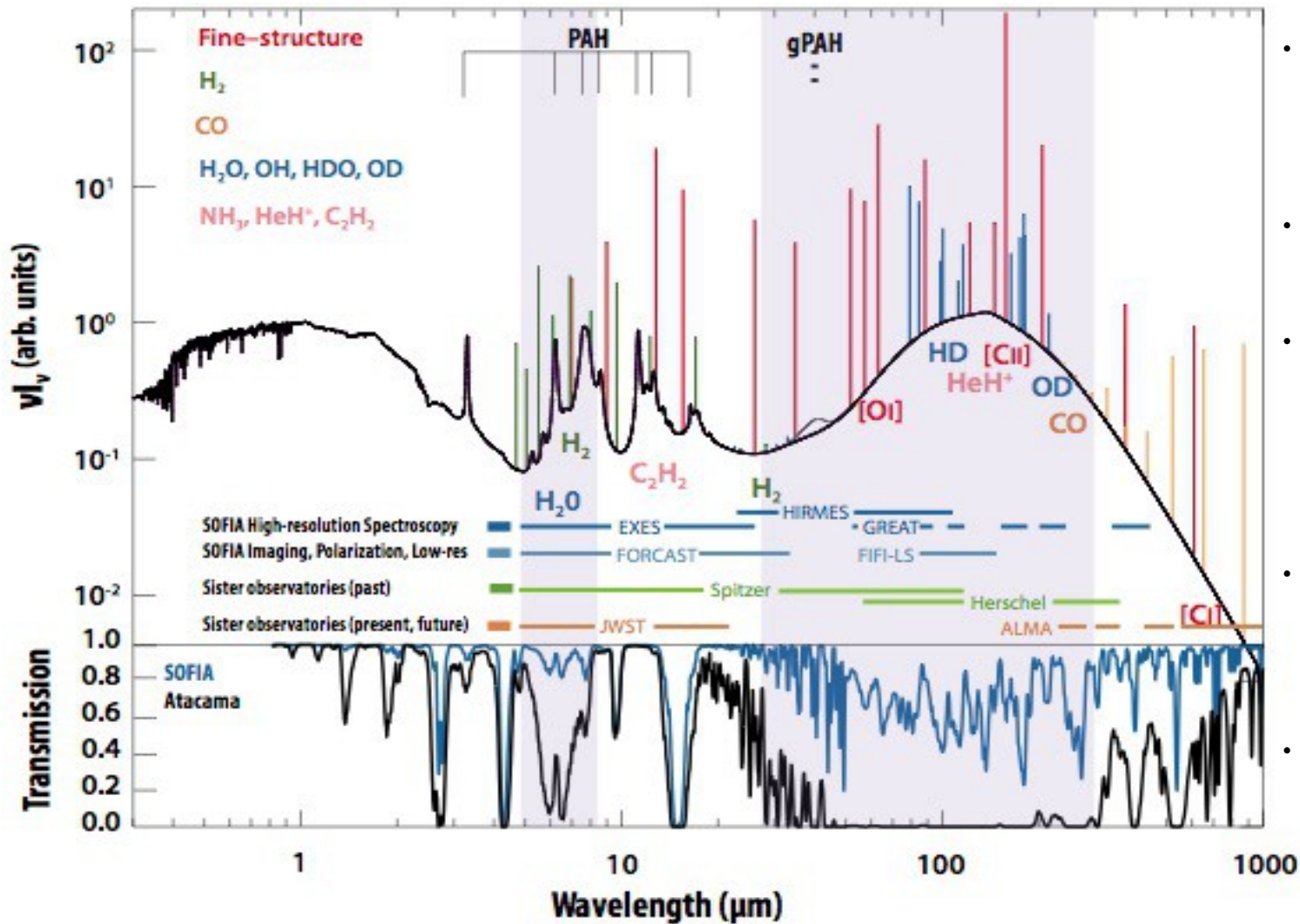


SOFIA in Cycle 9 : Overview and Proposal Process

Why Infrared Astronomy?

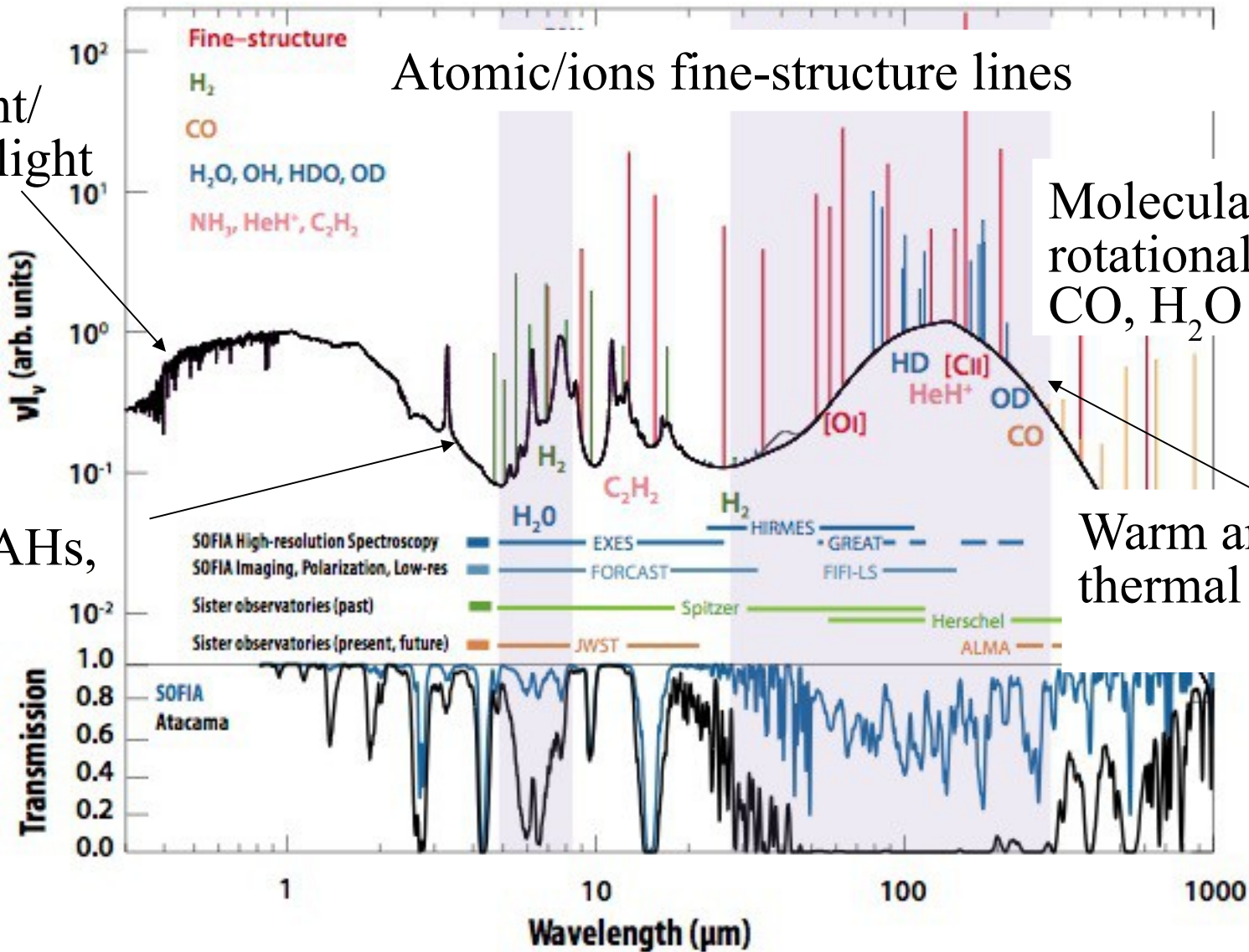


- Half of radiated energy in the Universe is **infrared**.
- Mostly re-radiated starlight
- Probes the cold-ish universe
- Most IR not observable from ground.
- SOFIA is a platform at up to 45000 feet km for IR observations.

Why Infrared Astronomy?

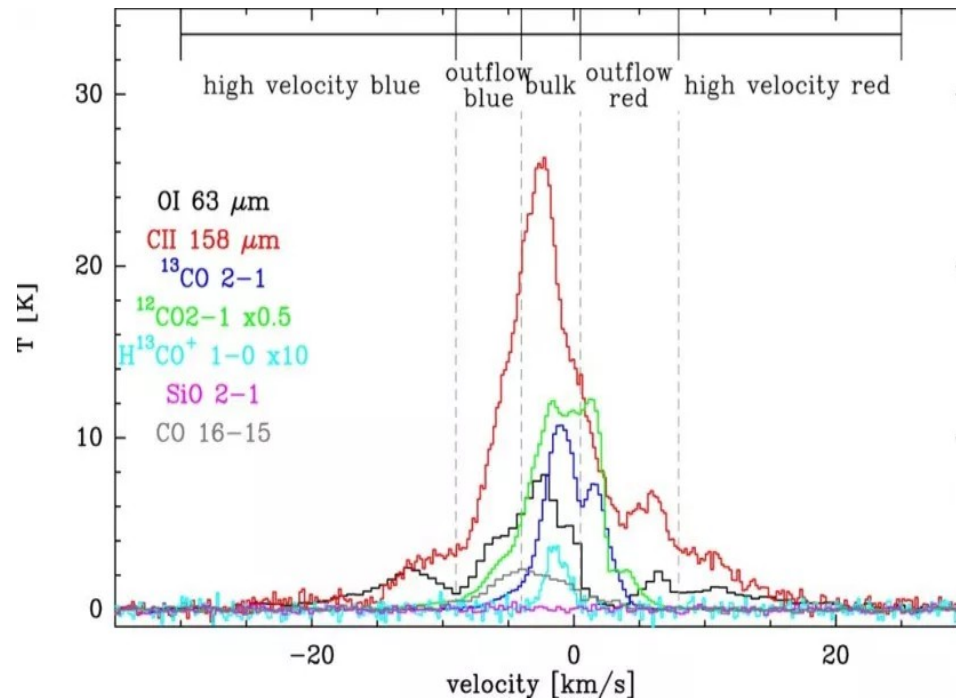
Some starlight/
reflected starlight

Dust spectral
signatures: PAHs,
silicates



Why Infrared Astronomy?

Schneider et al.,
2017: lines in star
forming region
nebula S106



- C, Na, Mg, Al, Si, S, Ca, Fe, Ni can all be easily ionized by background starlight

- H₂(2-0)-para: 28 μm, H₂(3-1)-ortho: 17 μm

- water rotational lines > 35 μm

Gas spectroscopy:

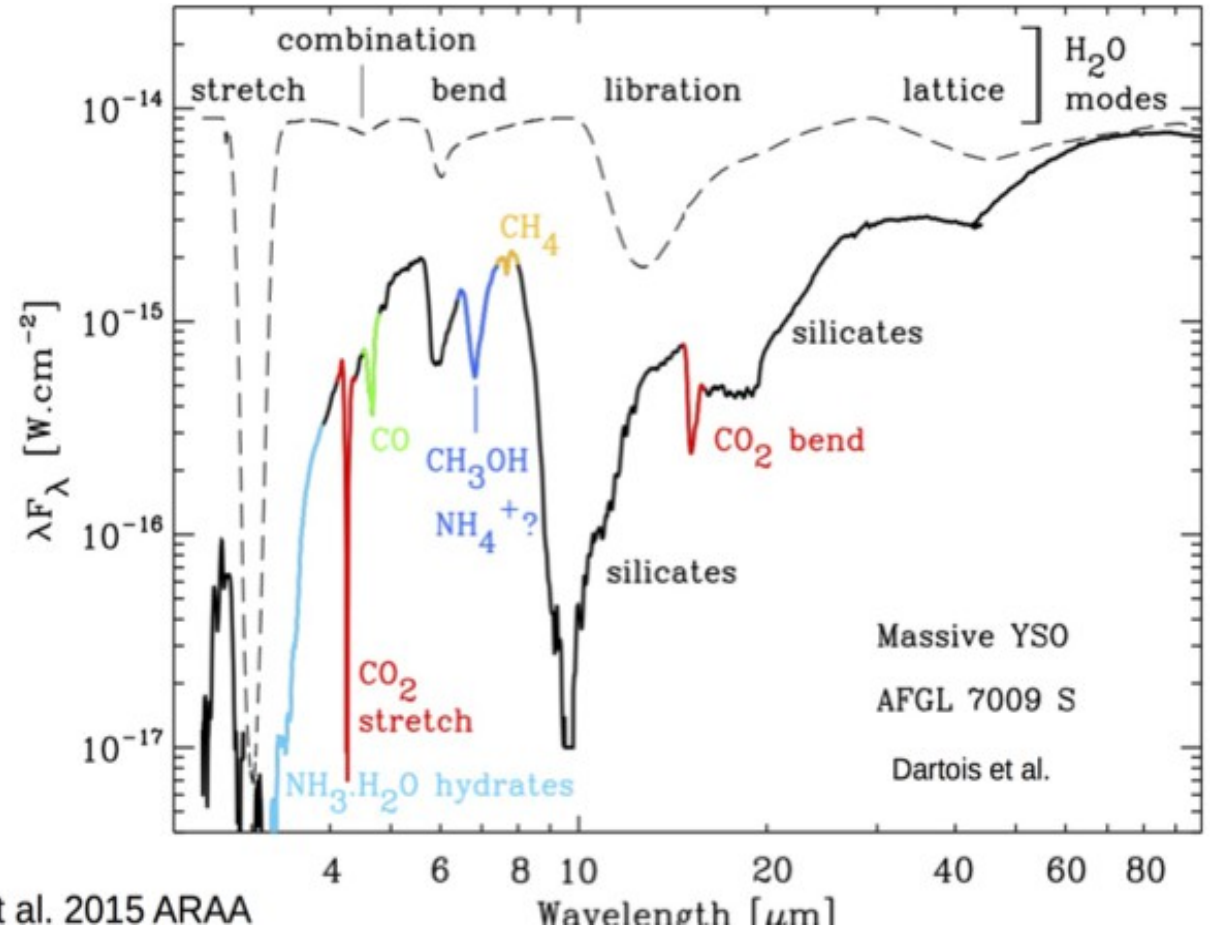
- composition
- kinematics
- temperature structure
- morphology (imaging): [OIII] traces very energetic UV fields
- role in heating/ cooling ([CII])

Why Infrared Astronomy?

Dust/ice spectroscopy/photometry:

- composition
- size distribution
- morphology (imaging)
- polarization fraction/orientation

- role in heating / cooling
- role in solid/gas chemistry
- role in hydrodynamics
- magnetic field coupling



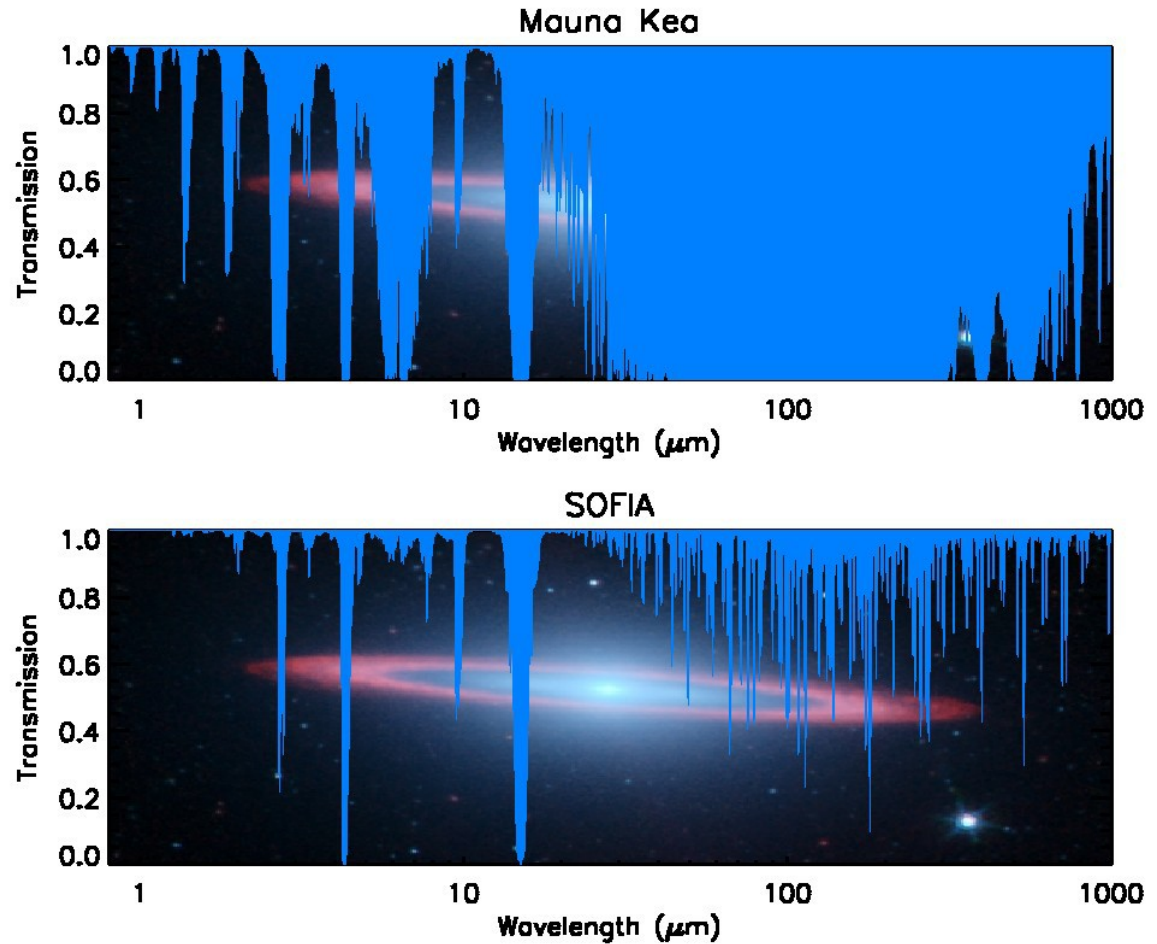
300qert et al. 2015 ARAA

Wavelength [μm]

A flying telescope: some considerations

- SOFIA flies above ~99% of water vapor in the atmosphere, **but remaining 1% is still significant...**
 - SOFIA pwv: 4 – 27 um (45k – 35k feet)
 - Mauna Kea pwv: 0.8 – 4.5 *mm*

Choice of wavelength must be done considering transmission, instrument noise (sometimes source velocity)



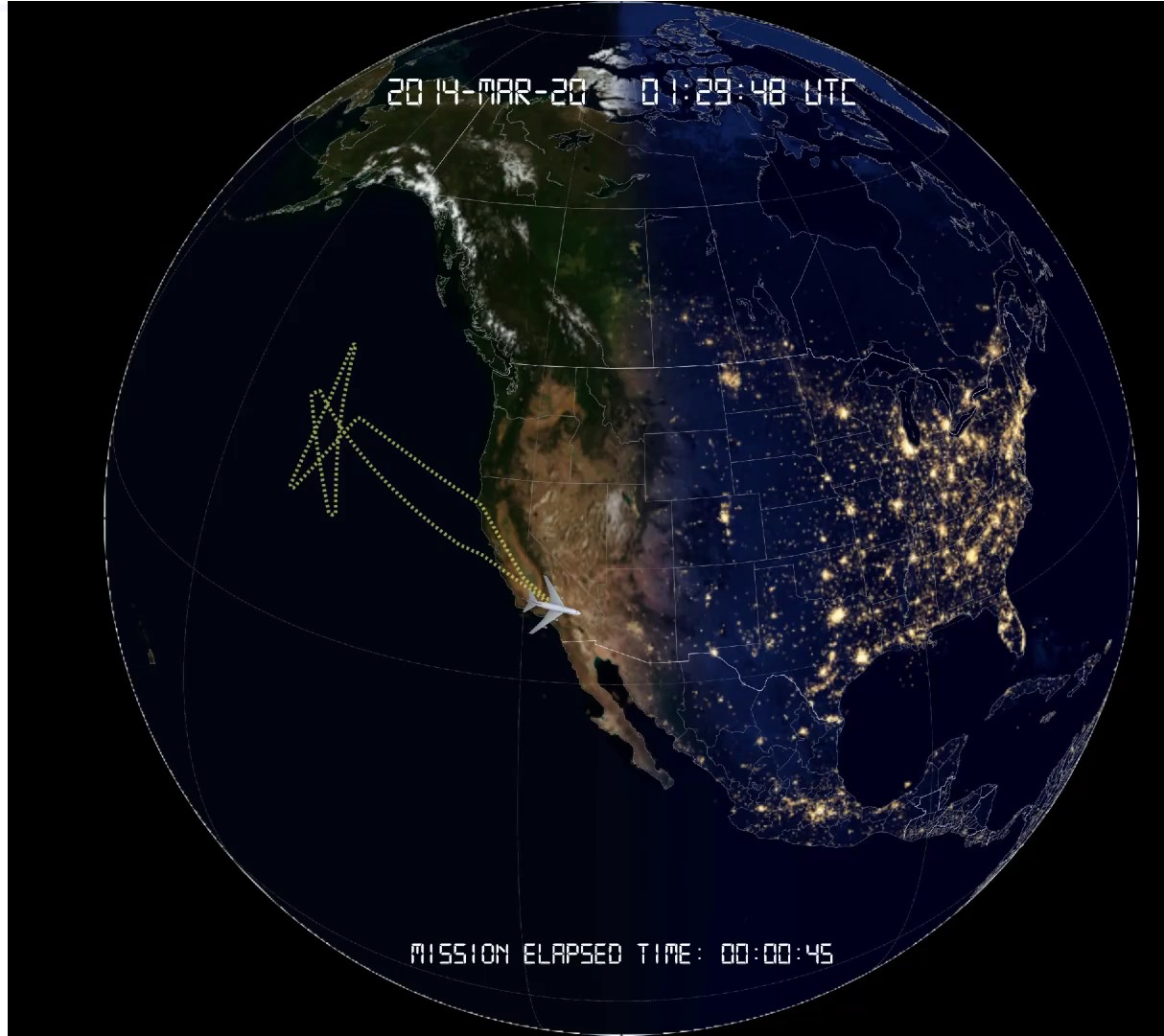
A flying telescope: some considerations



The telescope tilts up and down inside the plane: 22 – 58 deg elevation range

The telescope can rotate in all directions by +/-3 deg

A flying telescope: some considerations



SOFIA Flight #153 with FORCAST

- ✈️ 1. Takeoff
- 2. delta Lep (Calibrator)
- 3. Orion Bar
- 4. NGC 4144
- 5. IRAS05341+0852
- 6. alpha Boo (Calibrator)
- 7. IC2233
- 8. HD 200775
- 9. BD+40 4124
- 10. Landing

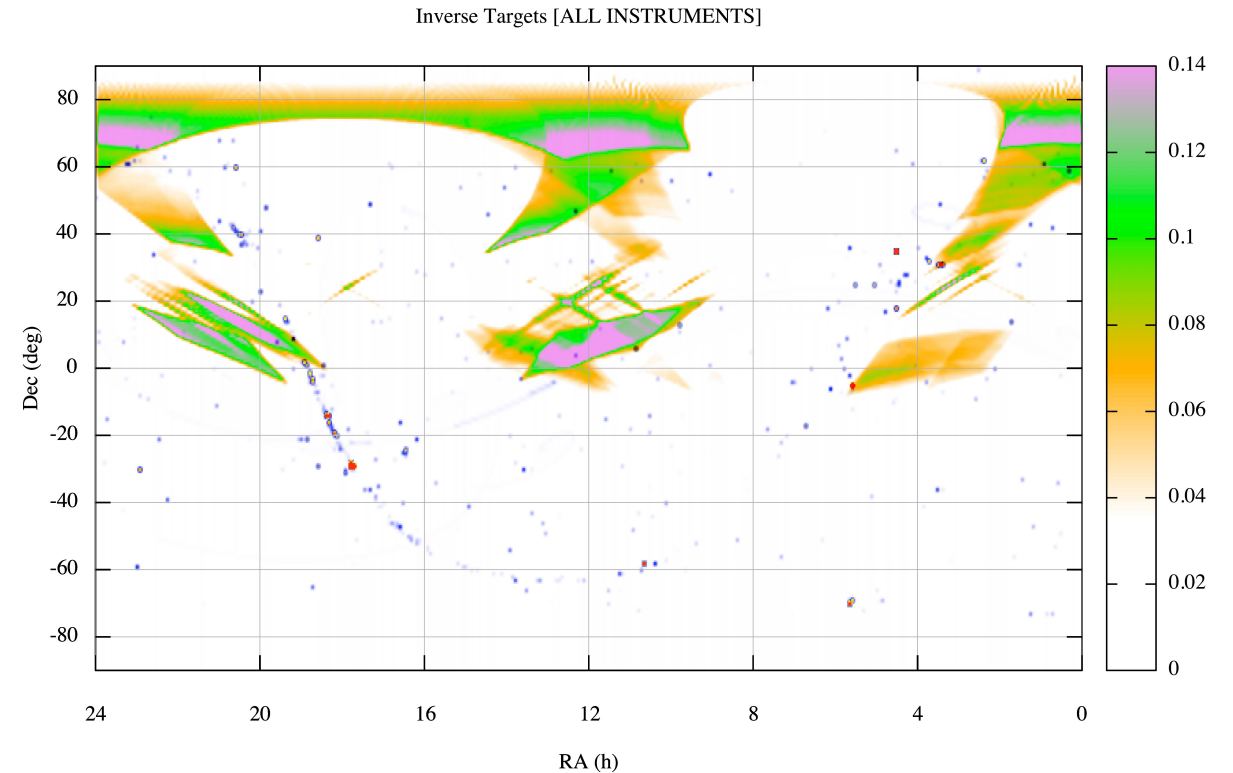
Maximum leg length ~ 4 hours : easier to schedule observations which can be easily 'chopped' in a few hours chunks

Plane usually returns to base at the end of flight

A flying telescope: some considerations

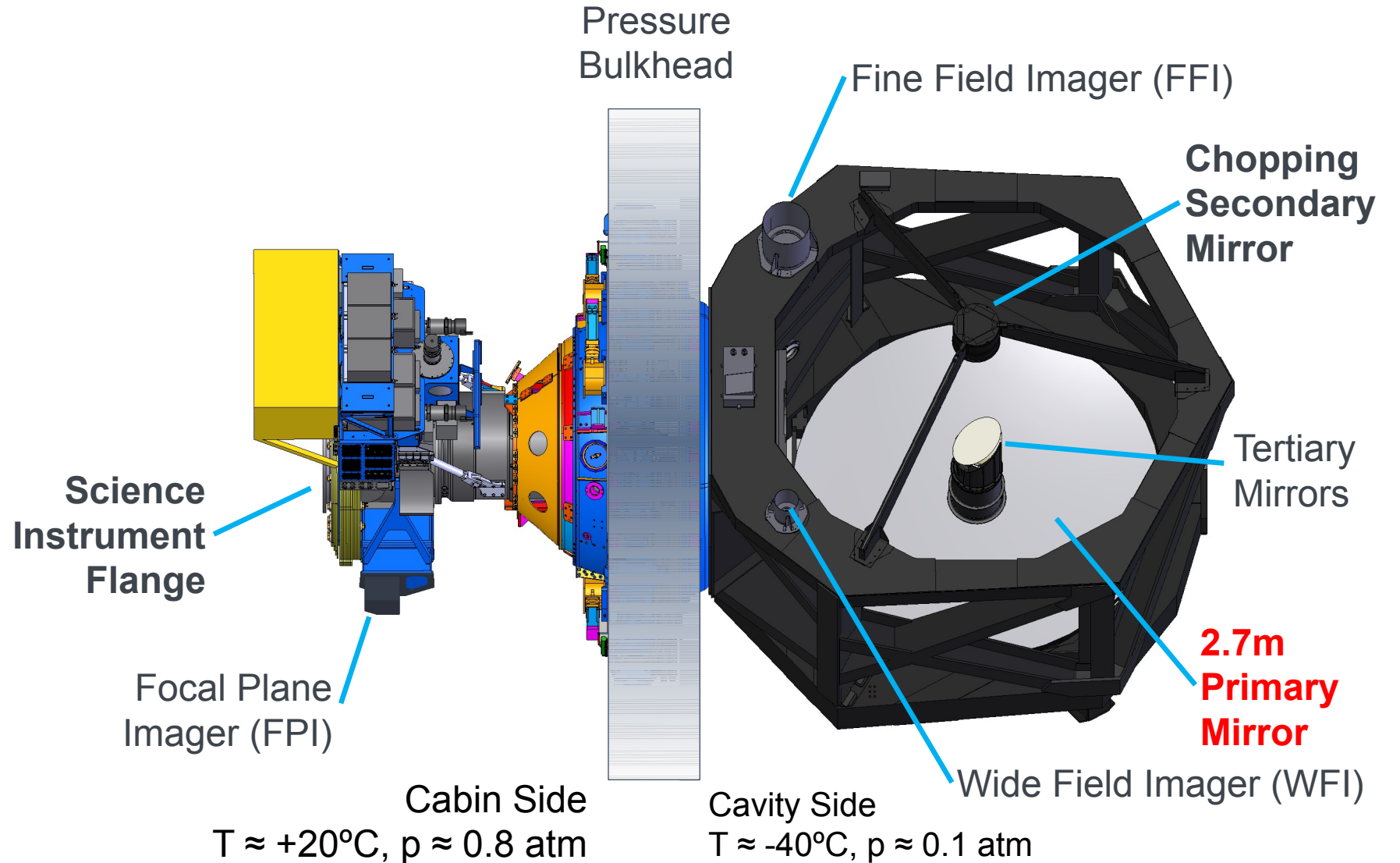
Even though bulk of targets are concentrated in the GP and ecliptic, you can only spend 1/2 of the time flying to view those directions and the other 1/2 on the return

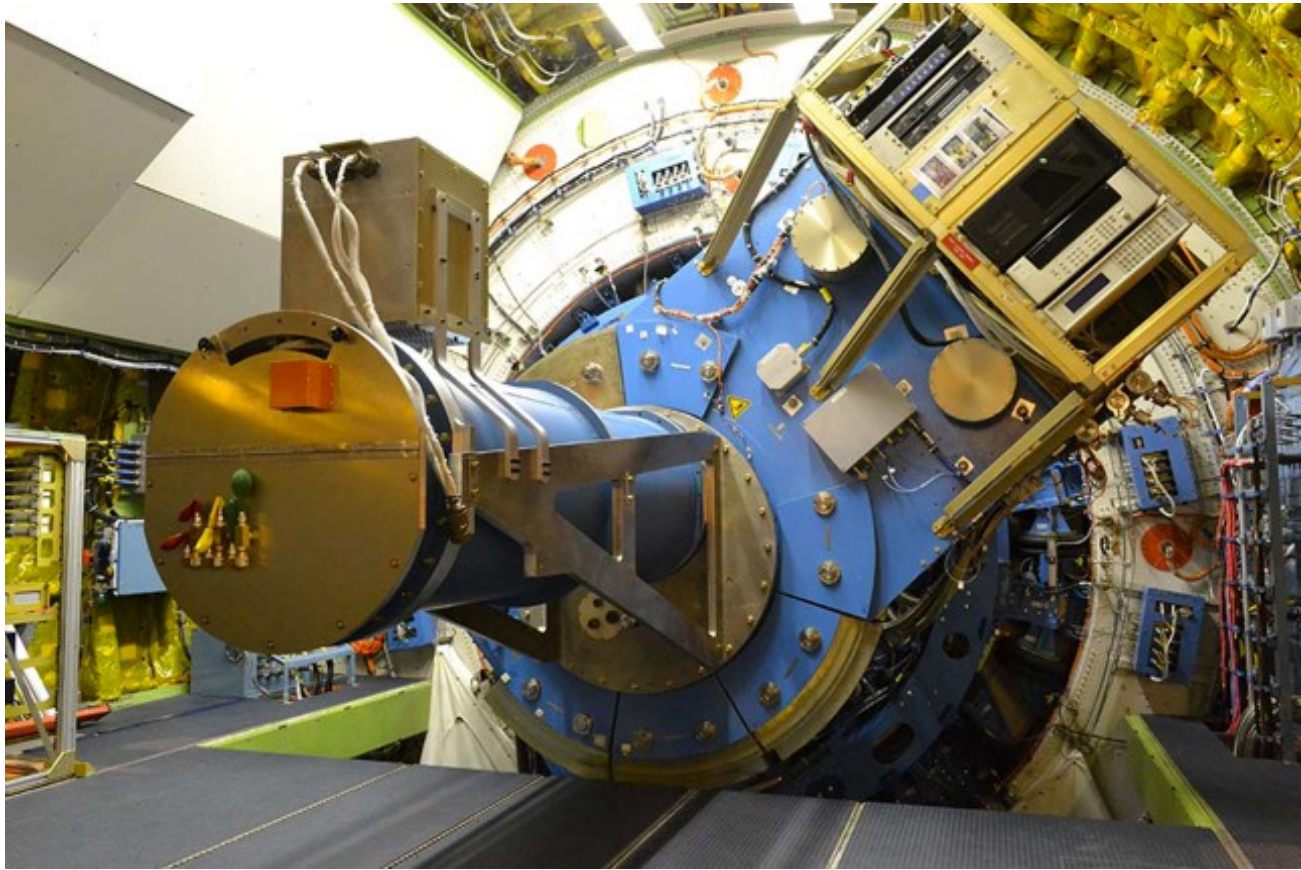
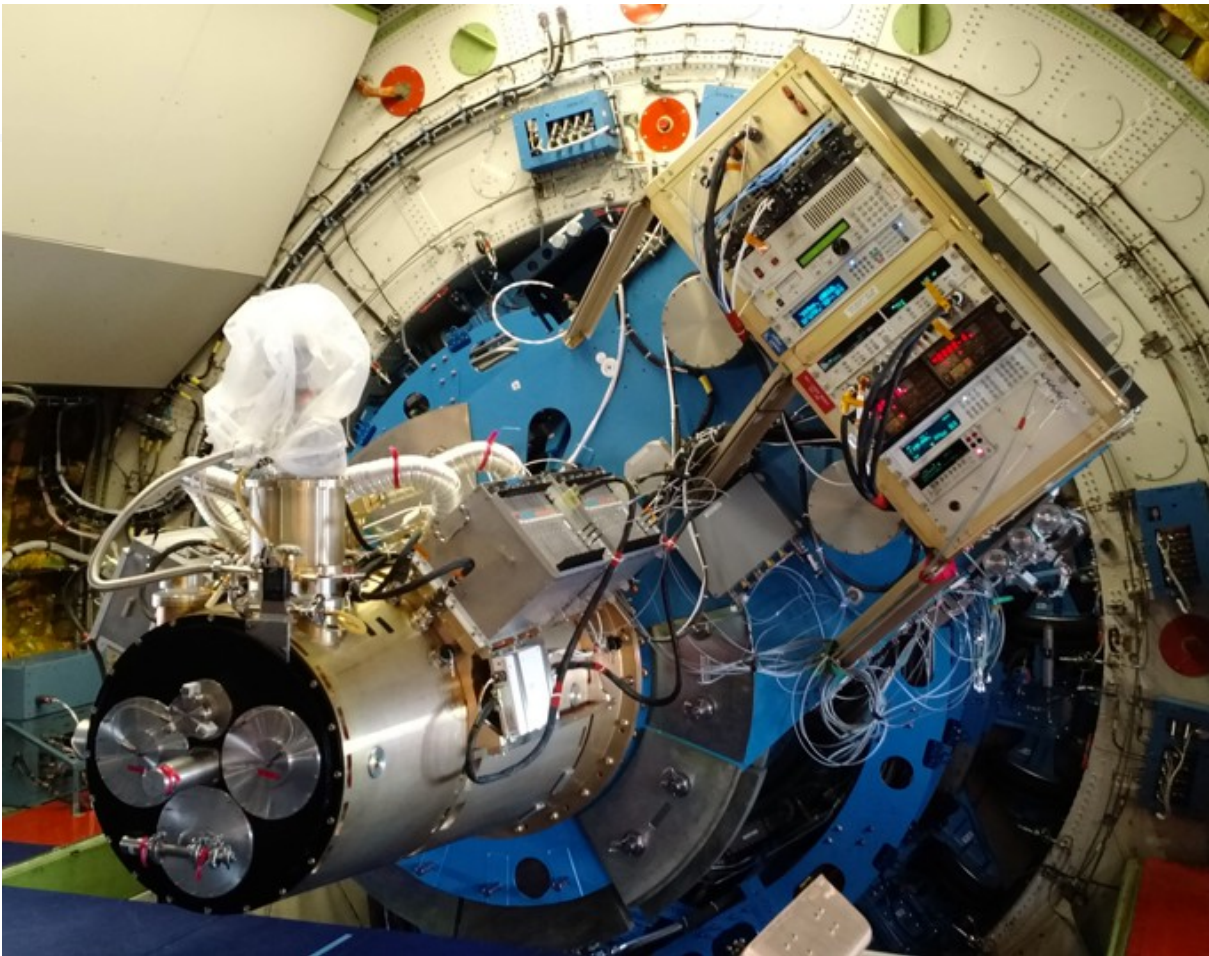
Whenever possible (surveys), choose targets with distribution at all parts of the sky. High latitudes are desirable.



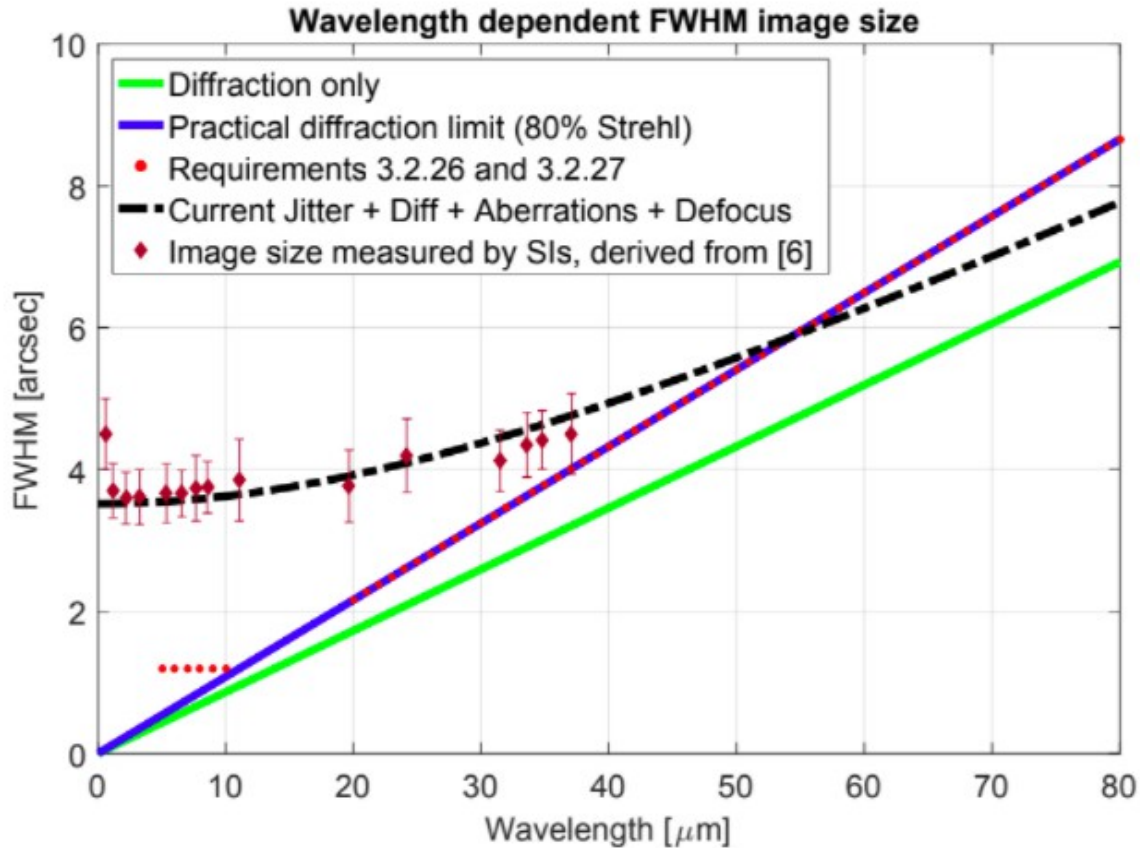
Optics and Imaging

- Rotates on spherical bearing (3-axes)
- Actively stabilized by gyros and star trackers in closed-loop control





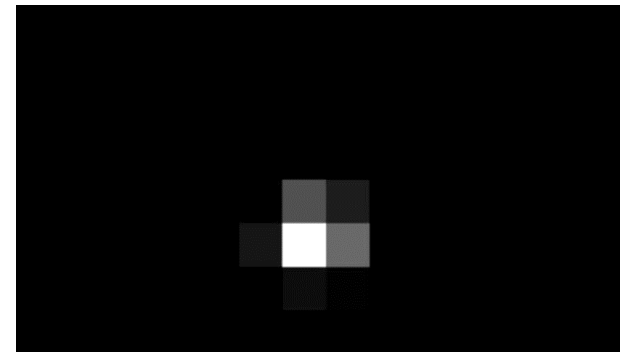
Optics and Imaging



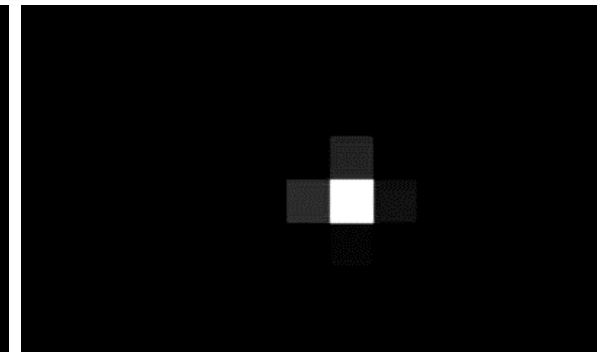
PSF FWHM $\sim 3.5''$ at short wavelengths,
diffraction limited $>35 \mu\text{m}$. Beam size ($''$) λ
(μm)/10

PSF contribution comes from Pointing jitter +
Diffraction + Aberrations + Defocus

Image stabilization - Pointing done by Focal Plane
Imager, 50 Hz updates to tip-tilt secondary mirror



off



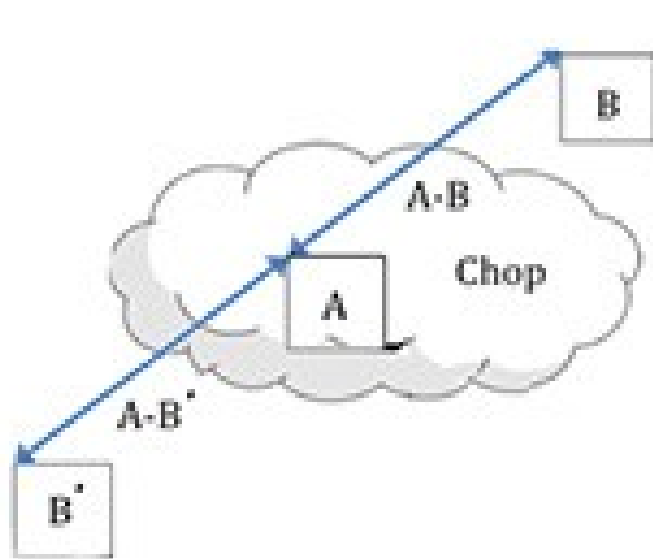
on

Optics and Imaging

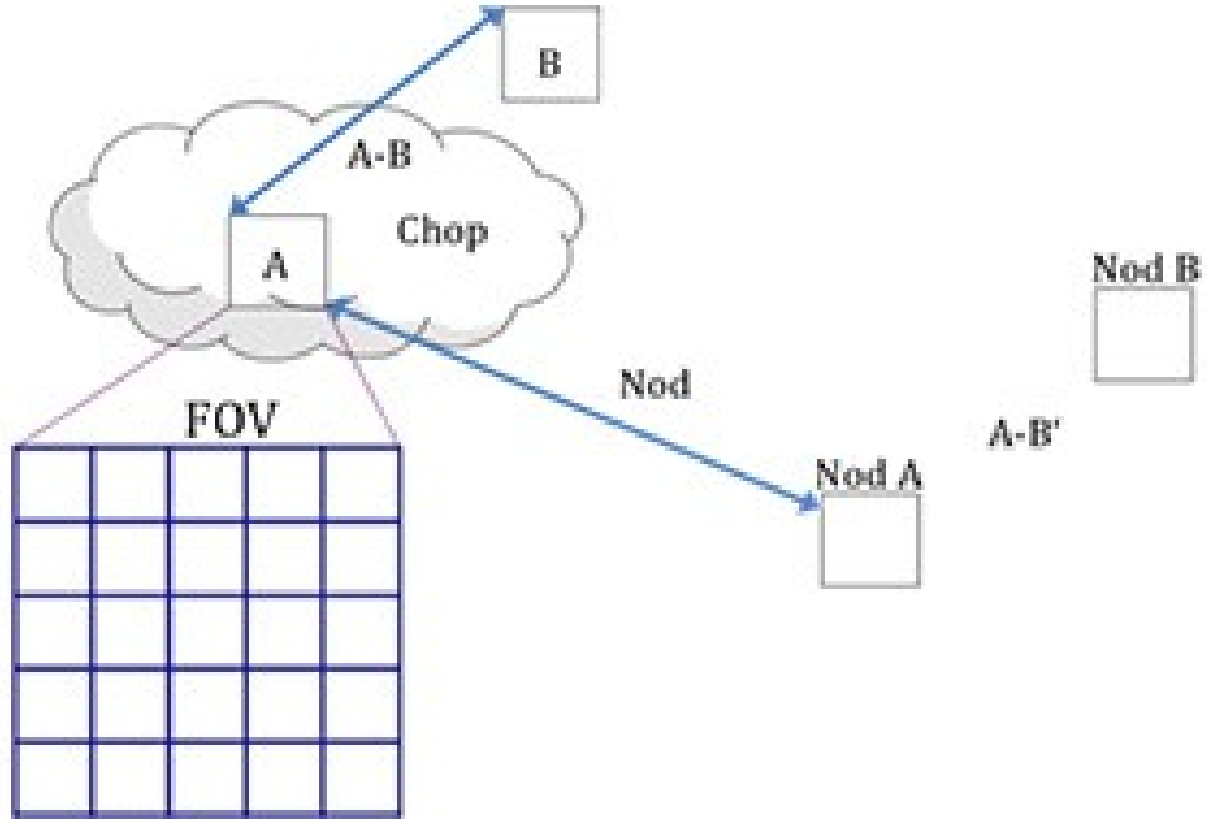
- IR observations are completely background (sky + telescope) dominated. **Background can be $>10^6$ times brighter than most sources**
- Sky background varies rapidly (order of less than a few sec) -Telescope background varies on timescales of minutes
- Different methods are used to achieve background subtraction:
 - Chopping and Nodding (fixed telescope during observations)
 - On-the-fly observations (telescope is moving during observations)

Optics and Imaging

Symmetric vs Asymmetric Chop Modes



Symmetric



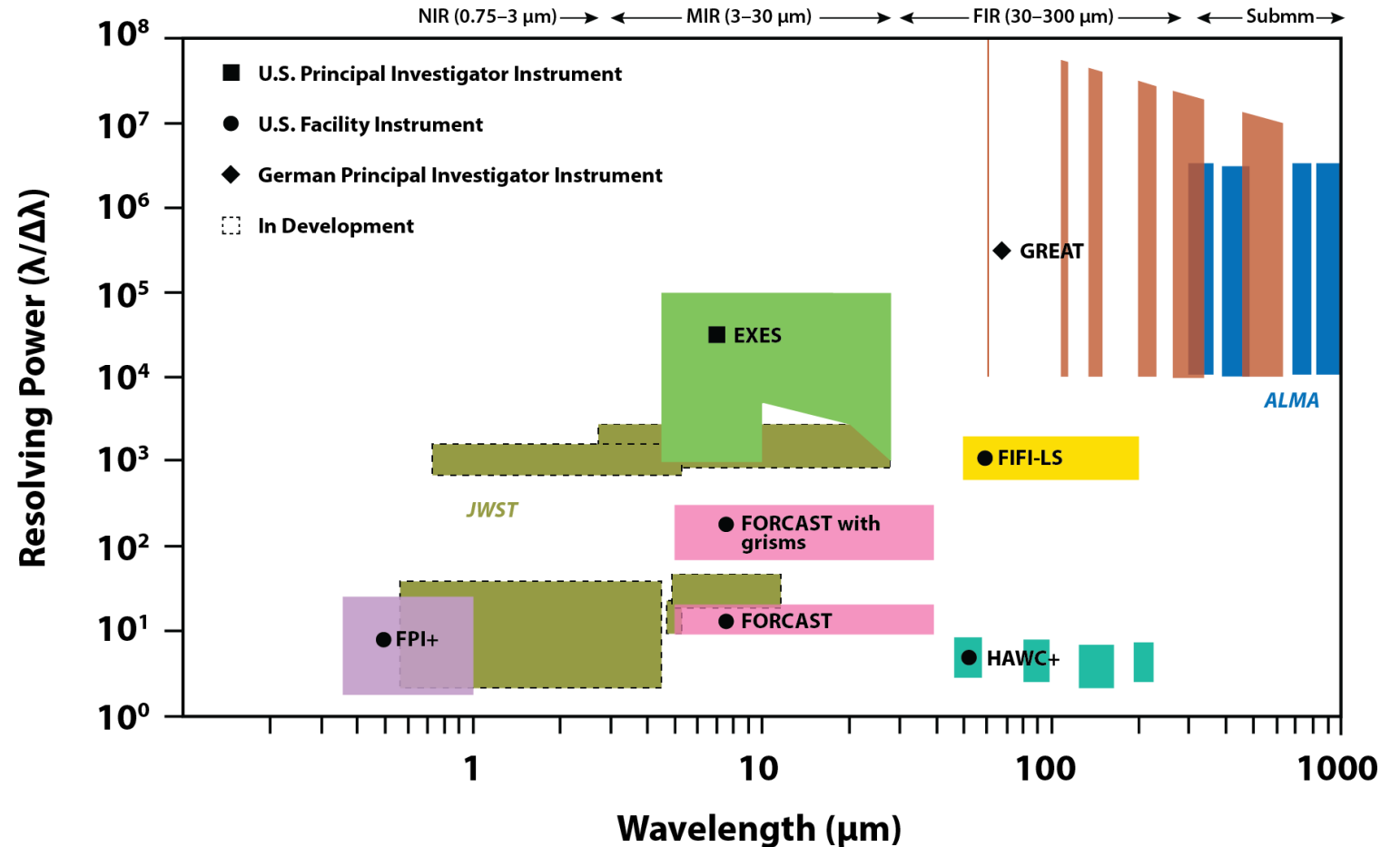
Asymmetric

SOFIA Instrument Suite

SOFIA covers most of the Mid and Far-IR spectrum (5-600 μm), at a variety of spectral resolutions

Instruments are installed for series of consecutive flights (1-4 weeks each) during a Cycle

Series scheduling made based on proposal pressure



FORCAST: MIR Imager + grisms

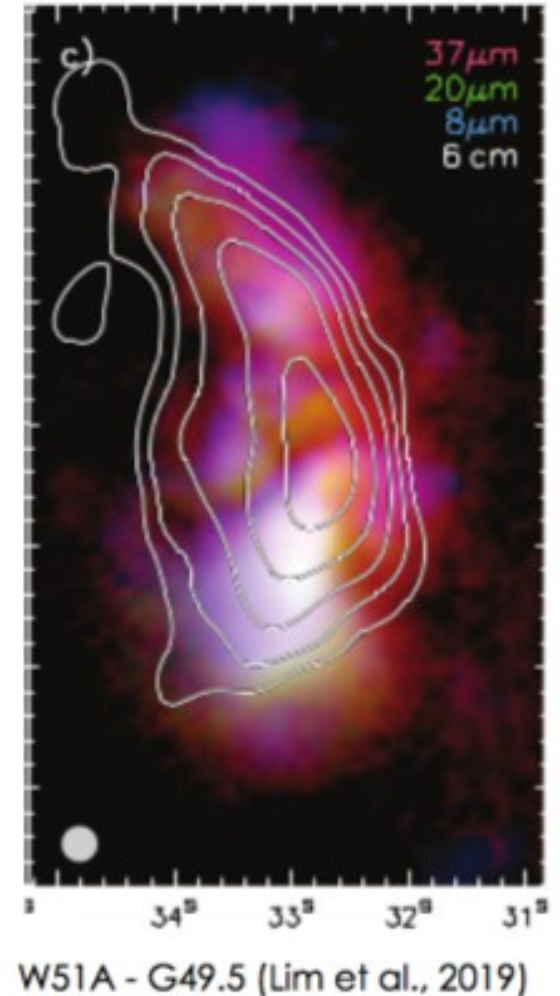
- 5-40 microns
- 256x256 pixels array
- $R \sim 70-300$ with grisms
- PAHs, amorphous silicates, atomic/ionized features, does not saturate on bright sources

Grism Details

Grism	Coverage (μm)	$R (\lambda/\Delta\lambda)^a$
G063	4.9–8.0	120 ^c /180
G111	8.4–13.7	130 ^c /260
G227	17.6–27.7	110/120
G329	28.7–37.1	160/170 ^b

Filter Parameters

SWC Filters		LWC Filters	
λ_{eff} (μm)	$\Delta\lambda$ (μm)	λ_{eff} (μm)	$\Delta\lambda$ (μm)
5.4	0.16	24.2	2.9
5.6	0.08	31.5	5.7
6.4	0.14	33.6	1.9
6.6	0.24	34.8	3.8
7.7	0.47	37.1	3.3
8.8	0.41	A subset of these will be chosen each cycle as the nominal set.	
11.1	0.95		
11.2	2.7		
11.3	0.24		
11.8	0.74		
19.7	5.5		
25.4	1.86		

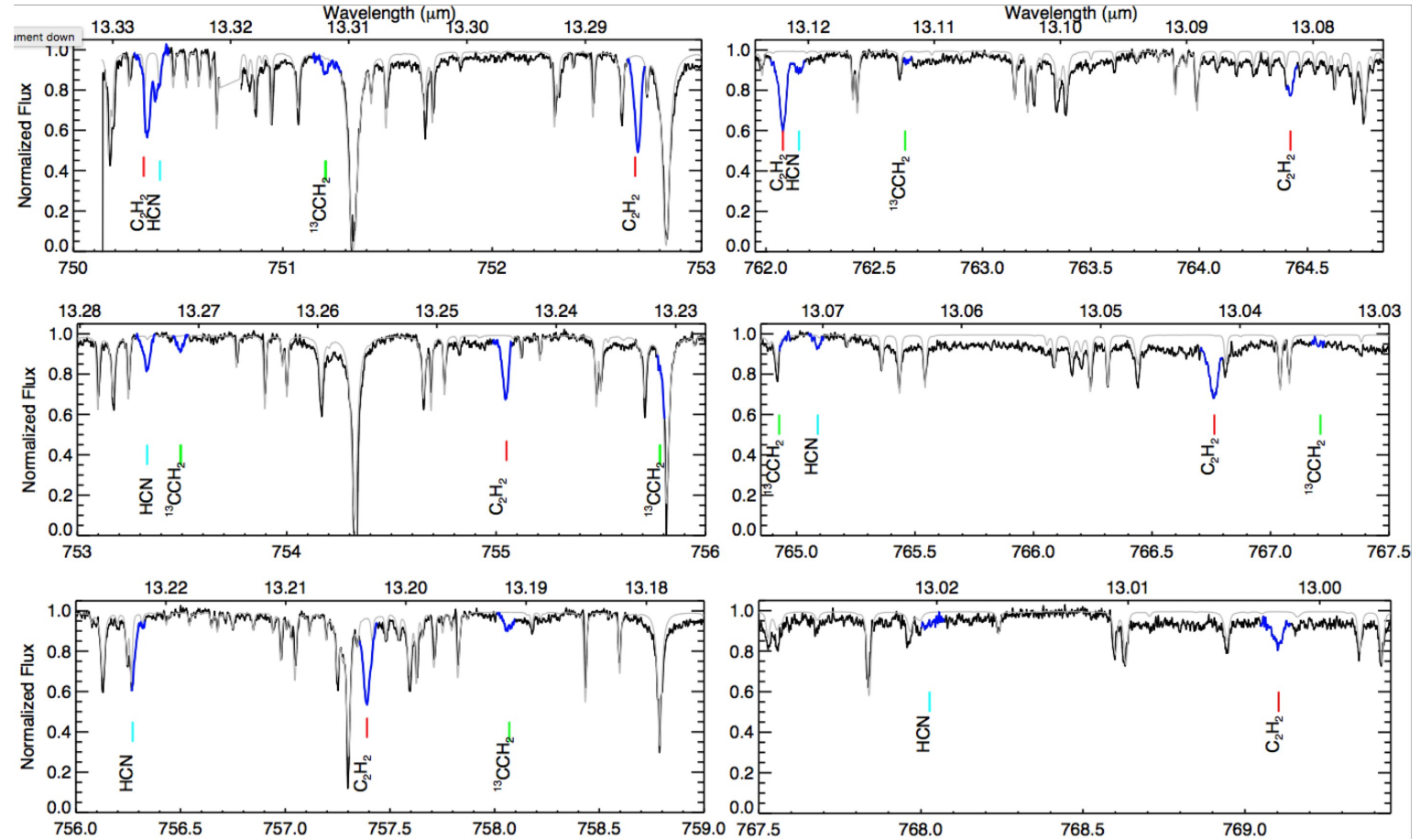


EXES: High-res MIR Spectrometer (echelon-cross-echelle)

- Mid-IR High-Resolution Spectrograph: **4.5-28.3 μm**
- *Slit mapping mode available*

Configuration	Slit Length	Spectral Resolution
Low	25" – 180"	1,000 – 3,000
Medium		5,000 – 20,000
HIGH_MED	1.5" – 45"	50,000 – 100,000
HIGH_LOW	1" – 12"	

In the Medium and Low configurations the slit lengths vary from 25" to 180" depending on the number of rows to be read.

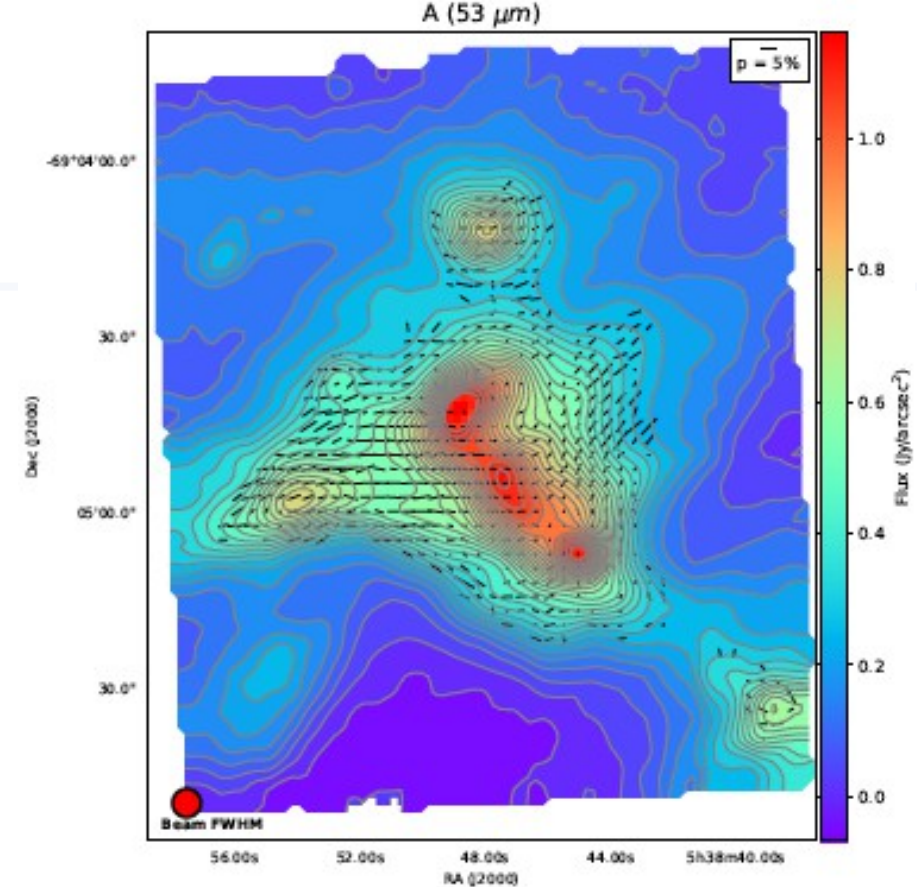


Orion Hot Core line survey (Rangwala et al. 2018)

HAWC+: FIR Polarimetric Imager

- **53-220 microns , 64x40 array**
- Superconducting TES
- **Polarimeter (half wave plates)**
- Diffraction limited at all bands
- dust polarization and distribution

30Dor polarization map
(Gordon et al., 2018)



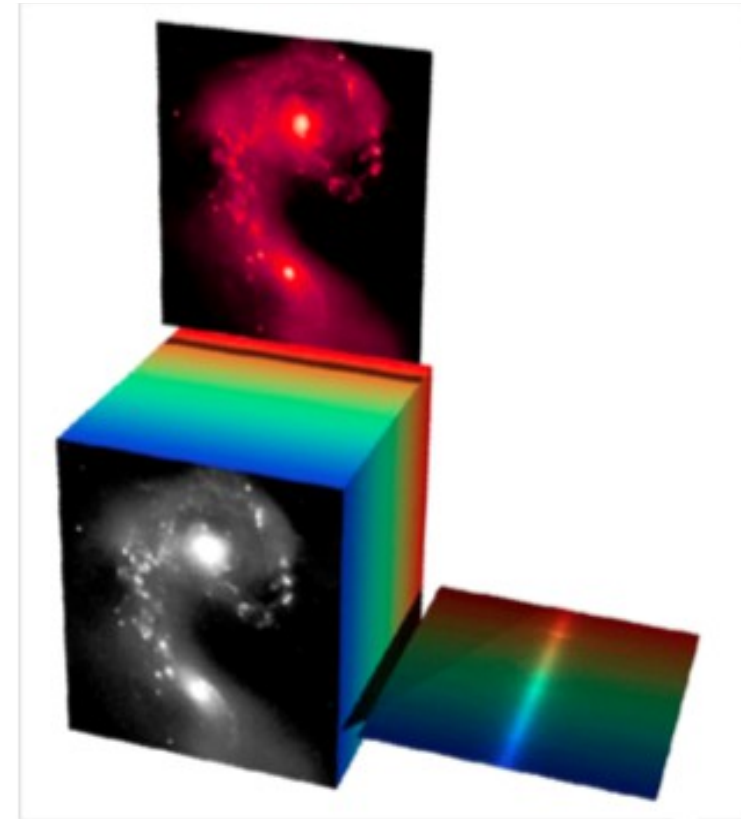
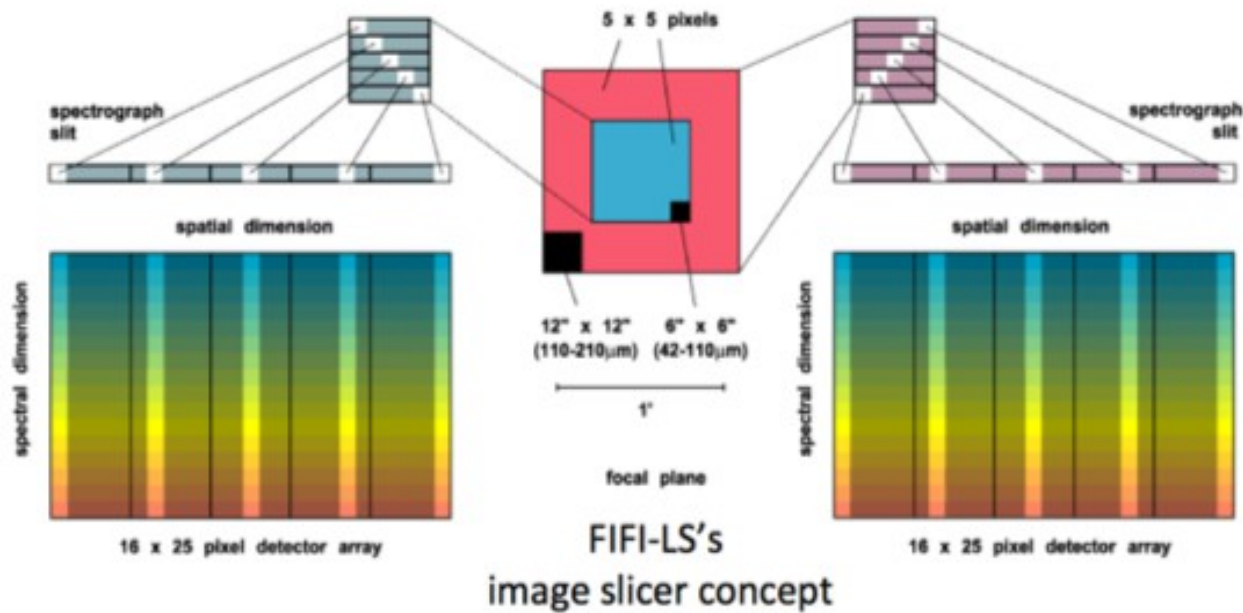
Band / Wavelength	$\Delta\lambda/\lambda$	Angular Resolution	Total Intensity FOV (arcmin)	Polarization FOV (arcmin)
A / 53 μm	0.17	4.7" FWHM	2.7 x 1.7	1.3 x 1.7
C / 89 μm	0.19	7.8" FWHM	4.2 x 2.6	2.1 x 2.6
D / 154 μm	0.22	14" FWHM	7.3 x 4.5	3.6 x 4.5
E / 214 μm	0.20	19" FWHM	8.0 x 6.1	4.0 x 6.1

FIFI-LS: FIR Integral field Spectrometer

FIFI-LS: Far-infrared spectrometer with two parallel channels and an integral field unit:

Blue 50-110 μm & Red 110-200 μm

Spectral resolution: $R=500-2000$

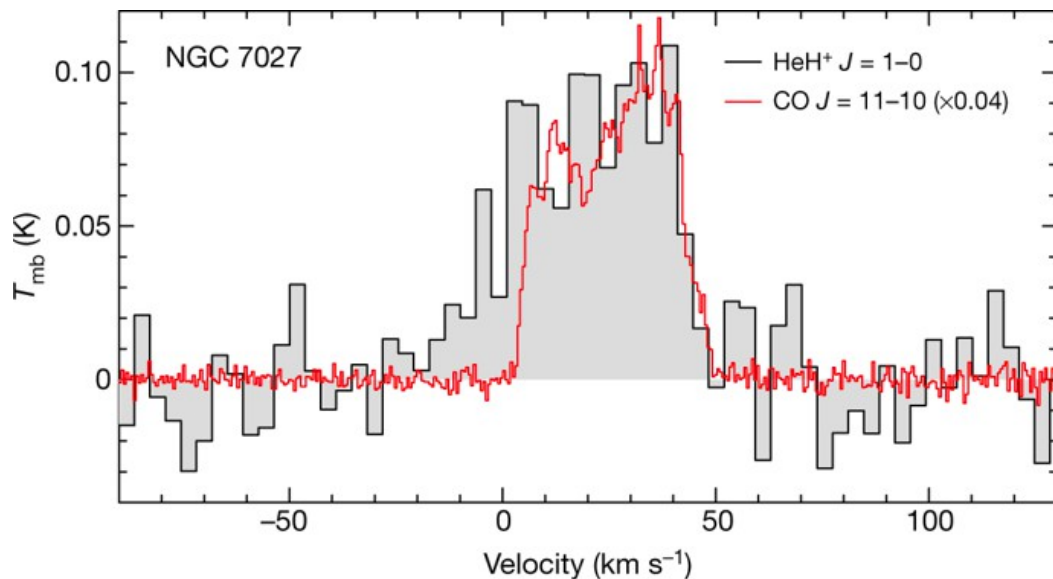


Standard pipeline product is a *datacube*.

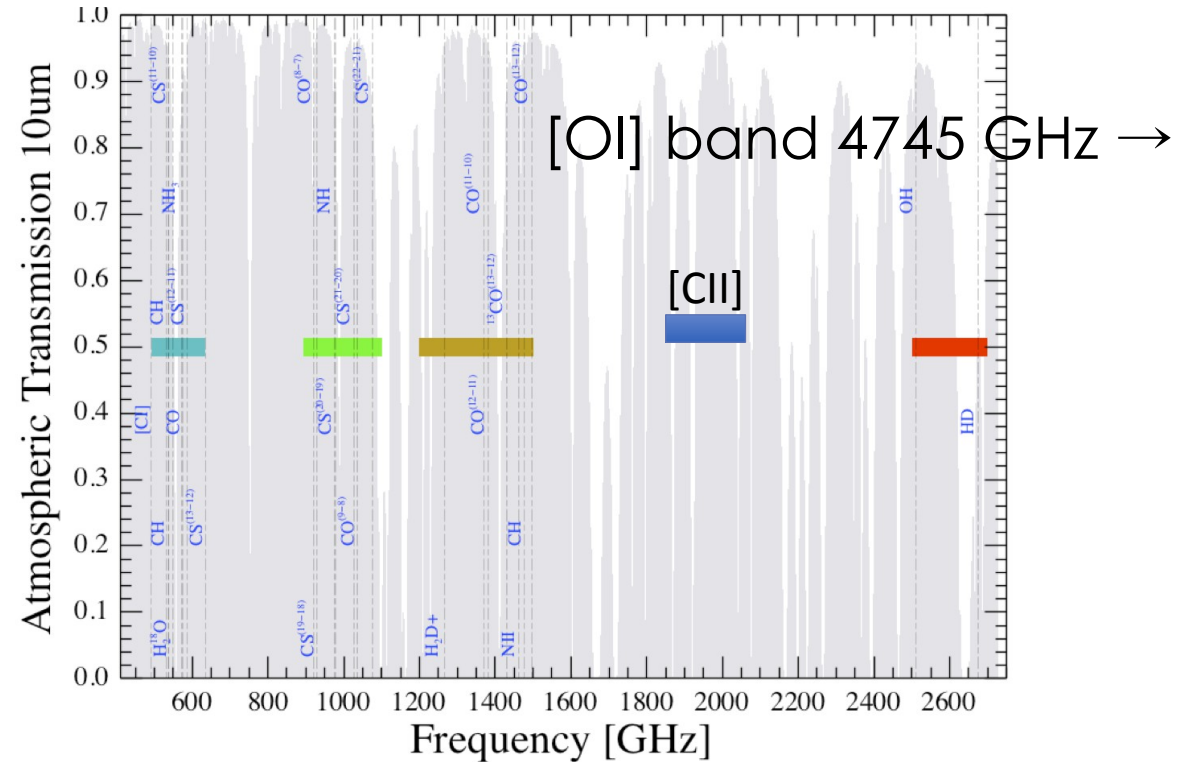
GREAT: THz heterodyne spectroscopy

- Six bands in the 0.5 – 4.7 THz range
- $R = 10^8$ (<0.1 km/s!)

- Two bands with 7-beam array (2 polarization)s 4 bands with 1 pixel
- Compares to Herschel-HIFI, with faster mapping and similar point source sensitivity

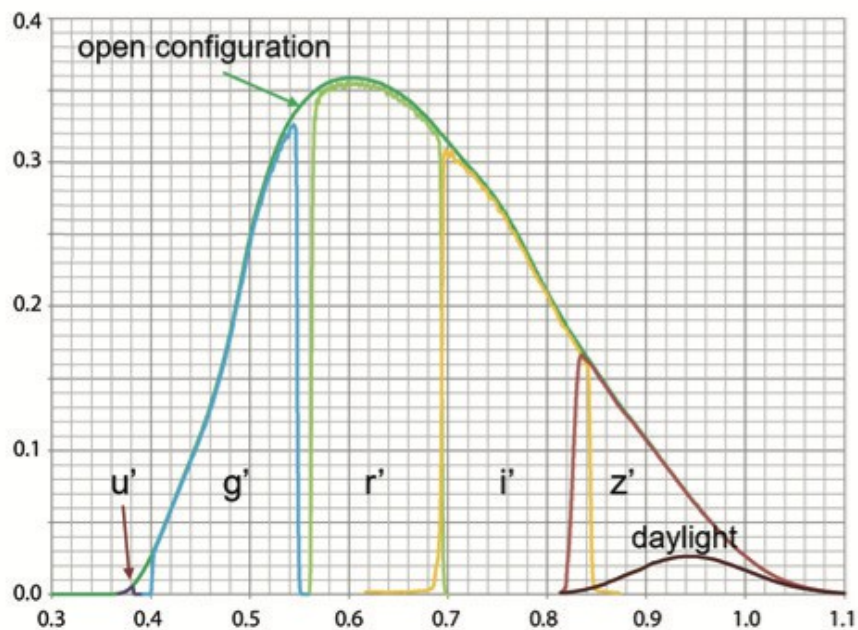


HeH+ first detection ($149\mu\text{m}$, NGC 7027),
Güsten et al. (2019) Nature 568, 357.

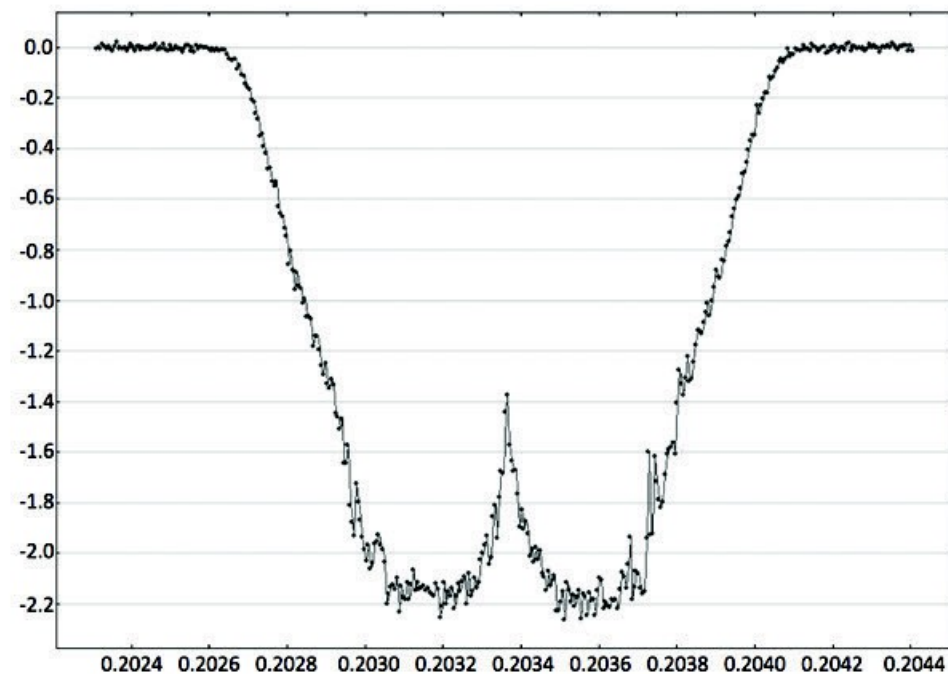


FPI+: The Guider that is a Science Instrument

- Guider camera with science grade EMCCD.
- Fast optical photometry for e.g. occultations.
- Different filters available: 330-1100 nm



Stellar Occultation by Pluto 2015-06-29



Preparing your SOFIA proposal

Science case

What is offered in Cycle 9

Evaluate feasibility

Define observations in USPOT

Upload justification and bio pdfs

Validate then Submit!

Deadline Sept 4th, 21h PDT



SOFIA Overview Proposing & Observing Data Instruments Publications Meetings and Events Announcements

Home » For Researchers » Proposing & Observing » Proposal Tools

Proposing & Observing

- ▶ Proposal Calls
- Proposal Documents
- Proposal Tools
- Current Cycle Flight Plans
- Flying on SOFIA

Quick Links

- Quick Guide
- Proposal Documents
- Current Flight Plans

Proposal Tools

Unified SOFIA Proposal and Observation Tool (USPOT)

All proposals are to be prepared and submitted using the Unified SOFIA Proposal and Observation Tool (USPOT).
[Download USPOT](#)

Exposure Time Estimation

Estimations of exposure times can be made using the SOFIA Instrument Time Estimator ([SITE](#)), 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.

Call For Proposals

Observers' Handbook

Time estimates: SITE

USPOT manual

USPOT (to download)

Any missing information: Help Desk
 sofia_help@sofia.usra.edu

SOFIA Instrument Time Estimator (SITE)

Please Check 'Notes and Known Issues' Before Proceeding

Spectroscopic Time Estimators and Tools

FIFI-LS FORCAST GRISM FLITECAM GRISM GREAT EXES

Imaging Time Estimators

FORCAST FLITECAM FLITECAM_HIPO HAWC_Plus FPI_Plus

Science case tips

- Preference given to substantial investigations that demonstrate significant scientific impact from SOFIA
- Programs using multi-wavelength data from major facilities (ALMA, HST, Spitzer, etc) are highly encourages
- Programs informing future JWST observations highly encouraged (up to 20 hours reserved)
- Joint proposal agreement with Green Bank Observatory
- Survey proposals are encouraged. Plan is to have up to 100 hours for survey proposals.
- Criterion: degree to which the investigation uses SOFIA's Unique capabilities.

What is offered in Cycle 9

In short:

- July 1, 2021 to Sep 30, 2022
- All six instruments
- 3 instruments deployed to NZ

GREAT and HAWC + (July-Sep 2021, 2022)
FIFI-LS (March 2022)

New:

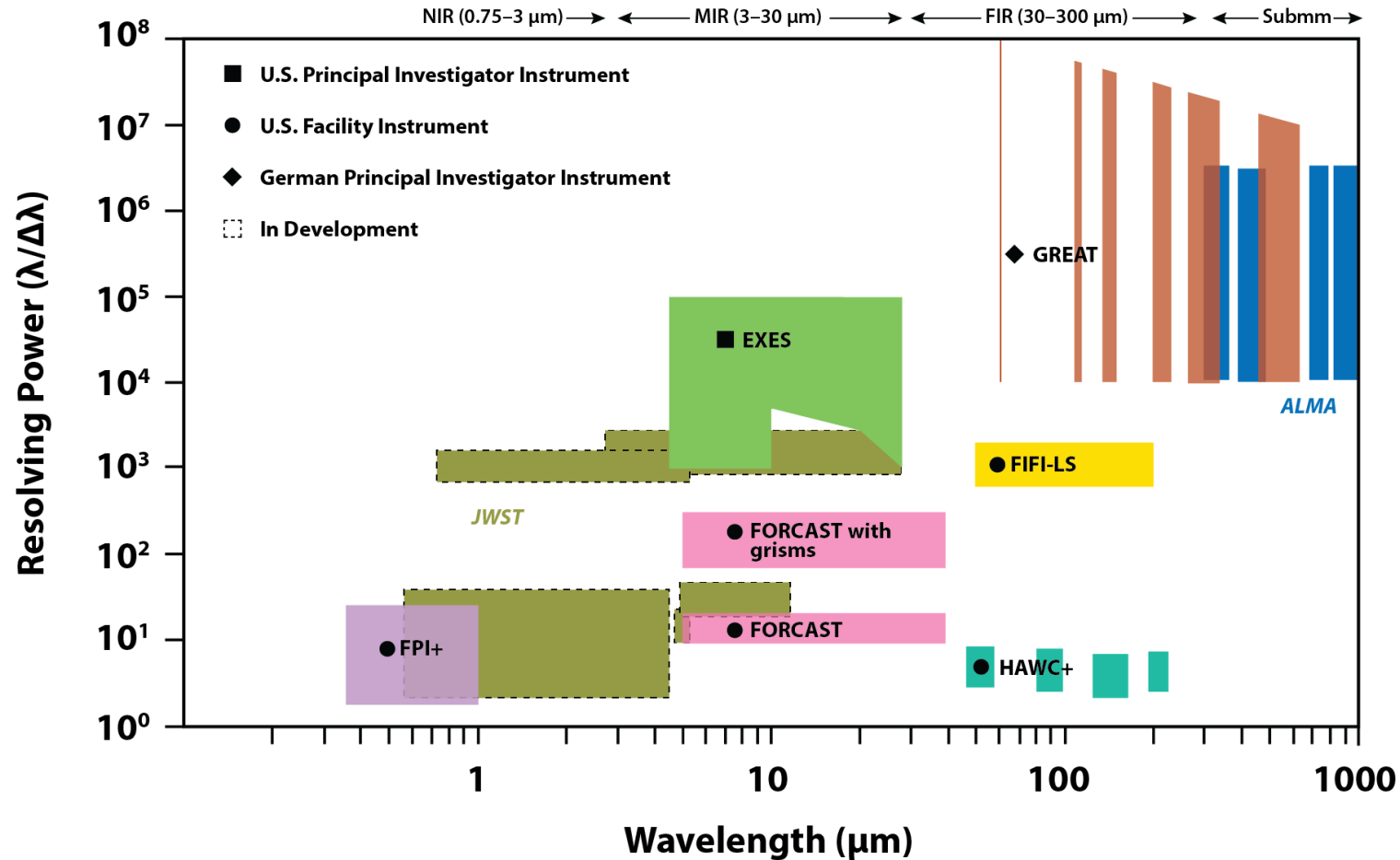
- more standard modes: GREAT honeycomb OTF maps, FIFI-LS total power
- in shared risk: FIFI-LS on-the-fly mapping mode, HAWC+ 63 microns (Band B)
- The two polarizations of the GREAT Low Frequency Array can now be set to two different frequencies

What is offered in Cycle 9

2 different types of proposals

- **Regular:** up to 500h total, includes surveys, ToO
- **Legacy:** 1-4 large proposals, up to 200h observations each over 2 cycles. Up to 400 h total in C9. No proprietary period, team contributes enhanced products

Feasibility: wavelength, spectral resolution, spatial resolution

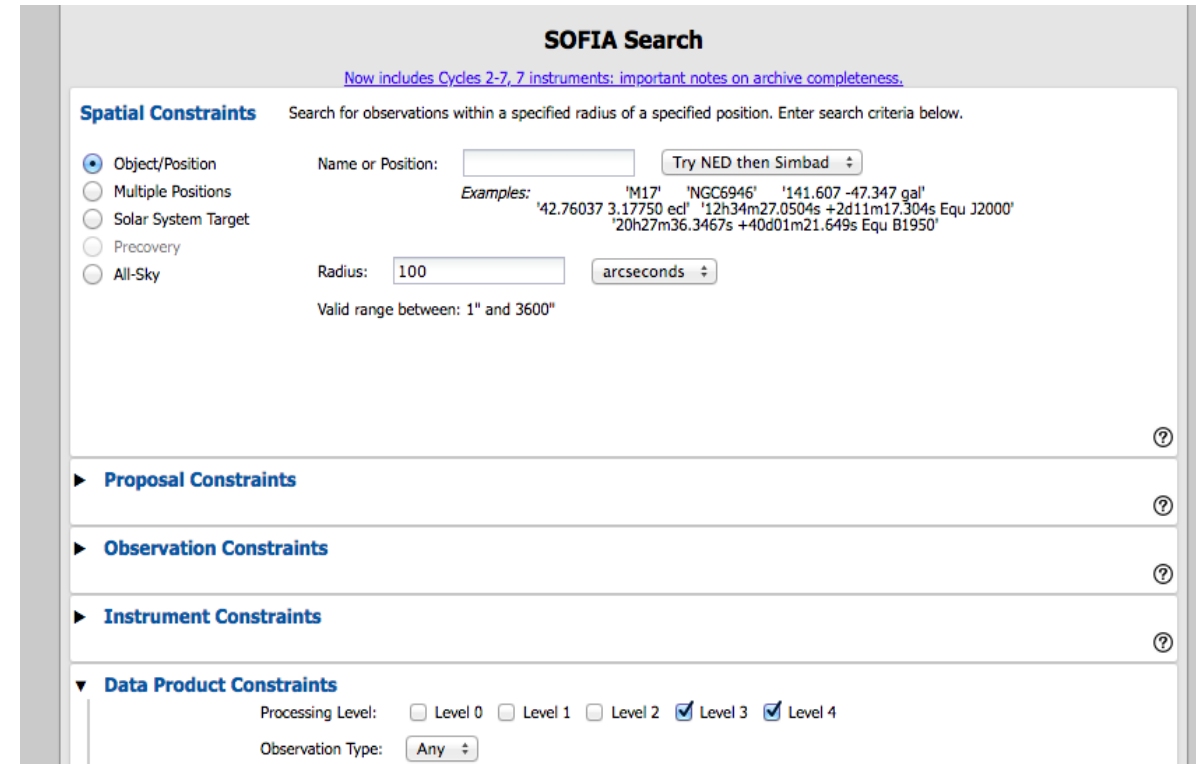


PSF FWHM $\sim 3.5''$ at short wavelengths, **diffraction limited** $>35 \mu\text{m}$. Beam size ($''$) $\lambda(\mu\text{m})/10$

Feasibility: Archival search and reserved observations catalogues

Reserved observations (GREAT and FIFI-LS):
duplicates from Reserved Observations Catalog (ROC) lists not allowed, unless explicit permission from the instrument's PI (SMO should be notified prior to proposal submission)

Duplication of observations:
generally not allowed, and if proposed for must be identified and explicitly justified.
Check the IRSA SOFIA archive



SOFIA Search
[Now includes Cycles 2-7, 7 instruments: important notes on archive completeness.](#)

Spatial Constraints Search for observations within a specified radius of a specified position. Enter search criteria below.

Object/Position Name or Position: ?
Examples: 'M17' 'NGC6946' '141.607 -47.347 gal'
'42.76037 3.17750 ecl' '12h34m27.0504s +2d11m17.304s Equ J2000'
'20h27m36.3467s +40d01m21.649s Equ B1950'

Multiple Positions
 Solar System Target
 Precovery
 All-Sky

Radius: ?
Valid range between: 1" and 3600"

► **Proposal Constraints** ?

► **Observation Constraints** ?

► **Instrument Constraints** ?

▼ **Data Product Constraints**

Processing Level: Level 0 Level 1 Level 2 Level 3 Level 4

Observation Type: ?

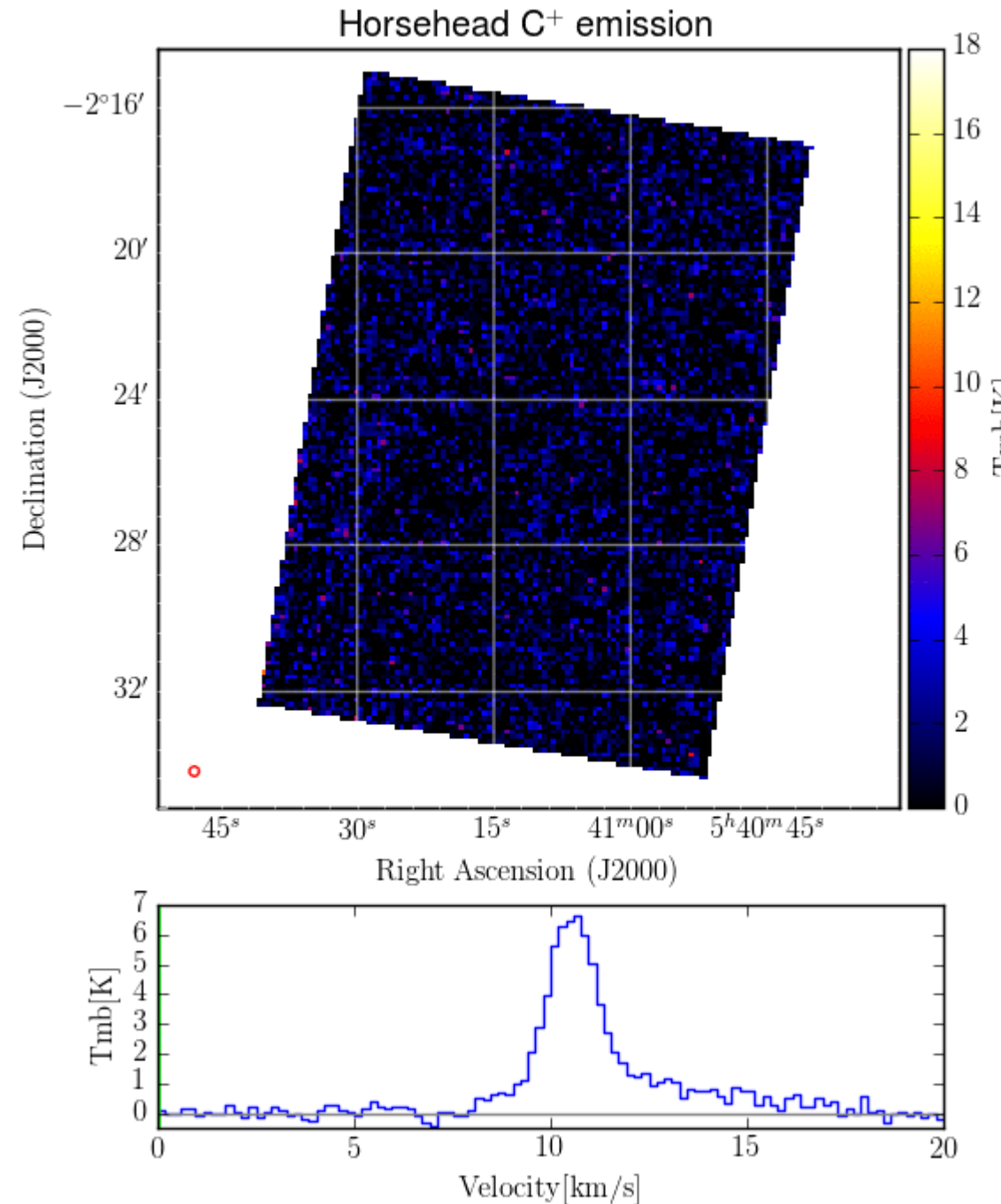
Feasibility: Signal

Expected source signal: needs to be soundly justified!

- archival data (possibly w. SED extrapolation)
- your own radiative transfer model (describe)
- classic models/ correlations: Hyperion (dust), Planetary Spectrum Calculator, Meudon PDR ...

Signal must be defined by **flux density by beam/pixel** or **surface brightness** (depends on instruments)

- Jy or $\text{W}\cdot\text{m}^{-2}\mu\text{m}^{-1}$ (flux density)
- Jy /arcsec² (surface brightness)
- $\text{W}\cdot\text{m}^{-2}$ (flux density integrated on resolution unit)
- T (brightness temperature)



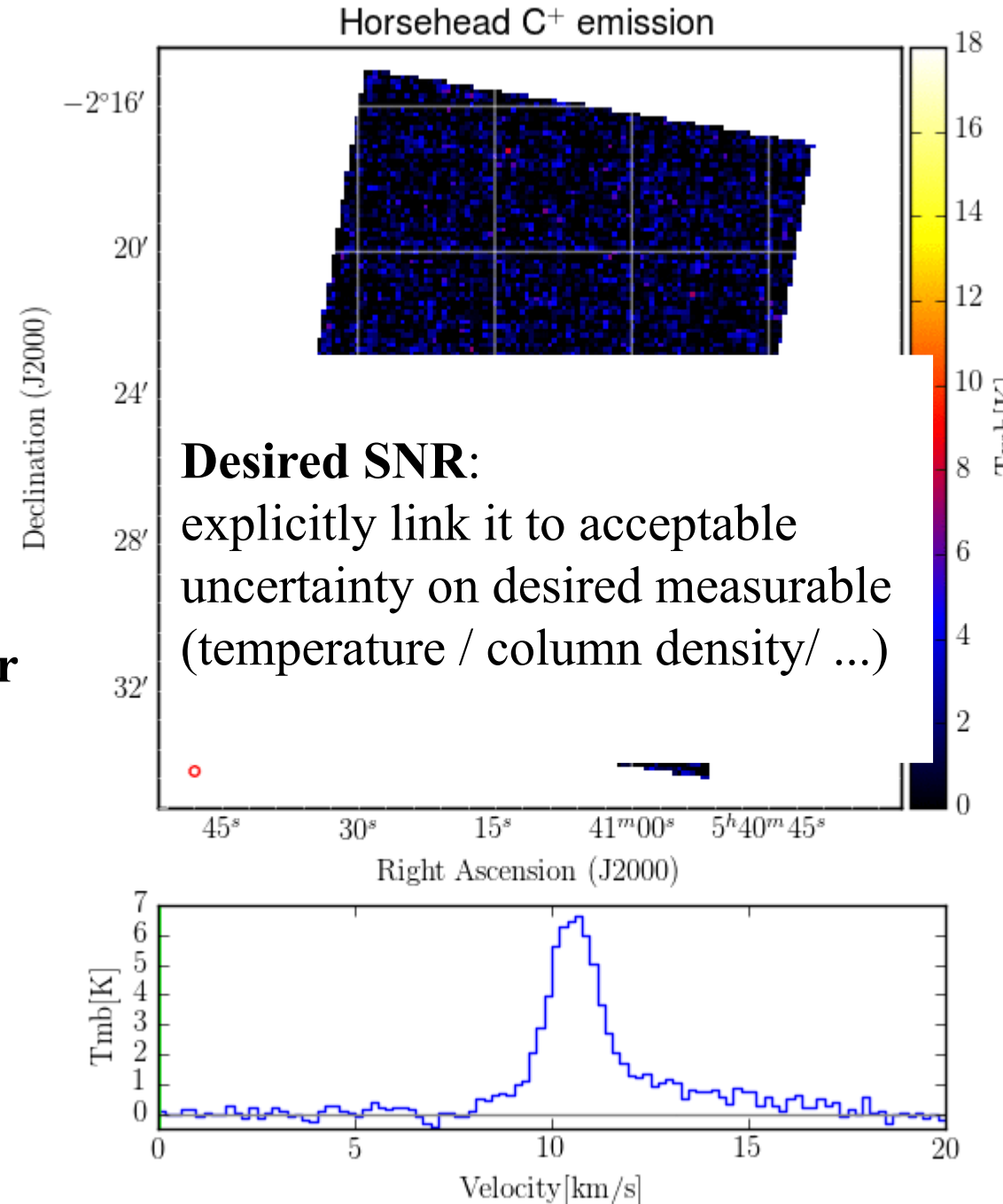
Feasibility: Signal

Expected source signal: needs to be soundly justified!

- archival data (possibly w. SED extrapolation)
- your own radiative transfer model (describe)
- classic models/ correlations: Hyperion (dust), Planetary Spectrum Calculator, Meudon PDR ...

Signal must be defined by **flux density by beam/pixel** or **surface brightness** (depends on instruments)

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- Jy /arcsec² (surface brightness)
- $\text{W}\cdot\text{m}^{-2}$ (flux density integrated on resolution unit)
- T (brightness temperature)



SITE: estimating corresponding observing time

<https://dcs.arc.nasa.gov/proposalDevelopment/SITE/index.jsp>

SOFIA Instrument Time Estimator (SITE)

Please Check 'Notes and Known Issues' Before Proceeding

Spectroscopic Time Estimators and Tools

FORCAST GRISM FLITECAM GRISM GREAT EXES ATRAN

Imaging Time Estimators

FORCAST FLITECAM FLITECAM_HIPO HAWC_Plus FPI_Plus

The following four sections of this form are for imaging configurations: select the instrument, astronomical source, telescope, observing condition constraints and calculation method. Click on the button to submit the parameters from all the sections to the server. The results are reported in a separate web page that can be resized and printed.

Instrument properties
Instrument properties: (more info, input parameter details)

Wavelength: microns (51 to 203)

Bandwidth: km/s microns

Observer Velocity (VLSR, km/s): OR Compute Velocity

Calculation Method
Calculation method: (more info)
Select the calculation method

S/N ratio resulting from a Total Integration Time of secs

Total Integration Time to achieve a S/N ratio of

Astronomical Source Definition

Source Flux: line (W/m²) continuum (Jy)

Source Velocity: LSR, km/s redshift

Output Parameters

V_{LSR}:	0.000 km/s
Velocity corrected Wavelength:	157.741 microns
Plotted wavelength range:	156.938 - 158.544 microns
Interpolated values from data table:	
Bandwidth =	0.803 microns
MDLF =	2.087e-17 W/m ²
MDCF =	0.570 Jy
Atmospheric Transmission:	0.843 0.862
	(smoothed) (unsmoothed)
Integration time (t_{on}):	<input type="text" value="0.107"/> 0.102 minutes
	(smoothed) (unsmoothed)

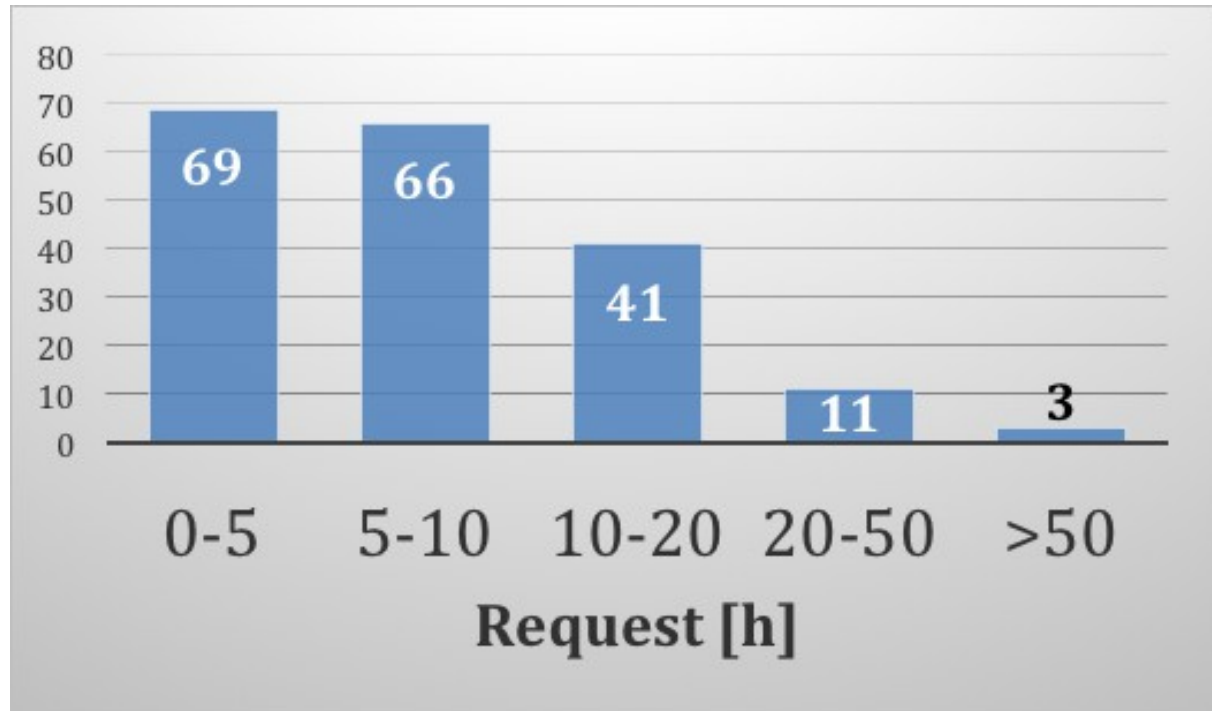
SITE: estimating corresponding observing time

This is a time estimate **per ON point or ON-OFF pair (depending on instrument mode)**: to estimate total integration time, multiply by number of pointings needed to cover desired area

This is a needed time estimate **per array element**: in some mapping modes, different pixels can 'sweep' the same area of the sky → more total integration time / area of the sky → less integration per pixel may be needed to reach same SNR

Does not include calibration overheads: those will be calculated by USPOT

SITE: estimating corresponding observing time



Distribution of time requests
in Cycle 8 (regular proposals,
US queue)

USPOT: cover page

Unified SOFIA Planning Tool (USPOT)

File Edit Targets Observation Tools Images Overlays Options Window View Help

Proposal

* Title

Proposal Info Investigators

* TAC Queue US

Category None Selected

Cycle ID OPEN CYCLE

* Science Keywords

* Proposal PDF Attachment

* Regular Yes

* Legacy No

* Target of Opportunity No

* Survey Program No

* Thesis No

* Waive Exclusive Use No

EPO Program Participation No

Archival Program No

Re-submission of Program ##_####

* Proposal Abstract

Related Proposals Status of Observations Special Instructions

0/2000 Clear Text

Proposal Observations

Target: None Specified Total Duration: 0 min Awarded: 0 min

Proposal - <No File> Net Up

- Reset Close
- ABSORPTION LINES
 - ACCRETION DISKS
 - AGN PHYSICS
 - ASTEROIDS
 - ASTROMETRY
 - ATMOSPHERES AND CH
 - BAL QUASARS
 - BL LAC OBJECTS AND BL
 - BLACK HOLES
 - CALIBRATION
 - CENTRAL STARS OF PLA
 - CHEMICAL ABUNDANCES
 - CLUSTER BINARY STARS
 - CLUSTERS OF GALAXIES
 - COMETS
 - COOLING FLOWS
 - COSMOLOGICAL PARAM
 - DAMPED LYMAN-ALPHA
 - DARK MATTER
 - DETACHED BINARIES
 - DUST
 - DWARF GALAXIES
 - DYNAMICS
 - ECLIPSING BINARIES
 - ELLIPTICAL GALAXIES
 - EMISSION LINES
 - ERUPTIVE BINARY STARS
 - EVOLUTION
 - EXOSPHERIC ATMOSPHE
 - EXTRA-SOLAR PLANETS
 - FAST IMAGING
 - GALACTIC BULGE
 - GALACTIC CENTER
 - GALACTIC DISK

USPOT: define targets

The image shows the Unified SOFIA Planning Tool (USPOT) interface. The 'Targets' menu is highlighted in the top menu bar. A 'Target' dialog box is open, showing the 'Target Name (required):' field with 'SIMBAD' selected in the dropdown. The 'Resolve the Name' button is circled in red. The dialog also shows options for 'Fixed Single' and 'Moving Single' target types, and fields for 'Coord Sys', 'RA', 'Dec', 'Epoch', and 'Proper Motion'.

Unified SOFIA Planning Tool (USPOT)

File Edit **Targets** Observation Tools Images Overlays Options Window View Help

Proposal

* Title

Proposal Info Investigators

* TAC Queue US

Category None Selected

Cycle ID OPEN CYCLE

* Science Keywords

* Proposal PDF Attachment

* Proposal Abstract Related Proposals Status of Observations Special Instructions

* Regular Yes

* Legacy No

* Target of Opportunity No

* Survey Program No

Target

Target Name (required): SIMBAD **Resolve the Name**

Fixed Single Moving Single

Coord Sys: Equatorial J2000

RA:

Dec:

Epoch: 2000.00

Proper Motion

Use Proper Motion

PM RA ("/yr): 0.000

PM Dec ("/yr): 0.000

OK Cancel Help

0/2000

Proposal Observations

Target: None Specified Total Duration: 0 min Awarded: 0 min

Proposal - <No File> Net Up

USPOT: define AOR

The image shows the USPOT software interface. The 'Observation' menu is highlighted with a red circle. The 'Proposal' window is open, showing fields for Title, TAC Queue (US), Category (None Selected), and Cycle ID (OPEN CYCLE). There are also buttons for Science Keywords, Proposal PDF Attachment, and Proposal Abstract. The bottom status bar shows 'Target: None Specified' and 'Proposal - <No File>'.

The image shows the 'Observing Condition & Acquisition / Tracking' configuration window. The 'Unique AOR Label' is 'FIFI_LS-0000'. The 'Target' is 'None Specified'. The 'Instrument Mode' is 'Symmetric Chop'. The 'On-source exp. time (sec)' is 60, and the 'On source exp. time per cycle (sec)' is 30.000. The 'Rest Wavelength Blue (micron)' is 63.184, and the 'Rest Wavelength Red (micron)' is 157.741. The 'MapType' is 'Grid'. The 'Reference Position' is set to 'By Offset'. The 'Map Ref. Pos.' is 'false'. The 'Position' is '0h00m00.0000s,+0d00m00.000s'. The 'Observation Order' is 0. The 'Width of Spectrum Blue (km/s OR micron)' is 0.000. The 'Width of Spectrum Red (km/s OR micron)' is 0.000. The 'Width of Spectral Feature Blue (km/s OR micron)' is 0.000. The 'Width of Spectral Feature Red (km/s OR micron)' is 0.000. The 'Source Velocity (km/s)' is 0.00000. The 'Dichroic' is '105_micron'. The 'Pointing Array' is 'Blue'. The 'Spectral 1' is 'FIF_BLUE' and 'Spectral 2' is 'FIF_RED'. The 'Custom Map Area (arcsec^2)' is 0.000. The 'Map Priority' is 'Map order'. The 'FOV Angle (deg)' is 0.000. The 'Chop Type' is 'Sym'. The 'Total Chop Throw (arcsec)' is 120.000. The 'Chop Angle Coordinate' is 'J2000'. The 'Chop Pos Angle (deg)' is 90.000. The 'Step Size Along Lat (arcsec)' is 30.000. The 'Step Size Along Lon (arcsec)' is 30.000. The 'Map Offset RA (arcsec)' is 0.000. The 'Map Offset Dec (arcsec)' is 0.000. The 'RA Offset (arcsec)' is 600.000. The 'Dec Offset (arcsec)' is 600.000. The 'RA (deg)' is 0.000000. The 'Dec (deg)' is 0.000000. The 'Number' of observations is 1. The 'Offset East/Row/Perpendicular (")' is 0.0. The 'Offset North/Column/Parrell (")' is 0.0. The 'Map Order' is 'Map order'. The 'Chop Angle Ranges' button is visible. The 'Reference Position' section has 'Ref Type' set to 'By Offset'. The 'Map Ref. Pos.' is 'false'. The 'Reference Name' is empty. The 'RA Offset (arcsec)' is 600.000. The 'Dec Offset (arcsec)' is 600.000. The 'RA (deg)' is 0.000000. The 'Dec (deg)' is 0.000000. The 'Position' is '0h00m00.0000s,+0d00m00.000s'. The 'Choose Position' button is visible. The 'Observation Est...', 'Comments...', and 'Proposal Info...' buttons are visible. The 'Import Map Offsets (Custom Only)', 'Export Map Offsets', and 'Export Map Positions' buttons are visible. The 'OK', 'Apply', 'Cancel', and 'Help' buttons are visible at the bottom.

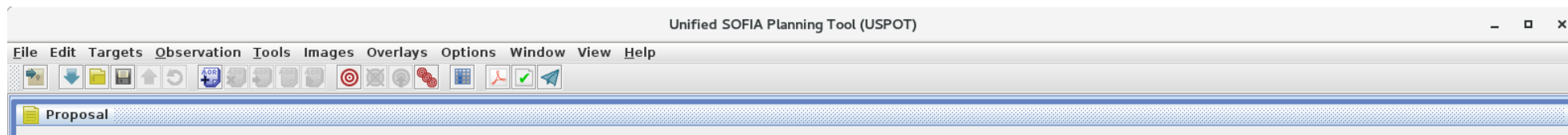
USPOT: building justification pdf (main body)

- Context, aim, methods, synergies, anticipated results (0.5p / 1p)
- Scientific justification (3p + references / 5 p)
 - Don't forget instrument and data justification (as opposed to i.e., TEXES, archival data, ...)
- Feasibility + path to publication (3p)
 - (instrument and modes, exposure time, time constraints)
- Budget (for Legacy only, 2p)
- Implementation (for Legacy only, 2p)
- Thesis enabling program (1 p)

Starting this Cycle: justification PDF must follow Dual Anonymous Guidelines

USPOT: building justification pdf (main body)

- The TAC will not know the identity of the proposers during the science review
- Goal is to make the review about science, and attenuate TAC biases
- Justification must be anonymized: no pronouns ('we have..'), obvious references to ongoing programs ('private comm'), overload references with own papers
- 'You are not trying to hide yourself, just not show who you are'
- Blatant disregard will lead to proposal rejection



Upload justification pdf, bio pdf, validate, submit (with DCS account)

Post deadline – what to expect

- December 2020: results announced
- Budget submission (US GOs)
- February 2021 : Phase 2 – further definition of AORs, supported by instrument scientists
- Observations (July 2021-Sep 2022): GOs receive flight summaries post-flight series

Post observations – what to expect

- Processed data delivered and staged in archive ~ 1 month after observations
- GOs notified by email. All data gathered in **IRSA**

<https://irsa.ipac.caltech.edu/Missions/sofia.html>

- Post-delivery: assistance available from science center / instrument scientists.
Proprietary length 6 months (regular), 0 months (DDT, legacy)

- Data analysis resources are available at the SOFIA website data section:

<https://www.sofia.usra.edu/science/data> : Cookbooks Recipes, Data Handbooks



Funding opportunities (for US-institutions only)-

- Up to \$4M for Regular Proposals (~\$10k/ h)
- Up to \$2M / year for Legacy Proposals

- For proposals which are central to a PhD thesis, additional funding can be requested through the Thesis-enabling Program (up to two years of graduate student funding)
- Timing of funding depends on program priority ('rank'): must do (~25% of available time), should do (50%), do if time

Helpdesk: sofia_help@sofia.usra.edu

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