SOFIA: Stratospheric Observatory for Infrared Astronomy

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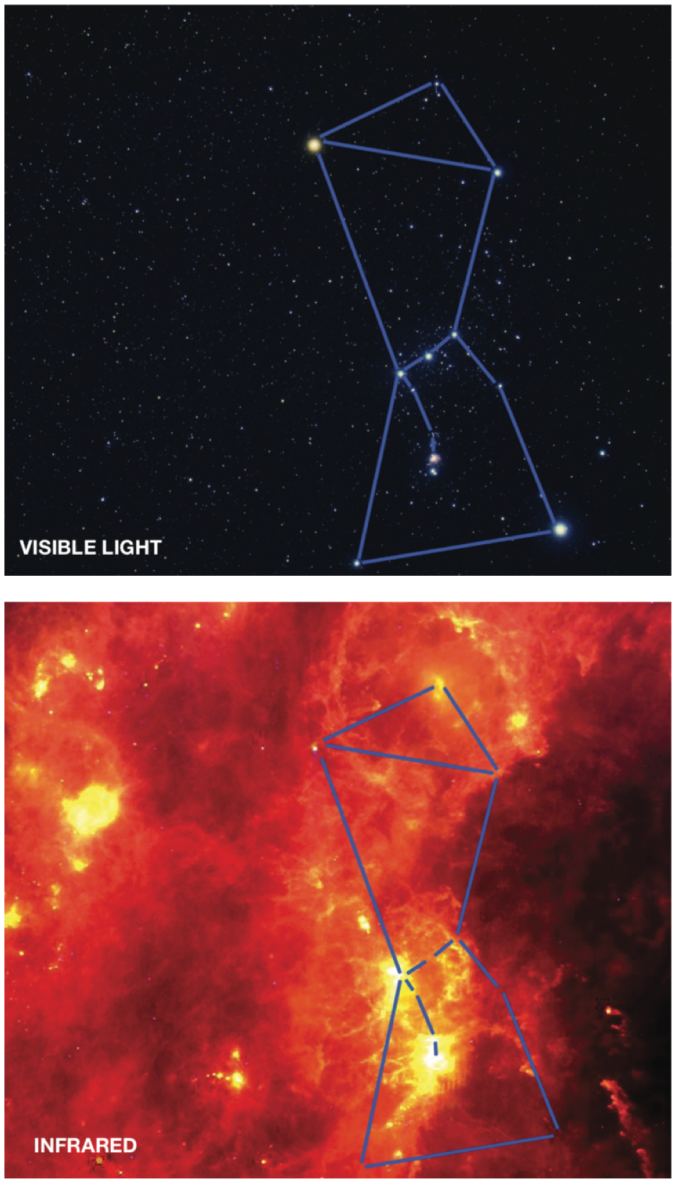
2018.12.21

Outlines

- Infrared Astronomy
- Basic Facts: SOFIA
- Instruments & Results of SOFIA

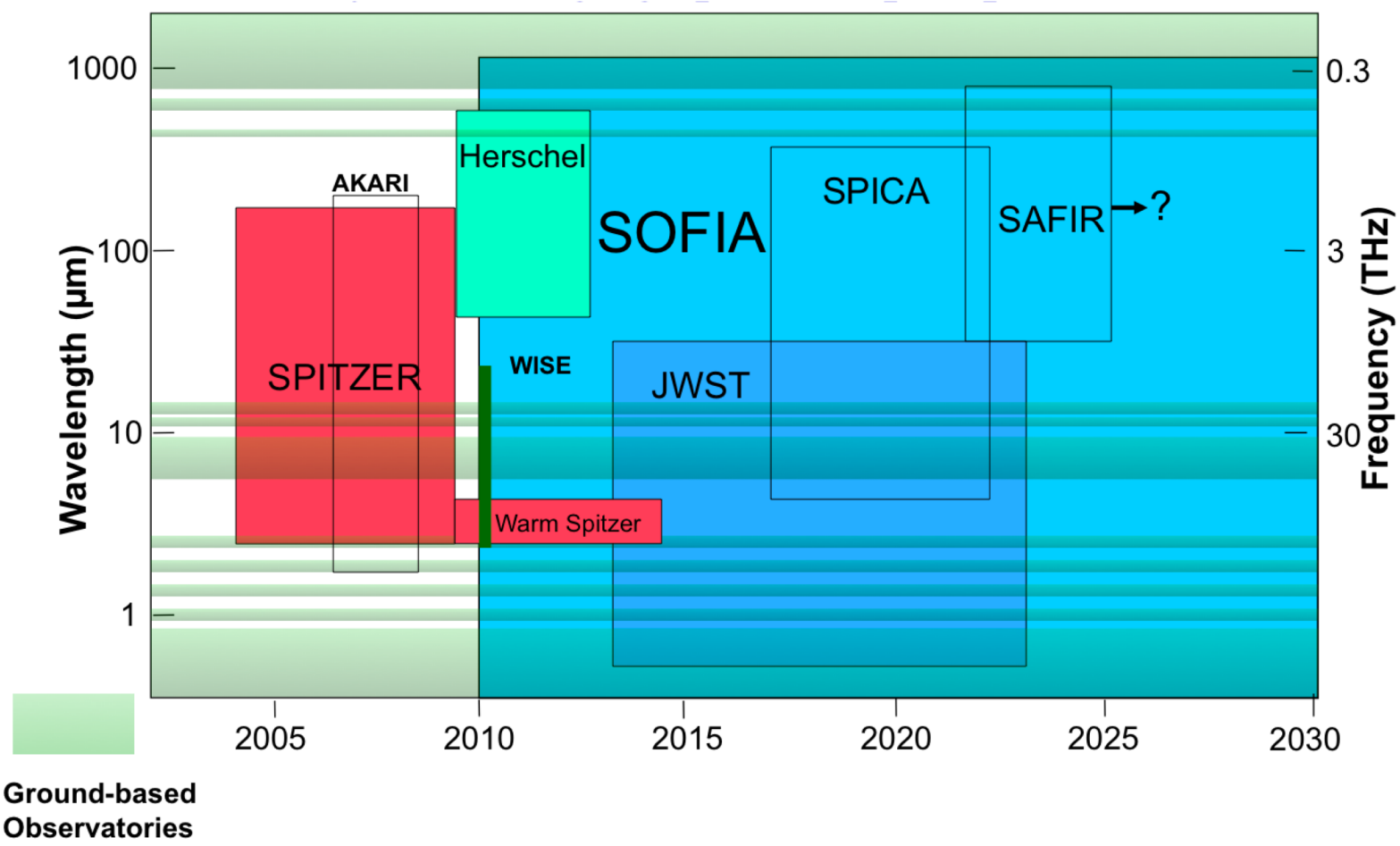
Infrared Astronomy

- **Building New Stars**
  - stellar nurseries
- **Building New Planets**
  - disks of dust around stars
- **Understanding Galaxies**
  - massive central black holes in galaxies
- **Observing the Past**
  - cosmological red shift



Views of the constellation Orion in visible light and infrared
Young stars' presence is revealed by infrared radiation

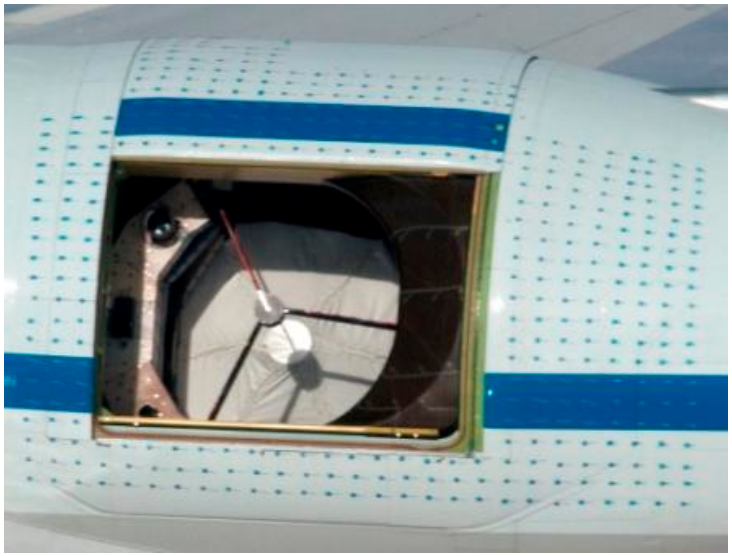
Infrared Observatories



SOFIA's flight lifetime and time-frame will make it the premier facility for doing far-IR and submillimeter wave astronomy from 2010 until the mid 2030s.

Overview of SOFIA

- SOFIA is 2.5 meter telescope in a modified B747SP aircraft
  - Optical-mm performance
  - Obscured IR (30-300 microns) most important
- Joint Program between the US (80%) and Germany (20%)
- First Science 2010 (NASA, DLR, USRA, DSI)
- Designed for 20 year lifetime

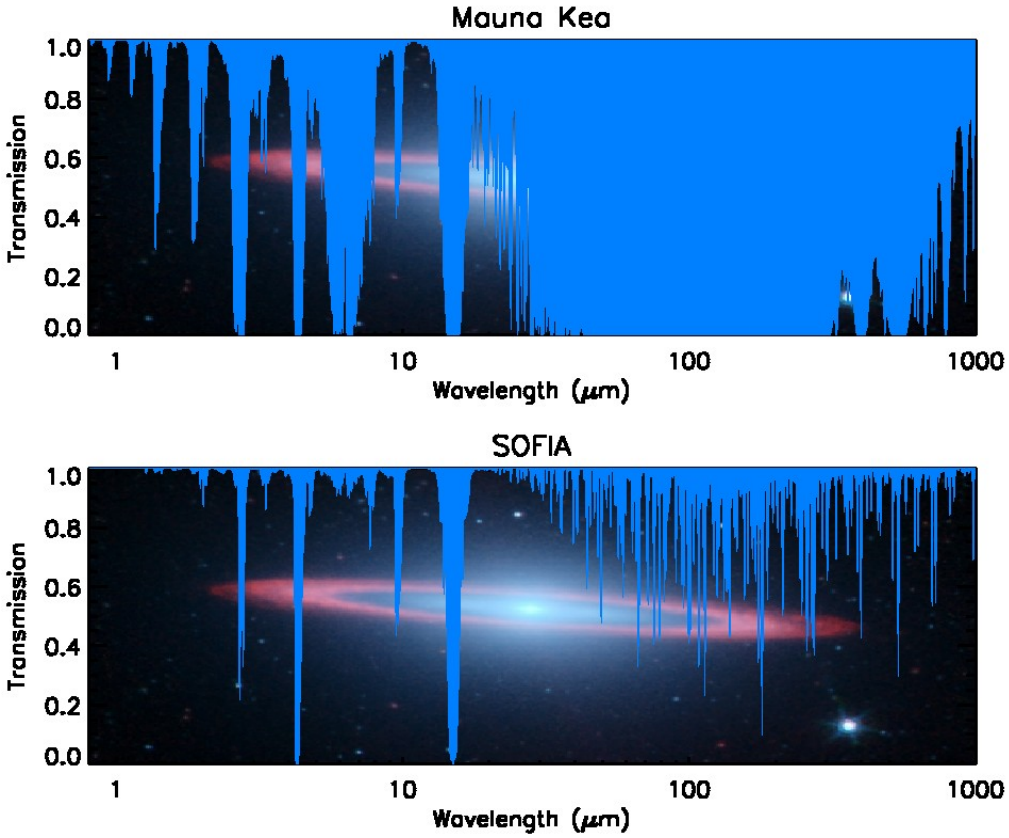


Overview of SOFIA (Cont)

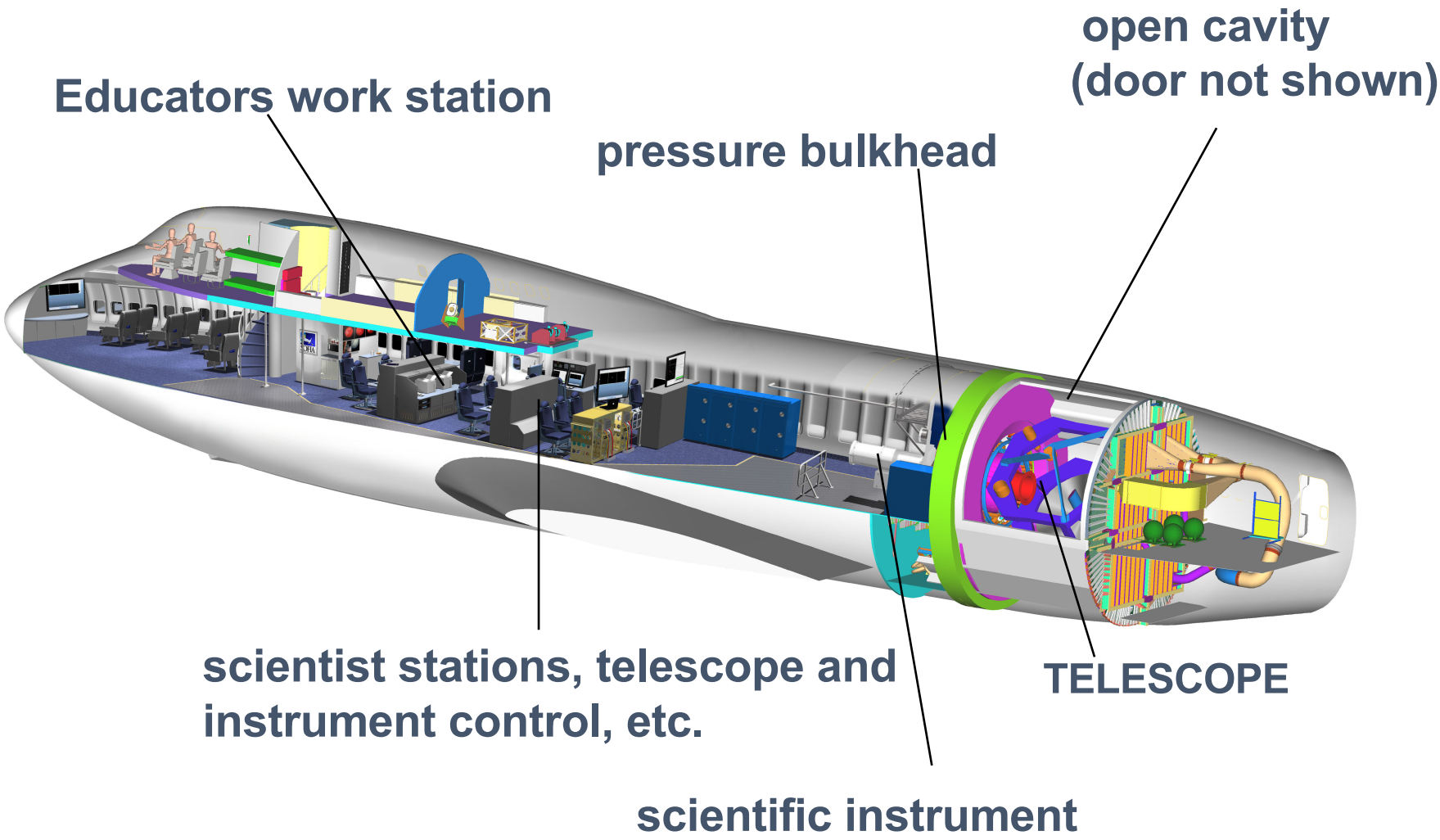
- Operating altitude
  - 39,000 to 45,000 feet (12 to 14 km)
  - Above > 99% of obscuring water vapor
- World Wide Deployments
- Ramp up to ~1000 science hours per year
- Build on Kuiper Airborne Obs (KAO) Heritage with improvements (More and longer flights, Facility Institutions, Science Support)
- Science flights originate from Palmdale, California; Aircraft operated by NASA Dryden Research Center (DFRC)
- Science Center is located at NASA Ames Research Center in Mountain View, California

Why SOFIA?

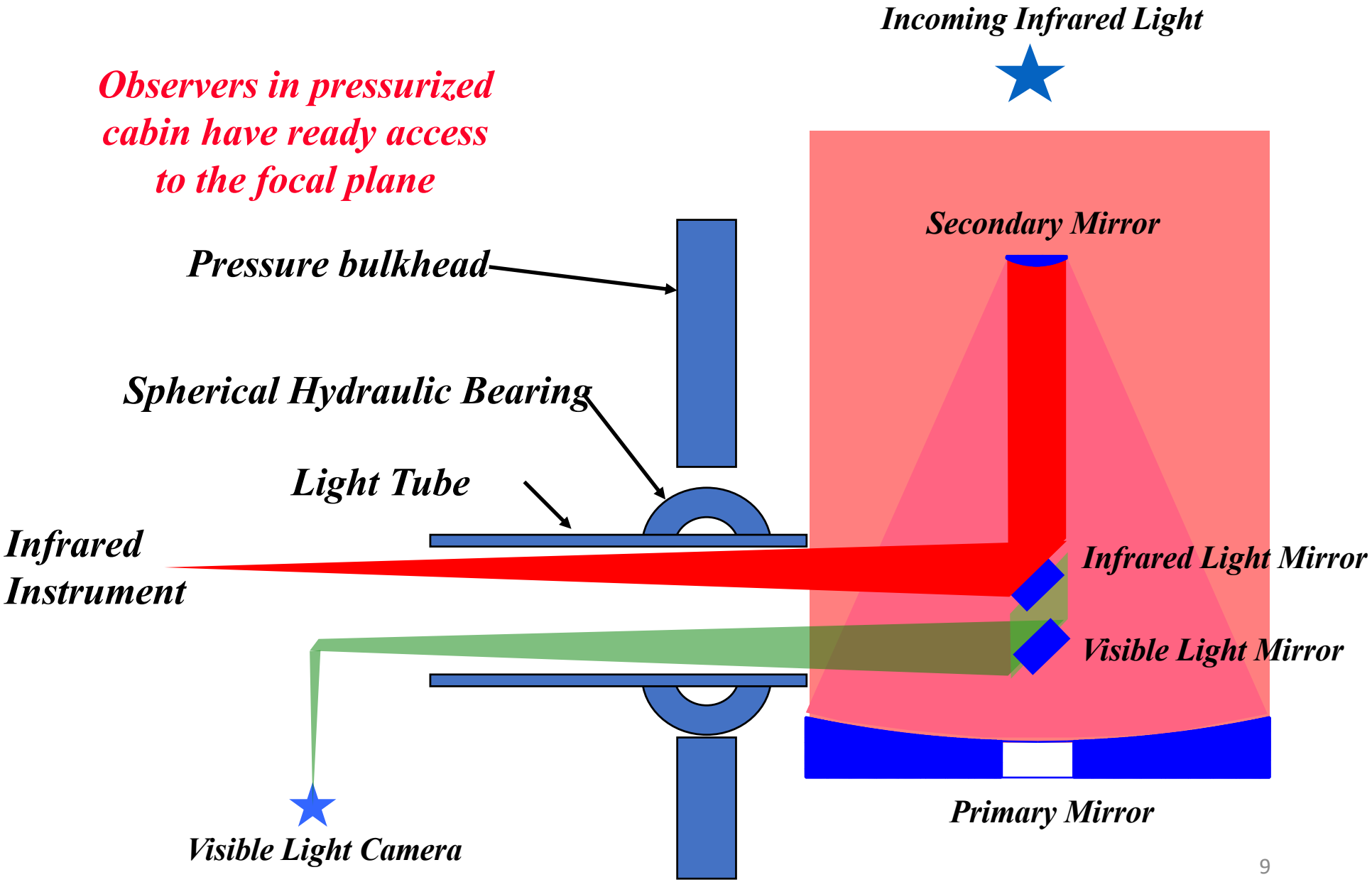
- Infrared transmission in the Stratosphere very good: >80% from 1 to 1000 microns
- Instrumentation: wide complement, rapidly interchangeable, state-of-the art
- Mobility: anywhere, anytime
- Long lifetime: ~20 years
- Outstanding platform to train future Instrumentalists
- Near Space Observatory that comes home after every flight



SOFIA — The Observatory



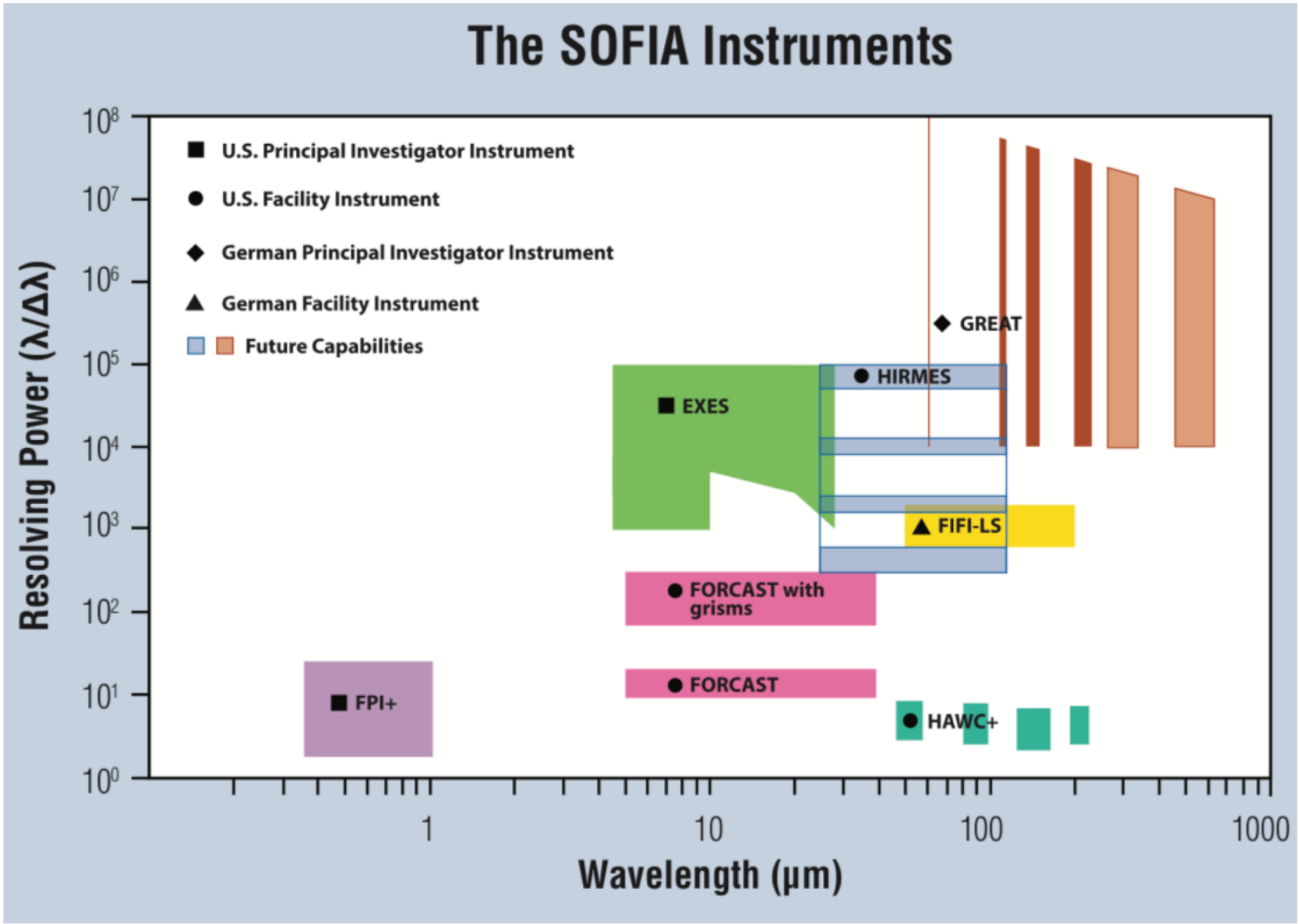
SOFIA Light Path



SOFIA Science Instruments

Name	Principal Investigator	Description	Wavelength Range Resolving Power R = $\lambda/\Delta\lambda$	Field of View Features
INFRARED INSTRUMENTS				
EXES	Matthew Richter, UC Davis	Mid-IR Echelle Spectrometer PI Instrument	4.5 – 28.3 µm R = 1,000 – 105	1" – 180" slit lengths 1024x1024 Si:As
FIFI-LS	Alfred Krabbe, DSI	Far-IR Imaging Grating Spectrometer Facility Instrument	51 – 200 µm R = 600 – 2,000	30" x 30" (Blue) 60" x 60" (Red) 2x(16x25) Ge:Ga
FORCAST	Terry Herter, Cornell University	Mid-IR Camera & Grism Spectrometer Facility Instrument	5 – 40 µm R = 100 – 300	3.2' x 3.2' 2x(256x256) Si:As, Si:Sb
GREAT	Rolf Güsten, MPIfR	Far-IR Heterodyne Spectrometer PI Instrument	63 – 612 µm R = 106 – 108	diffraction limited heterodyne receiver
HAWC+	Charles Dowell, JPL	Far-IR Bolometer Camera & Polarimeter Facility Instrument	50 – 240 µm R = 2.3 – 8.8	from 1.4' x 1.7' (53 µm) to 4.8' x 6.1' (215 µm) 3x(32x40) bolometer
HIRMES	Harvey Mosely, NASA Goddard	Mid-IR Bolometer Spectrometer Facility Instrument	25 – 122 µm R = 325 – 100,000	8.8" x 143" slit 119" x 103" imaging
OPTICAL INSTRUMENTS				
FPI+	Jürgen Wolf, DSI	Focal Plane Imager Facility Instrument	0.36 – 1.10 µm R = 0.9 – 29.0	8.7' x 8.7' 1024x1024 CCD

SOFIA Science Instruments

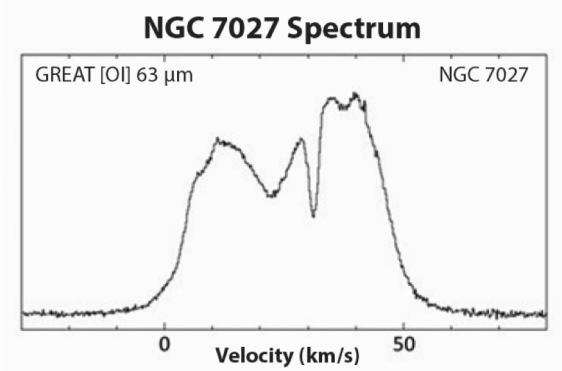


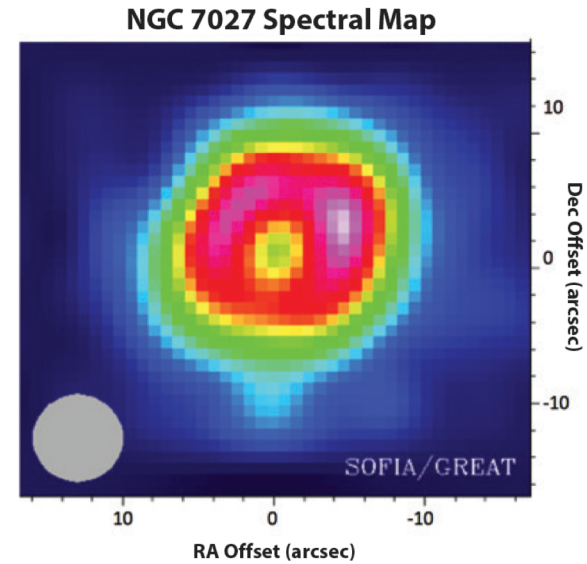
SOFIA Instruments: GREAT

- GREAT: German REceiver for Astronomy at Terahertz Frequencies
  - Detector: dual channel mixer
  - high resolution spectra (up to $R=10^8$) in the 0.490–4.747 THz range
  - Science: Spectroscopy of CII (158 µm) and HD (112 µm) and other lines
  - Targets: Galactic and extragalactic interstellar medium, circumstellar shells

Scientific results of GREAT

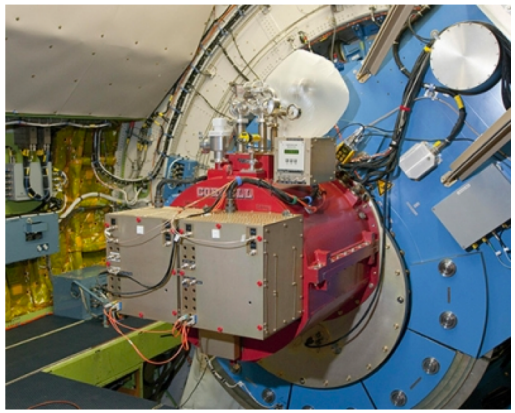
- Planetary Nebula NGC 7027
- Spatial scans:
  - in the [OI] 63 µm line
  - integrated spectrum
  - spectral map
  - gray circle: effective angular resolution
- Displays the characteristic shape for an expanding, optically thin shell
- Shows that the expanding nebula has multiple components moving at different velocities





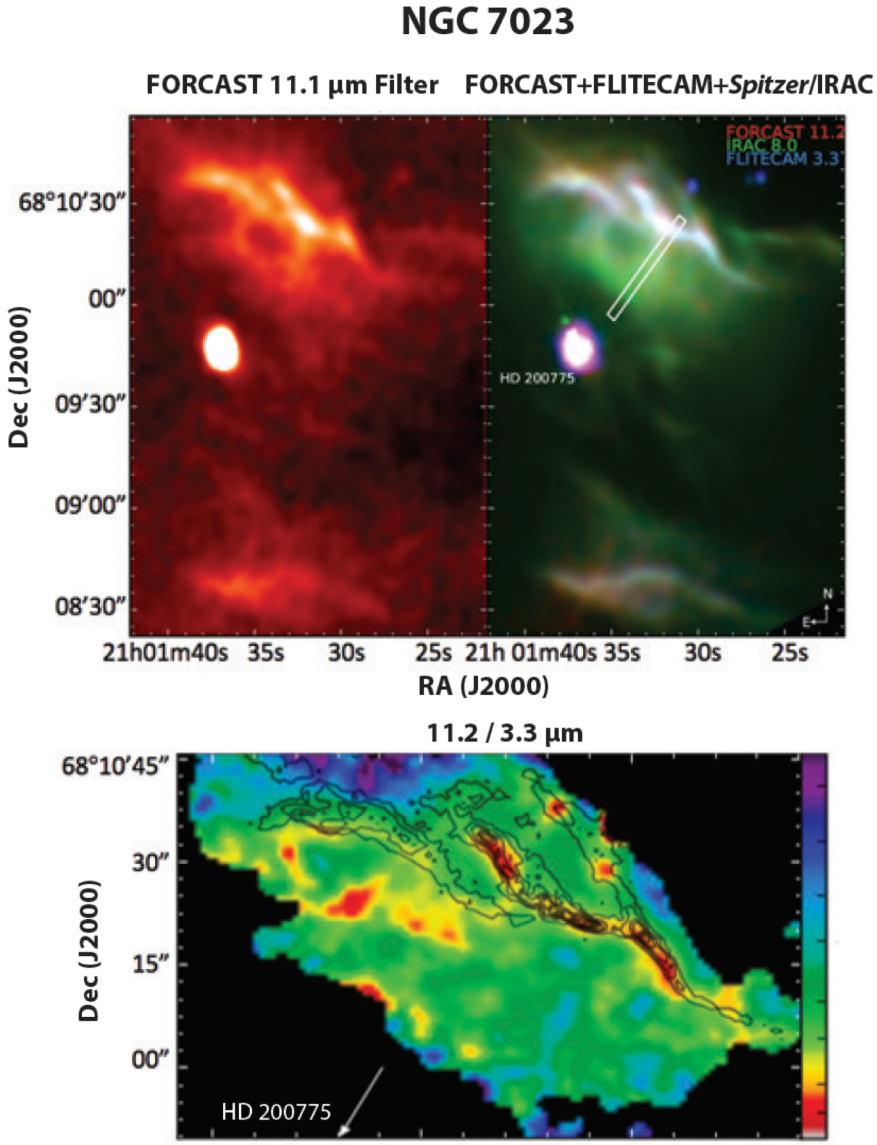
SOFIA Instruments: FORCAST

- FORCAST: Faint Object InfraRed Camera for the SOFIA Telescope
- Mid-IR Camera & Grism Spectrometer
  - Detectors: Dual channel
    - 256 x 256 arrays;
    - Wavelength Range 5 – 25 μm (Si:As Detector)
    - Wavelength Range 20 – 40 μm (Si:Sb Detector)
  - Field of View: 3.2’ x 3.2’
  - Diffraction limited imaging for $\lambda > 15$ μm is expected during full operations
  - Science: Thermal and narrow band imaging And Grism spectroscopy
  - Targets: Circumstellar disks, Galactic Center, Galactic and extragalactic star formation



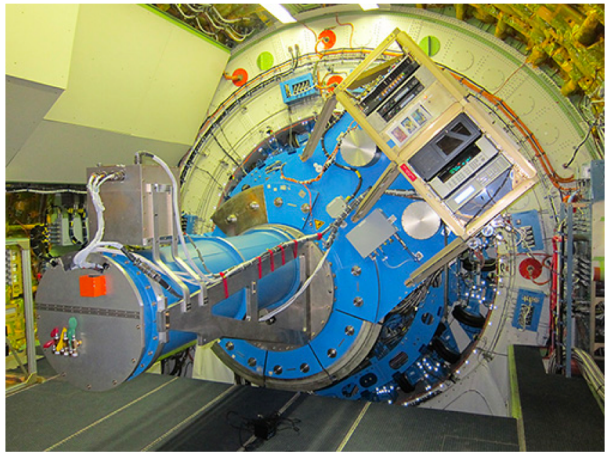
Scientific results of FORCAST

- PAH Tracing at 11.2 µm
  - FORCAST: 11.1 µm data of NGC 7023
  - Combined with FLITECAM 3.3 µm data and *Spitzer*/IRAC 8.0 µm data
  - yield a plot of the 11.2/3.3 µm flux ratio revealing the PAH size distribution
- Help to understand the photochemical evolution of PAHs resulting from illumination by the nearby star HD 200775.



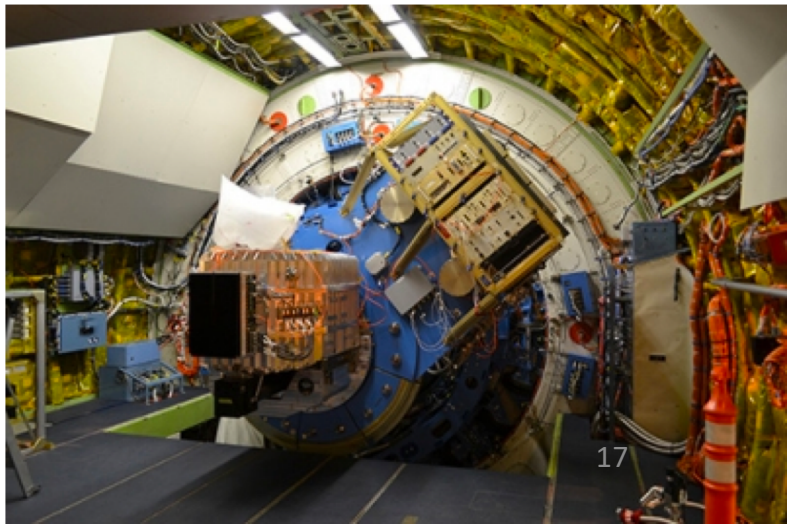
SOFIA Instruments: EXES

- EXES: Echelon-Cross-Echelle Spectrograph
- Mid-IR Echelle Spectrometer
  - Use a 1024^2 Si:As IBC detector
  - Wavelength Range 4.5-28.3 µm
  - Three Resolving Powers:
    - High: ~ 105
    - Medium: ~ 104
    - Low: ~3000
  - Science: molecules which are blocked by the Earth's atmosphere, such as molecular hydrogen, water vapor, and methane
  - Targets: molecular clouds, protoplanetary disks, interstellar shocks, circumstellar shells, and planetary atmospheres.



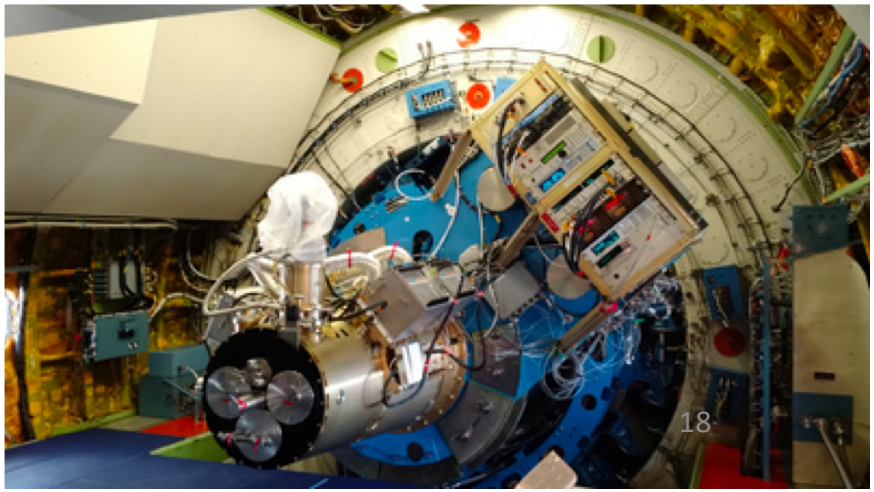
SOFIA Instruments: FIFI-LS

- FIFI-LS: Field Imaging Far-Infrared Line Spectrometer
- Far-IR Imaging Grating Spectrometer
  - Detectors: Dual channel 16 x 25 arrays;
    - 42 – 110 μm (Ge:Ga)
    - 120 - 210 μm (Ge:Ga stressed)
    - Field of View: 30” x 30” (blue), 60” x 60” (red)
  - Science: Imaging of extragalactic CII & OI
  - Targets: Extragalactic imaging



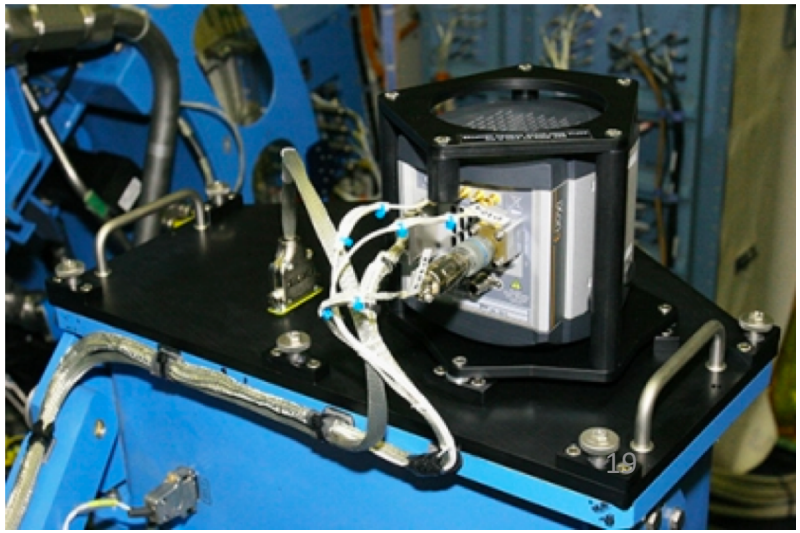
SOFIA Instruments: HAWC+

- HAWC+: High-resolution Airborne Wideband Camera Plus
- Far-IR Bolometer Camera and Polarimeter
  - bolometer detectors: 64x40 pixel array
  - Wavelength range: 42 - 210 µm
  - Science: infrared source energetics and morphology, interstellar magnetic fields
  - Targets: interstellar dust



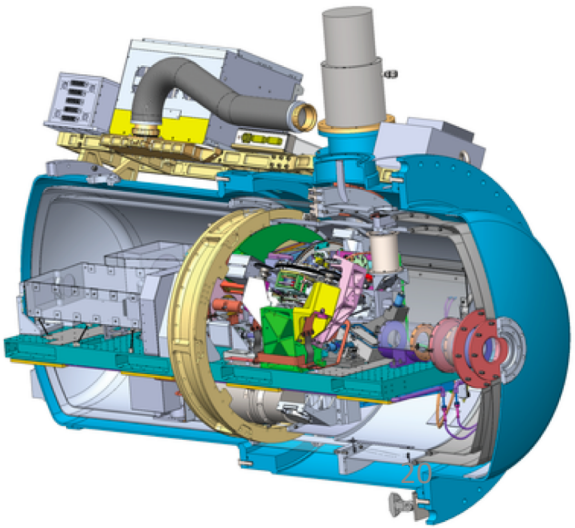
SOFIA Instruments: FPI+

- FPI+: Focal Plane Imager Plus
  - 1024x1024 CCD
  - Wavelength Range 0.36 – 1.10 µm: optical
  - Field of View: 8.7' x 8.7’
  - Science result:
    - Pluto Stellar Occultation : analysis of the upper atmosphere



SOFIA Instruments: HIRMES

- HIRMES: HIgh Resolution Mid-infrarEd Spectrometer
- Expected to begin observations in 2019
- Background limited bolometers and a combination of Fabry-Perot interferometers and gratings
  - Low, Mid, and Imaging Spectroscopy modes : 16x64 Mo:Au TES bolometer pixel array
  - High mode : 8x16 pixel array
  - Wavelength Range 25 – 122 µm
  - R = 325 – 100,000
  - Science: evolution of protoplanetary systems
  - Targets: protoplanetary systems, interstellar shocks



Summary

- Infrared Astronomy has extensive scientific prospects but can’t be detected at low altitude because of vapor
- SOFIA has many advantages comparing with ground-based telescopes and satellites
- With different science instruments, SOFIA has abundant scientific results in different areas