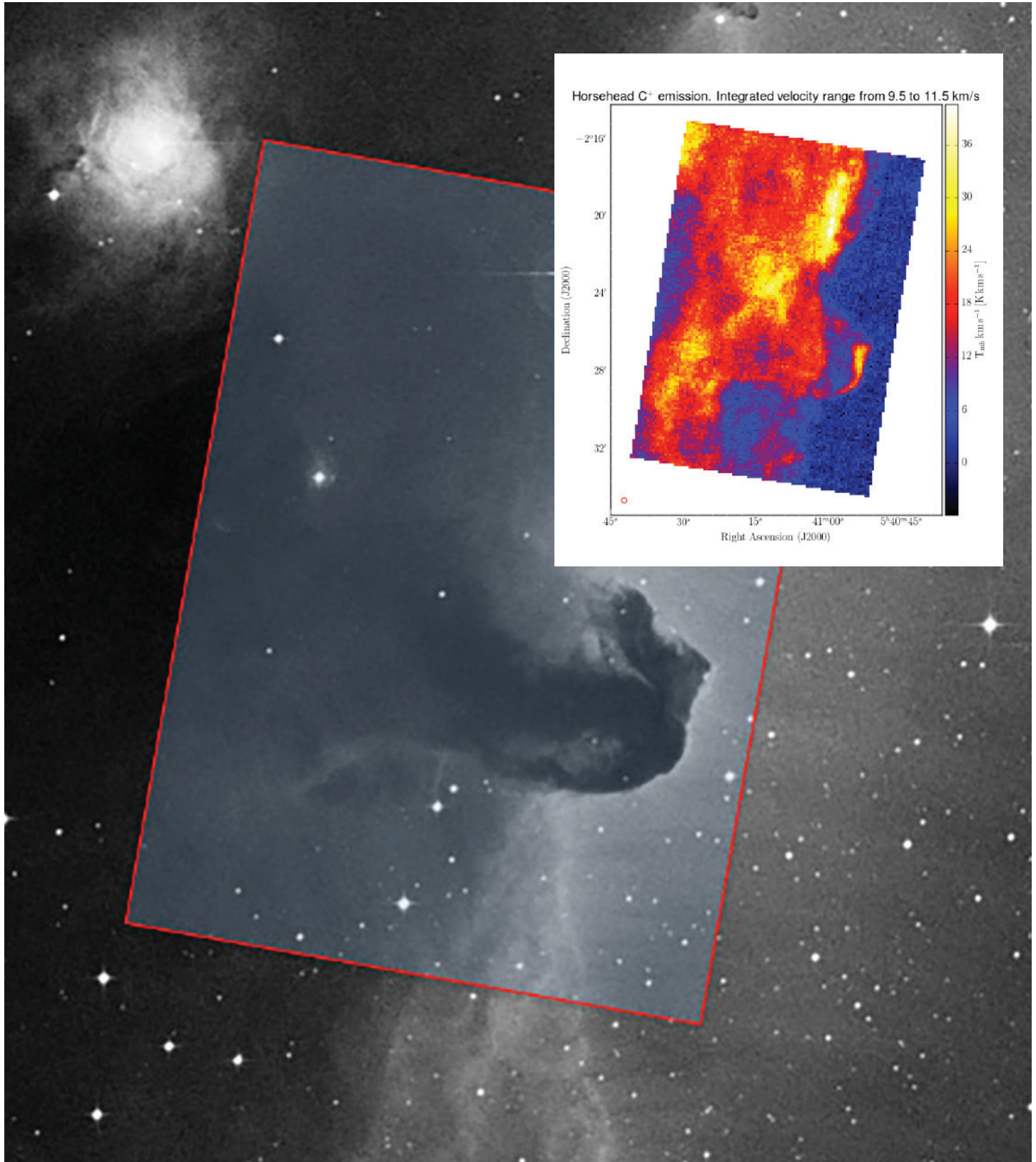


SOFIA Newsletter

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www.sofia.usra.edu



Mapped region overlaid on a POSS-red Sky Survey image. Inset: Integrated [C II] line intensity over velocity range 9.5 – 11.5 km/s.

Director's Message

Erick Young, *Science Mission Operations Director*



As I write this Director's Message, final preparations are being completed for this year's Southern Hemisphere deployment. SOFIA will be arriving at Christchurch, New Zealand on June 6 for a seven-week campaign, featuring three instruments and twenty-five flights. Normal operations of SOFIA out of its home base in Palmdale California require a huge amount of coordination between the many elements of the team, but moving an entire major observatory to another location is an even more complicated effort. Fortunately, we have a talented team of scientists, engineers, technicians, managers, and crew that have learned how to pull off this major challenge with aplomb, and we are looking forward to a successful series of flights from Christchurch, New Zealand, taking advantage of the long nights and superb infrared observing conditions available in the Southern Hemisphere winter.

Deployment 2016 will feature three instruments, two of which will never have been flown in the Southern Hemisphere. FORCAST, a mid-IR camera and grism spectrometer, will return again for a wide range of investigations including debris disks, star formation, and supernovae. FIFI-LS, one of the newer SOFIA instruments, is a far-IR integral-field spectrometer in the far infrared making its first deployment. It will be featured in studies of star formation and the interstellar medium in our galaxy as well as nearby galaxies. upGREAT is the second new instrumental configuration for the deployment. It has a 14-pixel far-IR heterodyne array that provides greatly increased mapping speeds than were previously available.

The cover of this newsletter provides an example of the power of upGREAT. The inset shows the data from a Director's Discretionary Time (DDT) map of the iconic Horsehead Nebula, Barnard 33, a classic example of a Photodissociation Region. Using the upGREAT array, the team mapped a 12' x 17' region in the 158 μm [C II] fine-structure line with 0.19 km/s velocity resolution. We estimate a comparable map would have taken ~200 hours on Herschel, but was accomplished on a single SOFIA flight

thanks to the advanced instrumentation. The full data set, including reduced, calibrated FITS data cubes, is freely available for downloading at the SOFIA website. I encourage astronomers working on the Horsehead Nebula to use these observations in their studies.

New instrumentation continues to be a key theme for SOFIA. This spring, we began commissioning HAWC+, the new far-IR camera and polarimeter. With HAWC+, SOFIA will be the only facility in the world to offer polarimetry at these wavelengths, enabling an entire class of investigations of magnetic fields in interstellar clouds. Commissioning of HAWC+ is expected to be completed in September, and the instrument subsequently will be available for use by the community.

Work is also moving forward on the Third Generation SOFIA instrument. Two teams, one from Goddard Spaceflight Center and one from JPL, are working on competitive concept studies that will be submitted this summer. NASA will organize a down-selection, and development of the new instrument will begin immediately thereafter. Bringing new capabilities to SOFIA will renew the observatory, and take advantage of continued expansion in the power of improved instrumentation.

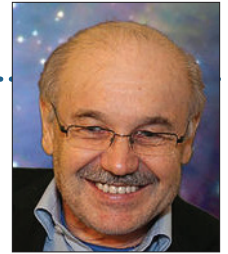
Finally, we invite the astronomical community to use the unique capabilities of SOFIA to obtain observations that will help answer important scientific questions. Please check our web site to find out about the [Cycle 5 Call for Proposals](#) that is open until July 1.

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German Perspective

Hans Zinnecker, *Science Mission Operations Deputy Director*



The Stratospheric Observatory for Infrared Astronomy, SOFIA, is a US/German (NASA/DLR) 80:20 partnership, sharing both the operational efforts and observing time. DLR's contract to run the German part of SOFIA is with the DSI (German SOFIA Institute, hosted by the Institute for Space Systems at Univ. of Stuttgart).

DLR's major contribution to SOFIA is the Telescope Assembly and the personnel to maintain, run, and improve the SOFIA telescope. The maintenance team in Palmdale consists of ~25 engineers under the management lead (since 2013) of Michael Huetwohl. A second German group of about six astronomers and engineers led by Juergen Wolf, are based at the SOFIA Science Center at NASA-Ames. Besides supporting the operation of Facility Class science instruments this group has steadily improved the optical guide cameras, one of which (FPI+) can meanwhile be used simultaneously as a science instrument that is particularly useful for occultation observations, as proven during the 29 June 2015 Pluto occultation.

Ames is also the base of the Science Mission Operations (SMO) deputy director (Hans Zinnecker) responsible for the adequate German representation in SOFIA's science mission operations and German observing time allocation, in close cooperation with the SMO director (Erick Young).

At present, NASA and DLR have agreed to extend the cooperation until December 2020, with the possibility of extension for additional periods. DLR has also started the process to implement a new (4th) 4-year contract with DSI to continue the German support of SOFIA (at the level of ~ 100 flights per year). In the past, DLR has supported the development and operations of the German PI instruments GREAT and FIFI-LS.

The German Receiver for Astronomy at Terahertz Frequencies GREAT is being expanded into upGREAT (PI: Rolf Guesten, MPIfR in Bonn), metamorphosing from a dual channel single-pixel heterodyne spectrometer to a dual channel multi-pixel array detecting two polarizations (2x7 pixels) at 1.9 THz. Commissioning has been successful and has produced a spectacular C+ map of the

Horsehead Nebula (cover illustration). In the near future a 7-pixel heterodyne array at 4.7 THz covering the 63 micron [O I] fine structure line should become available. The lion's share of these technological developments were funded by the Max Planck Institute for Radio Astronomy (MPIfR), Bonn, and by the University at Cologne supported by the German Research Foundation (DFG) with some contribution from the DLR Institute of Planetary Research in Berlin. To a great extent, GREAT has been one of the workhorses of SOFIA observations and no doubt upGREAT will continue being so.

The Field-Imaging Far-Infrared Line Spectrometer FIFI-LS (PI: Alfred Krabbe, University of Stuttgart) is now transitioning to become a Facility Science Instrument. The development of FIFI-LS had started at the Max Planck Institute for Extraterrestrial Physics (MPE), Garching, and was completed at the Univ. of Stuttgart. FIFI-LS commissioning is completed and it is beginning routine operations. The Cycle 4 joint impact C+ mapping observations of the M51 spiral galaxy and its companion with upGREAT and FIFI-LS are a case in point in which the German instruments are used for a joint US/German 80:20 proposal (joint PIs: Pineda/Stutzki). Although there is still discussion about the funding of future German instruments, it seems, from the German perspective, that SOFIA is currently in a good and healthy state, with a reliable and constantly improved telescope, with state of the art instrumentation and a high demand for observing time from the German science community.

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Science Highlights

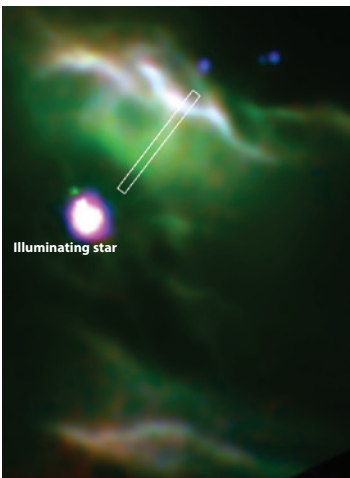
W. T. Reach, Deputy Director, Science



In this and future editions of the printed SOFIA Newsletter, this column will highlight some recent SOFIA scientific successes. Would you like to use this space to highlight your work? Please let us know and send an image and short writeup comparable to those included below, which are gleaned from recent papers and preprints. A reminder to our current guest investigators: keep those publications rolling out! There is no greater purpose for our observatory than the scientific discoveries that you are producing.

Evolution of Polycyclic Aromatic Hydrocarbons

Interstellar carbonaceous material evolves depending upon the strength of the radiation field to which it is exposed. A guest investigator project led by Olivier Berné (IRAP Toulouse, France) utilized a luminous, B-type star as illumination source and measured variations in the carbonaceous material with distance from the star. The figure to the left shows a composite infrared image of the region including a SOFIA/FLITECAM 3.28 μm PAH image (blue), a *Spitzer*/IRAC image including the 7.7 & 8.6 μm PAH bands (green), and a SOFIA/FORCAST image in the 11.3 μm PAH filter. The 7.7 & 8.6 μm bands are brighter relative to the 11.3 and 3.28 μm bands closer to the star. This can be explained by relatively more ionized PAH, and less of the larger “very small grain” PAH clusters in the more-intense UV radiation field near the star, with the daughter products converting to the relatively hardy buckminsterfullerene (C_{60}) molecule closest to the star. (Croiset et al. 2016, A&A, astro-ph; Berne & Tielens 2012, PNAS, 109, 401). SOFIA was essential



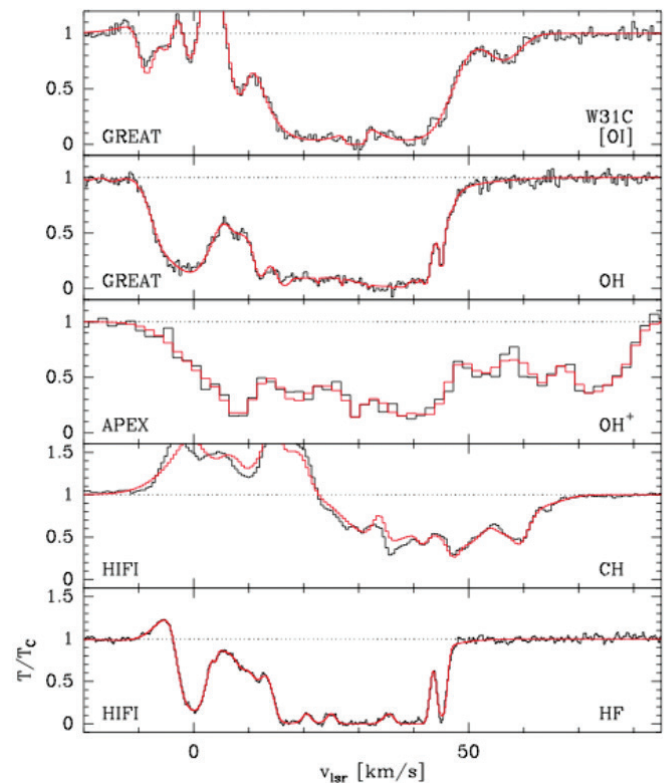
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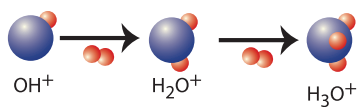
Astrochemistry

Oxygen chemistry is the key to formation of water in the interstellar medium, and therefore of water in planetary material after molecular cloud material condenses around young stars. A SOFIA-based study of oxygen chemistry was recently published by Wiesemeyer et al. (2016, A&A, 585, A76). The SOFIA/GREAT instrument together with observations using a complementary ground-based facility, the Atacama Pathfinder Experiment (APEX), plus *Herschel*/HIFI archival data were used to develop a fundamental test for the most critical steps in the astrochemistry of oxygen by tracing neutral atomic oxygen (OI), the



Science Highlights

hydroxyl radical (OH), and ionized hydroxyl (OH^+) together with atomic hydrogen (H) and proxy measures for the molecular hydrogen abundance, specifically hydrogen fluoride (HF) and methylidene (CH). The key reason the far-IR observations enabled by SOFIA are important to this work is that we can trace cold gas directly in the primary molecular and atomic forms of oxygen. The results confirm the ion-molecular pathway to water formation through these intermediate steps:



Reports the SOFIA Guest Investigator for this project, Helmut Wiesemeyer:

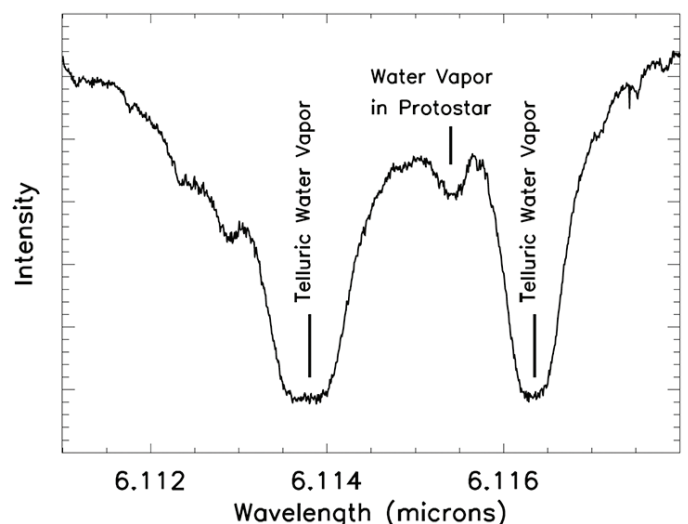
“As a major outcome, we confirm that the reaction rate for formation of water in the diffuse cold, neutral gas of our Galaxy — the reservoir for future formation of stars and their planetary systems — agrees with what has been measured in laboratories on Earth. We also confirm the abundance of oxygen in its atomic form, with the question remaining as to whether denser interstellar clouds, forming stars or on the verge of doing so, contain a so far unknown carrier of oxygen. Currently, SOFIA is the only observatory in the world allowing us to pursue such studies, for two reasons: In the far-infrared domain, only accessible from the stratosphere or space, the spectroscopy of atoms and molecules of the underlying chemical network does not suffer from fundamental uncertainties affecting studies at other wavelengths. The second reason is the high spectral resolution of SOFIA’s instrumentation, which is absolutely necessary for separating the spiral arms of our Galaxy, where the diffuse gas phase is the setting for this fundamental yet complex chemistry. This is only possible because an observatory like SOFIA, returning to its base after the observations are done, allows us to make use of the latest technological advances.”

Targets of Opportunity

SOFIA has observed several types of Target of Opportunity (ToO), including supernovae and novae. For SN 2014J in M82, the FLITECAM spectrum showed that recent non-LTE delayed-detonation models do not fit the entire observed 1.1-3.4 μm wavelength range simultaneously (Vacca et al. 2015, ApJ 804, 66). For nova V339 Del, the FORCAST spectrum shows hydrogen emission lines across the mid-IR; emission from heavier elements is quenched due to the high volume density in the shell (Gehrz et al. 2015, ApJ 812, 132). “SOFIA/FORCAST and FLITECAM grism spectroscopy will revolutionize our understanding of the mineralogy of grains and the abundances of gases produced in nova explosions”, says Guest Investigator Bob Gehrz (U. Minnesota, USA).

Water in a protostar

Using the high spectral resolution of SOFIA/EXES and a Doppler shift due to the relative motion between a protostar and the Earth, the presence of warm water in a protostellar envelope was detected. Figure 3 shows the spectrum of AFGL 2591 revealing the water in the Earth’s atmosphere (“telluric”) and in the protostar (Indriolo et al. 2015, ApJ, 802, 14).



Science Operations and Outreach

B-G Andersson, *Associate Director for Science Operations*

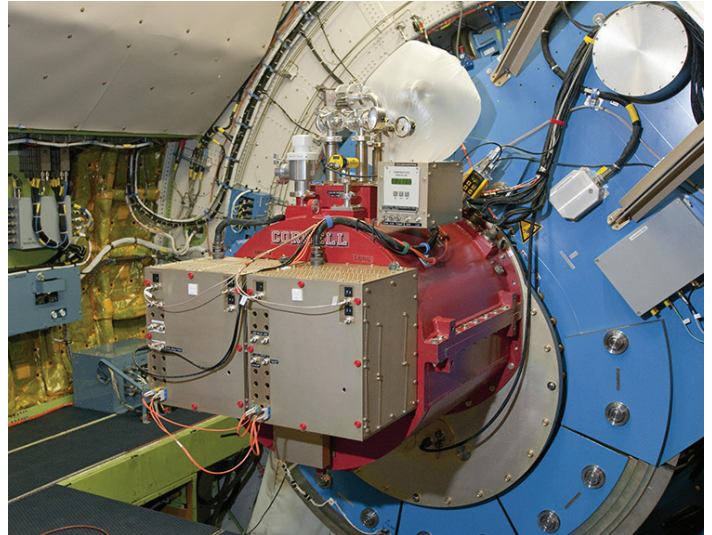


As of this writing, SOFIA Cycle 4 observations that began February 1 are in full stride, with three flight series completed using the FORCAST mid-IR camera, the FIFI-LS far-IR imaging spectrometer, and the EXES mid-IR spectrometer, executing so far more than 108 hours of General Investigator (GI) observations. The first segment of commissioning flights for the HAWC+ far-IR camera was also successfully completed. By the time this newsletter comes out, the fourth Cycle 4 flight series employing the upGREAT/GREAT far-IR heterodyne spectrometer will also be underway, and the aircraft plus staff will be in New Zealand for the third Southern Deployment with GREAT, FIFI-LS and FORCAST.

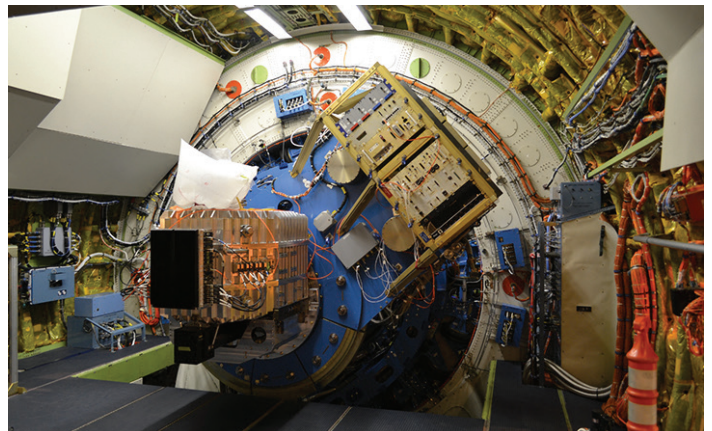
Our science flight planning staff, together with the support scientists and the Principal Investigator Science Instruments teams, continue to generate high-efficiency observing plans and provide flexibility in scheduling. For example, in our OC4-A (FORCAST) series, two Target of Opportunity observations were accommodated at short notice with minimal impact on the over-all observing efficiency. Together with the Mission Operations staff, the SOFIA science team continues to ensure that our GIs received the best possible data for the projects.

The SOFIA Cycle 5 USRA/NASA Call for Proposals was released on April 29, offering approximately 476 hours of observing time to the U.S. and international community, supported by an expected GI funding budget of about \$5M. The parallel DSI/DLR CfP offers approximately 84 hours of observing time to Germany-based investigators. The deadline for U.S. proposal submission is July 1, 2016 (9 p.m. PDT); the deadline for German proposal submission is July 8, 2016. Proposal selection is expected by early October, with Cycle 5 observations commencing in February of 2017.

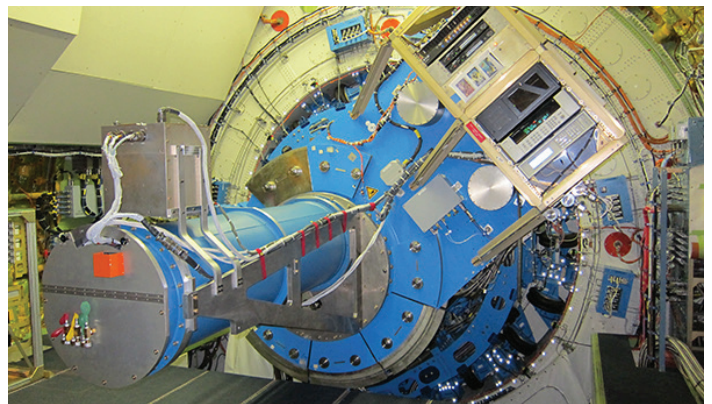
The full complement of first and second generation instruments is available for Cycle 5 investigations, providing observing capabilities from the visual to far-IR wavelengths and employing all three 'legs' of the observational astronomer's tripod: photometry, spectroscopy, and



FORCAST instrument (NASA/Tom Tschida)



FIFI-LS instrument (NASA/SOFIA/USRA/Greg Perryman)



EXES instrument (NASA/SOFIA/EXES/Matthew Richter)

Science Operations and Outreach

polarimetry. A Southern Hemisphere deployment is planned for mid-2017, with up to three instruments. The instruments selected for Southern Hemisphere observations will be determined primarily by the scientific merit of the submitted proposals. So, put on your thinking caps and use SOFIA to produce the best possible science in 2017! For questions (and comments) about Cycle 5 observing, please contact us at sofia_help@sofia.usra.edu.

We are looking forward to an exciting science conference this fall (October 17–20) on the theme of “The Local Truth: Star-Formation and Feedback in the SOFIA Era”, at the lovely Asilomar conference facility in Pacific Grove, CA. This meeting also gives us the opportunity to celebrate the half-centennial of the beginning of airborne astronomy. With SOFIA’s wide range of abilities, including broad wavelength coverage, high spectral resolution, high mapping speed, and far-IR polarimetry, many questions about the processes regulating star formation can be uniquely well-addressed in great detail. We’re pleased with the positive response of our invited speakers and expect that, together with contributed talks and posters, we will have an enjoyable and highly informative meeting. Information about the conference can be found at the SOFIA Science Center web site: (www.sofia.usra.edu/Asilomar2016). Registration and abstract submission are now open. Lodging can be booked directly via the Asilomar website.

As many of you will have noticed, we have a fresh new look for the SOFIA web site, which was implemented by our User Support and Outreach teams. We hope you find the site informative and easy to navigate. If you have any feedback, let us know.

**The Local Truth:
Star Formation and
Feedback in the
SOFIA Era**

**Celebrating 50 Years of
Airborne Astronomy**

Asilomar Conference Grounds
Pacific Grove, California
October 17–20, 2016

A meeting to discuss the current framework of star formation and feedback processes in Galactic molecular clouds and nearby galaxies. High spatial and spectral resolution mid- and far-infrared observations of these local environments, as provided by SOFIA, are critical for a detailed understanding of the key physical processes involved. Such “local truth” is a prerequisite for a reliable interpretation of star formation tracers in distant galaxies.

SOC/LOC:
B-G Andersson, John Bally, Eric Becklin, Edwin Bergin, Adwin Boogert, Crystal Brogan, Andrew Helton, Suzanne Madden, Margaret Meixner, Ravi Sankrit, Michael Werner, Friedrich Wyrowski, Harold Yorke (co-Chair), Erick Young (co-Chair), Hans Zinnecker

www.sofia.usra.edu/Asilomar2016

SOFIA Science Center
Stratospheric Observatory for Infrared Astronomy

Home For Researchers For the Public

SOFIA Cycle 5 Call for Proposals Announced

Welcome

View Edit Outline Revisions

SOFIA is an SOGO partnership of NASA and the German Aerospace Center (DLR), consisting of an extensively modified Boeing 747SP aircraft carrying a reflecting telescope with an effective diameter of 2.5 meters (100 inches). The aircraft is based at NASA's Armstrong Flight Research Center in Palmdale, Calif. The SOFIA Program Office is at NASA Ames Research Center in Moffett Field, Calif., which manages SOFIA's science and mission operations in cooperation with the Universities Space Research Association (USRA; Columbia, MD) and the German SOFIA Institute (DSI; University of Stuttgart).

Tweets by @SOFAtelescope

SOFIAtelescope @SOFAtelescope
Infrared & visible images of the dust around the black hole at the center of the Milky Way (www.nasa.gov/175000)

Public Outreach

Dana Backman, *Outreach Director*



Educators Selected for 2016 Program

NASA's Science Mission Directorate (SMD) awarded management of the Airborne Astronomy Ambassadors (AAA) program to the SETI Institute during calendar years 2016–18, one of the 27 education Cooperative Agreements that include all NASA SMD education efforts.

The 2016 AAA cohort consists of 22 educators from eight states that were selected through a nationwide call for applications. Those applications were then peer-reviewed and approved by an independent panel of judges. The first step for the 2016 AAA educators will be to complete a graduate level astronomy course. They will then be paired with a team of professional astronomers conducting science observations aboard SOFIA flights in the second half of Fall 2016. Read more here: <http://go.nasa.gov/1Rum2Ta>

2015 AAA Educators Honored for Achievements

Airborne Astronomy Ambassadors Michael Shinabery and Jeffrey Killebrew, respectively from the New Mexico Museum of Space History and the New Mexico School for the Blind and Visually Impaired, were honored by the New Mexico House of Representatives for their work as Airborne Astronomy Ambassadors. Shinabery is sharing SOFIA's mission with the museum's visitors and Killebrew is creating hands-on learning tools to help the visually impaired experience SOFIA observations.

Airborne Astronomy Ambassador Stacy Lord received the Art Educator of the Year award from the Massachusetts Art Education Association, recognizing quality education and exemplary educators. One of Lord's goals is to show her students how complex astronomical phenomena can be interpreted through art.



Airborne Astronomy Ambassadors Adriana Alvarez, left, and Mariela Aguirre-Muñoz, far right, with SOFIA mission manager Charlie Kaminski. (NASA/SOFIA)



Standing in front of the telescope before take off are Airborne Astronomy Ambassadors Susan Oltman, Michael Shinabery, and Jeffrey Killebrew, VIP escort Ivor Dawson, VIP guest Nichelle Nichols, and Airborne Astronomy Ambassadors April Whitt and Jo Dodds. (NASA/SOFIA)

Find SOFIA on Facebook (SOFIA) and Twitter (@SOFIATElescope)

