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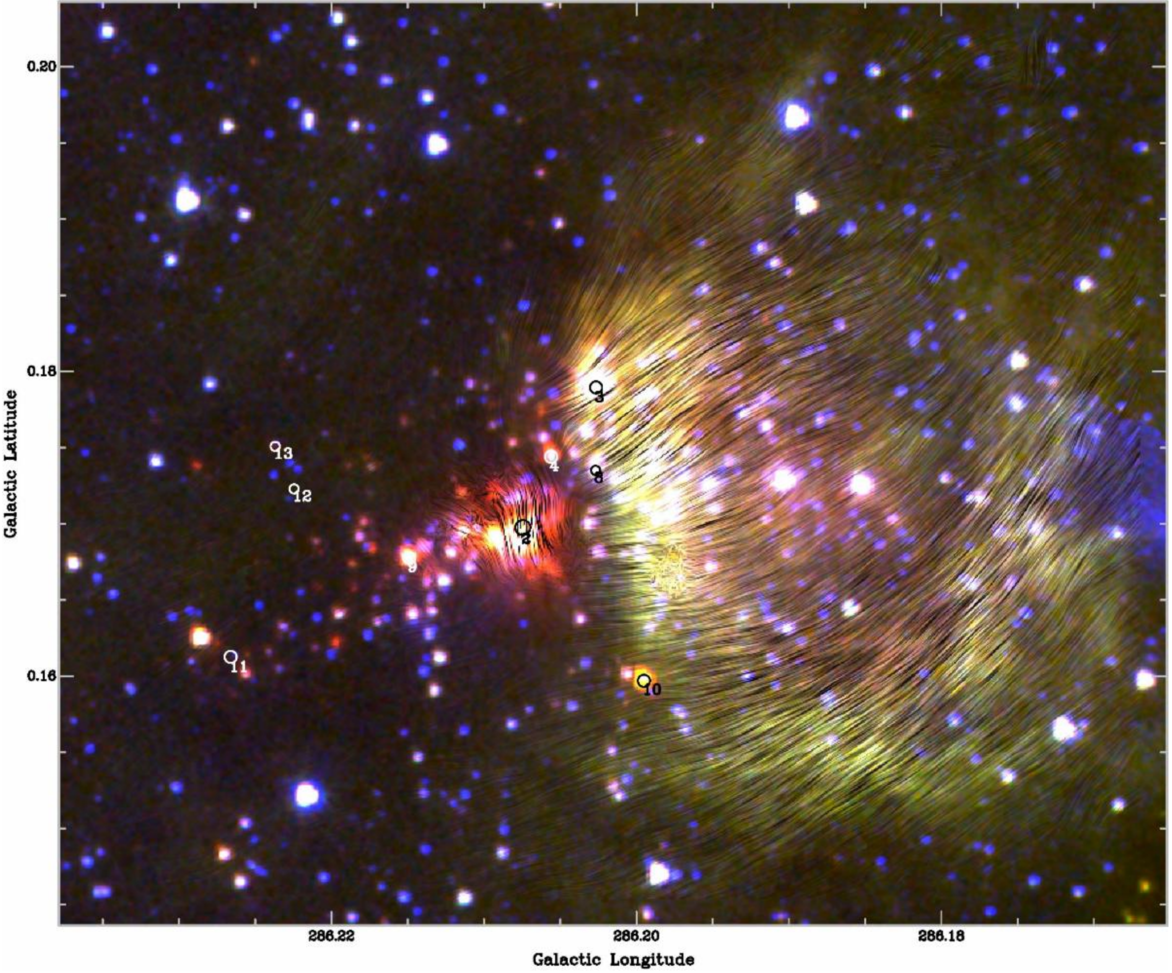
Formation of Massive Star Caught in the Act with Magnetic Field Mapping

Catching a massive star in the early stages of formation is a rare event in astronomy, making it an exciting moment to study. A group of researchers took advantage of the discovery of one youthful star and used SOFIA to reveal the magnetic processes that allow such a massive star to form.

The stellar nursery where the action is taking place, called BYF 73, is not your typical star-forming cloud. It's relatively small, but at its central core is a young star that holds the record for the highest known rate of protostellar mass accretion, the process by which a growing star accumulates mass from its surrounding material. Using SOFIA and ALMA, Peter Barnes (SSI) and his team examined the magnetic fields within this cloud amid ongoing star formation.

This helped the researchers determine the relationship between the cloud's magnetic field and gas density. The researchers found that both the strength of the magnetic field and density of the gas are on the higher end of the range typical for star-forming clouds, but the relationship between the two scales is as expected. This means what's happening in BYF 73 isn't necessarily something unique — it just happens to be massive, and its monstrous density compared to its small size may help astronomers uncover a threshold necessary for gravity to take over and allow stars to form. Read more here.



The magnetic field orientations of BYF 73, as derived from SOFIA data, are overlain on a composite image of the region taken by the Spitzer Space Telescope and Anglo-Australian Telescope. The circled areas are locations of protostars in the region identified by ALMA and the Gemini Observatory. Credit: NASA/Spitzer/SOFIA/ALMA/Gemini/AAT/Barnes et al.

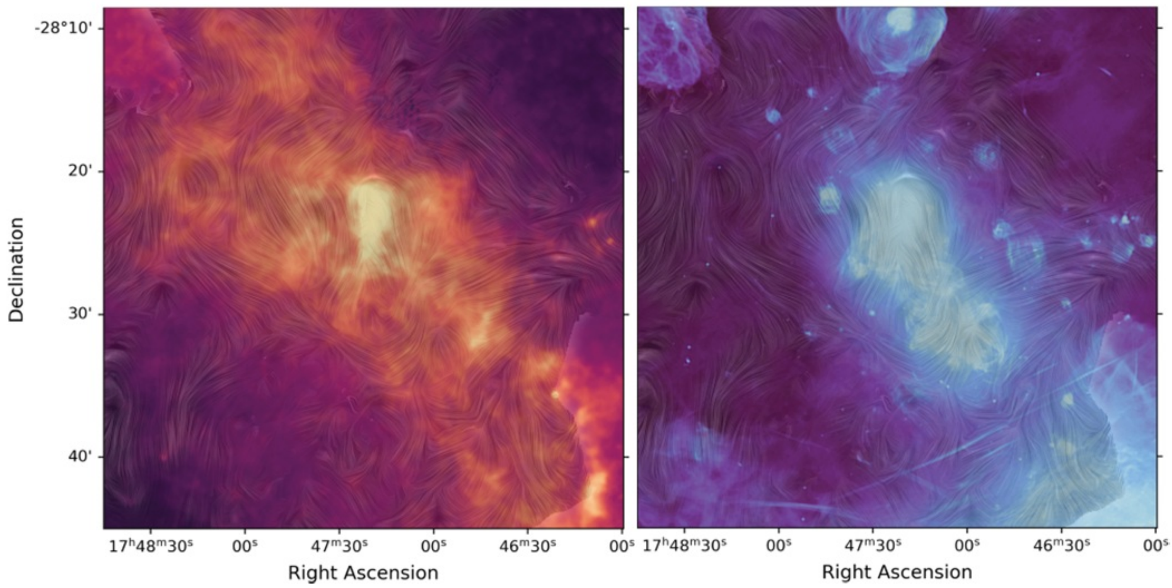
One stage that all protostars seem to go through, as they accumulate matter from their surroundings, is to eject excess angular momentum through powerful jet outflows. This animation shows the Doppler-shifted emission in the jets being expelled by MIR 2 measured by ALMA, stepping through the most blue-shifted CO gas (coming towards us at about 30 km/s), to less-quickly approaching material, then to slowly-receding (red-shifted gas) in the opposite jet, finishing with the fastest redshifts (about 25 km/s) at the end of the loop. Magnetic field lines, mapped from polarized emission in the CO jets by ALMA, are superimposed on the jet emission. Credit: ALMA/Barnes et al.

The Galactic Center Magnetosphere

The role that magnetism plays in the central engines of galaxies remains an open question. Our own Galactic Center (GC) exhibits phenomena and conditions that are rare and extreme within the Milky Way, and hence offers the closest look at the physics of these unique regions of spiral galaxies. One of the most striking features of the GC is the existence of the so-called “nonthermal filaments” (NTFs; Yusef-Zadeh, Morris and Chance, 1984), large, filamentary structures of radio synchrotron emission that highlight the GC’s magnetic field in regions of hot gas. Most of these structures are perpendicular to the orientation of the galactic plane, indicating that the field in the hot gas within the GC is poloidal. Molecular gas within a few hundred parsecs (pc) of the GC, known as the Central Molecular Zone (CMZ), also exhibits extreme characteristics that are typically only found in intense star-forming regions with high magnetic field strengths and molecular densities.

Measurement of polarized emission from magnetically-aligned dust grains using SOFIA/HAWC+ provides a mechanism for studying the magnetic fields in the cool dust of the CMZ. The FIREPLACE Legacy Survey (Far-InfraRed Polarimetric Large Area CMZ Exploration, PI D. Chuss) is designed to address two main questions: how does the magnetic field in the cooler, denser, dust-dominated phases of the GC relate to the poloidal field present in the ionized phase? Second, does such a connection relate to the physical mechanism responsible for the formation of NTFs?

The FIREPLACE survey measures the polarization at 214 μm across the entire CMZ at unprecedented resolution (<0.7 pc), with a pilot program (0.5 degrees around the Sgr B complex) undertaken in Fall 2021. This program is complementary to the SALSA Legacy program in which magnetic fields in external galaxies are measured and characterized (Lopez-Rodriguez+2022). All FIREPLACE data is publicly available in the IRSA Archive under program ID 09_0054. Read more here.



Magnetic fields inferred from the FIREPLACE pilot study are shown superposed on Herschel 250 um data (left) and MeerKAT 1 GHz data (right). Non-thermal filaments (NTFs) that run perpendicular to the galactic plane can be seen in the lower right part of the image on the right. Credit: Left: Herschel/SPIRE/Molinari et al., background; Butterfield et al., magnetic fields; Right: MeerKAT/Heywood et al., background; Butterfield et al., magnetic fields

SOFIA Finds New Home at Arizona Museum

The SOFIA aircraft has found a permanent home in the Pima Air & Space Museum in Tucson, Arizona. The airplane made its final flight from NASA's Armstrong Flight Research Center in Palmdale, California, to Tucson on Tuesday, Dec. 13.

At Pima, the plane will join other notable NASA aircraft, like the first Super Guppy that transported Saturn V rocket parts for the Apollo missions, and the KC-135 "Weightless Wonder V" that created low-gravity conditions by flying parabolic arcs – steep climbs and dives – to conduct science experiments and train astronauts. NASA plans to support the exhibition of the SOFIA aircraft with additional mission artifacts that speak to SOFIA's legacy. Read more here.

SOFIA aircraft being towed to the Pima Air & Space Museum in Tucson, Arizona. Credit: Florian Behrens

EXES Pipeline is now Public

We are pleased to announce that the first EXES data processing and calibration pipeline is now available to the public. Users may run the pipeline to better understand the different calibration steps, to customize their own data reductions, or to reprocess older archival data which may benefit from recent improvements to the pipeline (e.g. improved order merging).

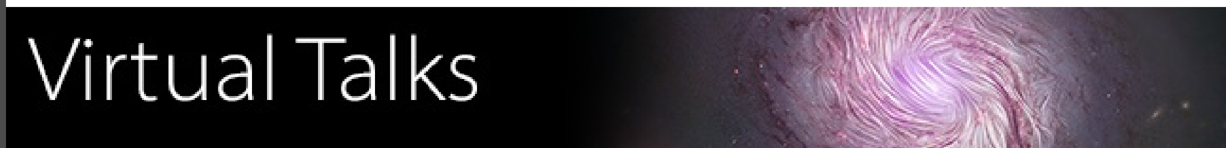
The pipeline software is available through SOFIA's pipeline GitHub repository. A detailed description of the data reduction process and pipeline capabilities is available in the pipeline user manual which can be found on our Data Pipelines web page.

Save the Date: SOFIA School, April 18-21, 2023

We are pleased to announce that the second SOFIA School will be held this year on April 18-21, 7:30-11 am Pacific Time. This free virtual event is designed for anyone who considers using astronomical mid- and far-IR data in their scientific research. Through scientific, analysis and data reduction examples, paired with lectures on fundamental concepts, attendees will be introduced to the range of scientific information leveraged by such data, on a variety of sources. The school will focus on SOFIA data, but the content presented will be relevant to other mid-/far-IR data from balloon facilities or satellites. The program will be announced in a few weeks, when registration will open.

SOFIA Archival Users Support Documentation

SOFIA users are likely familiar with the Observer's Handbooks that were maintained cycle-by-cycle for each instrument and contained up-to-date information on instrument performance and instructions on how to prepare proposals and observations. With the transition of SOFIA from an active observatory to a legacy data archive, the SOFIA Science Center is working on creating Archival Users Guides that will replace the Observer's Handbooks. These new guides are specifically targeted at archive users and will contain the information that they would need to know to understand the data from each instrument, and how to use the data properly to achieve their science. These guides will also contain information about the changes in the performance of the instruments with time, so that someone can understand the unique issues with the data and calibration from across multiple cycles. Like the data reprocessing effort, this documentation effort is scheduled to be completed by the end of FY23.



Join Science Talks Remotely: Tele-Talks

Tele-Talks are scientific presentations given via phone, with slides distributed ahead of time. The talks are held approximately twice a month on Wednesdays at 9:00 a.m. Pacific, noon Eastern. For information on how to participate, check the SOFIA Tele-Talk webpage.

Upcoming Tele-Talks

- February 1: Sarah Nickerson (BAERI); The Mid-Infrared Molecular Inventory Towards Orion IRc2 and Hot Molecular Cores
- February 8: Jane Greaves (Cardiff University); phosphine in Venus
- February 15: Archana Soam (Indian Institute of Astrophysics); H2 in the IC63 PDR
- March 15: Peter Barnes (SSI): magnetic fields and gas structures in the giant molecular cloud BYF73
- March 22: Yue Hu (University of Wisconsin); magnetic fields in Seyfert nuclei
- April 5: Darek Lis (NASA JPL); atomic oxygen abundance toward Sagittarius B2

Please direct questions and comments to the SOFIA Science Center help desk: sofia_help@sofia.usra.edu.