USRA NASA DLR SOFIA

SOFIA: The Stratospheric Observatory for Infrared Astronomy

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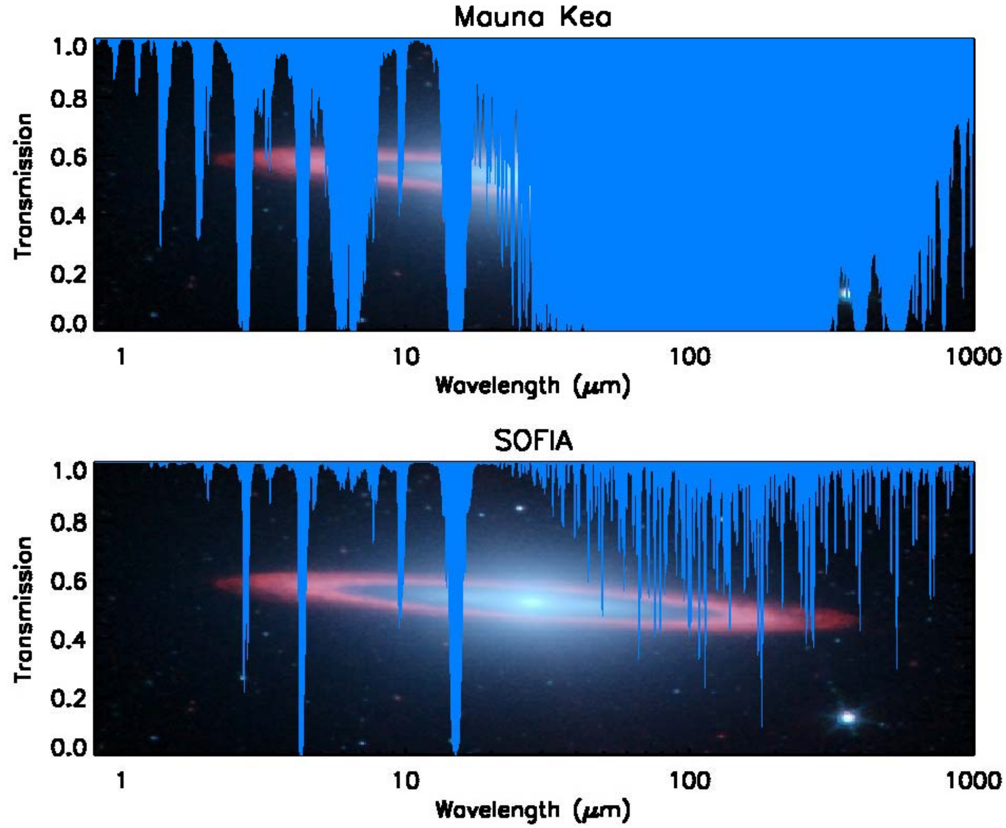
SOFIA Science and Mission Operations Center

Keck Institute for Space Studies Workshop on **Innovative Approaches to Exoplanet Spectra**

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
- Outstanding platform to train future Instrumentalists
- Near Space Observatory that comes home after every flight
- SOFIA will have an important role in education and public outreach



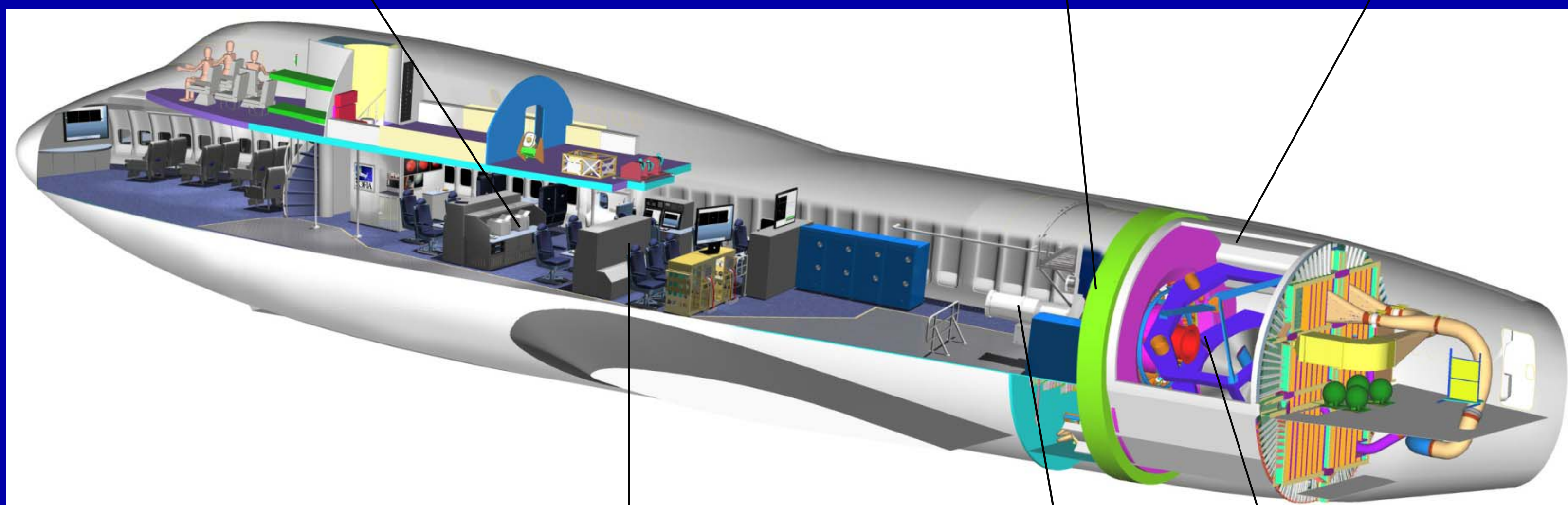
Overview of SOFIA

- SOFIA is a 2.5 m telescope in a modified B747SP aircraft
  - Optical-mm performance
  - Obscured IR (30-300 μm) most important
- SOFIA is a joint program between the US (80%) and Germany (20%)
- Operating altitude
  - 39,000 to 45,000 feet (12 to 14 km)
  - Above > 99% of obscuring water vapor
- First science flights will occur in 2010
- Designed for 20 year lifetime

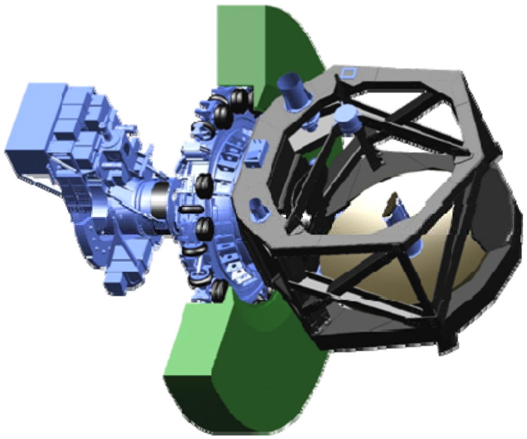
SOFIA Operations

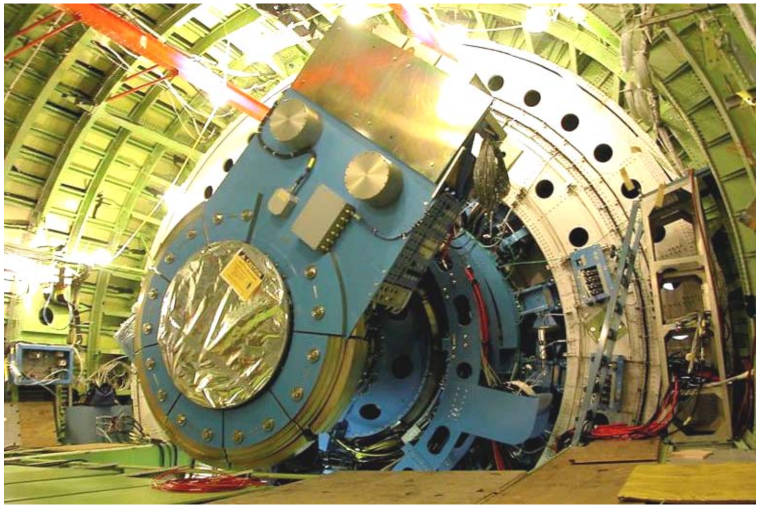
- Science flights to originate from Palmdale California
  - Aircraft operation by NASA Dryden Research Center from the Dryden Aircraft Operations Facility (DAOF)
- Science Center is located at NASA Ames Research Center
- World Wide Deployments
- SOFIA will ramp up to ~1000 science hours per year
- SOFIA will support the development of new generations of instruments, promising ever increasing capabilities

SOFIA — The Observatory



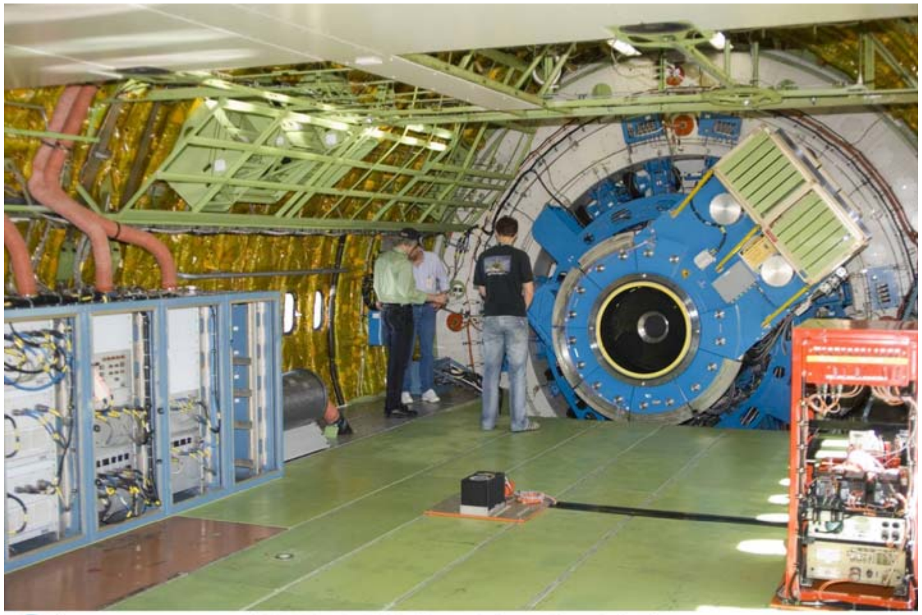
Telescope Assembly - DLR





Major Physical Installations Completed

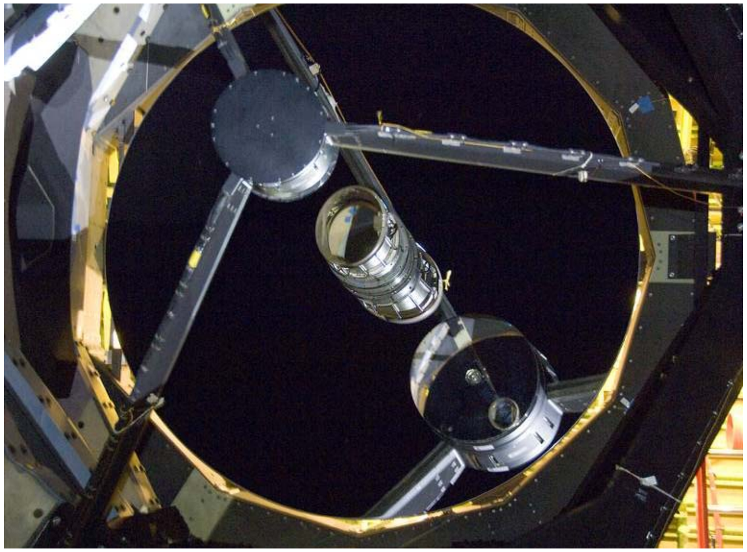
Main Deck, Looking Aft at Instrument Interface



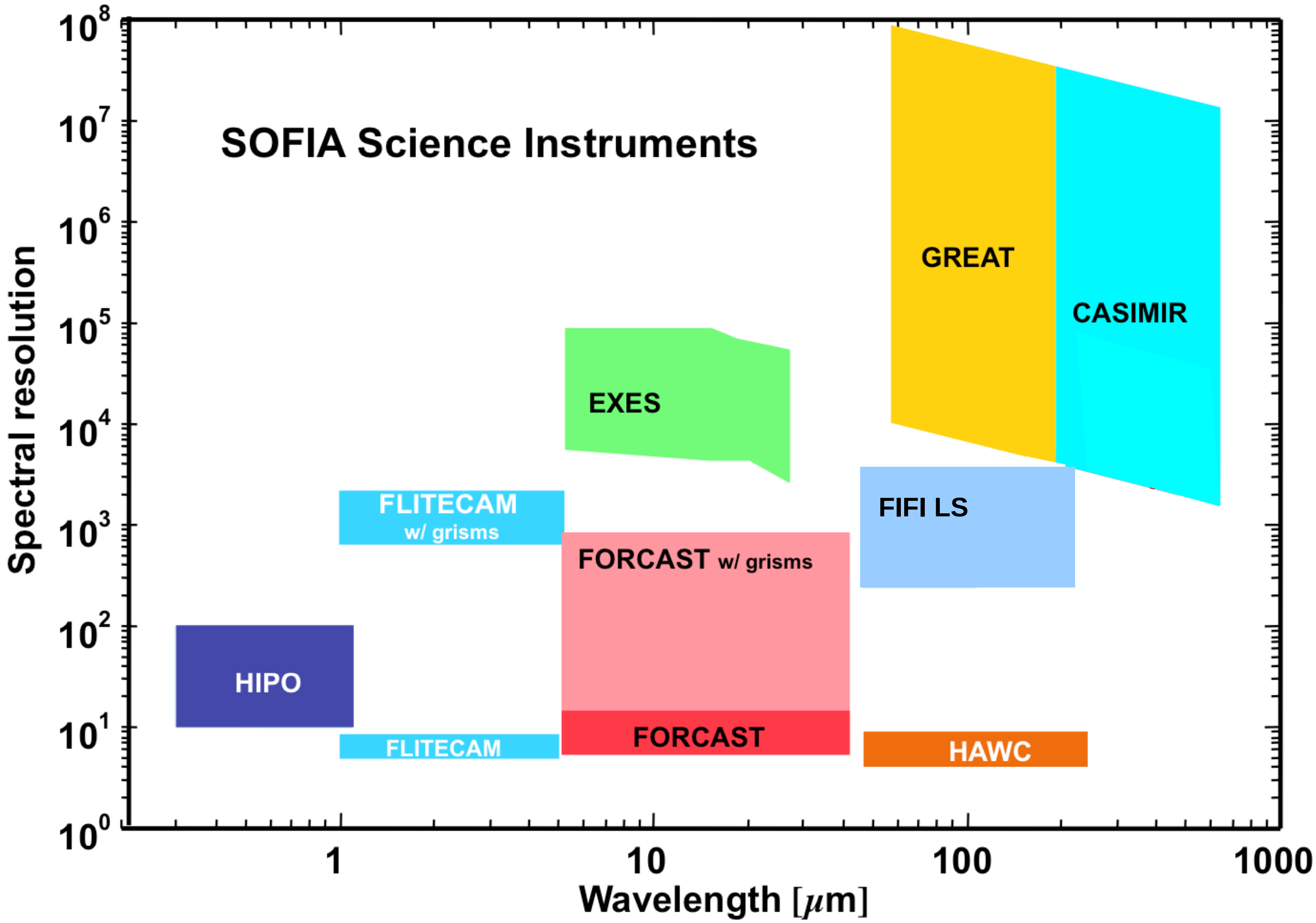
NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: ED07-0078-033 Date: April 25, 2007 Photo By: Tony Landis

Technicians check out the mounting structure of the infrared telescope installed in NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA).

Telescope Installed



First Generation Instrument Complement



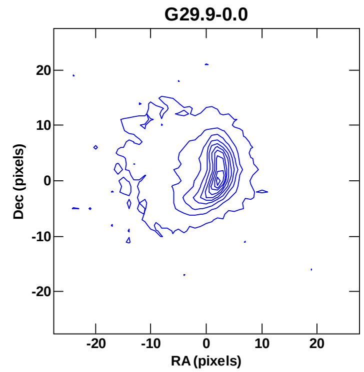
FORCAST: Mid-IR Imager

PI: T. Herter (Cornell Univ.)
herter@astrosun.tn.cornell.edu

Detectors: Dual channel
256 x 256 arrays;
5 – 25 μm (Si:As)
20 – 40 μm (Si:Sb)

Field of View: 3.2’ x 3.2’

G29.9-0.0

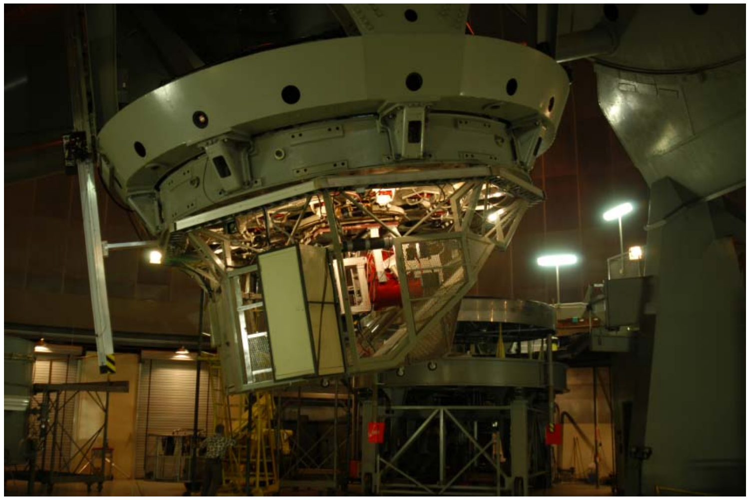


10.6 μm (Δλ = 0.23 μm) image and contour map of the cometary HII region G29.9-0.0 made with FORCAST. RA and Dec are in pixels (~ 0.5”/pixel).

Science: Thermal and narrow band imaging

Targets: Circumstellar disks, Galactic Center, Galactic and extragalactic star formation

NB: Diffraction Limited > 15 microns;
Grism upgrade funded (Ennico et al.)



FORCAST at Palomar Summer 2006

GREAT: Heterodyne Spectrometer

PI: R. Guesten, Max-Planck Institut, Bonn
guesten@mpifr-bonn.mpg.de

Detector: dual channel mixer (HEB);
60 – 200 µm (2 – 5 THz)

Field of View: single element

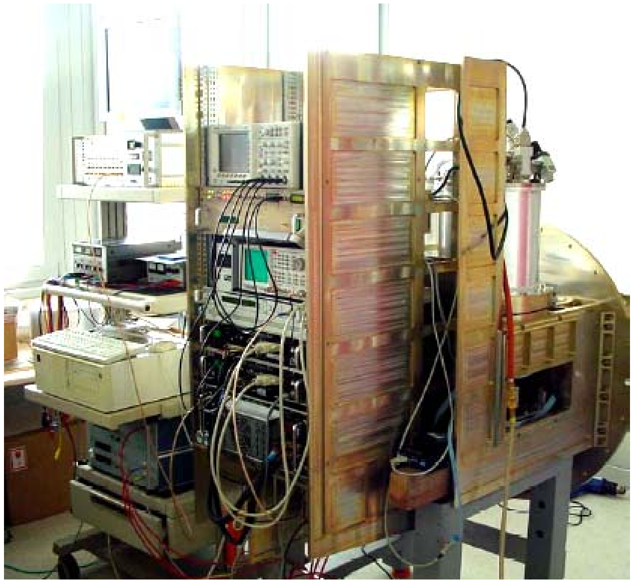
R= 10^6 -> 10^8

Science: Spectroscopy of CII (158 µm), and HD (112 µm)

Targets: Galactic and extragalactic ISM, circumstellar shells

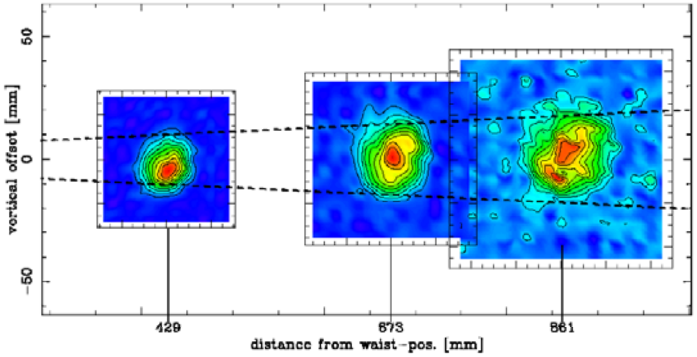
NB: T_S ~ 2500 K at 158 µm

High frequency upgrade at 4.7 THz expected for OI (63 µm).



Theoretical beam-width @ focal plane: 2.55mm

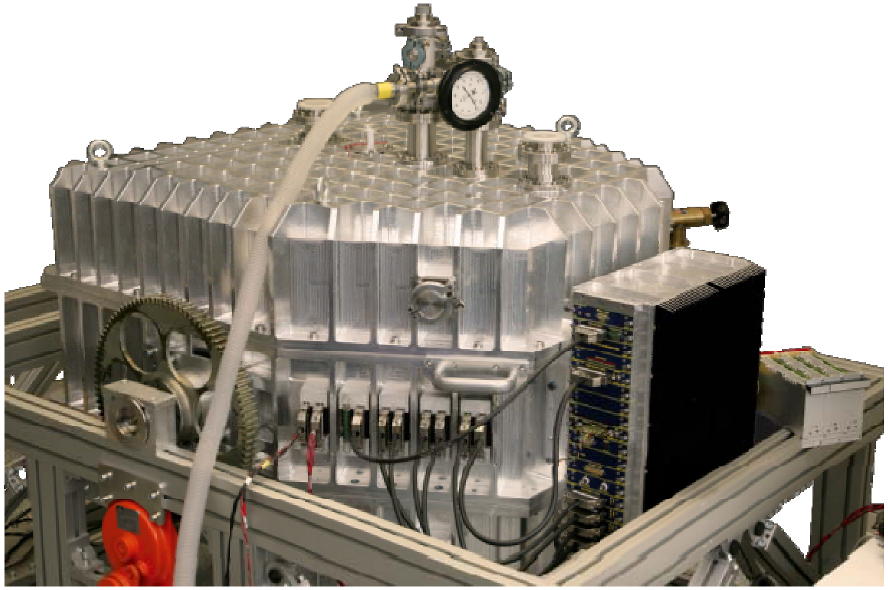
Measured	in x-direction	:	(2.2 ±0.2)mm
	in y-direction	:	(2.5 ±0.2)mm

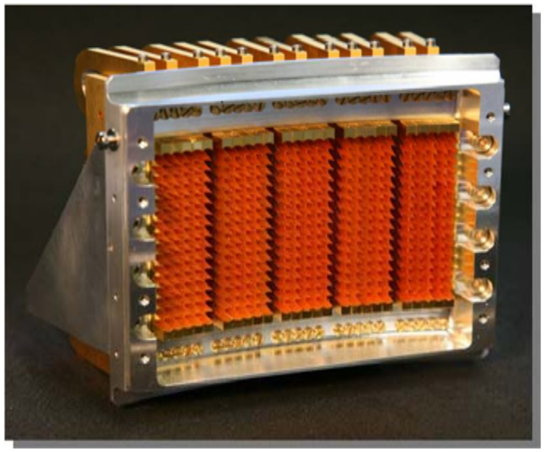


Successful lab demonstration of GREAT in Oct 2005

FIFI-LS Integral Field Spectrometer

- Principal Investigator:
  Albrecht Poglitsch (Max-Planck-Institut fur Extraterrische Physik)
- FIFI-LS will have two separate medium resolution (R ~ 1700) integral field spectrometers (5x5 pixels)
- Two Ge:Ga detector arrays (16 x 25 pixels each)
- Two Littrow spectrometers can simultaneously observe an object in two spectral lines in the wavelength ranges 42 - 110 μm, and 110 - 210 μm





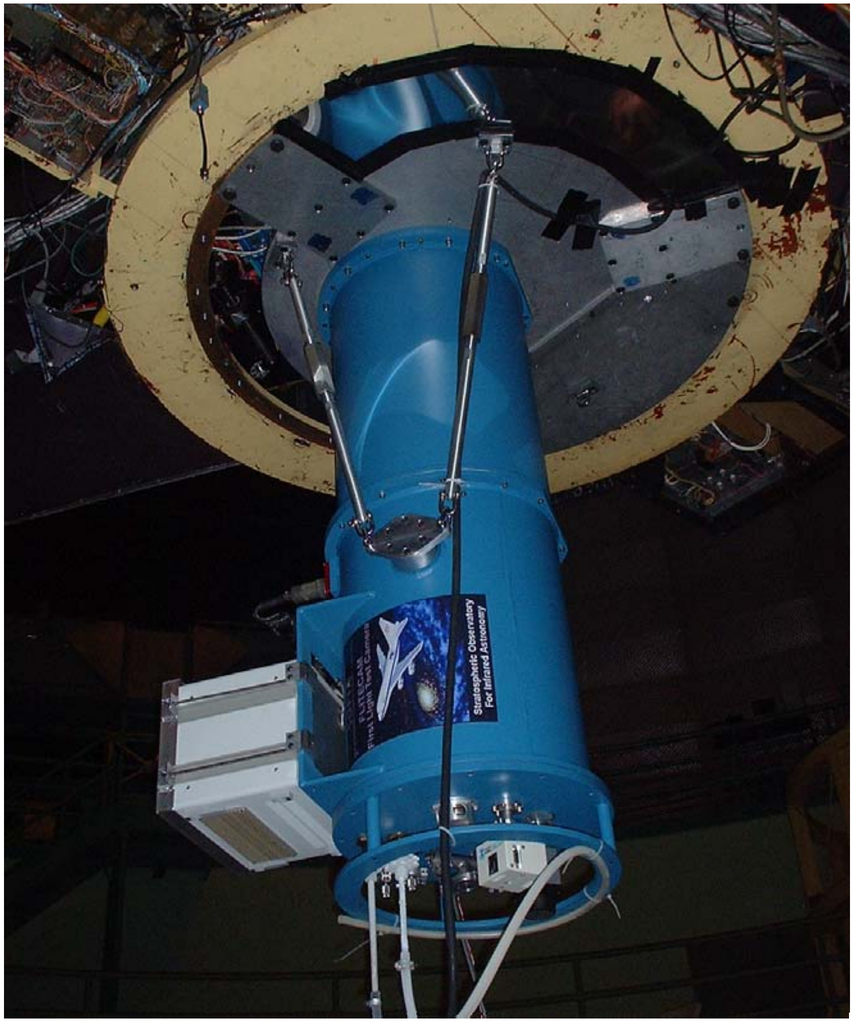
FLITECAM: Near-IR Imager & GRISM Spectrometer

Principal Investigator:
Ian McLean (University of California Los Angeles)

Detector: 1024 x 1024 InSb array

Imaging for 1 to 5.2 μm

GRISM will provide spectroscopic resolutions up to 2000



FLITECAM at Lick Observatory 2005

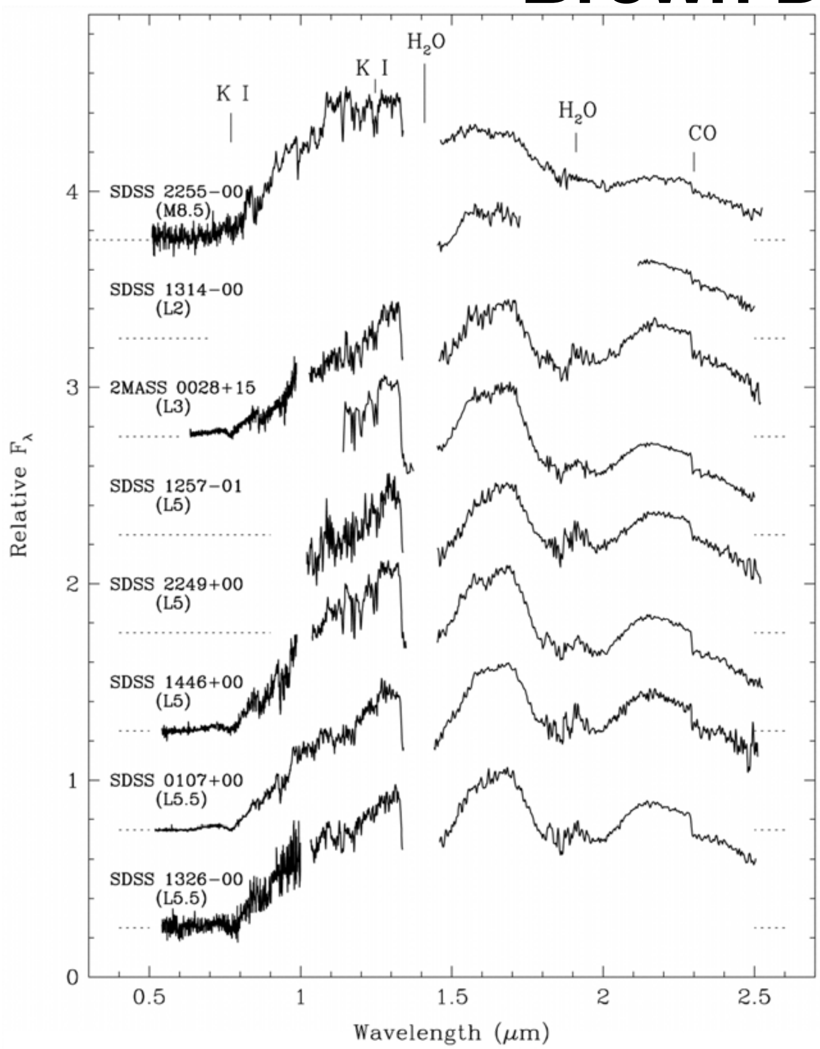
EXES High Resolution Echelon Spectrometer

- Principal Investigator:
  Matt Richter (University of California, Davis)
- 1024 x 1024 Si:As Blocked Impurity Band Detectors
- Covers 5 – 28 μm wavelength
- Three Spectral Modes:
  - R = 50-100,000 cross-dispersed
  - R = 15,000 long-slit
  - R = 4,000 long-slit
- The echelle cross disperser provides 5 cm^{-1} continuous spectral coverage at $R=10^5$

Brown Dwarf and Exoplanet Opportunities

- Spectroscopy in Obscured Windows
- Occultations
- Disk Studies

Brown Dwarf Spectra



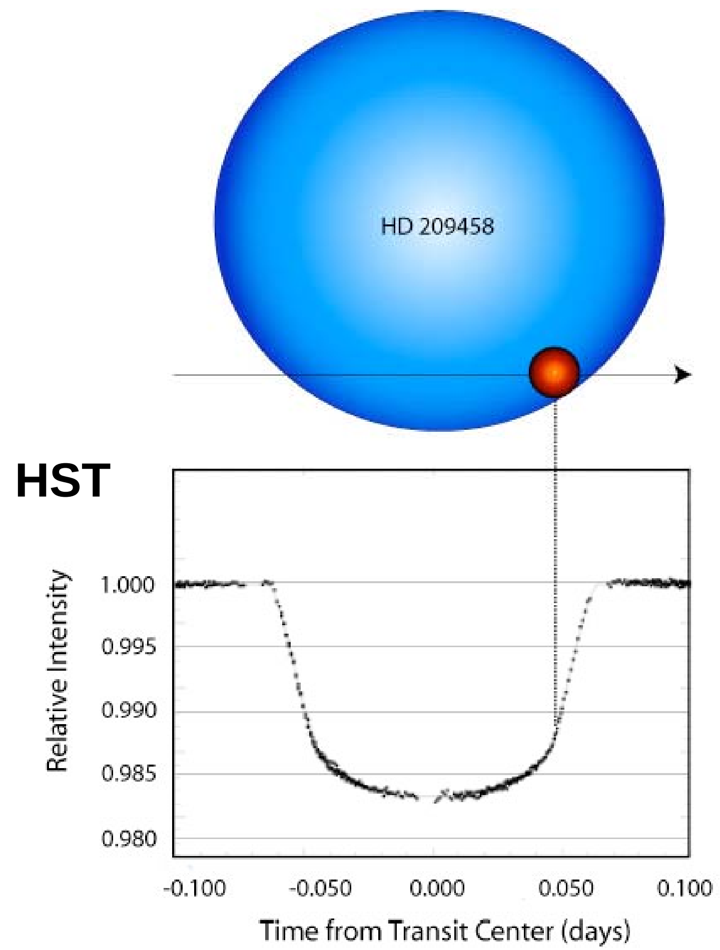
- Many of the features in Brown Dwarf spectra that make them interesting are also present in the Earth's atmosphere, namely water.
- SOFIA flies above 99% of the water, greatly cleaning up observations.

SETI INSTITUTE

Transits Provide a Wealth of Information about ESP

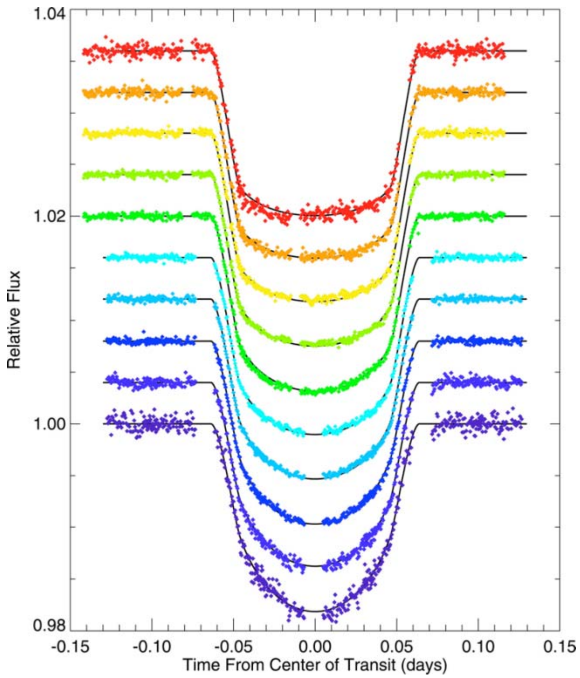
- SOFIA should be able to produce high quality transit data
  - Specialized Instrumentation for occultation work (HIPO)
  - Large Telescope
  - Minimal Scintillation Noise

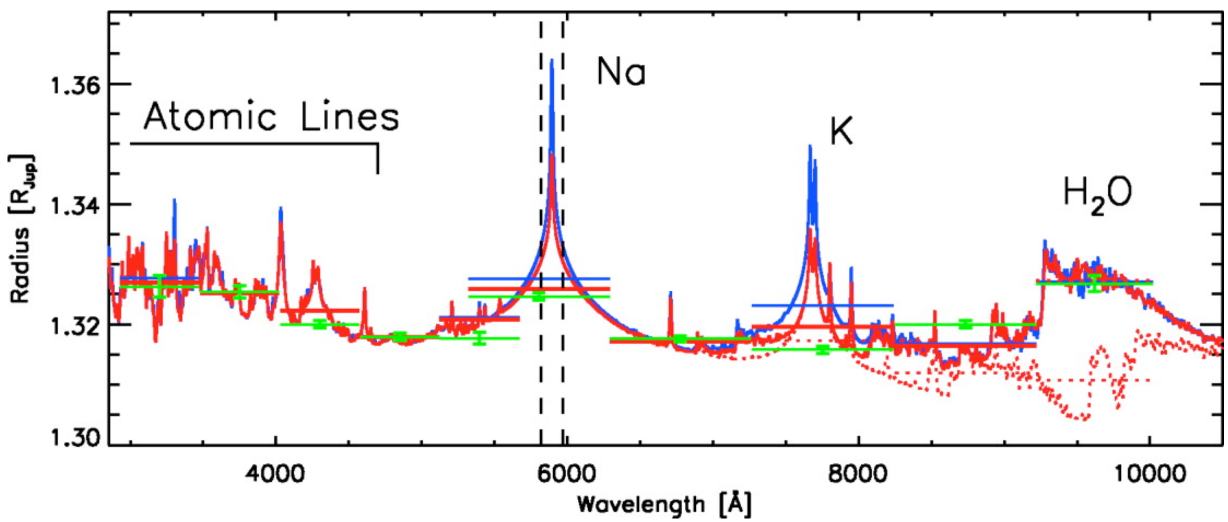
  - Occultation work with the KAO has demonstrated the power of an airborne observatory



Brown et al. (2001)

Transit Spectroscopy Can Reveal Atmospheric Structure in Exoplanets





Barman (2007)

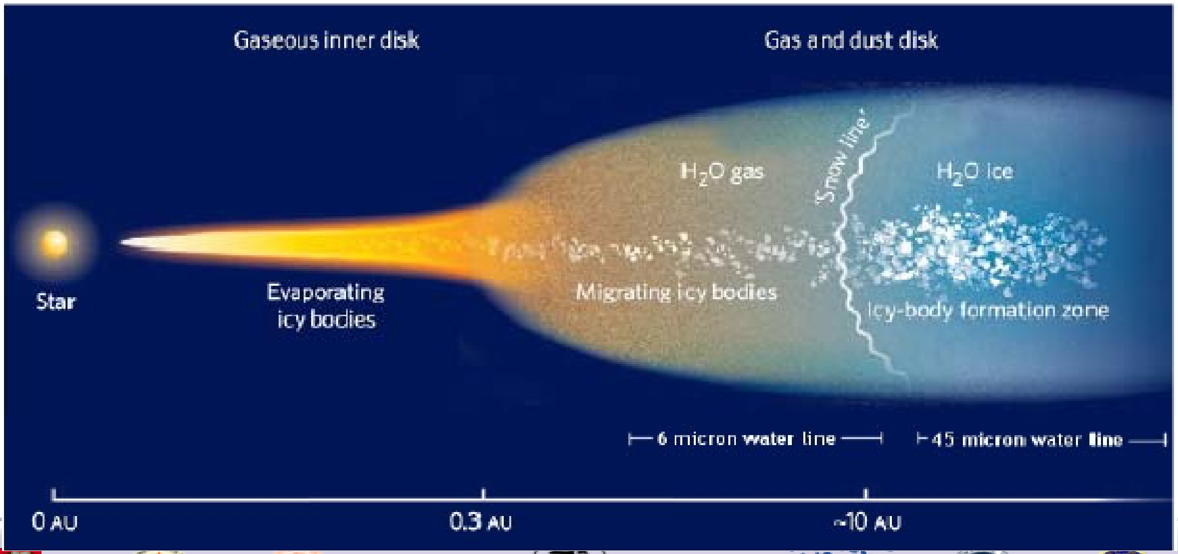
Knutson et al. (2007)

HD 209458

Technique of Transit Spectroscopy relies on variation of planet radius with wavelength.
In these STIS data, the signature of water is present.
SOFIA will permit broad wavelength studies with FLITECAM and HIPO co-mounted.

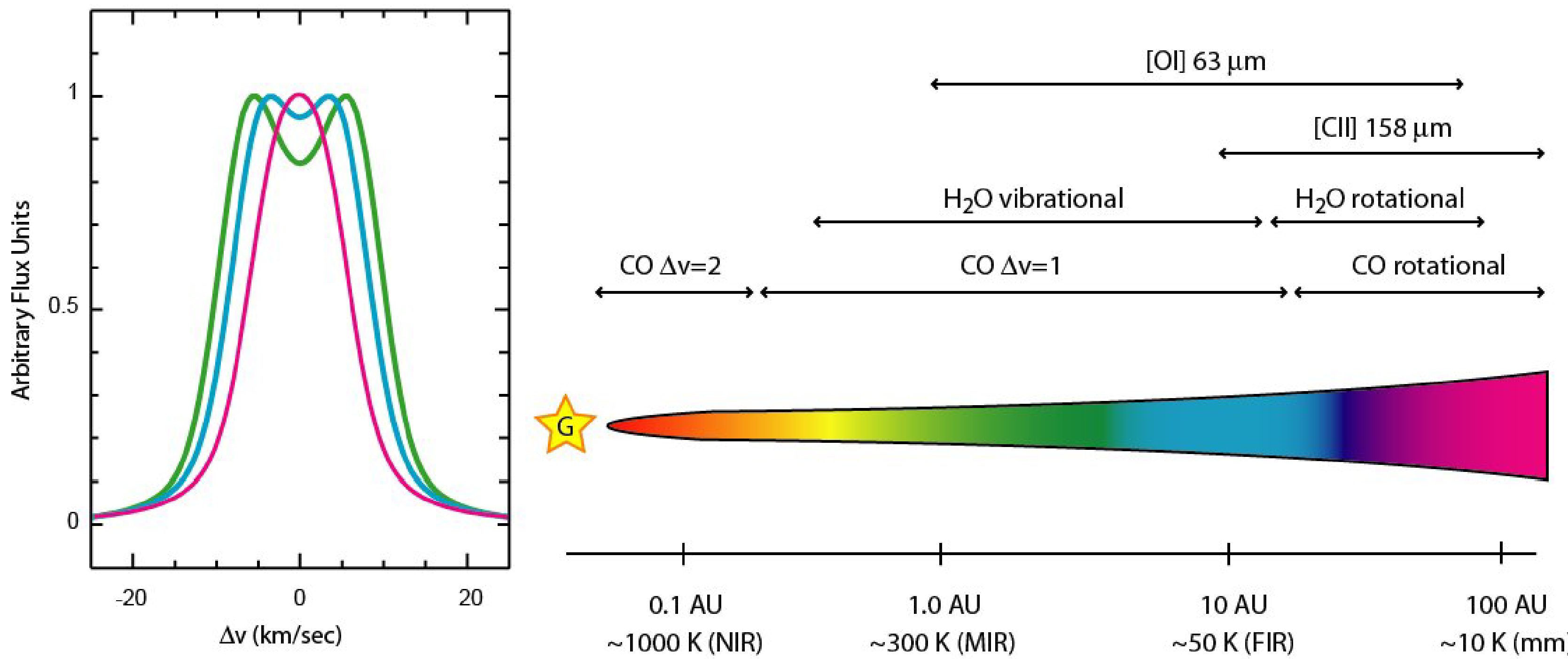
The Formation of Stars and Planets

- **SOFIA's high spectral resolving power is key to understanding the disks and the material in the disks that form planets. Such data will refine our understanding of:**
  - **the dynamical evolution and chemical evolution involved in forming planets from the dusty disk (grain growth, role of water ice condensation.**
  - **the chemical processes involved in both the ability of a disk to form planets and in producing the building blocks necessary for life.**
  - **accretion and cooling mechanisms and roles in circumstellar disks.**
  - **how planet formation occurred in our own Solar System.**



(Modified from van Boekel 2007)

SOFIA Can Dynamically Resolve Disks



- High spectral resolution can determine where species reside in the disk; small radii produce double-peaked, wider lines.
- Observing many sources at different ages in this way will trace the disk chemical evolution (GREAT, EXES, CASMIR)

SOFIA Schedule (Major Milestones)

• Open Door Flights at Palmdale	December 09
• First Science Flights	2010
• Open Call for Basic Science	2010
• Next Instrument call	2012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http://www.sofia.usra.edu