CYCLE 1 SCIENCE STATUS AND HOW TO PROPOSE TIME ON SOFIA

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ABSTRACT

SOFIA, the Stratospheric Observatory for Infrared Astronomy, is a joint project between NASA and the Deutsches Zentrum für Luft-und Raumfahrt (DLR) to provide a 2.5-m telescope that flies at stratospheric altitudes. Access to large parts of the otherwise obscured infrared spectrum is enabled. SOFIA is successfully conducting its Cycle 1 science observations in 2013. The instruments that will be commissioned are the FORCAST mid-infrared camera with Grisms, the GREAT heterodyne spectrometer, the HIPO photometer, and the FLITECAM near infrared imager with Grisms. In this paper we present current science highlights from Early Science and Cycle 1 and discuss the process for proposing observing time on SOFIA.

Key words: infrared: Cycle 1, science observations

1. INTRODUCTION

The Stratospheric Observatory For Infrared Astronomy (SOFIA) is a joint project of the National Aeronautics and Space Administration, USA (NASA) and the German Aerospace Center (DLR). SOFIA consists of a German-built 2.5-meter telescope mounted in a modified Boeing 747-SP aircraft supplied by NASA. Operations costs and observing time are shared by the United States (80%) and Germany (20%). Flying at altitudes up to 45,000-feet, SOFIA observes from above more than 99 percent of Earth's atmosphere water vapor, thereby opening windows to the universe not available from ground-based telescopes. SOFIA can observe at wavelengths from 0.3μm to 1.6mm. When SOFIA reaches full operations approximately 1000 high-altitude observing hours will be offered to the science community per year and will operate for 20 years. [1] The Universities Space Research Association (USRA) and the Deutsches SOFIA Institute (DSI) from the University of Stuttgart are the science mission contractors. Science flights originate from the NASA Dryden Flight Research Center (DFRC) in southern California and the science center is located at the NASA Ames Research Center (ARC) near San Francisco.

Five of the current suite of seven SOFIA instruments were developed in the US, providing multiple imaging and spectroscopic capabilities, and two were developed in Germany. The instruments are primarily divided into two classes. The Facility Science Instruments (FSI)s are supported by the SOFIA Science Mission Operations (SMO) organization which is made up of USRA and the DSI. The FSIs are maintained at the Dryden Aircraft Operations Facility (DAOF) in Palmdale for General Investigator (GI) use. Principal Investigator (PI) class science instruments are also available for GI use, but will be supported by the respective instrument PIs, better facilitating future instrument upgrades. [2]

Table 1

SOFIA First Generation Instruments

Name	Description	PI	Institution	Wavelengths (μm)	Spectral Resolution
FORCAST	Mid-infrared Camera and Grism Spectrometer	T. Herter	Cornell	5-40	200
GREAT	Heterodyne Spectrometer	R. Güsten	MPIfR	60-240	10^6-10^8
FLITECAM	Near-infrared Camera and Grism Spectrometer	I. McLean	UCLA	1-5	2000
HIPO	CCD Occultation Photometer	T. Dunham	Lowell Obs	0.3-1.1	
EXES	Mid-infrared Spectrometer	M. Richter	UC Davis	5-28	3000, 10^4, 10^5
$HAWC^+$	Far-infrared Camera and Polarimeter	C.D. Dowell	JPL	50-240	
FIFI-LS	Integral Field Far-infrared Spectrometer	A. Krabbe	U Stuttgart	42-210	1000-3750

Note: Details available at http://www.sofia.usra.edu/Science/instruments [3]

2. CYCLE 1 CALL FOR PROPOSALS

USRA has developed multiple tools for GIs to use to prepare their proposals for SOFIA. Those tools were listed and discussed (Hall, et al, AMOS tech proceedings, 2012).

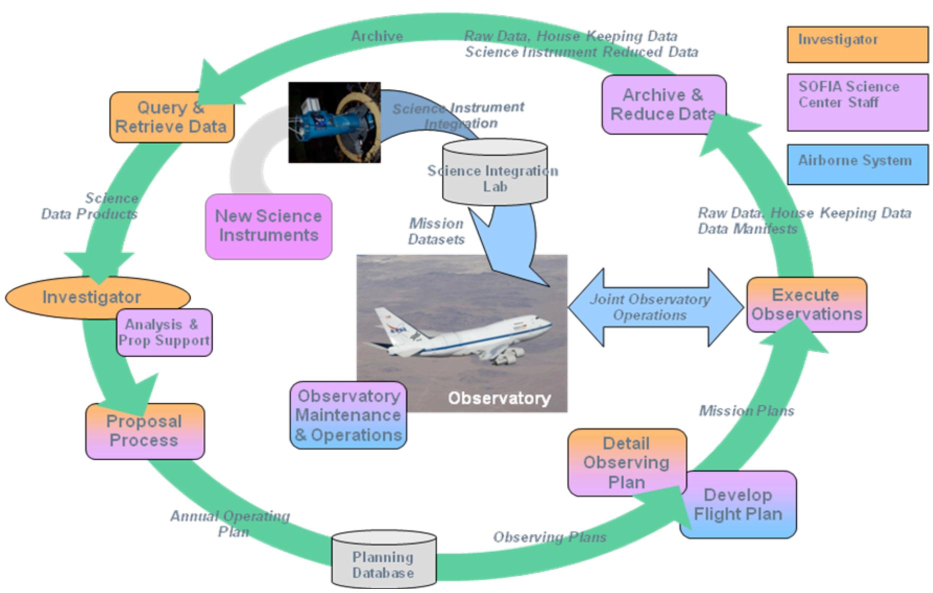

Fig.1 Data Cycle System Process for Annual Lifecycle

The Cycle 1 Call for Proposals (CfP) solicited proposals for approximately 200 hours of observing during calendar year 2013. The call was issued in November 2011 by USRA. Funding to support the selected applicants are issued through USRA. The total GI funding through Cycle 1 is approximately $600 K.

Science Instruments (SI)s available for Cycle 1 are FLITECAM, including Grisms, FORCAST, including Grisms, GREAT, and HIPO. The Cycle 1 Call for Proposals allowed for normal observations, Targets of Opportunity (ToO) observations, and included the possibility of a deployment to the Southern Hemisphere. In response to the SOFIA Cycle 1 Call for Proposals, 172 unique proposals were received - 133 to the US queue and 39 to the German queue. The available time was oversubscribed by a factor of about 5. The proposals were reviewed for technical feasibility internally by the SOFIA Science Center. The Cycle 1 observing selections were made August 2012 based on recommendations from Time Allocation Committees (TAC)s held in the US and Germany. The TAC members are independent experts in Infrared Astronomy covering multiple wavelenghts and scientific interests. The SOFIA Science Mission Operations (SMO) Director and German Deputy SMO Director discussed the results of the two queues and provided the combined approved Cycle 1 program.

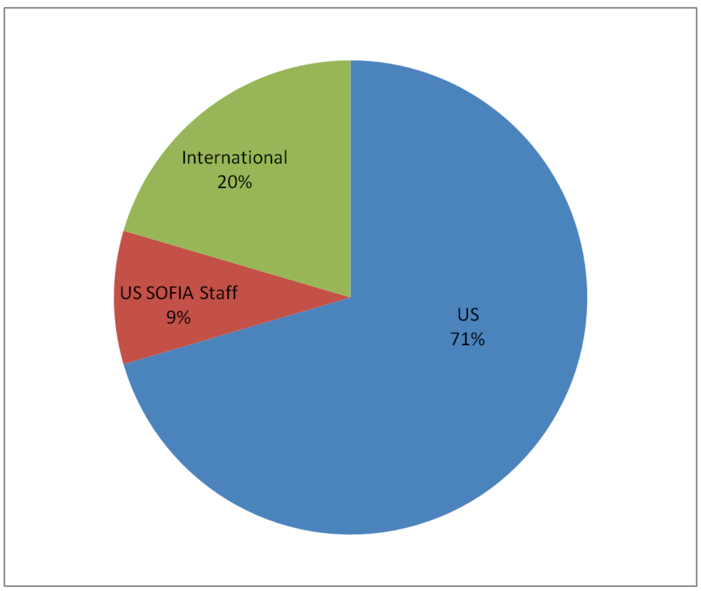

Fig.2 US Queue Distribution of Proposals

For Cycle 1 queue results for both US and Germany,
See http://www.sofia.usra.edu/Science/proposals/cycle1/index.html

Of the available Research Hours in Cycle 1, 7% is set aside as Director's Discretionary Time. The remaining Research Hours is allocated to Calibration Time, Guaranteed Time Observations, and General Investigators. Guaranteed Time is awarded to the instrument development teams as scientific reward for development of the instruments. The remaining hours go to the General Investigators, 80% being available to the US queue and 20% for the German Community. The US time includes two survey programs and two Target of Opportunity programs. Approximately 200 hours were awarded under the US CfP, 40 hours were allotted to the German Community, and 60 hours were set aside for the Guaranteed Time, Calibration Times, and the Director's Time.

SOFIA is primarily a star formation and interstellar medium observatory. It is a key facility for studying the dynamics and energetics in regions of star formation (e.g. cloud collapse) as well as astrochemical processes in the interstellar medium (ISM), including molecular rotational excitation. Observations of dusty optically obscured sources (spectral energy distributions) and time critical investigations of transient events (e.g. occultations of solar system objects) are also important. [4]

3. CURRENT SCIENCE HIGHLIGHTS

The massive star-forming region W3 was observed with the Faint Object InfraRed Camera for the SOFIA Telescope (FORCAST) as part of the Short Science program. Figure 3 shows composite of the multiwave bandpasses that were used to observe the emission of polycyclic aromatic hydrocarbon (PAH) molecules, very small grains, and big grains. [5]

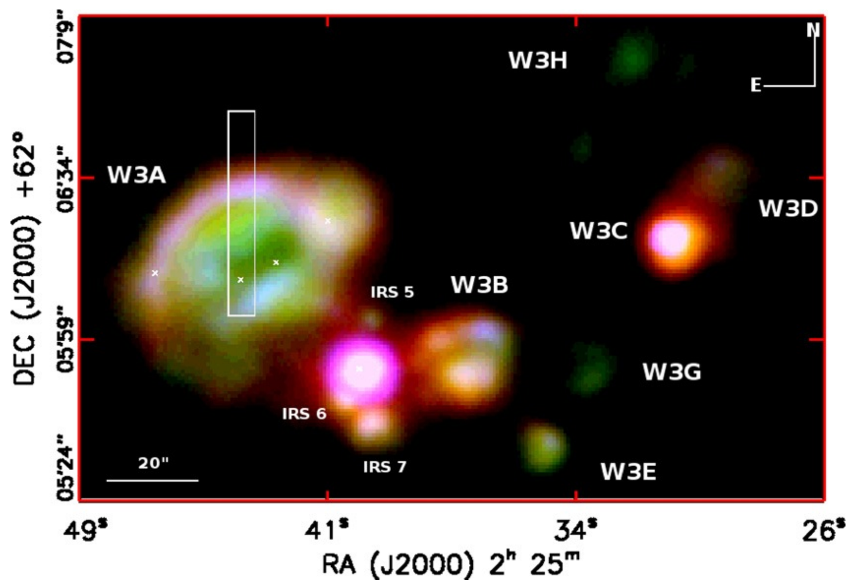

Fig. 3 – Composite images by SOFIA/FORCAST of the W3 main region, colors are blue 7.7 µm, green 19.7 µm, and red 37.1 µm. Sources show an OB star cluster and wind-blown cavities around W3A. The dust opacity in the cavities differs from that of the diffuse ISM, implying the dust properties are altered by winds from the massive stars. [5]

The FORCAST Team also took 19.7, 31.5, and 37.1 µm images of the inner 6 pc of the Galactic Center with a spatial resolution of 3.2-4.6" during Basic Science, June 2011. With image deconvolution, a resolution of 2.5" was achieved, (see figure 4). The images reveal in detail the structure of the warm dust on the inner edge of the Circumnuclear Disk (CND), which is the torus of gas and dust orbiting the supermassive black hole at the Galactic center, as well as the prominent streamers of hot, ionized gas and dust within the CND that compose the "minispiral." The emission at 19.7 µm from the dust in the CND closely traces the ionized gas emission as observed in the radio and near-IR, whereas the emission at 31.5 and 37.1 µm traces a cooler distribution of dust located slightly deeper in the CND. They also produced color temperature maps that exhibit the highest dust temperatures 120 K at the inner edge of the CND, which indicates that the dust is centrally heated by the inner cluster of hot O and B-type stars. Optical depth maps at 19.7, 31.5, and 37.1 µm show that the dust column density is concentrated around the ring of dust emission observed at 37.1 µm and peaks along the southern regions of the ring. Given the temperature and optical depth of the dust a consistent morphological model of the CND was suggested. [6]

Fig. 4 – FORCAST and NICMOS Images of the Inner 6 pc of the Galactic Center

More recently during Cycle 1 FORCAST looked at massive star formation.   SOFIA 24 and 37um imaging with approximately 3-arcsecond resolution is well-suited for revealing the embedded structures and sources within these regions. These SOFIA observations allow the comparison of the spatial distribution of the hot and warm dust within these GHII regions to the PAHs and hot ionized gas traced by other wavelengths. The observations also expose the population of massive stars in their earliest stages of formation within the GHII regions.

A survey is underway to study GHII regions starting with SOFIA's first observing cycle (which began June 2013), which upon completion will catalog all of the known bright GHII regions at the highest spatial resolutions yet achievable at IR wavelengths greater than 25um. [7]

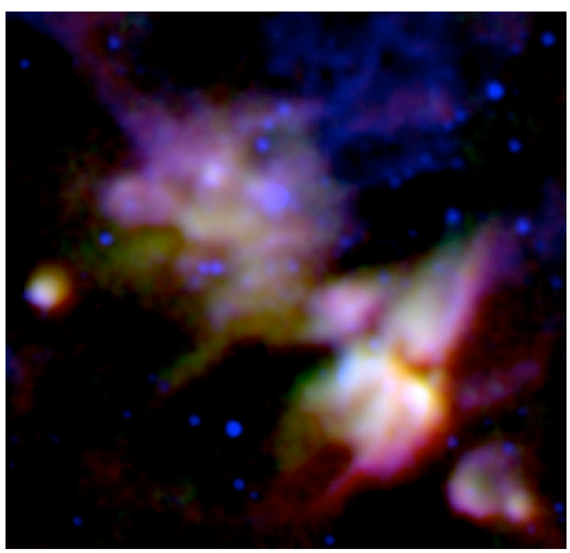

Fig. 5 – FORCAST Image of W51 West-1
red=SOFIA 37um, green=SOFIA 24um, blue=Spitzer 4.5um

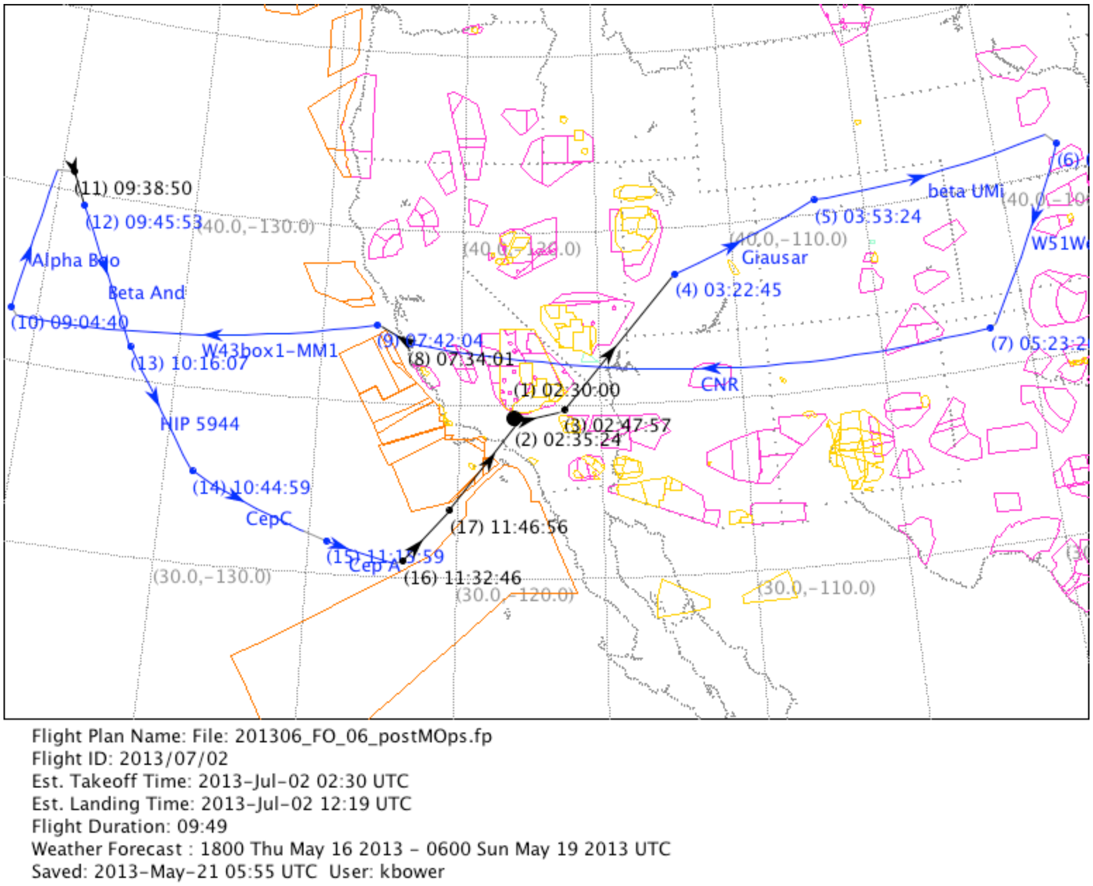

Fig. 6 – Sample flight plan from Cycle 1
Leg number 6 was the observation of W51 West depicted in Figure 5

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1. *The Science Vision for the Stratospheric Observatory For Infrared Astronomy,* NASA Ames Research Center, Moffett Field, CA, June 2009
2. Hall H., Young E., Zinnecker H., *Science Mission Operations and Early Science Instruments for SOFIA,* proceedings Advance Maui Optical and Space Surveillance Technologies Conference (AMOS Tech), 2012
3. Young E. et al, *Early Science with SOFIA, The Stratospheric Observatory for Infrared Astronomy,* ApJ Letters, 749:L17 (5pp), 2012 April 20
4. Zinnecker H., *SOFIA: first science highlights and future science potential,* Astron. Nachr. /AN **334**, No. 6, 558-575 (2013)
5. Salgado F., et al, *Firs Science Results from SOFIA/FORCAST: The Mid-Infrared View of the Compact H_{II}, Region W3A,* ApJ Letters, 749:L21 (5pp), 2012 April 20
6. Lau, R. et al*, SOFIA/FORCAST Imaging of the Circumnuclear Ring at the Galactic Center*, arXiv:1307.8443 (2013)
7. De Buizer, J., *Revealing the Embedded Structures and Sources within Giant HII Regions with SOFIA,* Poster 1B037, Protostars & Planets VI (2013)