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Composite image of the Omega Nebula. See Science Spotlight, page 6. *(NASA/SOFIA/J. De Buizer, W. Lim, J. Radomski; Spitzer/Herschel)*

Director's Message

Harold Yorke, *Science Mission Operations Director*

The past year has been a busy one for SOFIA in terms of both our programmatic evolution and our scientific production, which includes two *Nature* publications and the first astronomical detection of helium hydride. This newsletter contains highlights of these results as well as other recent publications. In addition, the program has made changes to the way we support the astronomical community to improve efficiency, science productivity, and impact.

After concluding its Cycle 6 observing campaign, SOFIA began its Cycle 7 campaign, which included a very successful deployment to New Zealand. During this deployment, we completed the first SOFIA Legacy Science Program (LSP) — a new program offering — and made significant inroads on a second LSP. Even as the LSP teams work toward enhanced (level 4) data products and tools, the level 3 (calibrated) data from both Cycle 7 LSPs are now available to all astronomers, in accordance with our new policy of non-exclusive use of Legacy Science data.

In addition to these LSP datasets, several other rich, archival datasets are available to the public, such as the 1+ square degree C+ map of Orion (Pabst, et al. 2019, *Nature*, 565, 618), the C+ map of M51 (Pineda, et al. 2018, ApJ, 869, L30), and the s-DDT HAWC+ polarization map of 30 Dor (Gordon, et al, 2018, arXiv:1811.03100). In the future, the SOFIA Science Center will continue to support such community-based Legacy Programs and/or Targeted Science Themes with between one third and one half of the available observing time, capitalizing on SOFIA's unique access to the far-infrared, while establishing scientific synergies with other observatories.

The LSP is only one of many recent changes. The SOFIA Science Center is transitioning its primary data archive from its Data Cycle System archive to the Infrared Science Archive (IRSA), hosted by the Infrared Processing & Analysis Center (IPAC). Data from all observing cycles and all instruments will be moved by the end of January 2020. To ease this changeover for users, the SOFIA Science Center will continue to support the Data Cycle System archive and its interface through 2020.

Astronomers based in the U.S. will be able to request funding support for analyzing SOFIA's rich archival dataset through either NASA's ADAP (Astrophysics Data Analysis Program) or through a new SOFIA Archival Research Program, which was first introduced in the Cycle 8 Call for Proposals. A clear distinction between these two programs has been made; the interested U.S.-based reader should carefully consider which program is appropriate for their research. As always, double-dipping is not allowed. SOFIA's Archival Research Program provides mini grants for one year only. The next opportunity for proposals to this program is scheduled for late Spring 2020, during our Call for Proposals for the Cycle 9 observing campaign.

Finally, on a personal note, I have announced my intention to step down from the Director's role and retire from the SOFIA Program in the Spring of 2020. It has been my great pleasure to serve the astronomical community in this capacity for the past three-plus years. ■

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William T. Reach, *Chief Science Advisor*

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Joan Schmelz, *Executive Editor*
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Science Spotlight

Maggie Thompson, *Graduate Student Researcher, UC Santa Cruz*
Ralph Shuping, *Pipeline Scientist*
Joan Schmelz, *Director, NASA Postdoctoral Program*

Planetary Collisions in a Binary Star System

Recent observations from SOFIA of a binary star system designated BD +20 307 indicate that there may have been a catastrophic collision between two planets within the last 10 years.

Many stars are brighter in the infrared than expected if the light were due to the star alone. This "infrared excess" results from dust in a circumstellar disk heated by visible and UV radiation from the central star. These dusty "debris disks" are thought to evolve via collisions and evaporation of solid bodies, ranging from small planetesimals to larger, planet-sized objects. Dust in these debris disks is typically low-temperature ($\lesssim$ 100 K) and orbits far from the host star, similar to the Kuiper Belt in our own solar system, which is located beyond the orbit of Neptune.

An unusually warm, dusty debris disk surrounds two mature stars in BD +20 307. Because it is small (<1 AU) and extremely dusty, this disk is predicted to have a short collisional timescale, making it an ideal target to search for changes in dust quantity and composition over time. However, given the old age (>1 billion years) and extreme dust flux of this system, collisional cascade alone cannot explain the large amount of observed dust. This result strongly suggests that the dust must be transient.

Studying warm debris disks gives astronomers a rare opportunity to examine compositional changes of circumstellar material that vary on extremely short timescales and to better understand catastrophic collisions that occur late in the formation history of a planetary system.

Collisional cascade, a process in which large planetesimals in a disk collide and continually break down into smaller objects, can explain the infrared emission from most debris disks. However, there is a small set of known stars with much warmer debris disks due to dust orbiting much closer to the host star. These smaller debris disks do not last long because the dust will either be blown out of the system or dragged into the star. Therefore, observations of these warm debris disks can be used to test collisional models developed to understand the final stages of planetary system formation.

Artist's concept illustrating a catastrophic collision between two rocky exoplanets in the planetary system BD +20 307, turning both into dusty debris. Ten years ago, scientists speculated that the warm dust in this system was a result of a planet-to-planet collision. Now, SOFIA found even more warm dust, further supporting that two rocky exoplanets collided. This helps build a more complete picture of our own solar system's history. Such a collision could be similar to the type of catastrophic event that ultimately created our Moon. *(NASA/SOFIA/Lynette Cook)*

Observations from 2015 of BD +20 307 using the Faint Object Infrared Camera (FORCAST) onboard SOFIA were compared with observations taken a decade earlier using Spitzer, Keck, and Gemini. Researchers found that the infrared emission from BD +20 307 increased significantly (~10 percent) in a 10-year timespan. There are several

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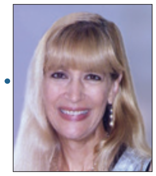
About this Spotlight

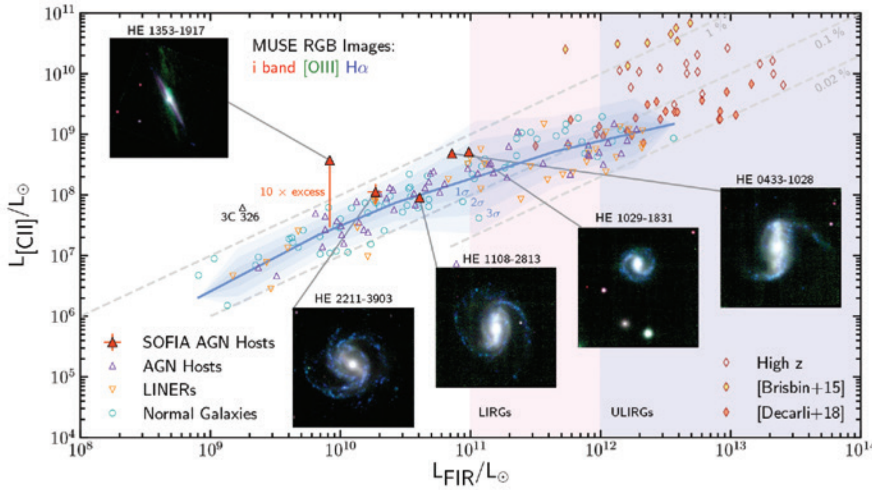
Paper: Studying the Evolution of Warm Dust Encircling BD +20 307 Using SOFIA
Authors: M. A. Thompson, A. J. Weinberger, L. D. Keller, J. A. Arnold, C. C. Stark
Reference: 2019, ApJ, 875, 45



Joan Schmelz, *Director, NASA Postdoctoral Program*

Star Formation Across Cosmic Time

How do astronomers understand galaxies that are so far away that they may appear as a simple point source, even when observed with the most powerful telescopes? One proven technique is to study local analogues, galaxies that might have similar properties but are close enough to resolve their structures. A study like this was underway when researchers discovered something extraordinary — their observation was 10 times stronger than predicted.



[C II] line luminosity as a function of FIR luminosity. Our five CARS targets are shown as red triangles compared to the literature compilation of Herrera-Camus et al. (2018a): normal star-forming and star-burst galaxies (green circles), AGN host galaxies (purple triangles), LINER galaxies (orange upside-down triangles), and high-redshift galaxies including the samples from Brisbin et al. (2015) and Decarli et al. (2018) (brown diamonds). The blue line is the mean of the low-redshift galaxies distribution, and the blue-shaded areas correspond to 1, 2, and 3σ. Pink and purple shades represent LIRG $L_{FIR} > 10^{11}$ and ULIRG $L_{FIR} > 10^{12}$ regimes. The luminosities for 3C 326 are taken from Guillard et al. (2015). *(Smirnova-Pinchukova, I., et al.)*

Recent results from SOFIA of a galaxy known as HE1353-1917 revealed that the emission of a spectral line of ionized carbon, [CII] at 158 microns (158 µm), is 10-times stronger than that observed in similar galaxies.

Newborn stars are the most common heating source in galaxies and the main mechanism for [CII] excitation. Therefore, the [CII] line is often used as a proxy to estimate the star formation rate of a galaxy. However, other sources of energy such as the radiation and shocks produced by Active Galactic Nuclei (AGN) may contribute significantly to the [CII] emission, thereby breaking the correlation between the line strength and star formation rate. The SOFIA observations of HE1353-1917 reveal an extreme example of how this correlation can break down.

The supermassive black hole at the center of this galaxy appears to be the key to understanding this mystery. Current galaxy evolution scenarios imply that the activity of the central object can regulate star formation and play a key role through the entire lifetime of galaxy. The Close AGN Reference Survey (CARS, www.cars-survey.org) explores this intimate AGN–host galaxy relation in detail by combining observations at many different wavelengths.

The research team observed the [CII] line in a sample of five AGNs with SOFIA's Far Infrared Field-Imaging Line Spectrometer (FIFI-LS). Team members were astonished to discover that the galaxy with the smallest star formation rate had the brightest [CII] line. In fact, in HE1353-1917, an exceptionally high fraction (five percent) of the total far-infrared radiation is emitted solely through the [CII] line.

While all five host galaxies in the sample have similar stellar masses, metallicities, and AGN luminosities, HE1353-1917 differs from the others in its peculiar

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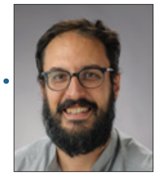
About this Spotlight

Paper: The Close AGN Reference Survey (CARS)

Authors: I. Smirnova-Pinchukova, B. Husemann, G. Busch, P. Appleton, M. Bethermin, F. Combes, S. Croom, T. A. Davis, C. Fischer, M. Gaspari, B. Groves, R. Klein, C. P. O'Dea, M. Pérez-Torres, J. Scharwächter, M. Singha, G. R. Tremblay, T. Urrutia

Reference: 2019, A&A, 626, 131.

Enrique Lopez-Rodriguez, *Instrument Scientist*
Joan Schmelz, *Director, NASA Postdoctoral Program*



SOFIA Confirms Predictions of the Density Wave Theory in NGC 1068

SOFIA astronomers have measured, for the first time, the magnetic field tracing the star forming regions along the spiral arms of NGC 1068, the nearest grand-design spiral with an active galactic nuclei and a large-scale, almost face-on disk.

The High-resolution Airborne Wideband Camera-Plus, HAWC+, instrument onboard SOFIA provides a new approach to study magnetic fields in galaxies. Far-infrared polarimetry of magnetically aligned dust grains provides measurements of the kiloparsec-scale fields in dense regions of the interstellar medium where star formation occurs.

Although magnetic fields have been measured in galaxies for several decades, these results have been limited to the radio and optical bands. In the radio bands, synchrotron polarization traces the magnetic fields "illuminated" by relativistic electrons. In the optical, starlight is extinguished by the diffuse interstellar dust. The HAWC+ observations in the far infrared add a complementary new dimension to these studies.

SOFIA researchers were able to combine these new observations with other tracers to confirm a prediction of the density wave theory. This theory predicts that stars form in the arms as gas moves into the wave and is compressed by its gravitational potential. Under this scenario, the spiral arms should look slightly different for several tracers because they appear at different phases of the wave. The spiral traces existing stars in the optical, the inter-arm diffuse medium in the radio, and ongoing star formation in the far infrared. This is the field seen by HAWC+.

Magnetic fields are present at all spatial scales and in all astrophysical sources observed to date in the nearby universe. Astronomers now understand that magnetic fields play a crucial role in the star formation and general dynamics of the Milky Way. These magnetic fields are

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Magnetic fields in NGC 1068, or M77, are shown as streamlines over a visible light and X-ray composite image of the galaxy from the Hubble Space Telescope, The Nuclear Spectroscopic Array, and the Sloan Digital Sky Survey. The magnetic fields align along the entire length of the massive spiral arms — 24,000 light years across. This implies that the gravitational forces that created the galaxy's iconic shape are also compressing the galaxy's magnetic field. The increased compression from both gravity and the magnetic field also helps fuel the exceptionally high rate of star birth observed in the arms. *(NASA/SOFIA; NASA/JPL-Caltech/Roma Tre Univ.)*

About this Spotlight

Paper: SOFIA/HAWC+ traces the magnetic fields in NGC 1068
Authors: E. Lopez-Rodriguez, C. D. Dowell, T. J. Jones, D. A. Harper, M. Berthoud, D. Chuss, D. A. Dale, J. A. Guerra, R. T. Hamilton, L. W. Looney, J. M. Michail, R. Nikutta, G. Novak, F. P. Santos, K. Sheth, J. Siah, J. Staguhn, I. W. Stephens, K. Tassis, C. Q. Trinh, D. Ward-Thompson, M. Werner, E. J. Wollack, E. Zweibel
Reference: in prep.

Wanggi Lim, *Postdoctoral Fellow*
Joan Schmelz, *Director, NASA Postdoctoral Program*

Massive Star Formation in the Omega Nebula

SOFIA scientists have been able to detect deeply embedded, massive young stellar objects and derive their physical properties in the extreme environment of the Omega Nebula (M17). With SOFIA providing the sharpest mid-infrared image ever obtained of this region, the study was able to reveal a number of objects for the first time and deliver important clues of the global evolutionary history.

M17 is an iconic celestial structure in the northern sky that has been studied for more than 250 years. Even with this long history of investigation, researchers have been able to understand only limited physical properties of the nebula due to its complex structure with high extinction.

As massive young stars start to ionize hydrogen in their immediate environment, the resulting ionized hydrogen (HII) regions become bigger as the stars evolve. These individual regions sometimes intersect and interact with their neighbors forming structures that span large areas. These giant HII regions are believed to be the most active massive star forming regions in the Milky Way. They are extremely bright at all wavelengths and, thus, easily detected in other galaxies.

M17 is the closest of the ~50 giant HII regions in the Galaxy, about 6,500 light-years from the Sun. The central stellar cluster is home to more than a hundred massive stars, which are responsible for the formation of the giant HII region and possibly for triggering new generations of stars.

The global evolutionary history of the entire M17 system is under active investigation. By utilizing the Faint Object infraRed Camera for the SOFIA Telescope, or FORCAST, instrument's 20 micron (20µm) and 37µm band images, researchers were able to peer deep into the nebula with high angular resolution. Images from The Spitzer Space Telescope and the Wide-field Infrared Survey Explorer (WISE) telescope were highly saturated at comparable wavelengths. The data reveal nine new mid-infrared point sources in addition to the seven already known.

Using these data in conjunction with non-saturated images from Spitzer at wavelengths ≤ 8µm and Herschel at wavelengths ≥70µm, the team was able to construct spectral energy distributions for these 16 sources. The results were then compared with theoretical models of

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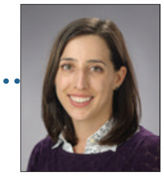
Composite image of the Omega Nebula. The blue areas near the center were detected by SOFIA with a 20-micron filter, revealing the gas structure as it is heated and ionized by the nebula's massive stars. The green areas near the blue areas were detected using SOFIA's 37-micron filter, and trace dust structure that is warmed up by the massive stars and nearby embedded young stellar objects. The red areas near the edge represent cold dust and were detected by the Herschel Space Telescope, while the white star field was detected by the Spitzer Space Telescope. The space telescopes could not observe the blue and green regions in detail due to saturation. SOFIA detected nine never-before-seen protostars, mostly in the green areas. *(NASA/SOFIA/J. De Buizer, W. Lim, J. Radomski; Spitzer/Herschel)*

About this Spotlight

Paper: Surveying the Giant HII Regions of the Milky Way with SOFIA: II. M17
Authors: W. Lim, J. M. De Buizer, J. T. Radomski
Reference: in prep.



Kassandra Bell, *Communications Specialist*

Magnetic Field May Be Keeping Milky Way's Black Hole Quiet

Supermassive black holes exist at the center of most galaxies, and our Milky Way is no exception. But many other galaxies have highly active black holes, meaning a lot of material is falling into them, emitting high-energy radiation in this "feeding" process. The Milky Way's central black hole, on the other hand, is relatively quiet. New observations from NASA's Stratospheric Observatory for Infrared Astronomy, SOFIA, are helping scientists understand the differences between active and quiet black holes.

These results give unprecedented information about the strong magnetic field at the center of the Milky Way galaxy. Scientists used SOFIA's newest instrument, the High-resolution Airborne Wideband Camera-Plus, HAWC+, to make these measurements.

Magnetic fields are invisible forces that influence the paths of charged particles and have significant effects on the motions and evolution of matter throughout the universe. But magnetic fields cannot be imaged directly, so their role is not well understood. The HAWC+ instrument detects polarized far-infrared light, which is invisible to human eyes, emitted by celestial dust grains. These grains align perpendicular to magnetic fields. From the SOFIA results, astronomers can map the shape and infer the strength of the otherwise invisible magnetic field, helping to visualize this fundamental force of nature.

"This is one of the first instances where we can really see how magnetic fields and interstellar matter interact with each other," noted Joan Schmelz, Universities Space Research Center astrophysicist at NASA Ames Research Center in California's Silicon Valley, and a co-author on a paper describing the observations. "HAWC+ is a game-changer."

Previous observations from SOFIA show the tilted ring of gas and dust orbiting the Milky Way's black hole, which is called Sagittarius A* (pronounced "Sagittarius A-star"). But the new HAWC+ data provide a unique view of the magnetic field in this area, which appears to trace the

Streamlines showing magnetic fields layered over a color image of the dusty ring around the Milky Way's massive black hole. The Y-shaped structure is warm material falling toward the black hole, which is located near where the two arms of the Y-intersect. The streamlines reveal that the magnetic field closely follows the shape of the dusty structure. Each of the blue arms has its own field that is totally distinct from the rest of the ring, shown in pink. *(Galactic Center dust and magnetic fields: NASA/SOFIA, star field image: NASA/Hubble Space Telescope)*

region's history over the past 100,000 years.

Details of these SOFIA magnetic field observations were presented at the June 2019 meeting of the American Astronomical Society and will be submitted to the

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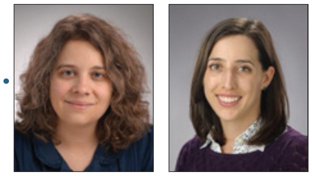
About this Spotlight

Paper: The Spiral Magnetic Field in the Central 5 Parsecs of the Galaxy
Authors: C. D. Dowell, D. T. Chuss, J. A. Guerra, M. Houde, J. M. Michail, M. Morris, J. T. Schmelz, J. Staguhn, M. W. Werner
Reference: in prep.



Arielle Moullet, *SOFIA Outreach Scientist*
Kassandra Bell, *Communications Specialist*

Clues to Mars' Lost Water

Mars may be a rocky planet, but it is not a hospitable world like Earth. It's cold and dry with a thin atmosphere that has significantly less oxygen than Earth's. But Mars likely once had a thicker atmosphere and liquid water, a key ingredient for life. Studying the history of water can help uncover how the Red Planet lost water and how much water it once had.

"We already knew that Mars was once a wet place," said Curtis DeWitt, scientist at the Universities Space Research Association's SOFIA Science Center. "But only by studying how present-day water is lost can we understand just how much existed in the deep past."

Some of this research can be conducted without leaving Earth using SOFIA, the Stratospheric Observatory for Infrared Astronomy. The world's largest flying observatory can find molecules and atoms in deep space and on planets — like forensic analysis for astronomy — because it flies above 99% of Earth's infrared-blocking water vapor. To learn more about how Mars lost its water, and how modern-day water vapor might vary seasonally, SOFIA studied how water vapor evaporates differently during two Martian seasons.

Water is also known by its chemical name H2O because it's made of two hydrogen atoms and one oxygen atom. But with special instruments, scientists can detect two types: regular water, H2O, and deuterated water, HDO, which has an extra neutrally-charged particle called a neutron in one of the hydrogen atoms making it heavier. Deuterated water evaporates less efficiently than regular water so it remains even after regular water evaporates. Therefore, studying the ratio of these two types in existing water vapor, which scientists call the D/H ratio, can retrace the history of liquid water evaporation — even if it no longer flows. But it's not clear if this ratio is affected by seasonal changes on the Red Planet.

Mars has ice caps at its poles. They are covered with carbon-dioxide ice and snow that expand and shrink with the Martian seasons. As the planet's Northern Hemisphere approaches its own Summer Solstice, the ice cap shrinks as

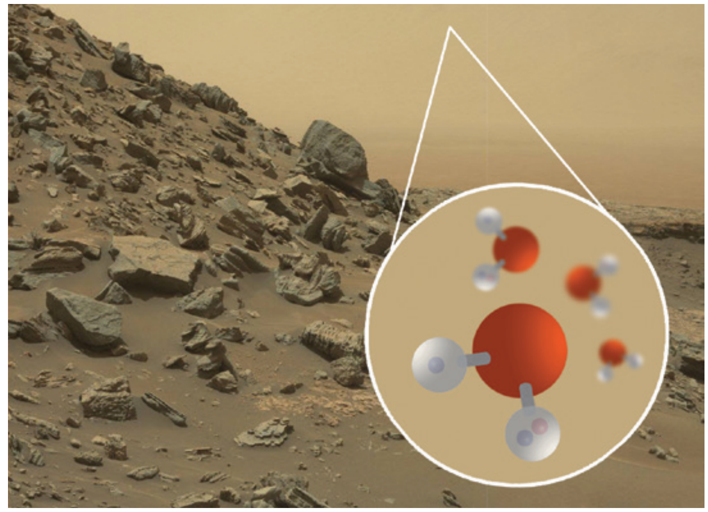


Image of a sloping hillside from the Mars Curiosity rover and an illustration of deuterated water molecules, called HDO instead of H2O because one of its hydrogen atoms has an extra neutrally charged particle. Infrared observations can study these particles that retrace the history of liquid water because the heavier molecules are more likely to remain even after liquid water has evaporated. SOFIA's observations reveal this tracer of liquid water does not vary between Martian seasons, bringing scientists closer to understanding just how much liquid water Mars once had. *(NASA/JPL-Caltech/MSSS/SOFIA)*

temperatures warm — causing some of the ice to evaporate and expose water ice. The southern ice cap, however, is covered with carbon-dioxide ice even during the summer. Scientists were not sure if these seasonal changes could affect the ratio of heavy water to regular water in the Martian atmosphere.

Previous measurements of this water ratio used different instruments, resulting in slightly different measurements across Martian seasons and locations. Researchers on SOFIA used the same instrument, the Echelon-Cross-

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About this Spotlight

Paper: New measurements of D/H on Mars using EXES aboard SOFIA
Authors: T. Encrenaz, C. DeWitt, M. J. Richter, T. K. Greathouse, T. Fouchet, F. Montmessin, F. Lefèvre, B. Bézard, S. K. Atreya, S. Aoki, H. Sagawa
Reference: 2018 A&A, 612, A112.

German Perspective

Bernhard Schulz, *Science Mission Operations Deputy Director*

This year turned out to be particularly busy. On top of the normal observatory operations, and after all the preparatory work, we finally supported the real Five Year Flagship Mission Review (FMR) and eventually received many useful conclusions and recommendations.

Most importantly, the review board emphasized the role of science as the ultimate driving force for all decisions regarding the observatory observations and priorities. A number of initiatives from our proposal document reappeared in the recommendations, and were thus endorsed. However, there were also points that deserved more recognition than we had given them in the past, and I am grateful to USRA and NASA for including me in their respective strategic planning teams to help plot the way forward toward success.

Increasing the scientific output and impact of the observatory is our key objective and we came up with a number of immediate initiatives. Improving and streamlining our internal procedures with focus on an extended proposal life cycle is one of them. Hiring more post-docs and instrument scientists will provide more research time for our scientists, positively impacting publications and SOFIA visibility at conferences. Maximizing our flight time above the troposphere in various creative ways is another of the many initiatives we are pursuing.

A straightforward way to stay above the troposphere is flying out of New Zealand in the boreal winter. This year's deployment went well again, although a few flights were cancelled due to inclement weather. The team came up with a smart plan to use Melbourne as a backup landing site, which allowed a few flights to go forward even if there was rain forecast for all possible New Zealand airports. The German telescope team (DSI) faced a challenge as well, when slightly extended star images appeared once the FORCAST instrument had been installed. Thanks to the dedication of the DSI team, the problem was found and fixed very quickly, thus securing the completion of an important legacy program.

The DSI team this year certainly pushed boundaries, as we supported the long requested, and finally realized, visit of SOFIA to Stuttgart, Germany. It coincided with the annual meeting of the German Astronomical Society (AG) as well as a Teacher Training Event in September. All three events were extremely well organized and we are grateful for the exceptional support we received from NASA, DLR and USRA as well as the University of Stuttgart and other sponsors. About 3,000 visitors from the general public as well as astronomers had a chance to tour the technological marvel we call SOFIA. We also performed the first-ever SOFIA science flight over Europe, which sent us across France, over the Atlantic, back to the Baltic Sea, then South crossing many countries almost to Sicily, before returning to Stuttgart airport, laying to rest any remaining concerns about the complexities of European Air Traffic Control for such a flight. We had media representatives and two camera teams on board, and I took particular pleasure in helping with a piece for the popular German children's show *Die Sendung mit der Maus (The Program with the Mouse)*, featuring SOFIA and its very special telescope door.

Scientifically this year turned out quite exceptional as well. In addition to firmly establishing SOFIA's scientific importance to the FMR, we also added some exciting scientific results to our portfolio. One in particular was the detection of helium hydride, presumed to be the first molecule that formed after the Big Bang, by Rolf Güsten and the GREAT team. This discovery generated quite a few headlines, but also drove home some scientific wisdom when it comes to discoveries. This particular detection was predicted to be too weak to be detected, however, the team tried anyway in their guaranteed time, and it turned out the model was wrong by a factor of four.

Now the new proposals for Cycle 8 and the respective ratings by the time allocation committees are in. As some boundary conditions have changed after the FMR, we are working hard to integrate the successful proposals into a coherent observing program for Cycle 8. Nevertheless, I am confident that we will have the new program ready in time and continue to supply our observers with even more exciting and unique data that only SOFIA can provide. ■

Star Formation Across Cosmic Time

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configuration. The orientation of the central AGN engine is such that most of its released energy is deposited into the cold gas disc of its host galaxy. A detailed multi-wavelength analysis revealed that a radio jet is launching a multi-phase outflow from the AGN into the surroundings. With FIFI-LS, researchers were able to confirm that the excess of the [CII] emission is indeed clearly confined to the center of this enigmatic galaxy where this AGN feedback is in action.

SOFIA observations are improving our understanding of the [CII] emission in galaxies. They provide a vital contribution to the interpretation of ongoing and future studies of distant galaxies where the [CII] line is redshifted into the radio band observed with the Atacama Large Millimeter Array (ALMA). These galaxies are so far away that they generally appear only as a point source in ALMA observations. Without the structural context provided by nearby galaxies like HE1353-1917, observers might continue to use the [CII] line strength as a simplistic proxy for the star formation rate, unaware of how other energy sources may be contributing to the [CII] emission.

These SOFIA FIFI-LS observations are establishing a local reference for high-redshift studies and launching new methods of investigating the details of AGN feedback across cosmic history. ■

Massive Star Formation in the Omega Nebula

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massive star formation to determine physical properties, including the mass of central stars.

The star formation history of M17 was then investigated by comparing two different evolutionary tracers of the proto-clusters: (1) the luminosity-to-mass ratio and (2) virial states of corresponding proto-clusters, which are defined from the SOFIA-FORCAST extended sources. In this analysis, in-depth studies toward the northern bar of M17 (see figure, page 6) were carried out for the first time, while previous studies focused mainly on southern bar. Results indicate that the northern bar is more evolved than the southern bar but younger than the central cluster. The virial states of these regions indicate that the northern bar underwent extreme kinematic episodes, possibly at the colliding interface of two different large-scale wind bubbles.

Since star formation is less active in the northern bar, the virial states revealed by the global kinematic analyses may indicate a negative feedback effect on star and star-cluster formation in such environments. SOFIA's ability to search inside dense molecular clouds with its mid-infrared vision allows researchers to move one step closer to understanding the past and present of M17. ■

Clues to Mars' Lost Water

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Echelle Spectrograph; or EXES, to get consistent measurements over two seasons and locations. First during summer in the planet's Northern Hemisphere and then summer in the Southern Hemisphere. So far, after comparing observations between the two hemispheres, they have not found any seasonal variations in the water ratio on Mars between the two locations. This is helping scientists more accurately trace the history of water on Mars.

"If we can eliminate seasonal dependence as a factor in this ratio, then we're one step closer to getting an answer to how much water was originally present on Mars," said DeWitt.

The results are published in Astronomy and Astrophysics. Further observations are underway to monitor different Martian seasons. Examining Mars' history and geology is important as NASA moves forward with plans to send humans to the Moon, with the eventual goal of crewed missions to Mars. ■

Planetary Collisions in a Binary Star System

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mechanisms that could give rise to such an increase. The dust could heat up, either by increasing the stellar luminosity or by moving the dust closer to the star, but both of these are difficult to implement on such short timescales. Increasing the amount of dust in the system in 10 years is relatively straightforward, but it does involve a catastrophic planetary collision.

SOFIA continues to monitor BD +20 307. Researchers are in the process of analyzing the 2018 dataset and are excited to see what changes they can detect since the original observations in 2015.

If the origin of the copious amount of warm dust orbiting BD +20 307 is due to an extreme collision between planetary-sized bodies, then this system provides a unique opportunity for astronomers to better understand planetary systems around binary stars and catastrophic collisions that occur long after planets form. ■

SOFIA Confirms Predictions of the Density Wave Theory in NGC 1068

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strong enough to influence the distribution and structure of the gas across the interstellar medium. Thus, the characterization of observations like those from HAWC+ allows astronomers to study how magnetic fields affect and influence different astrophysical environments.

However, the role of magnetic fields in other galaxies is not well understood. Further multi-wavelength observations of different galaxy types are necessary to get a more comprehensive picture of how magnetic fields influence the formation and evolution of galaxies. Together with other observatories, SOFIA/HAWC+ can provide this empirical picture. ■

Magnetic Field May Be Keeping Milky Way's Black Hole Quiet

(continued from page 7)

Astrophysical Journal.

The gravity of the black hole dominates the dynamics of the center of the Milky Way, but the role of the magnetic field has been a mystery. The new observations with HAWC+ reveal that the magnetic field is strong enough to constrain the turbulent motions of gas. If the magnetic field channels the gas so it flows into the black hole itself, the black hole is active, because it is eating a lot of gas. However, if the magnetic field channels the gas so it flows into an orbit around the black hole, then the black hole is quiet because it's not ingesting any gas that would otherwise eventually form new stars.

Researchers combined mid- and far-infrared images from SOFIA's cameras with new streamlines that visualize the direction of the magnetic field. The blue y-shaped structure (see figure, page 7) is warm material falling toward the black hole, which is located near where the two arms of the y-shape intersect. Layering the structure of the magnetic field over the image reveals that the magnetic field follows the shape of the dusty structure. Each of the blue arms has its own field component that is totally distinct from the rest of the ring, shown in pink. But there are also places where the field veers away from the main dust structures, such as the top and bottom endpoints of the ring.

"The spiral shape of the magnetic field channels the gas into an orbit around the black hole," said Darren Dowell, a scientist at NASA's Jet Propulsion Laboratory, principal investigator for the HAWC+ instrument, and lead author of the study. "This could explain why our black hole is quiet while others are active."

The new SOFIA and HAWC+ observations help determine how material in the extreme environment of a supermassive black hole interacts with it, including addressing a longstanding question of why the central black hole in the Milky Way is relatively faint while those in other galaxies are so bright. ■

SOFIA Science Image Highlights

SOFIA M82 image featured on the cover of the AAS 2019 Membership Directory: Composite image of M82, a starburst galaxy. The magnetic field detected by SOFIA, shown as streamlines, appears to follow the bipolar outflows (red) generated by the intense nuclear starburst. The image combines visible starlight (gray) and a tracing of hydrogen gas (red) from the Kitt Peak Observatory, with near-infrared and mid-infrared starlight and dust (yellow) from SOFIA and the Spitzer Space Telescope. *(NASA/SOFIA/E. Lopez-Rodriguez; NASA/Spitzer/J. Moustakas et al.)*

SOFIA Galactic Center image featured on Astronomy Picture of the Day, June 19, 2019: What's the magnetic field like in the center of our Milky Way Galaxy? To help find out, NASA's SOFIA imaged the central region with an instrument known as HAWC+. Now at our Milky Way's center is a supermassive black hole with a hobby of absorbing gas from stars it has recently destroyed. Our galaxy's black hole, though, is relatively quiet compared to the absorption rate of the central black holes in active galaxies. The featured image gives a clue as to why — a surrounding magnetic field may either channel gas into the black hole — which lights up its exterior, or forces gas into an accretion-disk holding pattern, causing it to be less active — at least temporarily. Inspection of the featured image brings out this telling clue by detailing the magnetic field in and around a dusty ring surrounding Sagittarius A*, the black hole in our Milky Way's center. *(NASA/SOFIA/Hubble)*

SOFIA is a Boeing 747SP jetliner modified to carry a 106-inch diameter telescope. It is a joint project of NASA and the German Aerospace Center, DLR. NASA's Ames Research Center in California's Silicon Valley manages the SOFIA program, science and mission operations in cooperation with the Universities Space Research Association headquartered in Columbia, Maryland, and the German SOFIA Institute (DSI) at the University of Stuttgart. The aircraft is maintained and operated from NASA's Armstrong Flight Research Center, Building 703, in Palmdale, California.

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