burst may develop in its very earliest phases, how it affects the fueling material and the host galaxy. Acquired observations of the radio continuum, cold molecular gas and tracers of shocks and HII regions will help us interpret the rich Spitzer data set and extract a coherent picture of the interstellar medium in our targets.

Spitzer Space Telescope - Directors Discretionary Time Proposal #492

An Extremely Metal-Poor Population of L* Galaxies at z~0.35

Principal Investigator: John Salzer
Institution: Indiana University

Technical Contact: Rose Finn, Siena College

Co-Investigators:
Rose Finn, Siena College
George Helou, IPAC/SSC

Science Category: starburst galaxies
Observing Modes: IracMap MipsPhot
Hours Approved: 4.9

Abstract:
We propose to obtain IRAC and MIPS observations of seven prototypes of a recently discovered class of star-forming galaxies with 0.29 < z < 0.41. Originally thought to be intermediate-redshift Seyfert 2 galaxies when first discovered in the KPNO International Spectroscopic Survey (KISS), recent optical spectroscopy in the far red has revealed these objects to be very metal-poor star-forming galaxies. These galaxies follow a luminosity-metallicity (L-Z) relation that parallels the one defined by low-redshift galaxies, but is offset by a factor of 10 to lower abundances! The amount of chemical and/or luminosity evolution required to place these galaxies on the local L-Z relation is extreme. Either they are late-forming massive systems, which would challenge the current paradigm of galaxy formation, or they represent intense starbursts in dwarf-dwarf mergers. In either case, these objects represent an extreme stage of galaxy evolution taking place at relatively low redshift. In order to arrive at a more complete understanding of the nature of these objects, we are applying now to DDT in order to capture a minimum of FIR information before Spitzer runs out of He coolant. We stress that the nature of these objects has only recently been recognized, so that it was not possible to apply to observe them during the most recent call for proposals.

Spitzer Space Telescope - General Observer Proposal #3177

Probing the Neutral to Molecular Transition in the Dwarf Starburst Galaxy NGC 4214

Principal Investigator: Evan Skillman
Institution: University of Minnesota

Technical Contact: Evan Skillman, University of Minnesota

Co-Investigators:
John Cannon, University of Minnesota
Fabian Walter, National Radio Astronomy Observatory

Science Category: starburst galaxies
Observing Modes: IrsMap
Hours Approved: 24.8

Abstract:
We propose to perform an in-depth study of the molecular ISM in the nearby low-metallicity dwarf galaxy NGC 4214. The goal is to study the transition from neutral to molecular gas in a metal-poor environment - a fundamental process that drives star formation in galaxies. NGC 4214 is one of the few nearby dwarf galaxies where high-quality CO and HI observations exist and where drastically different star formation environments are located in close proximity. Using IRS in spectral mapping mode, we propose to carry out a detailed study of the S(0), S(1) and S(2) pure rotational lines of H2 at 28.2, 17.0, and 12.3 microns in NGC 4214. We will accurately map the individual molecular clouds and HI peaks to empirically test models of star formation where low-metallicity molecular clouds are predicted to have dense CO cores, surrounded by diffuse neutral carbon envelopes with co-spatial H2. The results of this investigation will offer the first empirical insight into the behavior of the neutral-to-molecular transition at comparatively low metallicities, a typical environment expected to prevail at large lookback times.

Spitzer Space Telescope - Guaranteed Time Observer Proposal #40018

Mapping the frosty exotic ISM around the deeply buried AGN in the nearby starburst galaxy NGC4945

Principal Investigator: Henrik Spoon
Institution: Cornell University

Technical Contact: Henrik Spoon, Cornell University

Co-Investigators:
Vassilis Charmandaris, University of Crete
Jeronimo Bernard-Salas, Cornell University
John-David Smith, Steward Observatory
Helene Roussel, MPIA
Daniel Devost, Cornell University
Duncan Farrah, Cornell University

Science Category: starburst galaxies
Observing Modes: IrsMap IrsStare
Hours Approved: 10.8

Abstract:
The nearly edge-on galaxy NGC4945 is one of the closest galaxies where an AGN and starburst coexist. Hard X-ray observations have shown the central black hole in this galaxy to be obscured by a Compton-thick hydrogen column of N_H=5 x 10^24 cm^-2. Despite this huge column, the AGN in NGC4945 is one of the brightest extragalactic sources in the sky at 100keV. In contrast, at optical and infrared wavelengths the AGN has remained undetected until very recently. Instead, at these wavelengths the central region is dominated by a starburst responsible for a spectacular starburst wind-blown, conical shaped cavity aligned with the galaxy's minor axis. Near and mid-infrared spectroscopy of the nucleus have shown the central region to be dominated by very strong obscuration, rivaled only in strength by some of the most deeply obscured UltraLuminous Infrared Galaxies (ULIRGs). This obscuring medium is littered with cold molecular clouds, as evidenced by the presence of strong absorption bands of water ice and volatile ice species such as CO2, CO and 'XCN' in the 3-5 micron range, as well as by a very deep 10 micron silicate absorption feature. Other similarly inclined nearby starburst galaxies such as M82 and NGC253 do not show similar spectral properties on these scales. This makes NGC4945 a unique laboratory to study an environment otherwise only found in distant ULIRGs and, likely, their higher redshift counterparts. We therefore propose to map the bright central region of NGC4945 in SL, LL and SH to obtain the spatial distribution of ISM emission and absorption features, which will allow a characterization of the physical conditions in the frosty exotic ISM exposed to the hostile radiation from the circumnuclear starburst which coexists with a deeply buried AGN.

Spitzer Space Telescope - Archive Research Proposal #20198

Searching for the Most Massive Stars in Starbursts with Archival Spectra

Principal Investigator: Jean Turner
Institution: UCLA

Technical Contact: Jean Turner, UCLA

Co-Investigators:
Sara Beck, Tel Aviv University

Science Category: starburst galaxies
Dollars Approved: 28490.0

Abstract:
We believe that the upper mass end of the IMF in extragalactic starbursts has not yet been measured. It is crucial to know the population of the most massive stars; they are the most energetic and provide pressure, metals, winds and radiation tothe host galaxy. In most cases they cannot be observed directly, only through the infrared and radio nebulae they excite. The middle-infrared ionic emission lines can probe the nebulae and find the stellar types, but the validity of the results depends on the spatial structure of the starburst and the resolution of the observations. We have obtained infrared and radio images and spectra, with sub-arcsecond resolution, of a sample of 19 galaxies that contain very compact star formation sources. These sources are excited by embedded star clusters which are very young, contain thousands of O stars, and are the best place to look for the most massive stars. There are infrared spectra of these galaxies including all the ionic emission lines in the SPITZER archive, from which we can form the line ratios used to calculate the types of the exciting stars, but the emission from the compact sources must be distinguished from other components or their effects will be diluted and the massive stars will not be detected. We propose to use our high-resolution information to model the contributions of the different components off the starburst, and to use the IRS results and these models to find the stellar types. With these data, and the excellent libraries of stellar atmospheres and photoionization now available, we may finally be able to see the most massive stars in starbursts.

Spitzer Space Telescope - General Observer Proposal #3567

Uncovering Buried Treasures in Nearby Starburst Galaxies

Principal Investigator: William Vacca
Institution: SOFIA-USRA

Technical Contact: William Vacca, SOFIA-USRA

Co-Investigators:
Kelsey Johnson, University of Wisconsin

Science Category: starburst galaxies
Observing Modes: IracMap IrsMap IrsStare MipsPhot
Hours Approved: 2.4

Abstract:
We propose to observe two nearby starburst galaxies with the Spitzer Space Telescope in order to determine the properties of the ultra-dense H II (UDHII) regions in these objects. These compact, radio-bright regions are believed to represent the youngest phase in the evolution of super star clusters, in which a newly-born stellar cluster is still heavily embedded in the natal dust and molecular envelope from which it formed. The inferred sizes and masses of the buried clusters are consistent with those expected for the progenitors of globular clusters. Recent ground-based 10 micron images of He2-10 and NGC5253 reveal that the UDHIIs are extremely luminous in the mid-IR, and are responsible for more than half of the total IRAS flux from these galaxies. Although UDHIIs completely dominate the radio flux of their hosts, because they contain so much dust, they are completely invisible at optical and near-IR wavelengths. Hence, a detailed knowledge of their spectral energy distributions (SED) has been unavailable. To date, therefore, only crude models have been used to estimate the properties of the enveloping dust shells and the embedded clusters. We propose to remedy this situation by obtaining mid- and far-IR photometry with IRAC and MIPS, and mid-IR spectroscopy with IRS, of UDHIIs identified in radio maps of Haro 3 and IC 4662. The photometry and spectroscopy will be combined with the radio data to generate SEDs for the UDHIIs, which will then be fit with dusty radiative transfer models to determine the properties of the dust envelope. In addition, the emission lines expected in the IRS spectra will be used to estimate the extinction, electron density, temperature, abundances, and ionization rates in the embedded HII regions. The results will be used to place additional constraints on the ages and masses of the embedded stellar clusters. The sensitivity provided by the Spitzer Space Telescope will also allow us to search for fainter UDHIIs and construct their luminosity function.

Spitzer Space Telescope - Archive Research Proposal #40341

Opening the Window on Warm Dust in Starburst- and AGN-Driven Superwinds

Principal Investigator: Sylvain Veilleux
Institution: University of Maryland

Technical Contact: David Rupke, University of Maryland

Co-Investigators:
David Rupke, University of Maryland
Charles Engelbracht, University of Arizona
Michael Regan, Space Telescope Science Institute
Joss Bland-Hawthorn, Anglo-Australian Observatory
Jackie Cooper, Australian National University
Geoffrey Bicknell, Australian National University
Ralph Sutherland, Australian National University

Science Category: starburst galaxies
Dollars Approved: 97921.0

Abstract:
We propose an archival imaging survey to study galactic winds from starbursts and active galactic nuclei. We will use all IRAC channels to map the detailed distribution of warm (T~500-1000 K) dust and PAH molecules in a sample of galaxies that are known to host outflows. These data will be compared to state-of-the-art, 3D numerical simulations of superwinds and predicted IRAC fluxes. Direct and indirect evidence shows that dust is present on large (kiloparsec) scales in outflows in some starburst and active galaxies. However, this dust has never been mapped at wavelengths of 1-20 micron, and its geometry, mass, and energy are almost completely unknown. Recent spectacular IRAC results on M82, as well as preliminary IRAC color maps made with archival data, suggest that this survey will yield exciting new insights on the warm dust and PAH emission in these outflows. We will ascertain the significance of dusty superwinds in the context of outflow physics and the impact of the outflows on the host galaxies and the intergalactic medium. We will compare the distribution, mass, and energy of the warm dust to optical emission-line and absorption-line, X-ray, and radio data compiled by us and other groups. Using new numerical simulations, we will also compare to the distribution and quantity of dust predicted by theory. Our archival survey will use observations of outflowing warm dust from various Spitzer programs that are focused on other science and combine them into a coherent program to study outflows. No such comprehensive program currently exists, but one is necessary to take full advantage of Spitzer in this field. The proposed IRAC survey is complementary to a MIPS survey of cold (T<100 K) dust in outflows, and will provide many advantages over the MIPS data.

Spitzer Space Telescope - General Observer Proposal #20410

Outliers of the FIR-Radio Correlation: Beginning and End of a Starburst?

Principal Investigator: Jacqueline van Gorkom
Institution: Columbia University

Technical Contact: Jacqueline van Gorkom, Columbia University

Co-Investigators:
Pietro Reviglio, Columbia University

Science Category: starburst galaxies
Observing Modes: MipsPhot
Hours Approved: 13.7

Abstract:
We have identified a sample of 31 spectroscopically classified star-forming galaxies in the Sloan Digital Sky Survey 2DR that significantly deviate from the FIR-radio correlation, as being either radio-deficient or FIR-deficient. One possibility is that these outliers are in a specific evolutionary phase, the beginning or the end of a starburst. Early on they would lack radio emission since no supernovae have gone off yet, at the fading stage they would be bright in radio, since the last population of cosmic rays accelerated by supernovae diffuses out in ~10 Myr, while they would lack FIR emission since they miss a population of hot stars to heat up their dust. We have started a multiwavelength study (UV, radio and H-alpha) to investigate the nature of these potentially very interesting sources. We propose to obtain high quality infrared observations at 24, 70, and 160 microns for this sample of galaxies in order to understand the reason of their anomalous behaviour.