SOFIA Proposal Tools Webinar: Instruments

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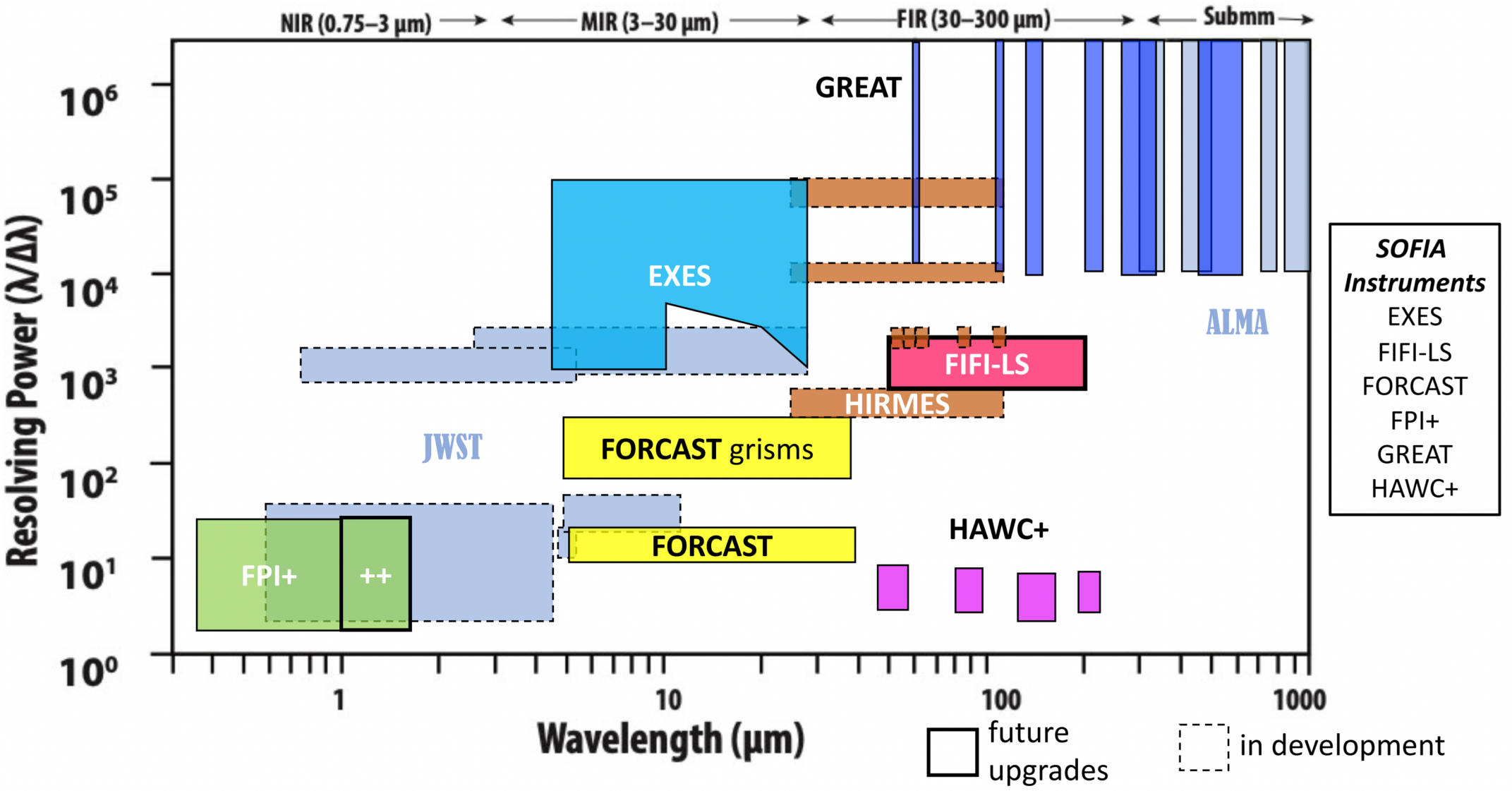
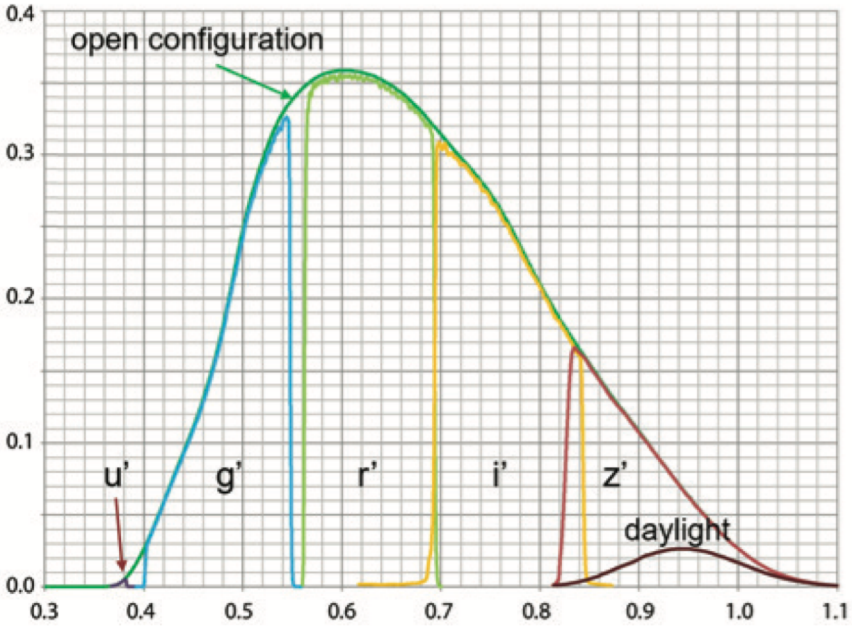
SOFIA Instruments and Complementary Observatories

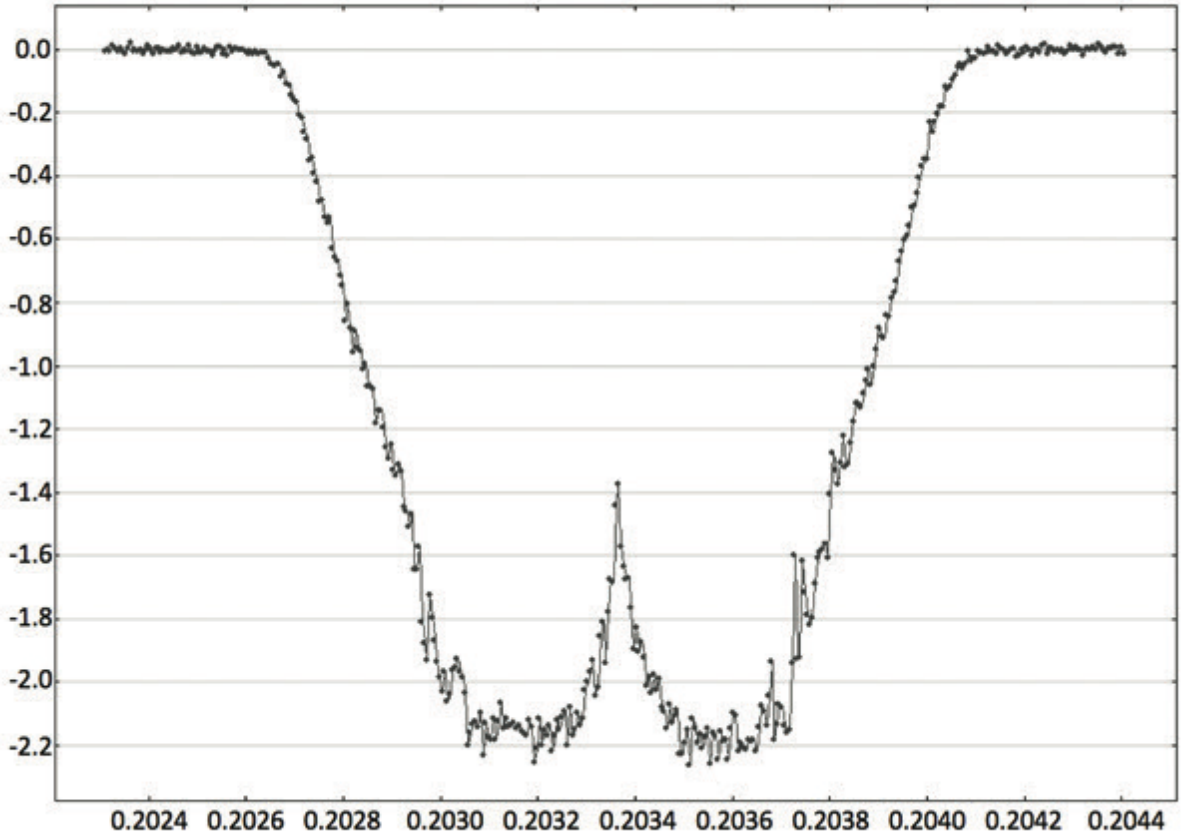


FPI+: The Guider that is a Science Instrument

- FPI+: guider camera with a science grade EMCCD.
- Fast optical photometry for e.g. occultations.
- Different filters available



Stellar Occultation by Pluto 2015-06-29



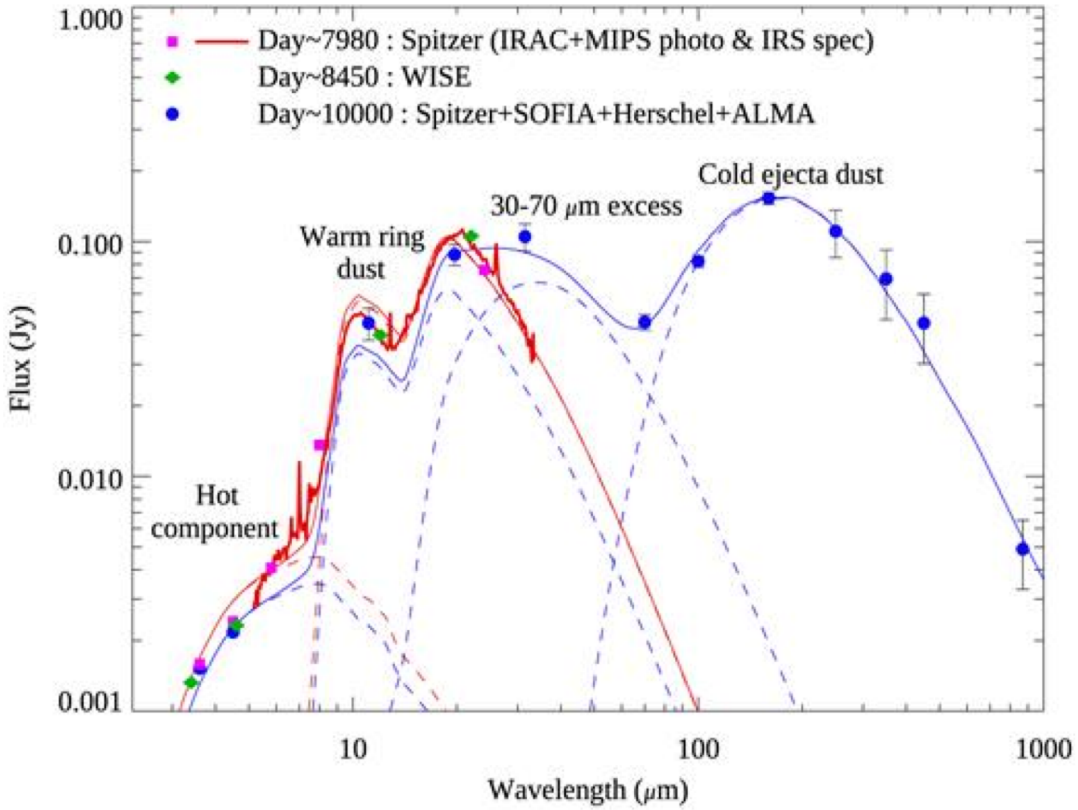
FORCAST: MIR Imager plus Grisms

Specs:

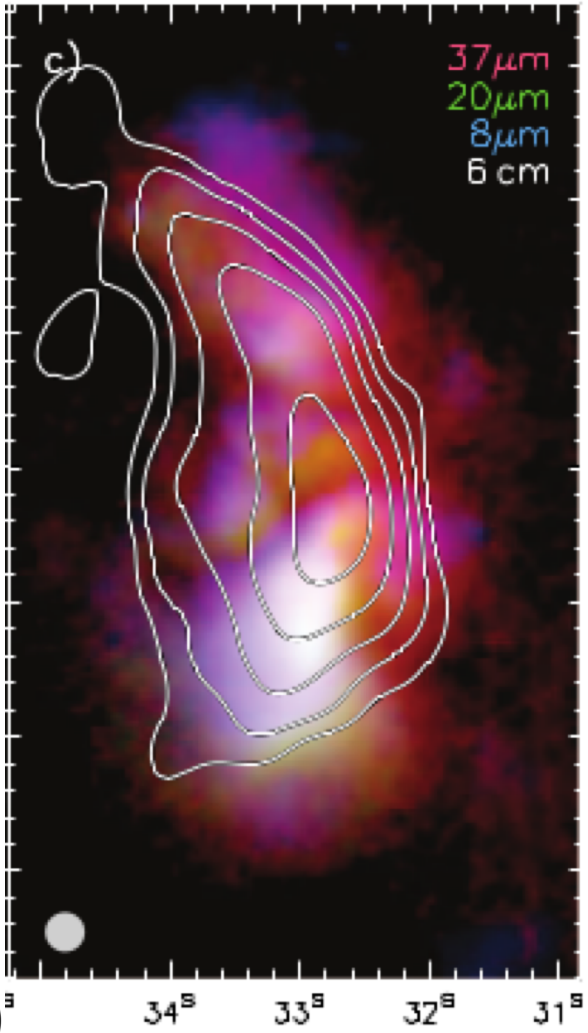
- **5-40 microns coverage**
- Imaging w 256x256 pix array
- Grism modes **R~70-300**
- Spatial resolution ~ 3-4”

Applications:

- Atomic/ionized/ molecular features
- PAHs, amorphous silicates
- Does not saturate on bright sources



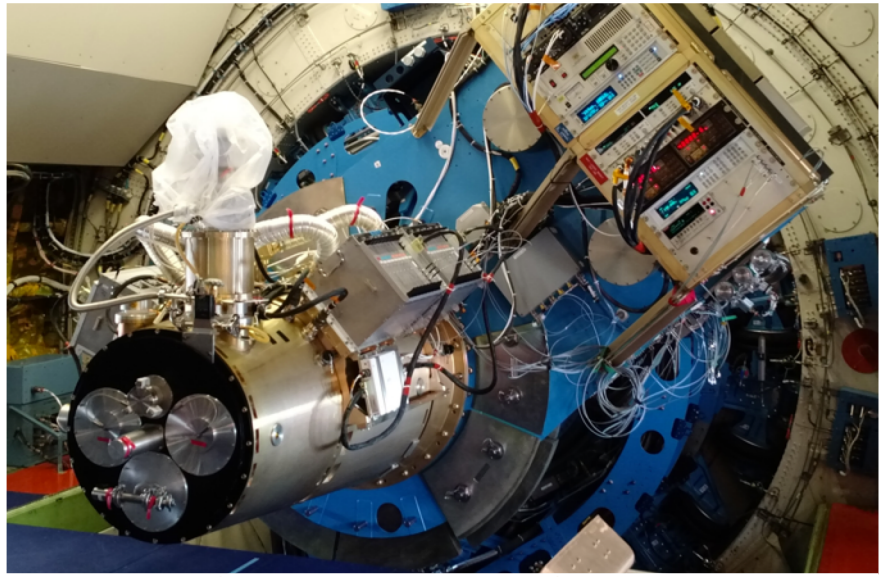
SED of supernova 1987A (Matsuura et al., 2018)



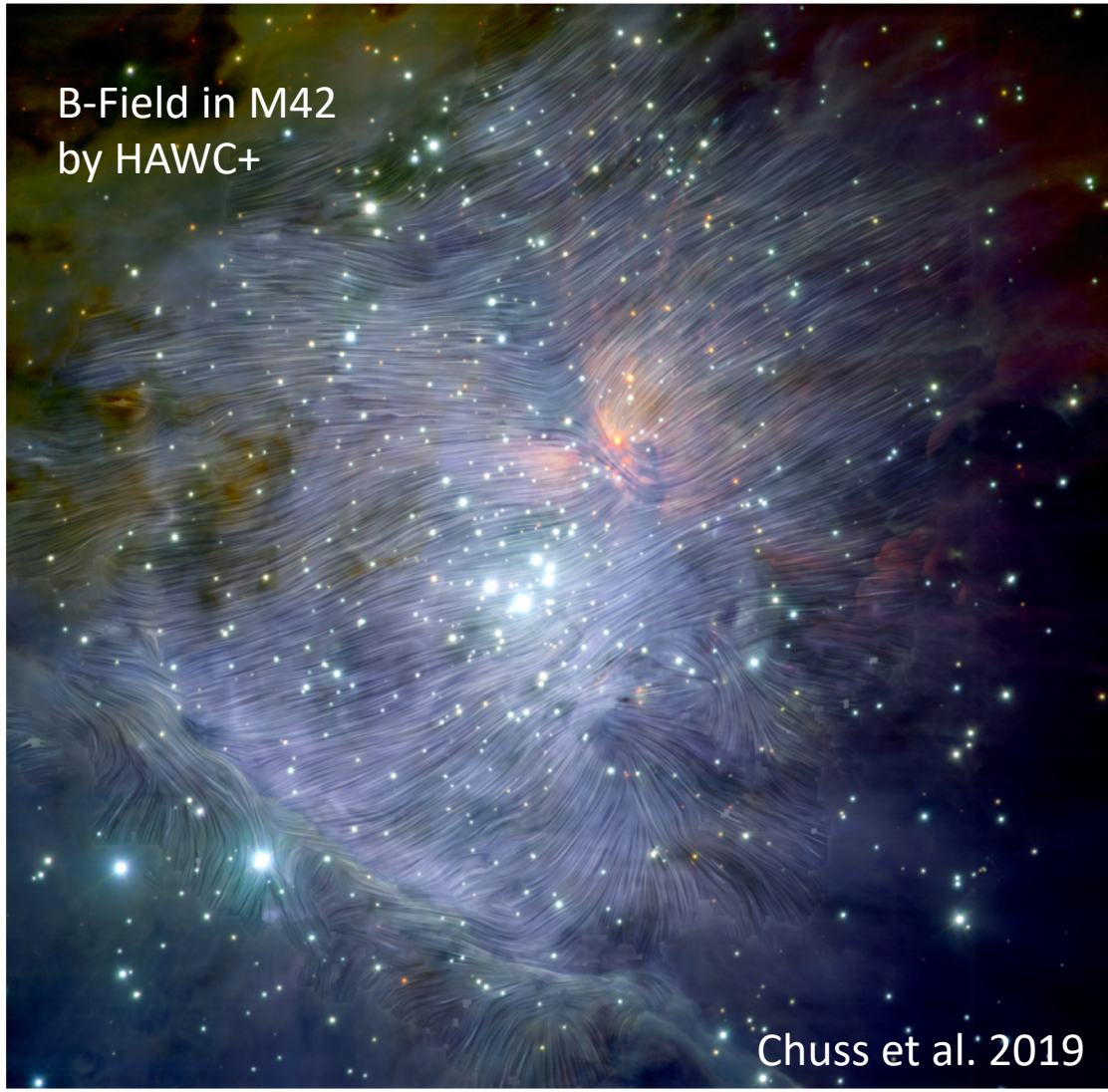
Imaging of Galactic HII region W51A - G49.5 (Lim et al., 2019)

HAWC+ - SOFIA's FIR photometer and polarimeter

- Imaging and polarimetry
- Half-Wave Plate and wire-grid polarimeter
- Superconducting transition-edge sensor



Band/ Wavelength	Δλ	Angular Resolution	Total Intensity FOV (arcmin)	Polarization FOV (arcmin)
A / 53 μm	8.70	4.85" FWHM	2.8 x 1.7	1.4 x 1.7
B[a] / 63 μm	8.90	10.5" FWHM	4.2 x 2.7	2.1 x 2.7
C / 89 μm	17.00	7.8" FWHM	4.2 x 2.7	2.1 x 2.7
D / 154 μm	34.00	13.6" FWHM	7.4 x 4.6	3.7 x 4.6
E / 214 μm	44.00	18.2" FWHM	8.4 x 6.2	4.2 x 6.2

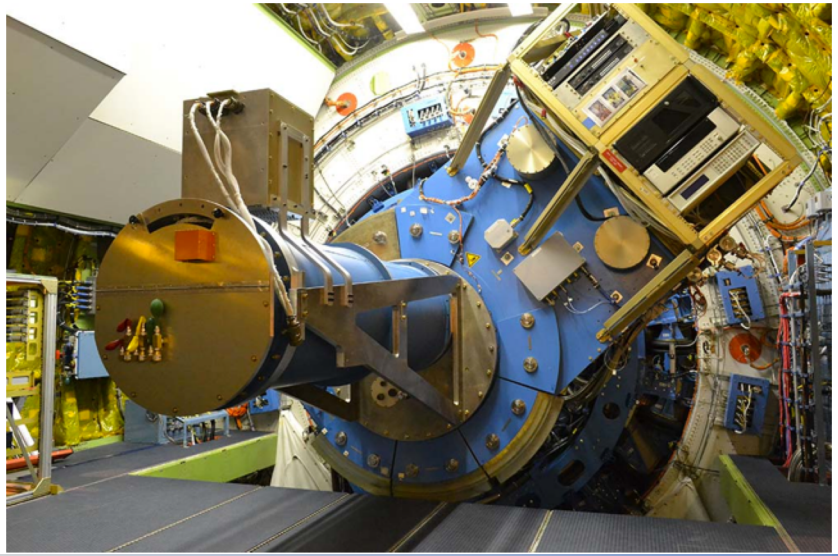


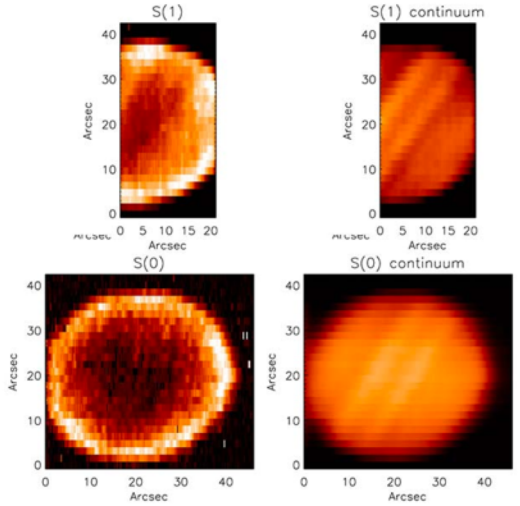
A Echelon-Cross-Echelle Spectrograph

Mid-IR High-Resolution Spectrometer:
4.5-28.3 µm

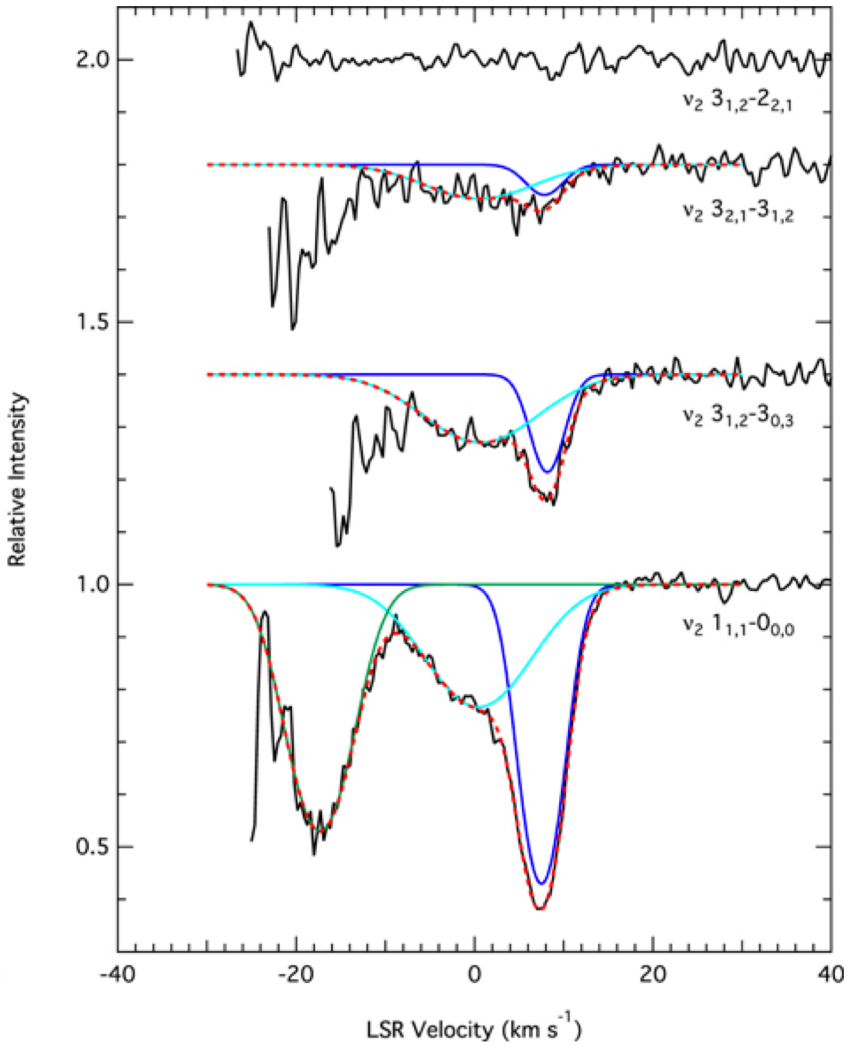
Configuration	Slit Length	Spectral Resolution
Low	25”– 180”	1,000 – 3,000
Medium		5,000 – 20,000
HIGH_MED	1.5” – 45”	50,000 – 100,000
HIGH_LOW	1” – 12”	

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





Jupiter’s para-H_2 distribution from SOFIA/FORCAST and Voyager/IRIS 17–37 µm spectroscopy (Flechter et al, 2016, Icarus 286, 223)

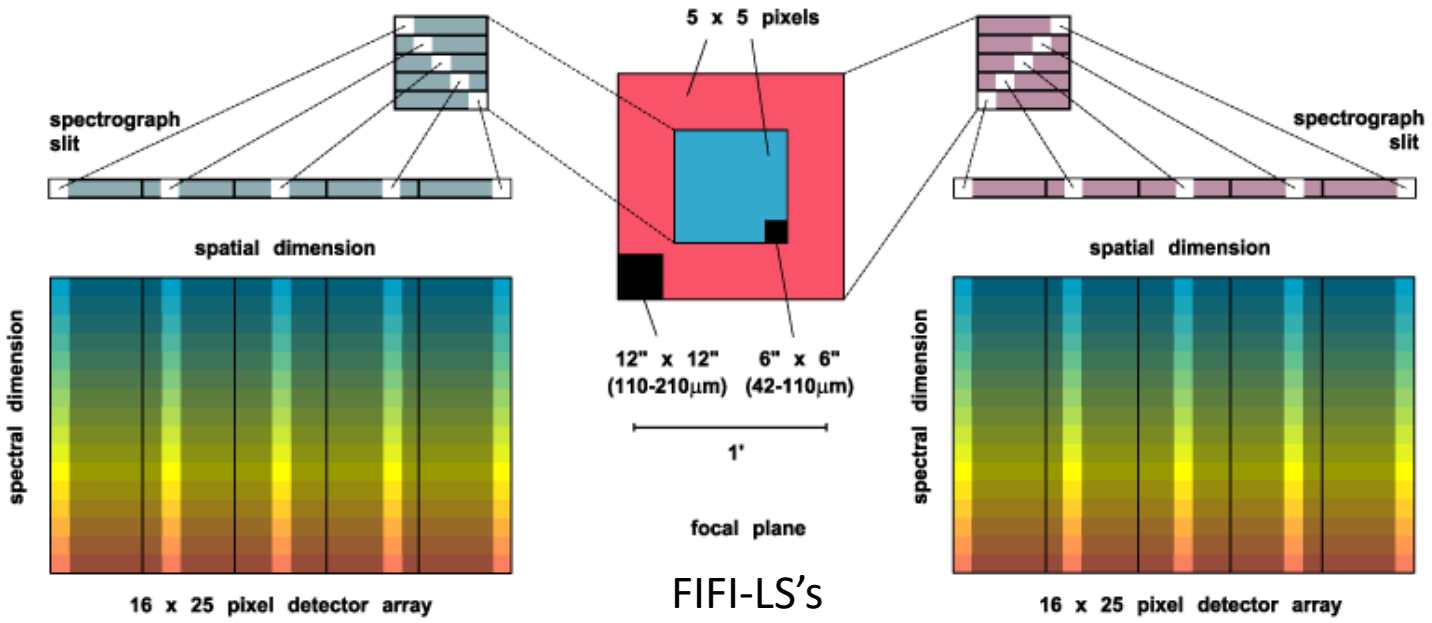


High spectral resolution observations toward Orion BN at 6 µm No evidence for hot water (Indriolo et al., 2018, ApJL 865, 18)

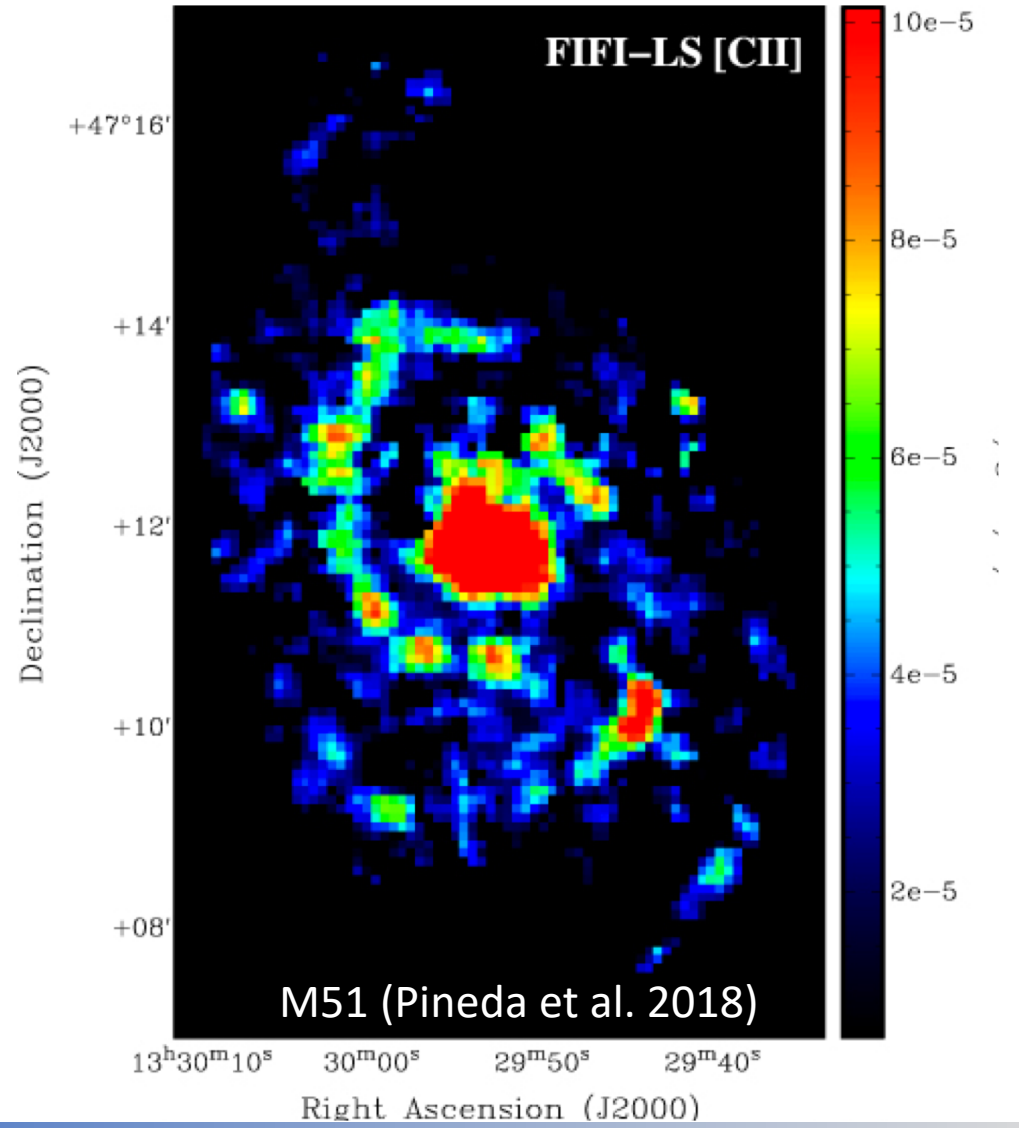
SOFIA's integral field spectrometer

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

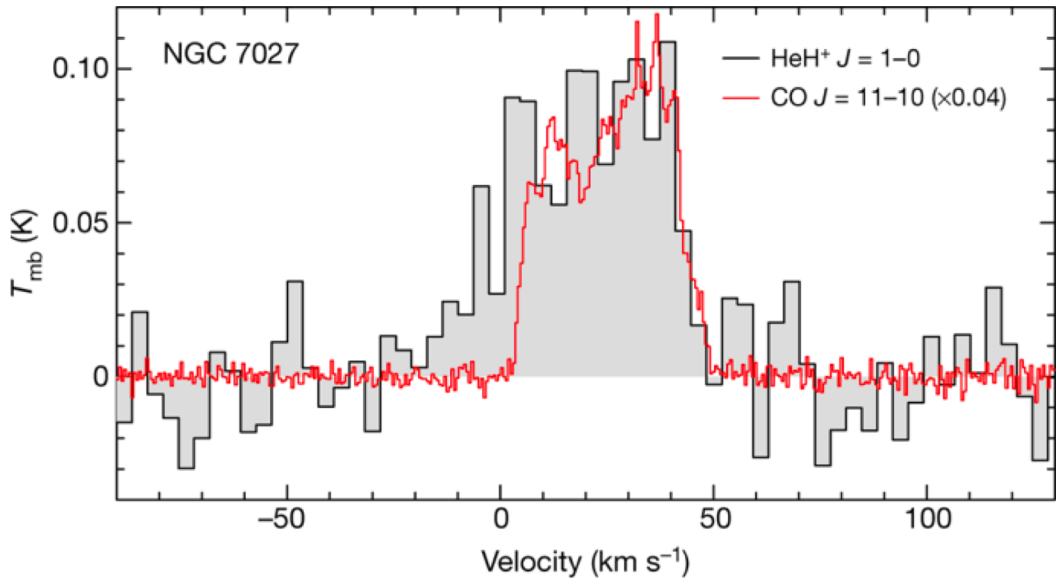


FIFI-LS's image slicer concept



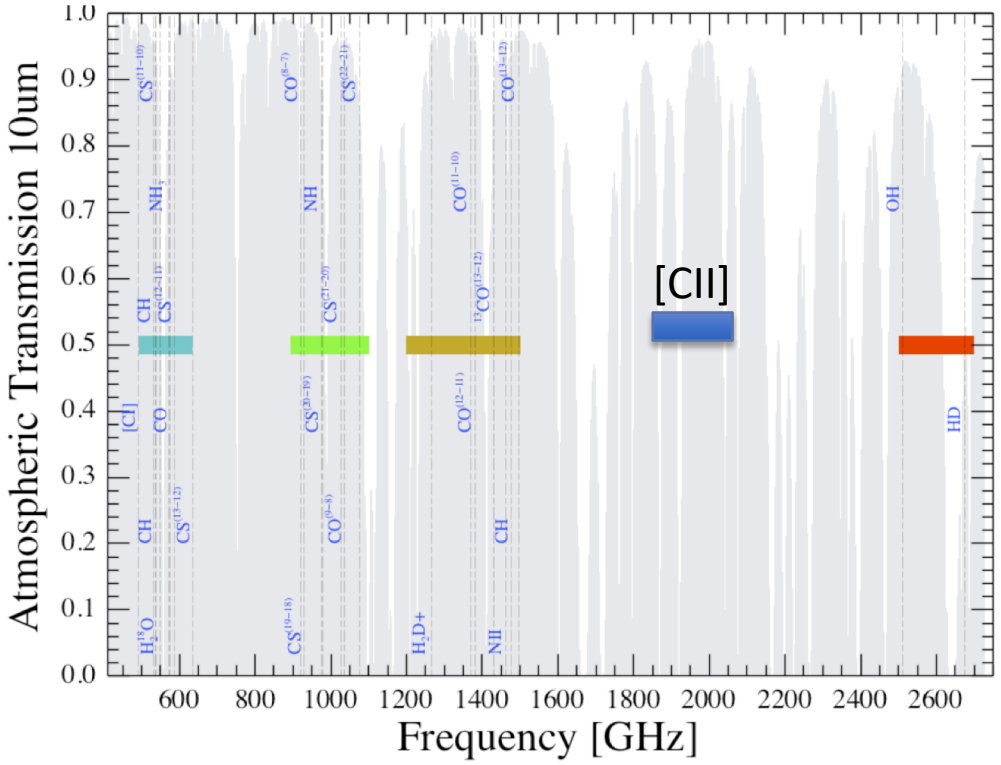
GREAT: THz heterodyne spectroscopy

- Six bands in the 0.5 – 4.7 THz range
- R = 10^8 (<0.1 km/s!)
- Compares to Herschel-HIFI, with faster mapping and similar point source sensitivity



HeH+ first detection (149μm, NGC 7027), Güsten et al. (2019) Nature 568, 357.

- HFA ([OI]63 μm) :
  7 pixels, 0.9 GHz-wide band
- LFA ([CII]):
  7 pixels dual pol., 200 GHz-wide bands
- 4GREAT: simultaneous single pixels, ~200GHZ wide bands

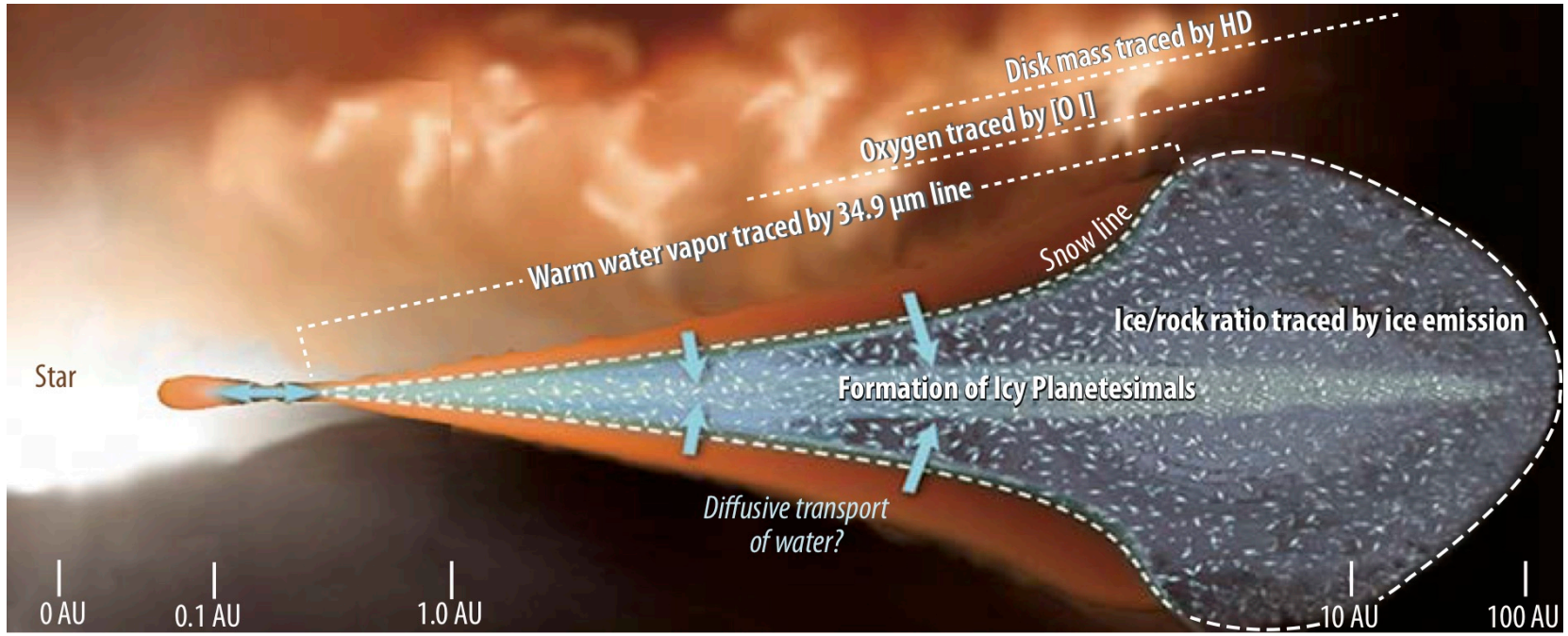


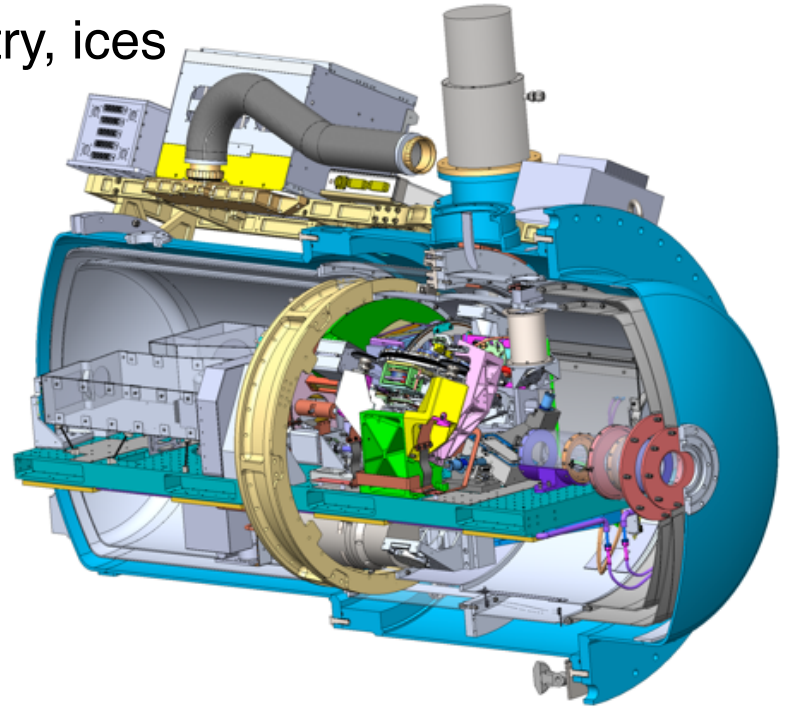
Under development:

HIRMES: **HI**gh-**R**esolution **M**id-infrar**E**d **S**pectrometer, combining Fabry-Perot Interferometers and traditional gratings with diffraction- & background-limited TES bolometers.

Range: 25-122 μm; Spectral resolutions: R ≈ 2k, 600, 10k, 100k

Primary science case: Proto-planetary disks – masses via HD, chemistry, ices



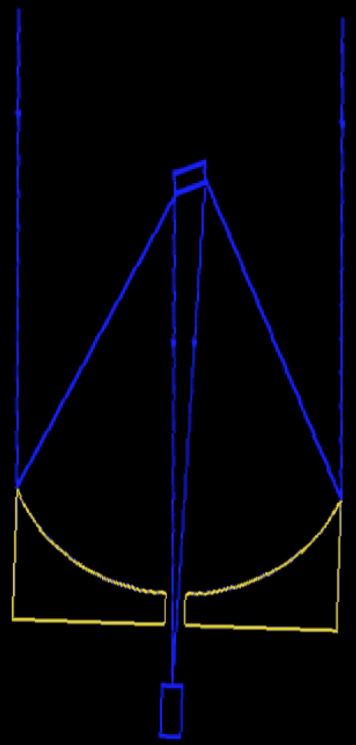


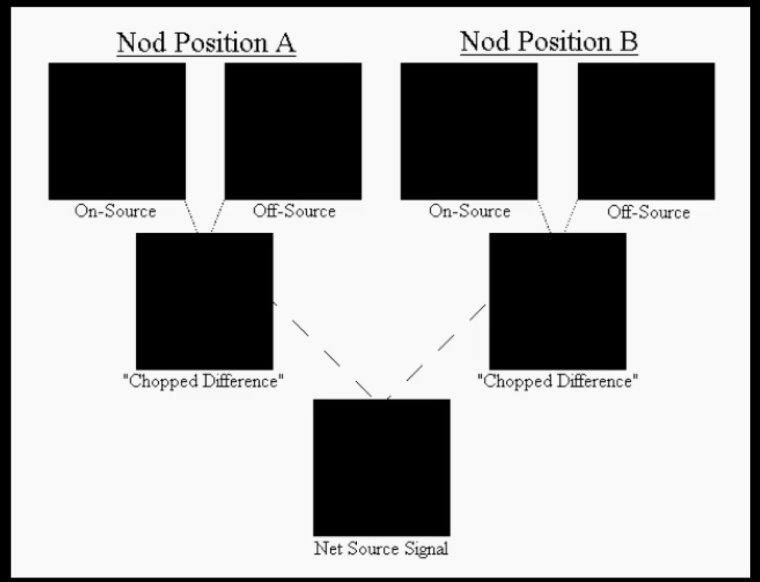
Chopping and Nodding &OTF

Background Subtraction

- IR observations are completely background (sky + telescope) dominated
  - Background can be >10^6 times brighter than most sources
  - Detector wells can fill in 1-100 msec
- 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)

Chopping & Nodding





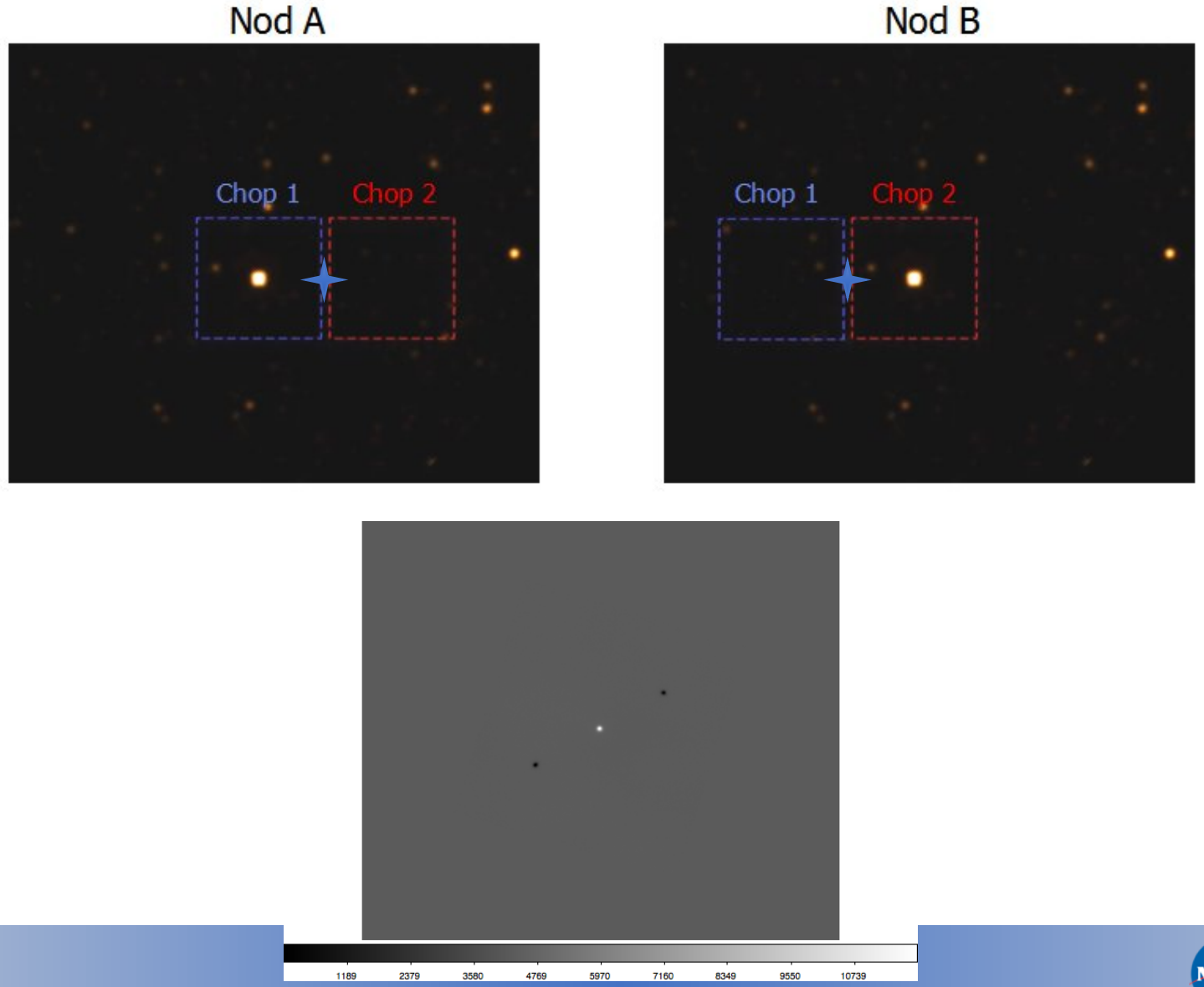
Chop Nod Animation

Nod Position A

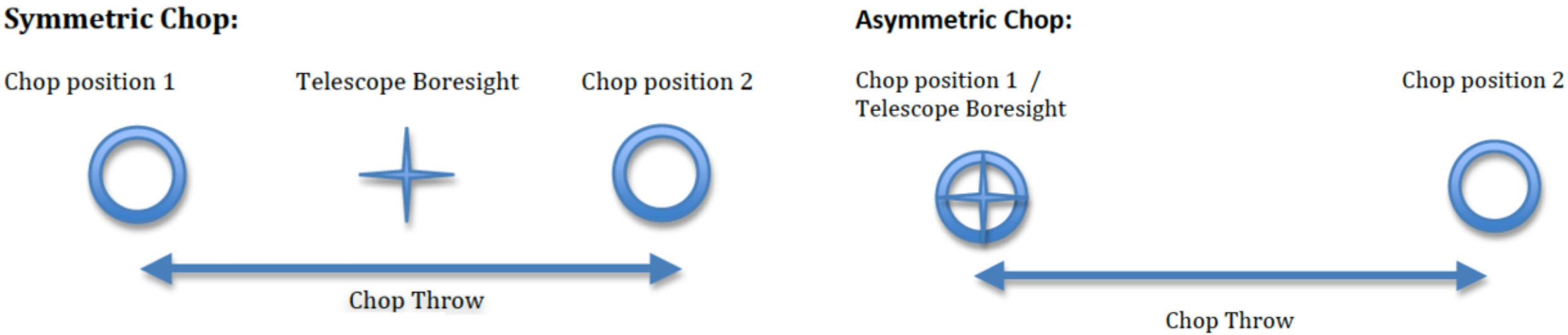
Plus Beam

$$\text{Source+Sky+Tel}_{+} - (\text{Sky+Tel}_{-})$$

Nod_Match_Chop (Symmetric Chop) Mode:

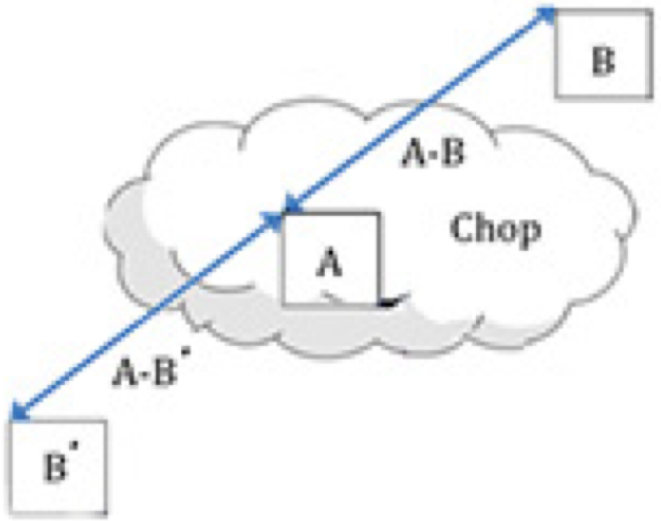


C2NC2 (Asymmetric Chop) Mode:

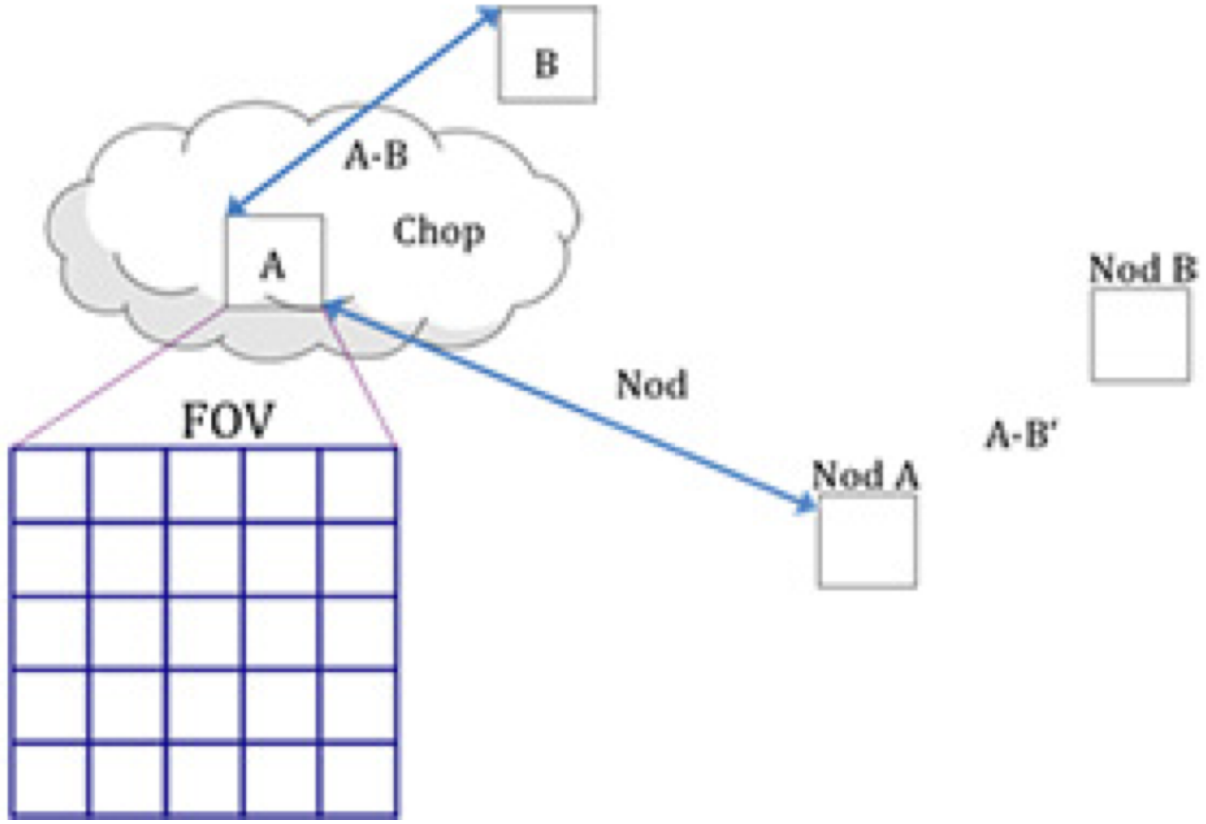


- Off-axis beams have coma degrading the image quality: 1” per 1’ chop throw
- Coma becomes an issue for large symmetric chop throws
- If large chop throws are necessary, an asymmetric chop is required. A matched chop becomes impossible.

Symmetric vs Asymmetric Chop Mode



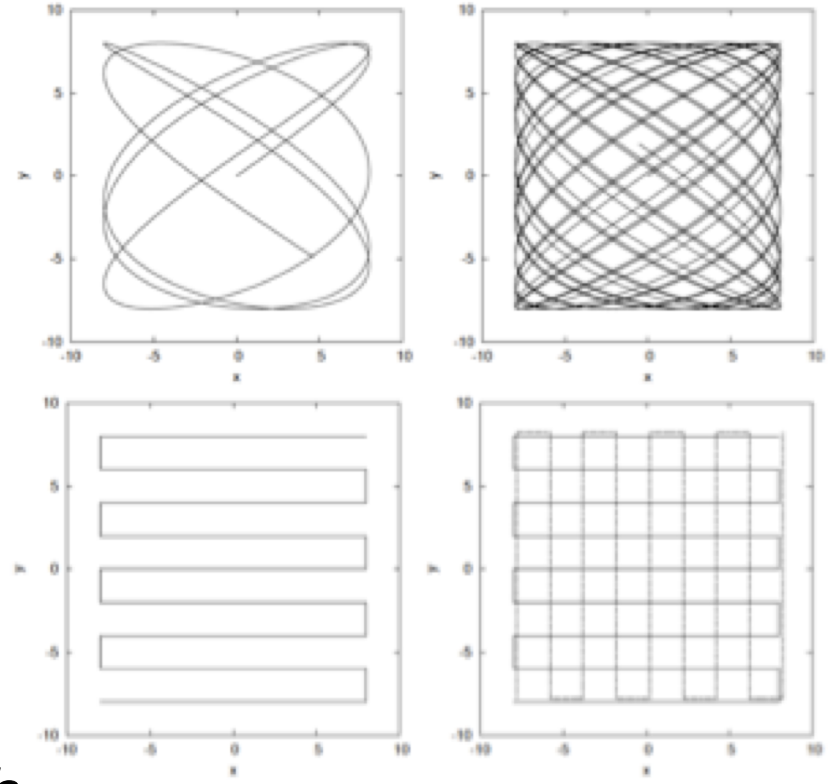
Symmetric/NMC



Asymmetric/C2NC2

On-the-fly mapping: HAWC+

- Total Intensity scan mapping is used with two available patterns:
  - Lissajous for small fields. Use this mode for fields comparable to the FOV of HAWC+
  - Rasters to map large fields.
- In both cases, two scans are required to avoid striping.
- To obtain an absolute flux calibration, part of the map must include regions with no extended flux.
- Polarimetric mode defaults to Chop-nod.
  A polarimetric OTF mode is under development with improved efficiencies. It will be offered to you during Phase II, if it can be applied (map size < 2x FOV)



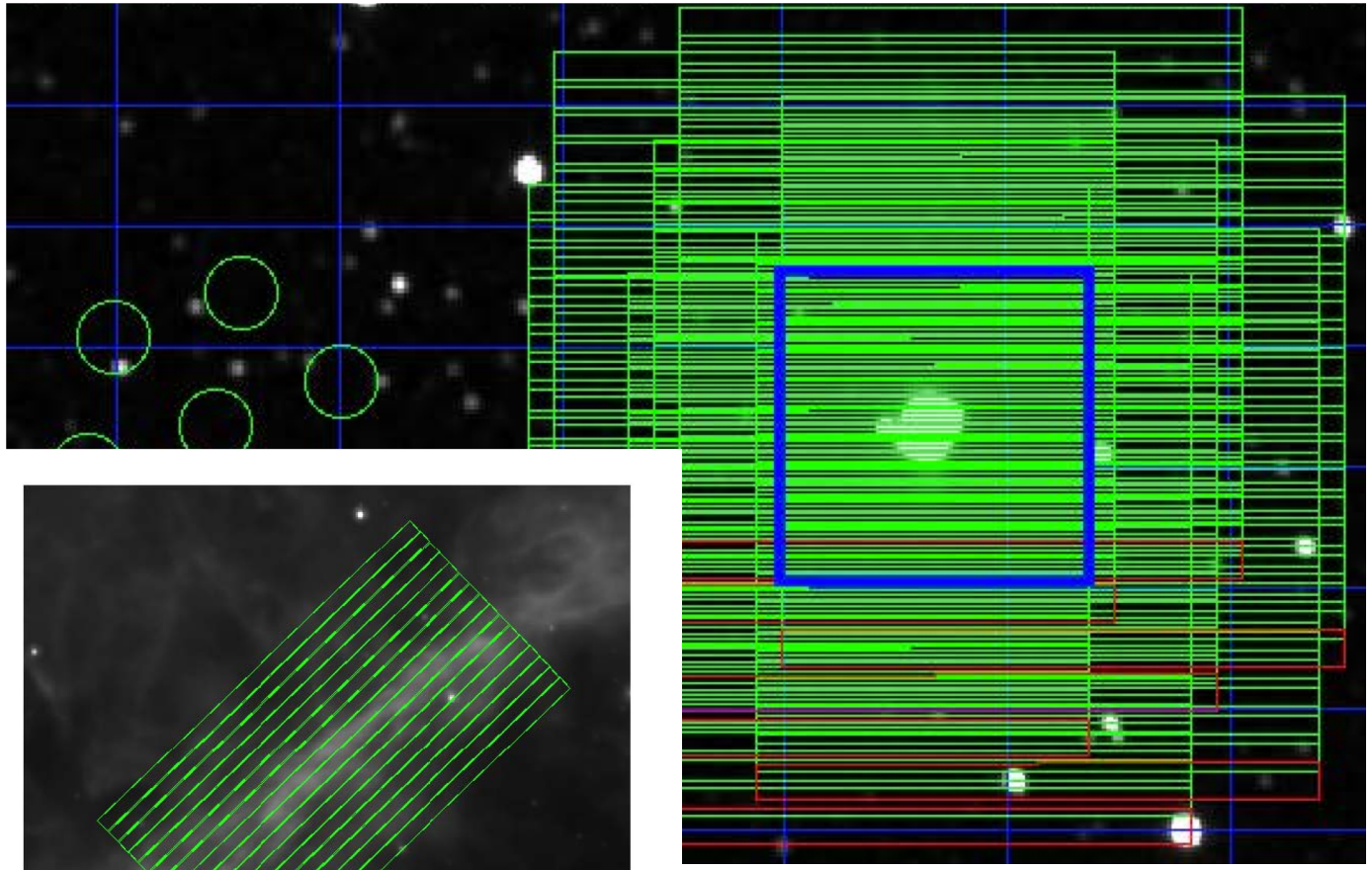
On-the-fly mapping: GREAT

There are two kinds of OTF maps with GREAT:

- **Classic – with any receiver**
- Array – requires array receivers

Both can be either in

- Total Power (TP) mode, i.e. no chopping
  More efficient, needs only one reference position
- Beam Switch (BSW) mode, i.e. with chopping secondary
  Better baselines, requires nearby (< few arcmin) empty area of sky of the same size as the map



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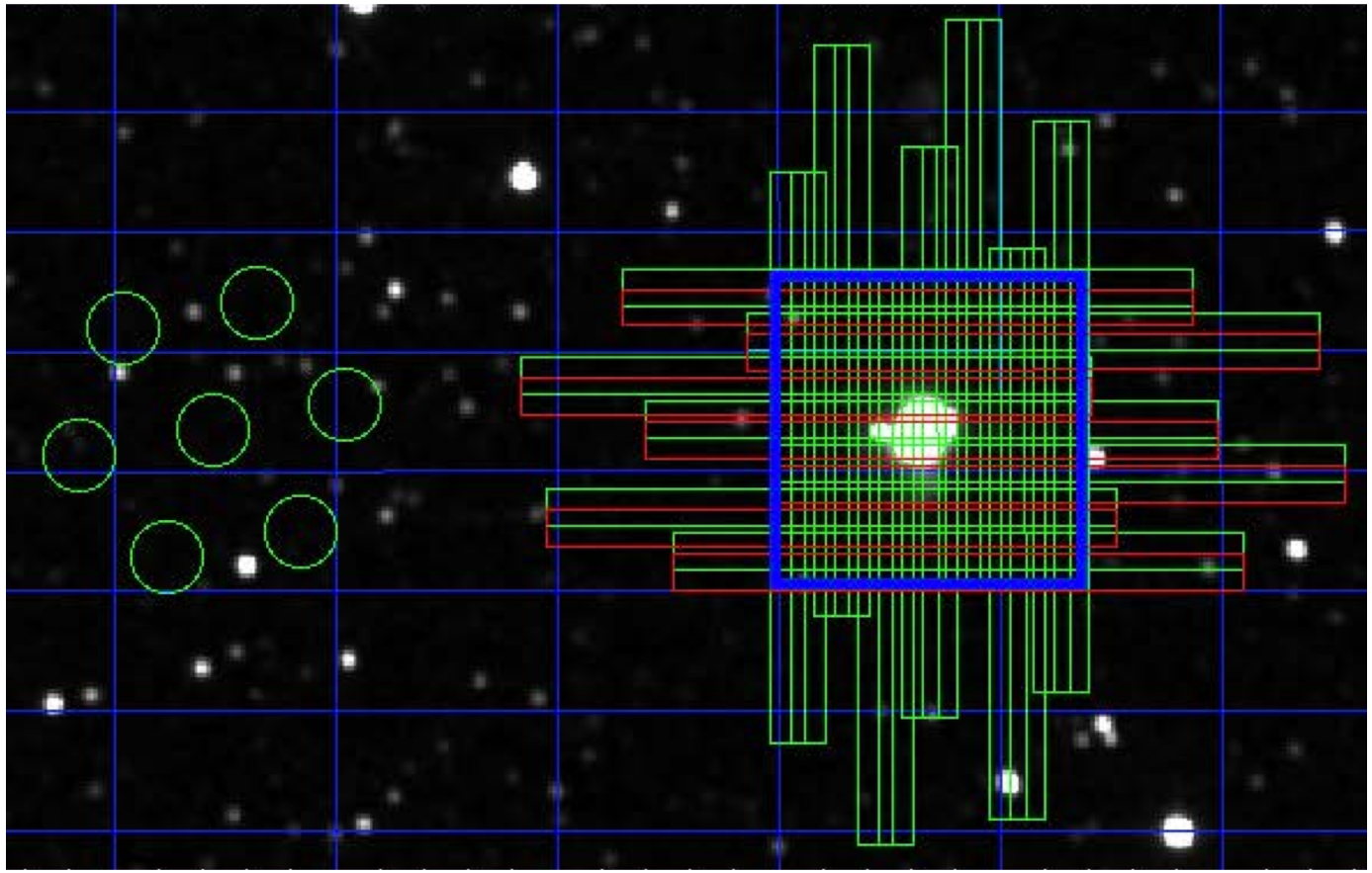

Field of View Rotation

- The Field of View rotates on the sky in a (quasi) horizontally mounted telescope like SOFIA.
- The position angle on the sky of the arrays or slits of the SOFIA instrument is arbitrary and varies over time.
- The exceptions are FIFI-LS and GREAT, which have a beam rotator. The beam rotator allows to choose the array orientation and keep it fixed during the observation.