Stratospheric Observatory for Infrared Astronomy

(SOFIA)

Observing Cycle 4

Call for Proposals

June 8, 2015

Version 2.1

This document and all other information pertaining to SOFIA observing Cycle 4 may be found at http://www.sofia.usra.edu/Science/proposals/Cycle4.

Key Dates

Release of Call for Proposals	May 1, 2015
Call for Proposals Update on Website	June 8, 2015
Proposals Due	July 11, 2015 04:00 UTC (July 10, 2015 21:00 PDT)
Anticipated Announcement of Selections	Early October 2015
Cycle 4 Period	1 February 2016 – 31 January 2017

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Change Log:

May 1, 2015: Original release

May 4, 2015:

- Clarified available configurations with the upGREAT (LFA) array
- Updated the FLITECAM grism band-pass wavelengths.

June 8, 2015:

- The Reserved Observations Catalogs are being updated to include information of execution status. Because the status, extent, and quality of GTO observations can be complicated to ascertain, we request that proposers who are considering observations potentially covered by the ROCs contact the SOFIA help desk (sofia_help@sofia.usra.edu) for detailed case-by-case assistance.

  - Parameters for HAWC+ and FPI+ have been updated in the on-line exposure time calculator SITE, and for GREAT in the on-line time estimator.

  - The "Guide to Planning Observations with SOFIA/GREAT" has been revised. The most recent version is version 8, June 5, 2015.

  - A description of exposure time calculation for EXES telluric calibrators has been added to the Observer's Handbook.

  - The Duplication Checking procedure, described on the Cycle 4, Phase I web page has been expanded. As part of this update documents listing the wavelength settings for EXES and FIFI-LS observations have been provided.

- A new version of the Visibility Tool that includes improved catalog searches for non-sidereal objects will become available by June 15th.

June 10

- Corrected FORCAST ROC versions

1. SOFIA Observing Cycle 4 Program Description

1.0. New policies and Capabilities for Cycle 4:

- The available GI funding for Cycle 4 has been significantly enhanced, by more than a factor 3, from the Cycle 3 level ($1.5M) to a total of $5.5M [Section 1.1].
- FLITECAM long wavelength observations, λ>3.5μm are offered in shared risk mode [Section 1.3.3].
- The cross-dispersed mode of FORCAST spectroscopy will **not** be offered in Cycle 4. Equivalent spectral coverage and/or resolution for the wavelength range are available through other FORCAST modes and EXES. [Section 1.3.5].
- The Focal Plane Imager (FPI+) has been added to the suite of available science instruments [Section 1.3.6].
- The GREAT M channel is not offered in Cycle 4 [Section 1.3.7]
- The seven-beam heterodyne array upGREAT in its "Low Frequency Array" mode will offer faster mapping in the [C II] line at 158μm. [Section 1.3.7]
- The far-infrared camera and polarimeter High-resolution Airborne Wideband Camera (HAWC+) has been added to the available instrument suite [Sections 1.3.8]
- The proposal deadline for Cycle 4 proposal will be at 9pm (PDT), July 10 [Section 1.4]
- The nominal Cycle 4 observing period will be from 1 February 2016 – 31 January 2017. [Section 1.4]
- SOFIA archival data analysis projects are as of 2015 eligible for funding via the NASA/ROSES/ADAP Call for proposals. [Section 1.9]
- Proposals for SOFIA Impact Programs are solicited. These multi-year programs are intended to address specific high scientific impact problems in astrophysics. Up to 4 projects per cycle, each requesting 50-100h of observing time over two-three years will be selected. Joint US – German Impact Programs will also be solicited through the two selection queues [Section 2.1.2]
- Highly ranked proposals for targets only observable during a Southern Hemisphere deployment, but requesting an instrument not selected for Cycle 4 deployment will be held over for up to two cycles for possible future instrument selection for southern deployment [Section 2.2.4]

1.1. Introduction:

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is pleased to invite proposals for Cycle 4 observations, which will take place in the time period 1 February 2016 – 31 January 2017. This Call for Proposals solicits proposals for approximately 500 hours of observing time. The Universities Space Research Association (USRA) is issuing this Call on behalf of NASA. Funding to support the selected applicants will also be issued through USRA. Contingent on budget confirmation and NASA approval, the total available General Investigator funding available for Cycle 4 is expected to be approximately $5.5M.

SOFIA Cycle 4 observations will take place in a number of Science Flight Campaigns over the duration of the cycle. The campaigns will be interspersed with aircraft maintenance and instrument commissioning. A single deployment with up to two Southern Hemisphere observing series is under consideration for the Cycle 4 time period, nominally in the summer of 2016.

For Cycle 4, the available instruments will be the mid-infrared high-resolution spectrograph EXES[1], the integral-field far-infrared spectrometer FIFI-LS[2], the near-infrared camera FLITECAM[3], including its grism modes, the mid-infrared camera FORCAST[4], including its grism modes, the focal plane CCD imager FPI+[5], in science mode, the heterodyne spectrometer GREAT[6], including the seven-beam receiver array upGREAT, the high-speed optical photometer HIPO[7], and the far-infrared camera and polarimeter HAWC+[8]. The combination of FLITECAM/HIPO will also be available. The HAWC+ instrument is being commissioned during late Cycle 3, and is offered for General Investigator observing in Cycle 4, contingent on the successful instrument commissioning.

The Call is open to all qualified astronomers, in the U.S. and outside the U.S., except for those currently affiliated with German institutions. Astronomers with a German professional affiliation must participate through a separate German Call for Proposals administered by the German SOFIA Institute (Deutsches SOFIA Institut; DSI) on behalf of the German Aerospace Center (Deutsches Zentrum für Luft und Raumfahrt; DLR). DSI personnel, even if based in the U.S., are considered affiliated with a German institution and must submit any proposals to the DLR queue. Scientists based in Germany and affiliated with the European Southern Observatory (ESO) or the European

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[1] Echelon-Cross- Echelle Spectrograph
http://www.sofia.usra.edu/Science/instruments/instruments_exes.html
[2] Field Imaging Far-Infrared Line Spectrometer
http://www.sofia.usra.edu/Science/instruments/instruments_fifils.html
[3] First Light Infrared Test Experiment CAMera,
http://www.sofia.usra.edu/Science/instruments/instruments_flitecam.html
[4] Faint Object infraRed CAmera for the SOFIA Telescope,
http://www.sofia.usra.edu/Science/instruments/instruments_forcast.html
[5] Focal Plane Imager,
http://www.sofia.usra.edu/Science/instruments/instruments_fpiplus.html
[6] German REceiver for Astronomy at Terahertz frequencies,
http://www.sofia.usra.edu/Science/instruments/instruments_great.html
[7] High-speed Imaging Photometer for Occultation,
http://www.sofia.usra.edu/Science/instruments/instruments_hipo.html
[8] HAWC+,
http://www.sofia.usra.edu/Science/instruments/instruments_hawcplus.html

Space Agency (ESA) are considered not to be affiliated with a German institution, and may respond to this Call for Proposals.

In addition to the approximately 500 hours available under this Call, approximately 60 hours of observing time will be available to German General Investigators through the DLR Call. An additional 7% of the Research Hours on SOFIA are set aside as Director's Discretionary Time, and the Science Instrument development teams have an allocation of Guaranteed Time as specified in the SOFIA Science Utilization Policies[9]. Calibration observations are part of the observatory overhead and the required time is accounted for when calculating the total observing time solicited herein.

A small number of SOFIA Science Center staff members will be directly involved in the proposal solicitation process for Cycle 4, and will therefore recuse themselves from proposing. Other SOFIA Science Center staff members may propose. Only researchers with a U.S. affiliation are eligible to receive financial support through this solicitation.

All proposals that are considered to be scientifically well-justified through scientific peer review will be considered for selection. Preference will be given to substantial investigations that demonstrate significant scientific impact from SOFIA observations.

1.2. The SOFIA Program

SOFIA is a joint project of NASA and DLR. SOFIA Science Mission Operations (SMO), located primarily at the NASA Ames Research Center, Moffett Field, California, is responsible for the scientific operation of the observatory. The SMO is operated by USRA under contract to NASA. The Deutsches SOFIA Institut (DSI), located at the University of Stuttgart, is the primary interface between SOFIA and the German astronomical community. The SOFIA aircraft operations are managed by the NASA Neil Armstrong Flight Research Center. The aircraft itself has its home base at Building 703 of the Neil Armstrong Flight Research Center (formerly the Dryden Airborne Operations Facility, DAOF) in Palmdale, California.

SOFIA is a 2.7m telescope, with an effective, unvignetted, diameter of 2.5m, housed in a Boeing 747-SP aircraft. Observations are typically carried out at altitudes between 11.9 km (39,000 ft) and 13.7 km (45,000 ft.). These altitudes place the observatory above at least 99% and up to 99.8%, of the obscuring atmospheric H_2O vapor. The observatory can operate in the 0.3-1600 µm wavelength range, and the eight instruments offered in this Call cover the range 0.3-250 µm. These instruments will provide imaging, spectroscopic and polarimetric capabilities for a wide range of scientific investigations.

Descriptions of the instruments can be found at http://www.sofia.usra.edu/Science/instruments/.

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[9] Available at http://www.sofia.usra.edu/Science/documents/index.html

A number of presentations on SOFIA science can be found at the SOFIA Speakers Bureau page at http://www.sofia.usra.edu/Science/speakers/ . A list of refereed SOFIA related publications can be found at http://www.sofia.usra.edu/Science/publications/index.html . In addition, a number of case studies of SOFIA science were recently presented at the recent "Ringberg Workshop on Spectroscopy with SOFIA", which can be found on the Cycle 4 web page. (http://www.sofia.usra.edu/Science/proposals/cycle4/phase1.html or at the conference web site https://indico.mpifr-bonn.mpg.de/indico/conferenceDisplay.py?confId=93).

These science cases illustrate the breadth of potential SOFIA capabilities. Two special issues reporting observations with SOFIA performed during the Early Science phase were published by the Astrophysical Journal Letters (Vol 749, No. 2) and Astronomy and Astrophysics (Vol. 542). An overview of SOFIA is presented in Young et al. 2012, ApJ, 749, L17: "Early Science with SOFIA, the Stratospheric Observatory For Infrared Astronomy" " and in Temi et al. 2014, "The SOFIA Observatory at the Start of Routine Science Operations: Mission Capabilities and Performance" (ApJS, 212, 24).

1.3. Available Instruments and Observation Configurations

Eight instruments will be available for Cycle 4 observations: EXES, FIFI-LS, FLITECAM, FORCAST, FPI+, GREAT, HIPO and HAWC+. The FLITECAM/HIPO combination will also be offered.

There are a number of observation configurations available or planned for each of the instruments. The following sections describe the observation configurations available for Cycle 4.

Details are available in the Observers Handbook for Cycle 4 which can be found at http://www.sofia.usra.edu/Science/proposals/Cycle4/ .

Each of the SOFIA Science Instruments falls into one of three classes: Facility-class Science Instruments (FSI), Principal Investigator-class Science Instruments (PSI) or Special Purpose Principal Investigator-class Science Instruments (SSI). The different classes of instruments require different levels of interaction among the proposer, the science instrument team, and the SMO staff providing support and are governed by the "SOFIA Science Utilization Policies of the Stratospheric Observatory for Infrared Astronomy (SOFIA)" available at http://www.sofia.usra.edu/Science/documents/ .

Facility-class Science Instrument (FSI) — A general purpose, reliable and robust instrument that provides state-of-the-art science performance at the conclusion of commissioning and upon acceptance of the instrument by the SOFIA project. FSIs will be operated and maintained by the SMO in support of General Investigators (GIs). No direct interactions with the instrument team are required to propose for or to use the instrument.

For Cycle 4, FIFI-LS, FLITECAM, FORCAST, FPI+ and HAWC+ are considered FSIs.

Principal Investigator-class Science Instrument (PSI) — A general purpose instrument that is developed and maintained by the instrument team throughout its useful operating life. PSIs will be operated by the Science Instrument team members, both for their own observations as well as for those of successful GIs. Proposers do not need to consult with the PSI Instrument team before submitting their proposals. However, GIs are encouraged to interact with the Instrument team early, since this maximizes the chances for successful observations. Guest Investigators will receive calibrated data from the EXES and GREAT teams.

For Cycle 4, EXES observations in all modes are PSI modes

Proposers are encouraged to work closely with the EXES team in the definition and execution of the observations. Proposers are strongly encouraged to consult the instrument team about the feasibility of their Cycle 4 projects. Proposers are also encouraged to include EXES team members on their publications, as appropriate.

For Cycle 4, all GREAT observations are considered PSI modes.

For GI publications resulting directly from accepted SOFIA proposals that involve GREAT observations, the GREAT PI may designate up to 3 co-authors.

Special Purpose Principal Investigator-class Science Instrument (SSI) — A special purpose instrument, specifically designed for a particular type of observation not possible or practical with FSIs or PSIs. It is expected that the Science Instrument Team will operate an SSI. *GIs can only use an SSI by partnering with the Instrument Team prior to proposal submission.*

For Cycle 4, HIPO and the FLITECAM/HIPO combination are considered SSI.

1.3.1. EXES supported configurations in Cycle 4

EXES completed most commissioning observations in early 2015, and analysis of the data is still ongoing at the time of writing of this Call for Proposals. Therefore, some details of the EXES performance are still uncertain.

EXES observations are defined by the observing modes, the spectroscopic configuration, and the central wavelength. The following EXES modes are available for Cycle 4:

Observing modes:

1. Nod mode
   – On-slit nod: Source moved between two points along slit for sky subtraction
   – Off-slit nod: Source moved off slit for sky subtraction

2. Map mode
   – Stepped maps with sky subtraction using edge of map or separate sky observation

Spectroscopic Configurations:

1. High-Medium
   – Echelon plus Echelle grating at angles 35-65˚

2. High-low
   – Echelon plus Echelle grating at angles 10-25˚

3. Medium (long-slit)
   – Echelle grating alone at angles 35-65˚

4. Low (long-slit)
   – Echelle grating alone at angles 10-25˚

Map mode is available for all spectroscopic configurations. For the HIGH_MEDIUM configuration, on-slit nodding is only available if the slit is longer than about four times the FWHM of the PSF. A more precise number will be determined during instrument commissioning. Slit lengths in this mode are a strong function of wavelength and grating angle, and users must consult the online Exposure Time Calculator (ETC) to determine if on slit nodding is possible. The ETC also provides information about expected resolving power and wavelength coverage for the selected instrument configuration.

EXES Configuration summary (See Observers' Handbook for details)

Configurations	**Wavelength (μm)**	**Slit**	**Max. Resolving Power**
High-medium	4.5 – 28.3	(1.4-3.2)"x(4-40)"	100,000
High-low	4.5 – 28.3	(1.4-3.2)"x(<12)"	100,000
Medium	4.5 – 28.3	(1.4-3.2)"x(25-180)"	20,000
Low	4.5 – 28.3	(1.4-3.2)"x(25-180)"	4,000

For the high-resolution modes, there is non-continuous spectral coverage for $\lambda > 19$ μm, but the central wavelength can be tuned so that lines of interest do not fall in the gaps (see the SOFIA Observers' Handbook for details).

The LOW configuration, which has not been tested yet in flight, may be strongly affected by saturation effects. Therefore, the efficiency and sensitivity cannot be accurately estimated prior to this Call for Proposals.

Proposers should use the information on the SOFIA website and the EXES exposure time calculator available at:
http://irastro.physics.ucdavis.edu/exes/etc/
to evaluate their proposed observation parameters.

The online information will be updated as the analysis of commissioning data is ongoing.

For the purposes of this Call for Proposals, the June update to this Call shall be considered definitive with regards to observing mode availability and capabilities.

1.3.2. FIFI-LS supported configurations in Cycle 4

FIFI-LS has two independently settable Littrow spectrometers that cover the spectral ranges 51 - 120 µm, and 115 – 203 µm, respectively. The spectrometers are fed by one of two dichroics enabling simultaneous observations of the same target at two wavelengths. FIFI-LS observation configurations for phase I require specification of the integration time, center wavelength and width of the proposed spectra for each of the two spectrometers, and an observing mode. Further observing details will be specified in phase II.

Observing modes:

1. Symmetric Chop mode: This is a nod-match-chop mode suitable for not too extended sources (smaller than the chop throw). For such sources this is the most efficient observing mode.
2. Asymmetric Chop mode: This mode is suitable for extended sources or crowded regions, where a symmetric chopping is not possible.
3. Bright Object mode: This mode is optimized for very bright sources, where the total observing time is dominated by the telescope moves. It employs an asymmetric chop.
4. Spectral Scan: *This experimental mode is offered on a shared risk basis*. While the above modes only allow the observation of gas lines, this mode is intended for broader, e.g. solid state, spectral features.

All modes allow mapping.

Please see the SOFIA Observers' Handbook for further details of observing modes and instrument capabilities.

1.3.3. FLITECAM supported configurations in Cycle 4

FLITECAM observation configurations consist of observing modes and filter selections in imaging mode and observing modes and grism selections in spectroscopy mode. The following are available for Cycle 4.

IMAGING

Observing modes:

1. Stare (Options of 5 and 9 point dither)
2. Nod Off Array

Filters:

Broad-band: J, H, K, L, M.

Narrow-band: Pa α, Pa α continuum, Water Ice (3.08 μm), PAH (3.29 μm), L_{narrow}, M_{narrow}

The Order Sorting Filters (H_W, K_W, K_{long}; used for grism spectroscopy) are **not** offered as stand alone filters.

As the instrument commissioning was performed in the combined FLITECAM/HIPO mode, with its associated elevated long-wavelength background, the performance in L and M band (regular and narrow filters), and the LMA grism mode (grism A with the L+M order sorting filter) have not been verified. Hence these modes, as well as the PAH (3.29μm) and Water Ice (3.08μm) filters, and the "LMB" grism mode, are shared risk observations. If the elevated backgrounds are not (fully) rectified, accepted proposals requesting these filters will be executed only after a case-by-case analysis of their actual feasibility.

SPECTROSCOPY

Observing modes:

1. Nod

The spectroscopic observing mode has not yet been fully evaluated, so the efficiency and sensitivity cannot be accurately estimated prior to this Call for Proposals. Proposers should use the information on the SOFIA website to determine sensitivity and should not expect performance to exceed those numbers.

Grisms

The FLITECAM slit mask has a 2' long slit, half of which is 2" wide and half 1" wide. The spectral resolution in the 2" slit is approximately 1200.

Designation	Grism	Order	Order Sorting Filter	Wavelength Coverage [μm]
FLT_A1_LM	A	1	L+M	4.395 – 5.533
FLT_A3_Hw	A	3	H_{wide}	1.550 – 1.828
FLT_A2_KL	A	2	K_{long}	2.270 – 2.722
FLT_B3_J	B	3	J	1.140 – 1.385
FLT_B2_Hw	B	2	H_{wide}	1.675 – 2.053
FLT_B1_LM	B	1	L+M	3.303 – 4.074
FLT_C4_H	C	4	H	1.500 – 1.718

FLT_C3_Kw	C	3	K_{wide}	1.910 – 2.276
FLT_C2_LM	C	2	L+M	2.779 – 3.399

1.3.4. FLITECAM/HIPO supported configurations for Cycle 4

FLITECAM observation can be performed in the short wavelength modes above when co-mounted with HIPO. Due to the additional background from the warm optics in this configuration, the L, M, L_{narrow}, M_{narrow} and FLT_A1_LM modes of FLITECAM are not available when FLITECAM and HIPO are co-mounted.

1.3.5. FORCAST supported configurations in Cycle 4

The FORCAST imaging configurations require specification of the observing mode and filter. FORCAST spectroscopy configurations require specification of observing mode and grism. The following configurations are available for Cycle 4:

IMAGING

Observing modes:

1. Two position chop and nod (C2N), which is implemented as Nod-Match-Chop (Nod-Perpendicular-Chop is available upon special request)
2. Two position large-amplitude chop (2-7 arcmin) with large nod offsets (C2NC2)

Filters:

The full complement of filters available for the FORCAST Short Wavelength Camera (SWC; listed below) exceeds the number of available filter wheel slots. A nominal filter set has been selected for Cycle 4. Depending on the proposal requests, this nominal set may be revised prior to the start of the cycle. If required, the SOFIA Project will consider one filter swap during the duration of Cycle 4. Proposals requesting any of the non-nominal SWC filters should, in addition to justifying their filter preference, discuss the impact on the proposed science if only the "nominal" filter set is available.

For the Short Wavelength Camera (SWC) the nominal filter set for Cycle 4 is:
6.4, 6.6, 7.7, 11.1, 19.7, 25.3 μm
Additional, potentially available, filters for the SWC are:
5.4, 5.6, 8.6, 11.3, 11.8 μm

For the Long Wavelength Camera (LWC):
31.5, 33.6, 34.8, 37.1 μm

Dichroic:
For Cycle 4, FORCAST can be used in a single channel configuration or dual channel configuration. In dual channel configuration, a dichroic is used to split the incident light towards the short and long wavelength arrays simultaneously. Any short wavelength filter can be used at the same time as any of the long wavelength filters. However, there is significant degradation of throughput for short wavelength filters less than 11 μm and greater than 30 microns in dual-channel configuration; this information is built into the sensitivity estimator (SITE).

SPECTROSCOPY

Observing modes:

1. Two position chop and nod (C2N), which isimplemented as Nod-Match-Chop
2. Two position large-amplitude chop (2-7 arcmin) with large nod offsets (NXCAC)
3. SLITSCAN (A non-zero Map Area must be given) Nod-Match-Chop while stepping slit across a source (SLITSCAN)

Due to their unexpectedly low throughput (and the availability of EXES spectroscopy), the FORCAST cross-dospersed grisms are not offered in Cycle 4.
An exposure time estimator tool is available on the Cycle 4 web page.

Grisms and Slits:

Grism	Wavelength (μm)	Slit	Resolving Power
Long Slit Spectroscopy in the Short Wavelength Camera			
FOR_G063	4.9-8.0	2.4”x191”	180
		4.7” x191”	90
FOR_G111	8.4-13.7	2.4” x191”	300
		4.7” x191”	150
Long Slit Spectroscopy in the Long Wavelength Camera			
FOR_G227	17.6-27.7	2.4”x191”	140
		4.7” x191”	70
FOR_G329	28.7-37.1	2.4” x191”	220
		4.7” x191”	110

Dichroic:
For Cycle 4, all FORCAST spectroscopic observations will be done using the single channel configuration.

1.3.6. FPI+ supported configurations in Cycle 4

The Focal Plane Imager (FPI+) is the primary tracking camera for the SOFIA telescope. The imager uses a 1024x1024 pixel EMCCD sensor with an 8.7’x8.7’ field of view and an angular resolution of 0.51 arcsec/pixel. The wavelength range of this visual light instrument is 360 nm to 1100 nm.

Its permanent installation on the SOFIA telescope allows for observing without installation overhead. Individual flight legs can be planned for the FPI+ and can be performed with any other science instrument installed on the telescope SI flange.
The three observing modes, offered in cycle 4 differ in sensor readout rate and the ability to use the FPI+ for telescope tracking in parallel to acquiring science data.

Observing modes:
FPI_TRACK_SLOW_STARE
- FPI_TRACK_MEDIUM_STARE
- FAST_STARE

Filters:
- Filter carousel 1: u', g', r', i', z' (Sloan Digital Sky Survey) or OPEN
- Filter carousel 2: ND1 (OD=4.0), ND2 (OD=2.6), ND3 (OD=1.3), Schott RG1000 "Daylight" or OPEN

Six spectral filters are available within the FPI+ wavelength range. These are five Sloan Digital Sky Survey filters u' g' r' i' z' and a Schott RG1000 near infrared cut on filter. Additionally three neutral density filters can be used to attenuate bright stars. The ND filters are required for the tracking function of the FPI+ and the optical densities are chosen in a way that stars within the brightness range of 0 < V mag < 16 can be imaged with an exposure time of 1 second. The "daylight" filter is also a requirement for telescope tracking to be able to acquire bright guide stars in twilight. A blocked position in the filter wheel can be used for calibration measurements (e.g. dark frames, bias frames).

Frame rates:
The FPI+ can be operated at high readout rates and achieves high imaging frame rates. The table below summarizes the highest temporal resolutions for acquiring full frames in the three observing modes. When no tracking with the FPI+ is required and sub-frames are selected, the frame rates can increase to a few hundred frames per second.

FPI+ frame rates in frames per second for the acquisition of full frames

	FAST_STARE	MEDIUM_STARE	SLOW_STARE
1x1	8.9 fps	3.8 fps	0.9 fps
2x2	17.5 fps	6.9 fps	1.7 fps
4x4	33.6 fps	11.0 fps	3.2 fps

1.3.7. GREAT supported configurations in Cycle 4

GREAT observation configurations consist of observing modes, receiver band, and backend selections. Contingent on its successful commissioning, the seven-beam upGREAT array receiver, in its low-frequency mode, will also be available.

The upGREAT Low Frequency Array (LFA) is a 7-beam heterodyne array arranged in a hexagonal pattern with a central beam. The spacings between the beams are approximately 2 beam widths. The on-the-fly mapping efficiency using the LFA is approximately an order of magnitude improved over the single pixel configuration.

The following are available for Cycle 4:

Observing modes:

1. Single pointing - position switching (PSW)
2. Single pointing - beam switching (BSW), chopping with the secondary
3. On-the-fly mapping in PSW or BSW mode (OTFMAP_PSW/BSW)
4. Raster mapping in PSW or BSW mode (RASTERMAP_PSW/BSW)

Receiver bands:

GREAT is a dual channel receiver where the two bands are operated simultaneously. Each band (front end) can be tuned separately. The usable instantaneous bandwidth is channel-dependent. For the L1, L2 bands the noise roll-off with intermediate frequency, intrinsic to HEB detectors, limits the usable 3-dB noise bandwidth to typically 2 GHz. Each front-end is connected to a digital FFT spectrometer providing 2.5 GHz bandwidth with 88 kHz spectral resolution (equivalent noise bandwidth).

For Cycle 4 the offered configurations for the single beam receivers will be: L1/L2, and L2/H. The upGREAT (LFA) array is only offered in the LFA/L1 configuration. Proposers requesting the L2/H configuration should, however, discuss in the Feasibility section the impact on their observations of a change to LFA/H. Depending on the results of the Call for Proposals, not all combinations may be executed. The frequency ranges of the bands are:

Band L1: 1.25 – 1.52 THz

Band L2: 1.81 - 1.91 THz

Band H: 4.74 THz

upGREAT (LFA): 1.9005 +/- 0.003 THz

Note that not all frequencies are available within the L1 and L2 bands, and availability will depend on specific performance of the local oscillators. Potential users should consult with the instrument handbook and the GREAT instrument team.

Based on the commissioning flights in May 2014, GREAT will offer the 4.7 THz (63 μm) H-Band. Because of the limited tuning range of the Quantum Cascade Laser local oscillator, only the velocity range -25 to +90 km/s around the 4744.77749 GHz [O I] line will be available with the standard local oscillator set-up. With the negative velocity set-up, the usable velocity range is -30 to -140 km/s. Potential proposers should contact the GREAT Principal Investigator regarding non-standard tunings.

Backends:

Fast Fourier Transform Spectrometer:

XFFTS: 2 x 2.5 GHz bandwidth with 0.088 MHz ENB.

The online information for upGREAT will be updated as the analysis of the commissioning data is ongoing. For the purposes of this Call for Proposals, the June update to this Call shall be considered definitive with regards to observing mode availability and capabilities.

1.3.8. HAWC+ supported configurations in Cycle 4

Completion of HAWC+ commissioning is planned for the middle of 2016, after the proposal selection for Cycle 4. Therefore, the execution of accepted HAWC+ observation is contingent on the successful completion of these activities. Required deviations from the assumptions made here and in other supporting documents will be decided by the SMO Director and communicated to selected PIs.

HAWC+ observation configurations consist of observing modes and filter selections in both Total Intensity and Polarization modes. The following are available for Cycle 4:

TOTAL INTENSITY

Observing modes:

1. Two position chop and nod (C2N) implemented as Nod-Match-Chop (NMC).
2. On-the-fly mapping (OTF).

Filters:

Five filters are available with central wavelengths (bandwidths) as follows –53 (9), 63 (9), 89 (17), 154 (34), 214 (44) μm.

POLARIZATION

Observing modes:

1. Two position chop and nod (C2N) implemented as Nod-Match-Chop (NMC).

Filters:

Five filters are available with mean wavelengths (bandwidths) as follows –53 (9), 63 (9), 89 (17), 154 (34), 214 (44) µm.

For each filter a corresponding half-wave plate (HWP) is used. The filter is matched to the HWP.

1.3.8. HIPO supported configurations in Cycle 4

A HIPO observation configuration is the combination of a detector operation mode and optical configuration. Optical configurations, which include the choice of filter sets (in each wheel), dichroic, and reimaging optics, are provided on a per-flight basis whereas detector operation modes are selected on a per observation basis. (The FLITECAM/HIPO combination has the same modes as HIPO, with the additional FLITECAM filters and grisms available.) The following are available in Cycle 4:

Observing modes:

1. Single frames
2. Basic Occultations
3. Fast Occultations

Filters:

U, B, V, R, I (Johnson)
u', g', r', I', z' (Sloan Digital Sky Survey)
Methane (890 nm)

Up to eight filters may be accommodated per filter wheel. For the dual-channel imaging mode, all combinations of filters and dichroics with overlapping transmission are available. For the red-channel (see below), all filters are available except U and u'. Filter wheel positions can also be left OPEN on any wheel if desired. All permitted filter/dichroic combinations can be used with any one of the detector operation modes for an observation.

Dichroics:

There are two dichroics available with cut-offs at 575 and 675 nm. The choice of dichroic is determined by a preference for where to split the wavelength coverage of the 'blue' and 'red' channels. For example, the 675 nm dichroic permits simultaneous observation in R and I bands in the 'blue' and 'red' CCD channels, respectively. HIPO also supports a 'red' channel only configuration (no dichroic) for higher optical throughput if two-color photometry is not required.

Custom Optical Configurations and Detector Operation Modes:

HIPO can accommodate custom filters and dichroics for specific observations. A 'bare CCD' configuration without re-imaging optics and with one filter wheel is also available. Additional engineering readout modes are also available for special purpose observations in collaboration with the HIPO instrument team.

1.4. Cycle 4 Schedule

The nominal schedule for the Cycle 4 observing program is as follows:

1 May 2015	Release of Call for Proposals
8 June 2015	Call for Proposals update
10 July 2015, 21:00 PDT	Proposal Submission deadline
11 July 2015, 04:00 UTC	Proposal Submission deadline
Early October 2015	Proposal Selections Announced.
1 February 2016 – 31 January 2017	Cycle 4 observing period.

SOFIA observations in Cycle 4 will be conducted in a number of Science Flight Campaigns[10] covering the periods February, 2016 - January, 2017. The detailed layout of Science Flight Series within each Science Flight Campaigns will depend on the selected proposals and instrument availability.

1.5. General Guidelines and Policies

At the time of writing of this Call for Proposals, EXES, FIFI-LS, FLITECAM, FORCAST, GREAT and HIPO have completed their commissioning observations, and FORCAST has passed its formal acceptance review. A significant part of the analysis of the commissioning data for EXES, FLITECAM & FORCAST grism-modes, and FIFI-LS

[10] SOFIA science observing definitions:

a) *Science Flights* - individual flights primarily devoted to obtaining astronomical science data.
b) *Science Flight Series* - Contiguous series of science flights, all with the same instrument.
c) *Science Flight Campaigns* - One or more science flight series, beginning and ending with a non-science, engineering activity.
d) *Science Observing Cycles* - One or more of flight campaigns that are covered by a single science Call for Proposals.

still remains to be completed. Hence observations with EXES, FIFI-LS and grism mode observations with FLITECAM and FORCAST carry a larger uncertainty and may require modifications or reconsideration by the SMO Director once the commissioning data have been fully analyzed. The commissioning of the seven-beam array received upGREAT is planned to take place in May 2015, contingent on the successful completion of this activity, upGREAT will be offered in Cycle 4. The status of upGREAT as pertains to Cycle 4 proposals will be updated in the Call for Proposals update, planned for June 8.

Observations lost due to observatory or instrument hardware or software failures, weather, or other reasons, will not automatically be rescheduled. Likewise, award of an investigation is not a guarantee that the observation will be executed. Sky visibility or other observing constraints may prevent completion of a selected investigation. In general, with the exception noted in Sec. 2.1, such observations will need to be re-proposed for in a subsequent Cycle.

1.5.1 Proposal Process

The SOFIA Cycle 4 proposal process will consist of two steps – Phase I and Phase II. Phase I requires the preparation and submission of a science justification, a feasibility analysis for the proposed program, and a high level description of the proposed targets and observations. This Phase I proposal will form the basis of the peer review and proposal selection by the SMO Director. Proposals that are awarded observing time based on the evaluation process described in Section 1.9 will subsequently be required to submit Phase II observation specifications following guidelines provided by the SMO. These submissions will provide the SMO and instrument PIs with the detailed definition of each observation to be executed for the program. In addition, proposers affiliated with U.S. institutions will be invited to submit a budget, based on funding guidelines provided by the SMO.

SOFIA Cycle 4 Phase I proposals must be prepared and submitted using the SOFIA Proposal Tool (SPT) (http://dcs.sofia.usra.edu/proposalDevelopment/installSPT), which is a Java based application. The prospective proposer should download SPT to a local computer. The proposal consists of formatted information filled in via the SPT form fields (such as proposer information, scientific category, instrument, target and exposure information) and a file containing the scientific justification and other information (details in section 2.2.1), to be uploaded in PDF format. SPT is available for most commonly used platforms, including Mac OS X, Windows and Linux (http://dcs.sofia.usra.edu/proposalDevelopment/installSPT/index.jsp).

An outline of the proposal preparation process may be found in section 2 and further details about SPT in the Observers Handbook.

1.5.2. Who May Propose

Participation in the U.S. SOFIA Cycle 4 Program is open to scientists from all categories of U.S. and non-U.S. organizations, including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies. Members of German organizations, including DSI staff stationed in the U.S., must participate through the DSI led program.

Each SOFIA Cycle 4 proposal must identify a single Principal Investigator (PI) who assumes responsibility for the conduct of the scientific investigation. Proposal Co-Investigators must have well defined roles in the investigation, which will be evaluated as part of the proposal review process. Following selection by the SMO Director, the SMO staff will communicate formally only with the PI (or a person designated by the PI) of each proposal, except for funding issues where communications will be primarily with the institutional Sponsored Research Office (or equivalent). It is the responsibility of the PI (or designee) to provide the SOFIA project, in a timely manner, all information necessary for implementing observations, and to respond to any questions concerning observational constraints or configurations.

Note: those with a German professional affiliation may participate as Co-Investigators on proposals submitted in response to this Call. They may not be Principal Investigators on the proposals, nor in any way be designated as the contact or lead investigator.

1.5.3. Late Proposals

Consistent with USRA and NASA policy, no late proposals will be considered. A proposal will be considered "on time" only if all necessary components have been received by the published deadline. Note that processing delays at the proposer's home institution, shipment delays of the proposal, or Internet delays, do not excuse the late submission of a proposal.

1.6. Data rights and distribution

All scientific data from SOFIA observations will be distributed via the SOFIA Data Cycle System's Science Archive (https://dcs.sofia.usra.edu/dataRetrieval/SearchScienceArchiveInfo.jsp)

All data will be archived as Level 1 data (raw). Where appropriate, Level 2 (corrected for instrumental and atmospheric effects) and Level 3 (flux calibrated) will also be archived.

These data will be accessible to the general community after a proprietary period of twelve months. The proprietary period for all data products will end twelve months after the GI is given access to the calibrated (level 3) data, either though delivery from the instrument team or though staging to the SOFIA data archive.

1.7. Targets for Observations

All scientifically valid observations may be proposed for, with the exception of those duplicating the ones in the "Reserved Observations Catalog" lists (Appendix A), designated by each Science Instrument team. Duplication of observations obtained in earlier cycles are generally not allowed, and if proposed for, must be identified as such, and the necessity for duplication must be explicitly justified.

Observations that are part of an active Cycle 3 SOFIA program, but which have not been executed at the time of the Cycle 4 proposal deadline may be re-proposed, but must be clearly identified as such. If the Cycle 3 observation is executed and the Cycle 4 request qualifies as a duplication (target, mode and exposure time) the latter will be disallowed. The proposal may provide potential substitute targets, but must then clearly discuss the relative scientific justification for the original target[s] and the substitute targets.

Non-sidereal tracking of SOFIA observations has been implemented, but only limited operational experience has yet been gained. Such observations therefore carry a somewhat larger risk. Proposals of such observations are allowed, but the SMO Director will decide in each individual case whether an accepted observation is to be executed.

1.7.1. Reserved Observations

As part of the instrument development contracts, the instrument teams were awarded a limited amount of Guaranteed Time Observing (GTO). To protect the interests of the instrument development teams, the SOFIA Science Mission Operations has allowed the Cycle 4 instrument teams to set aside a limited number of targets and associated exposure times as "Reserved Observations". These reserved observations may not be proposed for in Cycle 4.

A Reserved Observation consists of the combination of position on the sky, instrument, observation configuration, and length of observation. The observation configuration encompasses the basic scientific intent of the observation by specifying, for example, the wavelength range for broad-band photometry or grism spectroscopy or the frequency of observation for GREAT. Similarly, proposed observations are considered duplicate to previously observed observations if they duplicate the combination of position on the sky, instrument, observation configuration, and length of observation. Hence, observations of the same target but in different filters are not considered duplicates.

The Reserved Observation Catalogs for the instruments are independent of each other. The Reserved Observation list only applies to Cycle 4, and the Instrument PIs will have the opportunity to revise their Reserved Observation Catalog prior to subsequent proposal calls.

If a reserved observation is proposed for, the justification for such a duplication must be clearly addressed in the proposal. At a minimum, any such proposals must aim to achieve a signal-to-noise ratio of twice that expected from the Reserved Observation or have a scientifically justified duplication such as for temporal variability studies. Final determination of acceptability of proposed observations rests with the SMO Director.

The Reserved Observations Catalogs can be found in Appendix A.

1.8. Proposal Evaluation and Selection Process

Proposals submitted in response to this Call will be evaluated in a competitive peer review. The peer review panel, including its chair, will be recruited from the astronomical community and be subject to the standard NASA procedures and rules.

The following factors will be used in evaluating proposals for the SOFIA Cycle 4 Program.

1. The overall scientific merit of the proposed investigation.
2. The broader scientific impact of the investigations to astronomy.
3. The feasibility of accomplishing the objectives of the investigation.
4. The degree to which the investigation uses SOFIA's **unique** capabilities.
5. The competence and relevant experience of the Principal Investigator and any collaborators to carry the investigation to a successful conclusion.

The scientific review panels will be given an assessment of the technical feasibility of each proposal as determined by the SMO. After acceptance of an observing program, successful proposers must provide the required inputs to detailed observing plans for submission to the SMO. Instructions for completing these Phase II inputs will be distributed to the PIs of the selected proposals.

Proposals of all sizes will be considered. For Cycle 4, the SMO encourages substantial investigations with significant impact and plans to allocate at least 20% of the available observing time to high scientific impact proposals in excess of 40 hours. Up to 100% of the time may be assigned to these larger proposals if the Time Allocation Committee judges them sufficiently meritorious.

The SOFIA project reserves the right to select only a portion of a proposer's investigation, in which case the PI of the proposal will be given the opportunity to accept or decline the implementation of the partial selection.

Because of the complicated process of flight scheduling involving sky visibility, instrument availability, and the need to produce efficient flight plans, selection of an investigation does not guarantee observation. At the discretion of the SMO director, an appropriate over-subscription of the available flight times may be accepted via the peer review process with an associated prioritization, which will allow for contingencies in flight planning. The SMO Director will approve the implementation of the observing prioritization and target selection.

1.9. Funding for U.S.-based Investigators

Funds for awards under this solicitation are expected to be available to investigators at U.S. institutions subject to the annual NASA budget cycle. Successful proposers at U.S. institutions, including, at the discretion of the SMO Director, U.S. Co-Investigators on successful non-U.S. proposals, will be eligible for funding.

Budgets should not be submitted with the proposals in response to this Call. The **selected** investigators will receive a funding guideline from the SOFIA Science Center based on the scope of the approved observing program, complexity of the data analysis, and the available budget for the SOFIA Cycle 4 program. One of the inputs to this budget guidance will be the scope and complexity of anticipated data analysis associated with the program. Proposers are asked to include a description of the data analysis plan as part of the Technical Feasibility section of their Phase I proposal. A budget summary and narrative description of how these funds will be used must be submitted after the receipt of the guideline. The deadline for budget submittal will be announced after the proposal selection and included in the funding guidelines document. An institutional signature will be required when a budget is submitted.

It is noted that archival SOFIA data may represent the primary source for an Astrophysics Data Analysis Program (ADAP) Proposal under the NASA Research Opportunities in Space and Earth Sciences (ROSES) solicitation, (http://science.nasa.gov/researchers/sara/grant-solicitations/).

1.10. Proposer Participation in Observations

The SOFIA Program anticipates the availability of limited funding to support the participation of SOFIA GIs during flights executing their observations. Note, however, that observations from many different programs are usually executed on any given flight. This has several impacts on GI in-flight participation: 1) Only a limited number of observations in the GIs program are likely to be executed on any given flight. 2) While many optimizations of a given observation are possible in-flight, the ability to interactively modify a program is limited to the specific observation. Changes that would affect the remainder of the flight plan (e.g. target changes), or that could cause conflicts with other accepted programs (such as filter settings not originally awarded to the current program), will generally not be allowed. 3) With the many different required and requested flight crew complements the number of "Astronomer seats" on any given flight is limited. For a given flight, if the number of GIs requesting seats exceeds the number available, then the SMO Director will decide on which GIs will be invited on that flight.

1.11. Outreach

1.11.1 Education and Public Outreach

The SOFIA project strongly encourages observing programs to include an Education & Public Outreach (E&PO) component, supported by the SOFIA Outreach office. **The proposer does not need to add any E&PO text to the submitted observing proposal**. For selected programs, the SOFIA Outreach staff will contact the program PI during the Phase II stage, to collaborate in designing an E&PO program related to the program's science.

For E&PO planning purposes, proposers are requested to indicate, in their Phase I submittals, whether or not they are interested in one particular E&PO option, namely the Airborne Astronomy Ambassadors (AAA) program. Participation in the AAA program will involve a partnership between the GI team and a team of educators who will be put in contact with the scientists before the observing flight(s) of the program in question. The educator team will be trained by SOFIA Outreach to understand the planned investigation, will fly on SOFIA with a flight facilitator/escort, and then continue to partner with the GI team in a mutually agreeable fashion after the flight(s). The selection of the AAA educators is carried out through a proposal process, which runs in parallel to the Cycle 4 observing proposal process.

Please note that by choosing the AAA option the proposer is not required to recruit the educators, give them materials, or fund their activities; the SOFIA Outreach office will provide all such support. If the AAA program option is chosen, and the GI chooses to participate in the SOFIA observing flight(s) for their program, the AAA team (plus escort) will accompany them on the flight(s).

The proposal cover page in SPT includes a button allowing the proposer to indicate an interest in participating in the AAA program. The SOFIA project requests that you indicate whether you are interested in participating in the AAA program in the Phase I stage since this will provide important information for the planning, execution and review of the AAA educator proposal and selection process. The choice of whether or not to indicate an interest in participating in the AAA program will not affect the evaluation of the Cycle 4 observing proposal.

1.11.2 Press Releases and Presentations

SOFIA is already capturing the imagination and attention of the press and the public. To continue this successful publicity, SOFIA observers have a responsibility to share potentially newsworthy results with the public. NASA/DLR have an interest in helping them reach a larger audience and gain a bigger impact. Specifically, NASA and DLR retain the right to be the initial organizations to issue press releases regarding SOFIA results. Therefore, if a GI believes that there is a possibility that his/her new results could be of interest to a wide public audience, they should contact the SOFIA Public Affairs officer Nicholas Veronico (nveronico@sofia.usra.edu) who will evaluate the news value of the results, communicate with NASA and DLR Headquarters, and then work with the GIs on the most suitable course of action. Releasing results without coordinating with the program or agency will prevent the result from being included in a subsequent NASA/DLR press release.

NASA and the DLR will jointly issue press releases associated with SOFIA observations during Cycle 4. The U.S. SOFIA Public Affairs officer and the German/DSI Public Affairs counterpart will coordinate the press release process. Other relevant press releases by participating organizations (including PI institutions) should be coordinated with the SOFIA program, NASA and DLR. Other presentation material based on the Cycle 4 observations can be generated by any member of the proposal team and will be considered part of the team's collective set of material. Any member of the team may use these materials (e.g., in public science talks or conference proceedings).

1.11.3 Internal NASA Presentations

Noteworthy SOFIA results are of great interest to NASA. GIs are encouraged to support internal presentations to NASA management, with the understanding that results will be made public only with the agreement of the GI. GIs will also be encouraged to make early results available in more public venues like the SOFIA website and presentations.

2. Proposal Preparation and Submission

2.1. Types of Programs

Four types of programs are solicited in response to this Call: Regular Programs, Impact Programs, Survey Programs, and Target of Opportunity Programs. A single proposal may not mix different program types.

As for Cycle 3, a limited fraction (approximately 5% of allocated observing time) of the most highly ranked Regular Programs in Cycle 4 will be assigned status as "guaranteed observations" and may be carried over between cycles if they fail to be scheduled during the Cycle 4 period. Proposers do not need to, and cannot, request this status, as it will be assigned by the SMO Director as part of the proposal selection process.

Starting in Cycle 4 the SOFIA program introduces the Impact Program category. These are large, multi-year, programs aimed at addressing specific high-importance issues in astrophysics.

With the exception described above, proposals are active only for the duration of the Cycle 4 observing period. Accepted observations not executed during Cycle 4, for whatever reason, will not be carried over to future cycles.

In addition, the SOFIA program accepts proposals for Director's Discretionary Time programs. This category is intended for short, urgent observations that could not have been foreseen at the time of the proposal Call and that cannot wait for the next proposal cycle. In exceptional cases, proof-of-concept observations may be requested through the DDT path. However, a strong justification for not proposing such observations through the regular proposal process will be required. DDT proposals are not solicited through this Call for Proposals, and should be directly addressed to the SMO Director, Dr. Erick Young. Further information about the DDT program can be found at the SOFIA web site under: http://www.sofia.usra.edu/Science/proposals/DDT/instructions.html

2.1.1. Regular Programs

Observations of specific targets with known positions and timing constraints (including targets with no constraints) will constitute regular observing programs. This includes time critical observations and observations of known Solar System objects.

The intent is to execute all the highly ranked observations accepted in a regular program. Of necessity, efficient scheduling of SOFIA requires a larger pool of candidate observations in a given Cycle. The SMO director may therefore accept regular proposals as "Do if Time". Such programs will be scheduled at secondary priority, but with the intent to execute as large fraction of the observations as possible.

2.1.2. Impact Programs

To enable significant, flexible, investigations of important problems in astrophysics, SOFIA in Cycle 4 introduces the program category "Impact Programs". These are multi-year programs of approximately 50-100h each of exposure time, aimed at addressing high-importance scientific problems. Impact Programs may utilize any combination of offered SOFIA instrument and modes. Impact programs are not, primarily, intended to enable large general survey programs, but should be targeted to answer specific scientific questions.

All targets of an accepted Impact Program are expected to be observed. The original proposal should include a complete target list on which the proposal will be evaluated, but target modification will be allowed as per below. Because of the operational and budget impact, Impact Proposals with large target pools only available during Southern Hemisphere deployments, especially if requesting multiple instruments, will require a especially high scientific justification.

Accepted Impact Programs will be carried out in several phases:

After proposal selection and an expedited phase II process, a sub-section of the proposed observations (~10-15h) will, in coordination between the program PI and the SMO, be selected and prioritized for early observations. The intent of these early observations is to demonstrate the technical approach to the observing program prior to scheduling the balance of the program.

After these initial observations have been performed and analyzed, but prior to the release of the Cycle 5 CfP, a review will be convened by the SMO Director to evaluate and confirm the viability of the science goals of the program. Upon the successful completion of this first review, the impact program PI will be allowed to update the target list and observation details (subject to SMO Director approval and regular observation duplication restrictions), including instrument mode modifications. The full program will be targeted for completion in two observing cycles, but depending on the size of the accepted program, instrument requests, and target distribution, observations may stretch over three. The program PI will be allowed, with SMO Director approval, to update the remaining observing program prior to the release of the CfP for each affected observing cycle.

A second review of the program will take place toward the end of the second observing cycle (for Cycle 4 Impact Programs, nominally December 2017) which will evaluate the progress of the program, including observational progress, data reduction status and schedule for delivery of high level products and core publications. Upon the successful conclusion of this second review, the remainder of the impact program will be executed at heightened priority.

2.1.3.1. Joint Impact Programs

To encourage US-German collaborations and to optimize the proposed programs, SOFIA will consider joint Impact Program proposals. These shall be submitted as identical proposals (Scientific and technical justification, target pool, observation request, etc.), except for the Principal Investigator, which must adhere to the usual affiliation constraints (Section 1.5.2).
A time request distribution adhering to the 80/20 US-German SOFIA total allocation will be assumed (i.e. a joint proposal pair requesting 100h, will be treated as an 80h proposal in the U.S. selection and a 20h proposal in the German selection).
The title of such proposals must start with the phrase: "Joint Impact Proposal:". The two peer review processes will evaluate such proposal pairs independently. If both reviews approve the proposals, a joint program will be executed with the U.S. and German PIs treated as co-PIs. If the joint proposal is declined in the U.S. selection, the German proposal will automatically be declined. Should the German peer review decline the proposal, while the U.S. review recommends approval, the SMO Director will have the authority to approve the U.S. proposal as stand alone, nominally at the 80% U.S. partial request.
The same funding restrictions apply as for regular proposals (Section 1.9)

2.1.3. Survey Programs

The Survey proposal category are intended to allow studies of a target class, as well as provide the SOFIA project flexibility in flight planning. These programs should identify a sample of targets and observations with a common scientific justification. The selection of survey proposals will be primarily judged on scientific merit, but samples with uniform sky distributions will be prioritized as they provide the best flexibility in flight planning.

The intent is that a useful fraction of the targets in a given survey program will be observed, but with no given target observation guaranteed to be executed. The proposal should discuss and justify a minimally useful fraction of completion.

2.1.4. Target of Opportunity Programs

Target of Opportunity (ToO) proposals are invited. Both programs with known targets, but unknown timing of the observations, such as observations of a specific target at an unknown time (e.g. an identified recurrent nova in outburst), and programs targeting a class of astronomical events, but with unknown targets and timings (such as observations of an as yet unidentified comet or supernova), will be considered. For ToO observations, the proposal should contain a discussion of the triggering criteria, the required turn-around time between triggering and observation, and any other timing constraints.

Since SOFIA can only observe with a single instrument at the time (with the exception of the co-mounting of HIPO and FLITECAM), rapid turn-around ToO requests with a specific instrument may be difficult to implement. Hence, ToO proposals should also address the viability and utility of observing the event/target with each of the available SOFIA instruments.

The SMO Director will have ultimate authority in recommending or rejecting the request that a selected ToO program be activated.

Observations of specific Solar System targets or events whose times of occurrence can be predicted in advance (e.g. occultations) ***do not*** *constitute ToO observations and should not be flagged as such.*

2.2. Proposal Preparation

Each Cycle 4 proposal must be prepared using the SOFIA Proposal Tool (SPT). The proposal information is entered directly, while text sections including the scientific justification and feasibility analysis should be in PDF files, uploaded via SPT[11].

Proposals must be written in English. The length of each section of the proposal should not exceed the page limits indicated in Section 2.2.2, using single-spaced 8.5x11 inch or A4 format with 1 inch (2.5 cm) margins. Proposals must be printed to the PDF files with a font size no smaller than 11 points (about 6 characters per cm). Reviewers will only be provided the portion of each proposal that complies with the page limits.

[11] http://dcs.sofia.usra.edu/proposalDevelopment/installSPT/index.jsp

The abstract provided using the Proposal Information form is limited to 300 words (see Section 2.1.2).

2.2.1 The SOFIA Proposal Tool (SPT)

The SOFIA Proposal Tool (SPT) provides the user with a simple form-based interface for preparing a proposal and for electronic submission to the SOFIA Science Mission Operations. After downloading the appropriate package and following the installation instructions, the user starts a new proposal by launching the SPT application. The proposer then fills out the necessary form fields including proposer information, abstract, instrument(s), and target lists. The Science and Technical Justification may be prepared using any text editor (e.g. MS Word, LaTeX, etc...) and saved as a PDF file. Using SPT, the proposer then identifies this PDF file on a local disk for attachment to the proposal summary information. When the proposal is complete, the user submits the complete proposal directly to the SMO using SPT. Upon successful submission, a unique identifier is returned for later reference. Proposals that have been submitted to the SMO can be ***resubmitted*** using SPT at any time up to the proposal deadline (note that old versions are not retained). On-line help for SPT is available as a pop-up function in the application.

Please note that "Blackout Periods", and "Long Term Observations" are not supported in Cycle 4 and will be ignored in the SPT form.

2.2.2 Proposal Text Sections (To be uploaded as a single PDF file)

Proposal Sections – The uploaded PDF file must contain the following sections in the order indicated for each proposed observing program. The page length limits are indicated.

1. **Scientific Context (up to 0.5 pages)** – Briefly summarize the proposed investigation with the following elements:
   Context – What is the context and significance of this proposal to the broader field of astronomy?
   Aims – How will the observations address the specific scientific questions in this proposal?
   Methods – What are the key measurement techniques utilized in this investigation? How do they pertain to the unique capabilities of SOFIA?
   Anticipated results – What are the expected data sets that will be produced in this investigation?

2. **Scientific Justification (up to 3 pages)** - Describe the scientific objectives of the proposed investigation, clearly stating the goals and their significance to astronomy, and why SOFIA data are essential to the investigation. The results and status of previous, related, SOFIA observations should be summarized. The page limit includes all text, figures and tables. An additional page for references only is allowed.

3. **Feasibility (up to 2.5 pages)** – This section forms the basis for assessment of the technical feasibility of the proposed observations. The requested exposure time for each observation must be justified. The section should include the expected target fluxes and the signal-to-noise ratio required for each observation. The source (or method) for the flux estimates, and their accuracies should be mentioned. Where applicable the spectral resolution required must be explicitly stated. Any other information about the proposed observations that would help the reviewer relate the technical needs to the scientific goals should be included in this section. Observing overheads and other indirect time estimates should follow the instructions given in the Observers Handbook. This section should also contain the justification for special calibration procedures, if they have been requested (Section 3.2.2).

   The technical feasibility section should include a brief discussion of the anticipated data analysis needed to accomplish the investigation. Specifically, describing the analysis tasks performed by proposers after receiving the calibrated data from the SOFIA Science Center will assist the reviewers in assessing the scope of the proposed effort.

4. **Principal Investigator and Co-Investigator Biographical and Publication Data (one page for the PI with one additional page for CoIs)**. A short biographical sketch for the PI should be provided and include a list of the most recent refereed publications relevant to the scientific proposal. Short biographical data, including their roles in the proposed project, should be provided for the CoIs

2.2.3. Exposure time estimates

Estimates of exposure times for imaging with FLITECAM, FORCAST, FPI+, and HAWC+ can be made using the SOFIA Instrument Time Estimator (SITE)[12], a web-based tool that provides total integration time or S/N for a given instrument, filter(s), source type (point, extended, emission line) and water vapor overburden. Algorithms and assumptions used are given in the help link on the SITE webpage.

Stand-alone Exposure Time Calculator (ETC) tools for the FLITECAM- and FORCAST-grism modes and for EXES, FIFI-LS and GREAT observations have been added to the SOFIA web site under Cycle 4 information.

Because this Call for proposals is being issued prior to in-flight commissioning of some instrument modes, the sensitivities of some of the instruments are somewhat uncertain.

[12] http://dcs.sofia.usra.edu/proposalDevelopment/SITE

2.2.4. Sky availability during Cycle 4

The sky availability for SOFIA observations is constrained by several factors, including the need to return to the Palmdale, California home base at the end of a flight and the avoidance of restricted airspace. Due to these constraints, the southernmost declination available on flights departing and landing in Palmdale is -36˚. This limit is calculated based on limits of flight plans and telescope pointing. Note that, depending on the sensitivity of a given observation to atmospheric opacities, the limiting Declination may be significantly more stringent in practice.

Current flight rules prohibit observations when the sun is above the local horizon and require that the aircraft touch down at least 15 minutes prior to sunrise.

The instantaneous pointing of the telescope, relative to the aircraft, is restricted to ±3˚ cross-elevation (on the port (left hand) side of the plane) and elevations between 21 and 58 degrees (unvignetted). A somewhat larger vignetted elevation range is possible, but the proposer should contact the SMO regarding possible performance issues.

The SOFIA Program expects to conduct a single Southern Hemisphere deployment with up to science instruments during Cycle 4. The deployment flights would occur during the June-August 2016 period out of Christchurch New Zealand. The number of supportable flights as well as the number of instruments (one or two) available during the proposed deployments will be dependent on the funding for SOFIA during the Cycle 4 period. The over-all scientific justification (number and urgency of accepted proposals) for the different offered instruments will be a key determinant in which instruments will be available on these deployments.

In order to allow for a potentially broader pool of Southern Hemisphere science, starting in Cycle 4, highly ranked proposals for targets only observable during a Southern Hemisphere deployment, but requesting an instrument not selected for deployment in that cycle may be held over for up to two cycles for possible future instrument selection for southern deployment. The PIs of such proposals will be given the option of having the proposal carried over, and if so given the opportunity to submit a short (about one-half page) update to the proposal in time for subsequent proposal deadlines. The proposals, and update information, will be reviewed by subsequent peer reviews to confirm the continued scientific merit and validity of the proposed investigation. The titles, abstracts and observing requests for these "carried-over" proposals will be disclosed in the proposal solicitation information for the affected, subsequent, cycles.

Cycle 4 proposers are not expected to lay out flight plans or perform detailed visibility analysis for their proposals. Such considerations are also not needed for the phase I proposals. The SMO staff and the instrument teams will do the flight planning for the observing program. General target availability for a specific set of dates can be judged using the SOFIA Visibility Tool (VT). The stand-alone version is available for down-loading at:

https://dcs.sofia.usra.edu/observationPlanning/installVT/

2.3. Proposal Submittal

Proposals must be submitted using the SPT application. Upon successful upload, the system will generate an automatic message acknowledging the submittal. A confirmation email will be sent to the address provided in the proposal. Details about the SPT may be found in the Observers Handbook.

Proposals can be resubmitted at any time before the proposal due date. Note that a resubmitted proposal **replaces** all previously submitted versions - the SMO keeps only the latest proposal submission associated with a given proposal number.

3. Observations and Data

3.1. Flight Planning & Target Prioritization

Flight planning is not part of the proposal process. However, source selection with the constraints of an airborne observatory in mind can increase the ability of a program to be scheduled. It may be expected that certain regions of the sky, such as the inner Galactic Plane, and Orion will be oversubscribed. These targets force SOFIA to fly westwards since they are towards the south (and the telescope looks out on the port - left-hand - side of the aircraft). Since, in regular operations, SOFIA has to return to Palmdale at the end of each flight, targets in the northern half of the sky will be required for roughly the same amount of time as these southern regions. (Note that southern and northern half of the sky here does not refer to south and north of the celestial equator but to sources culminating south or north of the zenith.)

The ranking by the peer review panel and selection by the SMO Director will result in a prioritized target pool, which will be provided to the SMO staff. The SMO will then produce flight plans in consultation with the instrument teams and proposal PIs. The effort will be carried out under the scientific direction of the SMO Director.

3.2. Data Processing, Calibration and Distribution

3.2.1 Data Processing, Archiving and Distribution

The SMO will be responsible for the processing of data obtained by Facility Class Science Instruments. The instrument development teams will be responsible for the data reduction for Principal Investigator Class and Special Purpose Science Instruments. All scientifically meaningful data obtained during the Cycle 4 phase will be made available to observers via the SOFIA Science Archive

For HIPO, only level 1 data will be stored at the SOFIA Science Archive. (No processing is done, so as to maintain highest fidelity for time-variability studies.)

3.2.2 Calibration

It is expected that a photometric calibration accuracy of at least 20% will be achieved for FLITECAM and FORCAST imaging and for GREAT observations, except in spectral regions of strong telluric interference. For FIFI-LS a photometric calibration accuracy of 30% is expected to be achievable, contingent on the availability of suitable calibration data.

The EXES temperature-controlled blackbody source is expected to provide flux calibration to better than 20%. Experiments focused on line profile information and those that can normalize the continuum level, or use past observations for setting the continuum, are likely to be lower risk. Correction for the impact of Earth's atmosphere will also be done using the black body source. Corrections, using the blackbody, are expected to be accurate in wavelength regions where the atmospheric transmission is >0.50 and is spectrally smooth over the region of interest. Projects requesting additional telluric calibration should include such requests in the phase I proposal. Because of the difficulty of scheduling a given telluric calibrator with the science target in a given flight, the specific calibrator will need to be chosen at the time of flight planning in consultation between the program PI, the instrument PI and the SMO support scientist. For those observations requiring an associated telluric standard observation, a separate observation entry should be entered via SPT with name “Cal_target”, where “target” is the name of the associate science target (i.e. “IRC+10216” and “Cal_ICR+10216”), and given the coordinates RA:12:00:00, Dec:+90:00:00. The observing request for such a telluric standard observation will depend on the mode and wavelength observed. The analysis of the EXES commissioning observations is still ongoing and therefore, the time requirements for such calibrations will be distributed through the EXES section of the SOFIA Observers’ Handbook for Cycle 4, but the Call for Proposals update, planned for June 8. For specific questions, please contact the SMO or the EXES instrument PI Dr. Matt Richter."

Absolute calibration for HIPO is not expected to be an issue for its scientific usage, but may be brought up by the proposer during discussions with the Instrument PI before preparing and submitting a proposal.

Cycle 4 proposals do not generally need to include time for calibration target observations. Observations of astronomical calibrators will be performed by the Observatory and will be allocated as general overhead and will not be counted against the awarded General Investigator time. Proposers wishing to implement specific calibration strategies may propose to do so, but must identify the specific calibration target observations to accomplish these goals and explicitly request the observing time to accomplish these observations. The calibration strategies and targets will be evaluated in the technical and science reviews, and if recommended by the review process will be treated as part of the proposal.

4. Contacts and Further Information

For further information about the Cycle 4 Call for Proposal or help in preparing proposals, please see the "Information for Researchers" (http://www.sofia.usra.edu/Science/) section of the SOFIA web site, or contact the SOFIA help desk at sofia_help@sofia.usra.edu.

Questions about the SOFIA General Investigator program can be directed to the SOFIA Science Operations Manager, Dr. B-G Andersson (bg@sofia.usra.edu), or SOFIA User Support Scientist Dr. Ravi Sankrit (rsankrit@sofia.usra.edu).

For further information about the SOFIA Science project, please contact the above, or the Science Mission Operations Director, Dr. Erick T. Young (eyoung@sofia.usra.edu)

Note:
Some of the following lists of Reserved Observation Catalogs contain entries for both observation intended to be executed in Cycle 4, and observations already performed by the instrument teams as part of their Guaranteed Time Observing (GTO) programs. For detailed information about completeness of the GTO observation, please follow the Duplication Checking procedure laid our on the Cycle 4, Phase 1 web pages (https://www.sofia.usra.edu/Science/proposals/cycle4/phase1.html), or contact the SOFIA help desk (sofia_help@sofia.usra.edu).

Appendix A1 - EXES Cycle 4 Reserved Observations Catalog (ROC)

Target	R.A.	Dec	$\lambda_{central}$	Config.	t_{exp}	Executed
	(2000)	(2000)	[μm]			
IRC+10216	09:47:57.41	+13:16:43.56	5.85	High-Low	600	
IRC+10216	09:47:57.41	+13:16:43.56	6.00	High-Low	600	✓
IRC+10216	09:47:57.41	+13:16:43.56	6.15	High-Low	600	
Sirius	06:45:08.92	-16:42:58.02	5.85	High-Low	900	
Sirius	06:45:08.92	-16:42:58.02	6.00	High-Low	900	✓
Sirius	06:45:08.92	-16:42:58.02	6.15	High-Low	900	
Mon R2 IRS3	06:07:48.40	-06:22:55	5.705	High-Med	1600	
Sirius	06:45:08.92	-16:42:58.02	5.705	High-Med	600	
Mon R2 IRS3	06:07:48.40	-06:22:55	6.175	High-Med	1600	
W3 IRS5	02:25:40.4	+62:05:52	5.705	High-Med	900	
NGC 7538 IRS1	23:13:45.4	+61:28:09	5.705	High-Med	3600	
W3 IRS5	02:25:40.4	+62:05:52	6.175	High-Med	900	
NGC 7538 IRS1	23:13:45.4	+61:28:09	6.175	High-Med	3600	

All observations to be taken in the "nod" Observing Mode
The High-Low

Appendix A2- FIFI-LS Reserved Observations Catalog (ROC) – Pending observations

Target	RA (J2000)	DEC (J2000)	Extent (arcmin)	Lines B λ in μm	Lines R λ in μm	Time (h)
Brick	17:46:08.6	-28:42:46.0	3 x 5	[OI] λ63 OH λ79	[OI] λ145 [CII] λ157	3
M17-SW	18:20:23.1	-16:11:43	2.5 x 4	[OIII] λ52 [OIII] λ88 [OI] λ63	[CII] λ157 [OI] λ145 CO (17-16) λ153	3
W43-main	18:47:40.0	-01:57:00.0	5 x 5	OH λ79	CO (14-13) λ186	1
W40 - IRS5	18:31:14.82 18:31:21	-02:03:49.8 -2:06:51	2 x 2 2 x 1	[OI] λ63	[CII] λ157	1
DR21(OH)	20:39:00.7	+42:22:46.7	1 x 1	[OIII] λ52 [OIII] λ88 OH λ79	[OI] λ145 [CII] λ157	1
SgrA*	17:45:40	-29:00:28	2.5 x 2.5	OH λ79 OH λ119 [NII] λ57	CO (15-14) λ174 CO (19-18) λ137 CO (20-19) λ130	2
SgrA*	17:45:40	-29:00:28	10 x 10	[OI] λ63 [OIII] λ88 OH λ119	[CII] λ157 [OI] λ145 CO (14-13) λ186	6
Sickle	17:46:12	-28:48:30	3 x 3	[OIII] λ52 [OIII] λ88 [OI] λ63	[CII] λ157 [OI] λ145 CO (17-16) λ153	2
Arches	17:45:47	-28:50:40	1 x 1.5	[OIII] λ52 [OIII] λ88 [OI] λ63	[CII] λ157 [OI] λ145 CO (17-16) λ153	1
M83	13 37 00.9	-29 51 57	3 x 3	[OIII] λ52 [OIII] λ88 [OI] λ63	[CII] λ157 [OI] λ145 CO(14-13) λ186	4
IC10	00:20:17.3	+59:18:13.6	5 x 5	[NIII] λ57	[OI] λ145	1.5
NGC1140	02:54:33.6	10:01:39.9	2x2	[OIII] λ52	[OI] λ145	1.5
NGC4449	12:28:11.12	+44:05:36.8	2 x 2	[OIII] λ52 [NIII] λ57	[OI] λ145	3
NGC5253	13:39:55.96	-31:38:24.4	1x1	[OIII] λ52 [NIII] λ57	[OI] λ145	3
30Dor LMC	05:38:42.4	-69:06:03	4 x 4	[OIII] λ52 [OI] λ63	[CII] λ157 [OI]λ145	3
N159 E&W LMC	05:40:19 05:39:36	–69:44:52 -69:46:00	2 x 2 each	[OIII] λ52 [OI] λ63	[CII] λ157 [OI]λ145	2
N11 LMC	04:56:51.4	-66:24:44	3X3	[OIII] λ52 [OI] λ63	[CII] λ157 [OI]λ145	1.5
N44 LMC	05:22:06.9	-67:56:46	3X3	[OIII] λ52 [OI] λ63	[CII] λ157 [OI]λ145	1.5
N66 SMC	00:59:27.4	-72:10:11	3X3	[OIII] λ52 [OI] λ63	[CII] λ157 [OI]λ145	1.5

Appendix A3- FLITECAM Reserved Observations Catalog (ROC) – Pending observations

Table 1: Target List for PAH observations

Target	RA (J2000)	Dec (J2000)	Itime + O/H[1]	Type
HB 5	17:47:56.19	-29:59:41.9	1 hr	PN
NGC 6790	19:22:56.97	+01:30:46.5	1 hr	PN
BD +30 3639	19:34:45.23	+30:30:58.9	1 hr	PN
NGC 6886	20:12:42.81	+19:59:22.7	1 hr	PN
M 3-35	20:21:03.77	+32:29:23.9	1 hr	PN
SH2-106	20:27:27.1	+37:22:39.0	1 hr	HII Region
NGC 7027	21:07:01.59	+42:14:10.2	3 hr	PN
IRAS 21282+5050	21:29:58.42	+51:03:59.8	1 hr	PN
IC 5117	21:32:31.03	+44:35:48.5	1 hr	PN
CRL 618	04:42:53.67	+36:06:53.2	1 hr	PN
Orion Bar	05:32:55.3	-05:26:50.5	4 hr	HII Region
HD44179	06:19:58.22	-10:38:14.7	1 hr	Red Rectangle
Alpha Vul	19:28:42.32	+24:39:53.6	0.5 hr	Calibrator
75 Cyg	21:40:11.11	+43:16:25.8	0.5 hr	Calibrator
HD 10074	01:39:07.73	+36:32:36.1	0.5 hr	Calibrator
HD 13746	02:14:42.16	+30:23:41.2	0.5 hr	Calibrator

1. Total on-target integration time plus 30% overhead; total of 19 hours. Each observation requires a minimum of two narrow band images (on/off the PAH feature) and a 3.3 micron grism-mode spectrum. Up to ten “map” positions will be needed on the largest objects.

Table 2: Brown Dwarfs

Target	RA (J2000)	Dec (J2000)	Itime + O/H[1]	Type
Tdwarf1	07:22:27.27	-05:40:29.9	3 hr	J=16.5, W2=12.2
Tdwarf2	17:41:24.26	+25:53:19.5	3 hr	J=16.5, W2=12.3

1. Total on-target integration time plus 30% overhead; total of 6 hours. Each observation requires a minimum of three 3-5 micron grism spectra (L&M plus grisms A, B, and C using ABBA nodding) as well as two broad band images (5 point dither in L and M bands).

Table 3: Paschen Alpha Imaging

Target	RA (J2000)	Dec (J2000)	Itime + O/H[1]	Type
W51	09:23:27.61	+14:30:14.77	4 hr	Star Forming Region

1. Total on-target integration time plus 30% overhead; total of 4 hours. This observation requires a minimum of two narrow band images (5 point dithers in Paschen Alpha and Paschen Alpha Continuum) in at least six “map” positions. This observation is for FLIPO mode only.

Appendix A4 - FORCAST Imaging Reserved Observations Catalog (ROC)

Group	Target	RA (2000)	DEC	FOV (arcmin)	Sky Mode	λ SWC [μm]	λ LWC [μm]	Total time (incl. overhead) [h]
Galactic	Region H South	17 45 30.65	-28 55 29.0	3.2x3.2	C2NC2	19.7	31.5	0.449
Center	Region H South	17 45 30.65	-28 55 29.0	3.2x3.2	C2NC2	25.3	31.5	0.449
	Region H South	17 45 30.65	-28 55 29.0	3.2x3.2	C2NC2		37.1	0.449
	Region H North	17 45 38.66	-28 52 29.4	3.2x3.2	C2NC2	19.7	31.5	0.449
	Region H North	17 45 38.66	-28 52 29.4	3.2x3.2	C2NC2	25.3	31.5	0.449
	Region H North	17 45 38.66	-28 52 29.4	3.2x3.2	C2NC2		37.1	0.449
	Arches W	17 45 33.51	-28 49 34.0	3.2x3.2	C2NC2	25.3	37.1	0.449
	Arches NW	17 45 34.93	-28 46 25.0	3.2x3.2	C2NC2	25.3	31.5	0.449
	Arches NW	17 45 34.93	-28 46 25.0	3.2x3.2	C2NC2	19.7	37.1	0.449
	Arches NW	17 45 34.93	-28 46 25.0	3.2x3.2	C2NC2		37.1	0.449
	Arches NE	17 45 49.44	-28 45 34.5	3.2x3.2	C2NC2	25.3	31.5	0.683
	Arches NE	17 45 49.44	-28 45 34.5	3.2x3.2	C2NC2	19.7	37.1	0.971
	Arches NE	17 45 49.44	-28 45 34.5	3.2x3.2	C2NC2		37.1	1.497
	Arches E	17 45 49.43	-28 48 15.8	3.2x3.2	C2NC2	25.3	31.5	0.342
	Arches E	17 45 49.43	-28 48 15.8	3.2x3.2	C2NC2	19.7	37.1	0.342
	Arches E	17 45 49.43	-28 48 15.8	3.2x3.2	C2NC2		37.1	1.870
	Arches SE	17 45 46.07	-28 50 43.1	3.2x3.2	C2NC2	25.3	31.5	1.037
	Arches SE	17 45 46.07	-28 50 43.1	3.2x3.2	C2NC2	19.7	37.1	0.378
	Arches SE	17 45 46.07	-28 50 43.1	3.2x3.2	C2NC2		37.1	0.283
Circumstellar shells	R Scl	01 26 58.09	-32 32 35.4	3.2x3.2	NMC	19.7	34.8	1.237
	R Scl	01 26 58.09	-32 32 35.4	3.2x3.2	NMC	25.3	31.5	0.088
	R Scl	01 26 58.09	-32 32 35.4	3.2x3.2	NMC		37.1	0.321
Extra-galactic	NGC 4038/9	12:01:52	-18:52:02.9	3.2x3.2	NMC	19.7	37.1	0.321
	NGC 4038/9	12:01:52	-18:52:02.9	3.2x3.2	NMC		31.5	0.933
	NGC1068	02:42:40.8	-00:00:48.4	3.2x3.2	NMC	19.7	31.5	0.088
	NGC1068	02:42:40.8	-00:00:48.4	3.2x3.2	NMC		37.1	0.321
HII / PDR	Orion Bar	05 35 22.2	-05 25 37.6	12.8x9.6	C2NC2		11.3	0.933
Galactic	DK Tau	04:30:44.2	26:01:24.8	3.2x3.2	NMC	19.7		0.088
Star formation	DK Tau	04:30:44.2	26:01:24.8	3.2x3.2	NMC		24.2	0.321
	DK Tau	04:30:44.2	26:01:24.8	3.2x3.2	NMC		34.8	0.933
	GG Tau B	04:32:30.3	17 31 40.7	3.2x3.2	NMC	19.7		0.050

	GG Tau B	04:32:30.3	17 31 40.7	3.2x3.2	NMC		24.2	0.183
	GG Tau B	04:32:30.3	17 31 40.7	3.2x3.2	NMC		34.8	0.533
	FV Tau	04:26:53.5	26:06:54.1	3.2x3.2	NMC	19.7		0.050
	FV Tau	04:26:53.5	26:06:54.1	3.2x3.2	NMC		24.2	0.183
	FV Tau	04:26:53.5	+26:06:54.06	3.2x3.2	NMC		34.8	0.533
	UZ Tau	04:32:43.0	25:52:31.1	3.2x3.2	NMC	19.7		0.050
	UZ Tau	04:32:43.0	25:52:31.1	3.2x3.2	NMC		24.2	0.183
	UZ Tau	04:32:43.0	25:52:31.1	3.2x3.2	NMC		34.8	0.533
	NGC 2024	05 41 42.0	-01 54 00.0	3.2x3.2	C2NC2	19.7	31.5	0.225
	NGC 2024	05 41 42.0	-01 54 00.0	3.2x3.2	C2NC2	25.3	37.1	0.225
	NGC 2024	05 41 46.5	-01 55 45.0	3.2x3.2	C2NC2	19.7	31.5	0.225
	NGC 2024	05 41 46.5	-01 55 45.0	3.2x3.2	C2NC2	25.3	37.1	0.225

Appendix A5 - FORCAST grism Reserved Observations Catalog (ROC)

Target	RA (2000)	DEC	Sky Mode	SLIT	λ SWC [μm]	λ LWC [μm]	Total time (incl. overhead) [h]
W3OH-2MASS+6152344-1	02 27 08.87	+61 52 34.4	NMC	FOR_LS24	FOR_G111	OPEN	0.436
W3OH-2MASS+6152344-1	02 27 08.87	+61 52 34.4	NMC	FOR_LS47	OPEN	FOR_G329	0.436
NGC 2024 FIR 6c	05 41 45.14	-01 56 04.4	NXCAC	FOR_LS47	FOR_G111	OPEN	0.436
NGC 2024 FIR 6c	05 41 45.14	-01 56 04.4	NXCAC	FOR_LS47	OPEN	FOR_G329	0.436
HD 37022 (theta1c)	05 35 16.46	-05 23 22.85	C2NC2		FOR_F197	OPEN	0.160
HD 37022 (theta1c)	05 35 16.46	-05 23 22.85	C2NC2		OPEN	FOR_F371	0.778
Orion BN	05 35 14.11	-05 22 22.7	NMC	FOR_SS24	FOR_XG063	OPEN	0.096
Orion BN	05 35 14.11	-05 22 22.7	NMC	FOR_SS24	FOR_XG111	OPEN	0.096
Orion BN	05 35 14.11	-05 22 22.7	NMC	FOR_LS24	OPEN	FOR_G227	0.449
Orion BN	05 35 14.11	-05 22 22.7	NMC	FOR_LS24	OPEN	FOR_G329	0.449
IRc4	05 35 14.10	-05 22 34.7	NMC	FOR_LS24	OPEN	FOR_G227	0.042
IRc4	05 35 14.10	-05 22 34.7	NMC	FOR_LS24	FOR_G063	OPEN	0.096
IRc4	05 35 14.10	-05 22 34.7	NMC	FOR_LS24	FOR_G111	OPEN	0.096
IRc4	05 35 14.10	-05 22 34.7	NMC	FOR_LS24	OPEN	FOR_G329	0.032
DF Tau	04 27 02.79	+25 42 22.4	NMC	FOR_LS24	FOR_G063	OPEN	1.493

Appendix A6 - GREAT Cycle 4 Reserved Observations Catalog (ROC)

Science	Object Name	RA	DEC	ν 1	ν 2	ν 3	area	Time
		(2000)	(2000)	[THz]			arcmin	[hr]
PP disks	DG Tau	04:27:04.7	+26:06:16.3	all lines below			0.3	0.5
	HL Tau	04:31:38.4	+18:13:57.7	all lines below			0.3	0.5
	AB Aur	04:55:45.8	-06:57:59.5	all lines below			0.3	0.5
	HD50138	06:51:33.4	-06:57:59.5	all lines below			0.3	0.5
	HD100546	11:33:25.4	-70:11:41.2	all lines below			0.3	0.5
	HD163296	17:56:21.3	-21:57:21.9	all lines below			0.3	0.5
	HD97048	11:08:03.3	-77:39:17.4	all lines below			0.3	0.5
Star formation cores	IRAS16293-2422	16:32:22.6	-24:28:33.0	#1	#2	4.7	1	done
	SgrB2(M)(N)	17:47:20.4	-28:23:07.0	#1	#2	4.7	2	done
	W28A	18:00:30.4	-24:04:00.0	#1	#2	4.7	1	0.3
	W31C	18:10:28.7	-19:55:50.0	#1	#2	4.7	1	0.3
	W33A	18:14:39.4	-17:52:00.0	#1	#2	4.7	1	0.3
	W49N	19:10:13.2	+09:06:12.0	#1	#2	4.7	1	done
	DR21(OH)	20:39:00.7	+42:22:46.7	#1	#2	4.7	2	0.6
	W43-MM1	18:47:47.0	-01:54:28.0	#1	#2	4.7	1	0.3
	W3- IRS1	02:25:40.6	+62:05:51.0	#1	#2	4.7	1	0.6
	W3(OH)	02:27:04.1	+61:52:22.0	#1	#2	4.7	1	0.6
	G31.41	18:47:34.3	-01:12:46.0	#1	#2	4.7	1	0.3
	G29.96	18:46:03.8	-02:39:22.0	#1	#2	4.7	1	0.3
	NGC7538	23:13:45.3	+61:28:10.0	#1	#2	4.7	2	0.6
	W51D/E1	19:23:43.8	+14:30:26.0	#1	#2	4.7	2	0.6
	G34.26	18:53:18.6	+01:14:58.0	#1	#2	4.7	1	done
	G10.47	18:08:38.2	-19:51:50.0	#1	#2	4.7	1	0.3
	G5.89	18:00:30.4	-24:04:02.0	#1	#2	4.7	1	0.3
	Orion-KL	05:35:15.1	-05:22:26.6	#1	#2	4.7	2	0.5
	Orion-Bar	05:35:22.1	-05:25:13.4	#1	#2	4.7	2	0.6
	M17SW	18:20:27.6	-16:12:00.9	CO	#2	4.7	1	done
	G333.6	16:22:09.0	-50:06:15.0	CO	#2	4.7	30	1.0
	NGC2024	05:41:45.2	-01:55:45.0	CO	#2	4.7	2	1.0
	S106	20:27:26.7	37:22:47.9	CO	#2	4.7	2	1.0
	NGC6334I	17:20:53.3	-35:47:01.5	#1	#2	4.7	2	0.5
	NGC6334I(N)	17:20:55.1	-35:45:08.8	#1	#2	4.7	2	0.5
	IRAS17233	17:26:42.5	-36:09:18.1	#1	#2	4.7	2	1.0
	AG351.58-0.35	17:25:25.0	-36:12:45.4	#1	#2	4.7	2	0.5

p-H_2D^+ /o-D_2H^+	IRAS16293E	16:32:29.4	-24:28:52.6	1.37		1.48	1	1
	IRAS16293A/B	16:32:22.9	-24:28:39.7	1.37		1.48	1	0.5
Outflow studies	IRAS18151-1208	18:18:10.3	-12:07:27.0	CO	#2	4.7	1	0.5
	IRAS17233-3606	17:26:42.5	-36:09:18.0	CO	#2	4.7	1	0.5
	IRAS05358+3543	05:39:13.1	+35:45:50.0	CO	#2	4.7	1	0.5
	IRAS20126+4104	20:14:25.1	+41:13:32.0	CO	#2	4.7	1	0.5
	eta Carina	10:45:03.6	-59:41:04.3	CO	#2	4.7	1	0.5
	HH212	05:43:51.4	-01:02:53.0	CO	#2	4.7	2	0.7
	BHR71	12:01:36.3	-65:08:53.0	CO	#2	4.7	2	done
	HH111	05:51:46.3	+02:48:30.0	CO	#2	4.7	2	0.7
	NGC2071	05:47:04.7	+00:21:44.0	CO	#2	4.7	2	1.0
	NGC1333	03:28:55.6	+31:14:37.1	CO	#2	4.7	3	1.0
	HH54	12:55:50.3	-76:56:23.0	CO	#2	4.7	2	0.5
	G327-0.6	15:53:08.8	-54:37:01.0	CO	#2	4.7	2	0.5
	AG012.81-0.20	18:14:13.5	-17:55:32.0	CO	#2	4.7	2	0.5
	AG015.03-0.67	18:20:22.4	-16:11:43.8	CO	#2	4.7	3	0.5
Stars	ALF-Ori	05:55:10.3	+07:24:25.0	CO	1.9	4.7	1	0.5
	VY-CMa	07:22:58.3	-25:46:03.1	CO	1.9	4.7	1	0.5
	O-Ceti	02:19:20.8	-02:58:43.0	CO	1.9	4.7	1	0.5
	IK-Tau	03:53:28.9	+11:24:21.7	CO	1.9	4.7	1	0.5
(P)PNe	NGC7027	21:07:01.6	+42:14:10.2	CO	1.9	4.7	1	done
	CRL618	04:42:53.6	+36:06:53	CO	1.9	4.7	0.5	0.5
	CRL2688	21:02:18.7	+36:41:37.8	CO	1.9	4.7	0.5	0.5
	OH231.8+4.2	07:42:16.8	-14:42:52.1	CO	1.9	4.7	0.5	0.5
	NGC6302	17:13:29.3	-37:06:11.2	CO	1.9	4.7	0.5	0.5
	BD+30 3639	19:34:45.2	+30:30:58.8	CO	1.9	4.7	0.5	0.5
	IRAS21282+5050	21:59:58.4	+51:03:59.8	CO	1.9	4.7	0.5	0.5
Galactic PDRs	IC1396	21:40:42.3	+58:16:10.0	CO	1.9	4.7	60	1.0
	DR21C	20:39:00	+42:19:42.0	CO	1.9	4.7	4	done
	IC63	00:58:55	+60:53:11.0	CO	1.9	4.7	2	1.0
	Carina N	10:43:30.9	-59:34:16.3	CO	1.9	4.7	3	2.0
	NGC3603	11:15:08.9	-61:16:50.0	CO	1.9	4.7	5	1.0
	OMC2	05:35:25.0	-05:12:30.0	CO	1.9	4.7	7	1.5
	OMC3	05:12:30.0	-05:03:45.0	CO	1.9	4.7	7	1.5
	Orion-fSE1/2	05:36:15.0	-05:38:00.0	CO	1.9	4.7	15	2.0
upGREAT	Horse Head	05:40:59.0	-02:27:30		1.9		30	6.0

LMC PDRs	N159	05:39:57.2	-69:44:33.0	1.46	1.9	4.7	2	1.0
	30 Dor	05:38:42.4	-69:06:03.3	1.46	1.9	4.7	2	1.0
	N160	05:39:40.3	-69:39:01.1	1.46	1.9	4.7	1	1.0
SMC PDRs	N88	01:24:08.5	-73:08:53.2	1.46	1.9	4.7	1	0.5
	N66	00:59:27.4	-72:10:10.7	1.46	1.9	4.7	1	0.5
Galactic Center Studies	Sickle	17:46:14.7	-28:48:55.9	CO	1.9	4.7	3	0.75
	Arches	17:45:51.0	-28:48:22.0	CO	1.9	4.7	3	0.75
	M-002-007	17:45:51.7	-28:59:13.7	CO	1.9	4.7	3	0.5
	M-013-008	17:45:36.8	-29:05:23.8	CO	1.9	4.7	3	0.5
	SgrA /CND	17:45:39.9	-29:00:28.2	all bands			10	2.0
	M+0.253	17:46:09.0	-28:42:40.0	CO	1.9	4.7	3	1.0
	M-3.8+0.9	17:32:53.5	-31:43:21.8	CO	1.9	4.7	10	1.0
Chlorine chemistry	Venus	HCl		1.25		4.7	-	0.75
	Jupiter	HCl		1.25		4.7	-	0.75
	Saturn	HCl		1.25		4.7	-	0.75
Hydrogen chemistry	Mars	HDO, ($H_2{}^{16}O$), $H_2{}^{18}O$		1.27	1.89	4.7	-	0.75
		H_2O_2			1.85	1.90	-	0.75
nearby nuclei	M82	09:55:52.2	+69:40:49.6	all lines below			1	2.0
	NGC253	00:47:33.1	-25:17:17.6	all lines below			1	1.5
	NGC4945	13:05:27.5	-49:28:05.6	all lines below			1	1.5
	Cen-A	13:25:27.6	-43:01:08.9			4.7	1	1.5
MHD shocks	IC443	06:17:42.5	+22:21:30.0	all lines below			40	2.0
	W28F	18:01:52.3	-23:19:25.0	CO	#2	4.7	2	done
	W44 E/F	18:56:28.4	+01:29:55.0	CO	#2	4.7	2	1.0
	3C391	18:49:22.3	-00:57:22.0	CO	#2	4.7	2	1.0

Times given in the last column are total integration times (on and off source), but no overheads due to calibration/facility inefficiencies have been added. Min map size of observation is one arcmin (though in most cases this will be the central beam only). In most targets "CO" refers to the J–transition accessible in bands L1-L2, including selected isotopologues.

Frequency (THz) Species
set-up #2 (in band L2): 1.81 (NH3), #2 (OH), 1.9 ([CII])
set-up #1 (in band L1): 1.39 (OD), CO
1.37 p-H_2D^+
1.39 OD
1.46 [N II]
1.48 o-D_2H^+
4.7 [OI]

Appendix A7 – HAWC+ Cycle 4 Reserved Observations Catalog (ROC)

Source	Band	R.A.	Dec.	map area	Time	mode
		(J2000)	(J2000)	[arcmin]	[h]	
NGC253	A (53)	00 47 33.1	-25 17 18	3 x 2	0.5	polarimetry
NGC253	C (89)	00 47 33.1	-25 17 18	5 x 3	0.5	polarimetry
NGC891	D (155)	02 22 33.4	+42 20 57	7 x 5	3.5	polarimetry
W3_OH	C (89)	02 27 04.7	+61 52 24.7	5 x 3	1.4	polarimetry
W3_OH	E (216)	02 27 04.7	+61 52 24.7	10 x 6	0.3	polarimetry
NGC1068	A (53)	02 42 40.7	-00 00 48	3 x 2	0.5	polarimetry
NGC1068	C (89)	02 42 40.7	-00 00 48	5 x 3	0.5	polarimetry
IRAS4A	D (155)	03 29 10	+31 13 32	7 x 5	1.5	polarimetry
IRAS4A	E (216)	03 29 10	+31 13 32	10 x 6	1.3	polarimetry
HL Tau	A (53)	04 31 38	+18 13 58	3 x 2	0.6	polarimetry
HL Tau	B (62)	04 31 38	+18 13 58	5 x 3	0.6	polarimetry
HL Tau	C (89)	04 31 38	+18 13 58	5 x 3	0.5	polarimetry
HL Tau	D (155)	04 31 38	+18 13 58	7 x 5	0.5	polarimetry
HL Tau	E (216)	04 31 38	+18 13 58	10 x 6	0.6	polarimetry
L1527	D (155)	04 39 54	+26 03 10	7 x 5	1.6	polarimetry
L1527	E (216)	04 39 54	+26 03 10	10 x 6	1.4	polarimetry
L1544	E (216)	05 04 16.6	+25 10 48.0	10 x 6	3	polarimetry
OMC1	A (53)	05 35 17.8	-05 23 17.1	6 x 6	1.9	polarimetry
OMC1	B (62)	05 35 17.8	-05 23 17.1	8 x 8	1.5	polarimetry
OMC1	C (89)	05 35 17.8	-05 23 17.1	8 x 8	1.5	polarimetry
OMC1	D (155)	05 35 17.8	-05 23 17.1	8 x 8	0.3	polarimetry
OMC1	E (216)	05 35 17.8	-05 23 17.1	8 x 8	0.3	polarimetry
SN 1987A	C (89)	5 35 28	-69 16 11	5 x 3	0.6	total intensity
SN 1987A	D (155)	5 35 28	-69 16 11	7 x 5	0.4	total intensity
SN 1987A	E (216)	5 35 28	-69 16 11	10 x 6	0.5	total intensity
Vela C	C (89)	08 59 25.4	-43 45 58.9	5 x 3	1.4	polarimetry
Vela C	E (216)	08 59 25.4	-43 45 58.9	10 x 7	1.4	polarimetry
M82	A (53)	09 55 52.7	+69 40 46	3 x 2	0.5	polarimetry
M82	D (155)	09 55 52.7	+69 40 46	7 x 5	0.5	polarimetry
M51	E (216)	13 29 56.2	+47 13 50	10 x 6	3.5	polarimetry
Arp220	D (155)	15 34 57.1	+23 30 11	7 x 5	1	polarimetry
RhoOph L1688	A (53)	16 26 32.2	-24 23 32.2	3 x 3	3.3	polarimetry
RhoOph L1688	C (89)	16 26 32.2	-24 23 32.2	6 x 6	3.3	polarimetry
RhoOph L1688	E (216)	16 26 32.2	-24 23 32.2	10 x 12	2.2	polarimetry

NGC6334_S	B (62)	17 20 19.1	-35 54 45.0	5 x 3	1	polarimetry
NGC6334_S	C (89)	17 20 19.1	-35 54 45.0	5 x 3	0.3	polarimetry
NGC6334_S	D (155)	17 20 19.1	-35 54 45.0	8 x 5	0.3	polarimetry
NGC6334_S	E (216)	17 20 19.1	-35 54 45.0	10 x 7	0.3	polarimetry
CND	A (53)	17 45 40	-29 00 28	4.8 x 4.8	4.5	polarimetry
CMZ Warm Dust Survey	C (89)	17 45 54	-28 54 28	42 x 18	5	polarimetry
Sickle	A (53)	17 46 15	-28 48 11	9 x 5.4	3	polarimetry
M17	B (62)	18 20 29.3	-16 10 01.6	7 x 7	1.2	polarimetry
M17	C (89)	18 20 29.3	-16 10 01.6	8 x 8	1.9	polarimetry
M17	D (155)	18 20 29.3	-16 10 01.6	10 x 10	0.3	polarimetry
M17	E (216)	18 20 29.3	-16 10 01.6	10 x 10	0.3	polarimetry
L1157	E (216)	20 39 06	+68 02 16	10 x 6	2.5	polarimetry
NGC7023_POS1	C (89)	21 01 30	+68 09 48	3.5 × 3.5	2	polarimetry
NGC7023_POS2	D (155)	21 01 36.9	+68 09 48	6 × 6	1.5	polarimetry
NGC7023_POS2	E (216)	21 01 36.9	+68 09 48	6 × 6	1	polarimetry
BL Lac	E (216)	22 02 43.3	+42 16 40	10 x 6	1	polarimetry
Cas A	C (89)	23 23 24	+58 48 54	5 x 5	1	polarimetry