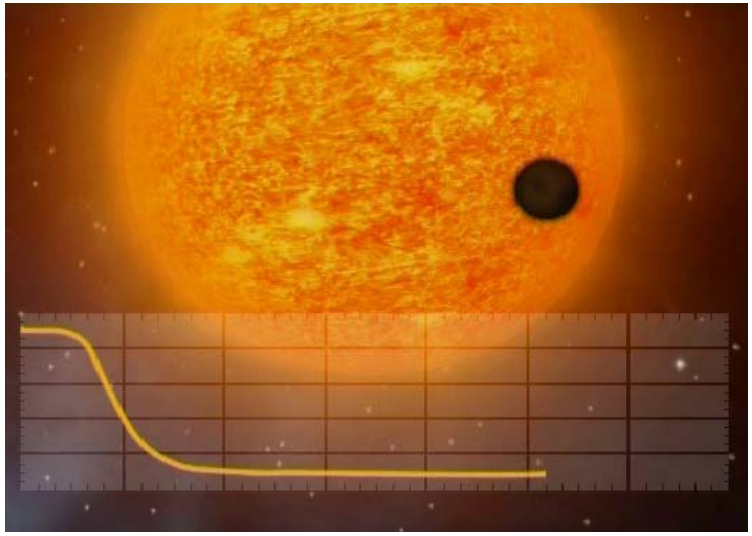
Observation of Exoplanets with the Stratospheric Observatory for Infrared Astronomy (SOFIA)



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http://www.sofia.usra.edu

In the Spirit of Lyot 2010, Paris, France, October 28, 2010

Outline

- *SOFIA Description and Status Report*
- *SOFIA Performance Specifications*
- *SOFIA Studies of Extrasolar Planetary Systems*
- *Summary and Conclusions*

SOFIA Program Overview

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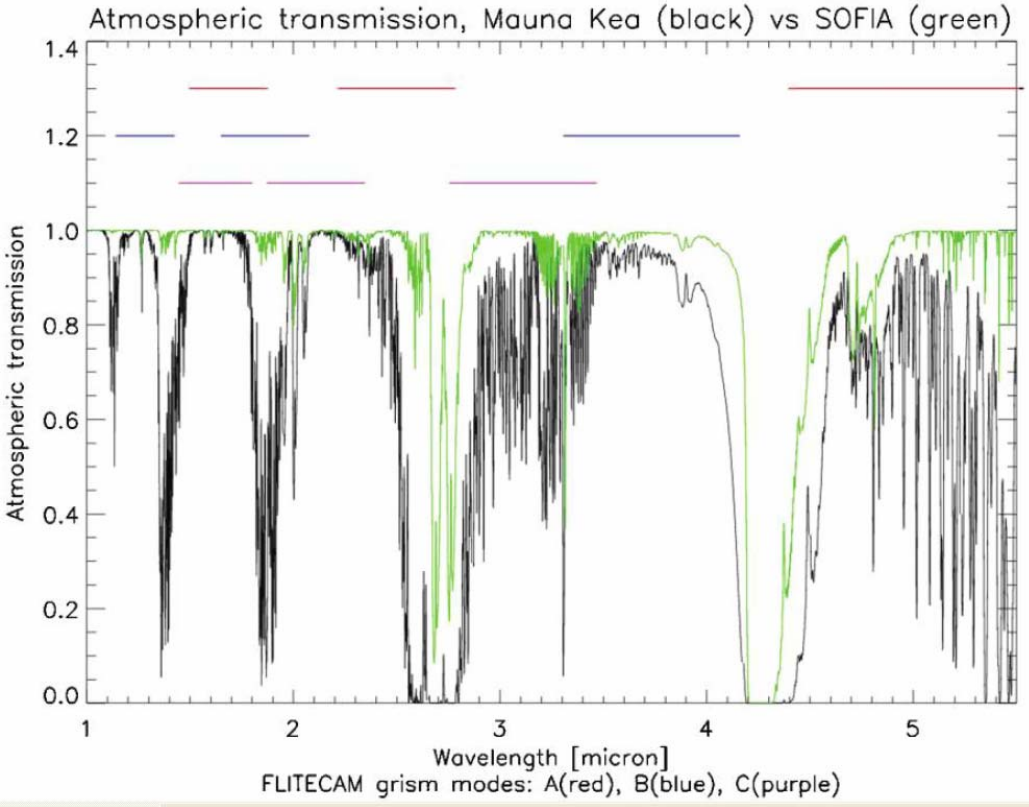
SOFIA Overview

- *2.5 m telescope in a modified Boeing 747SP aircraft*
  - *Imaging and spectroscopy from 0.3 μm to 1.6 mm*
  - *Emphasizes the obscured IR (30-300 μm)*
- *Operational Altitude*
  - *39,000 to 45,000 feet (12 to 14 km)*
  - *Above > 99.8% of obscuring water vapor; Transmission > 80%*
- *Joint Program between the US (80%) and Germany (20%)*
  - *First Light in 2010*
  - *20 year design lifetime –can respond to changing technology*
  - *Science Operations: NASA Ames Research Center, Moffett Field, CA*
  - *Flight Operations: Dryden Aircraft Operations Facility, Palmdale, CA*
  - *Deployments to the Southern Hemisphere and elsewhere*
  - *>120 8-10 hour flights per year*

The Advantages of SOFIA for Observations of Exoplanets

- *Significantly less absorption by water and methane; less background emission*
- *Observations not dependant on the weather that affects ground-based telescopes*
- *> 6 hour transits (e. g. HD80606b) can be observed continuously with SOFIA (HST can only observe for 96 minute stretches)*
- *SOFIA's lifetime and mobility support long-term studies of temporal variations in exoplanet atmospheres.*



Angerhausen, Krabbe, and Iserlohe 2010, PASP, 122, 1020

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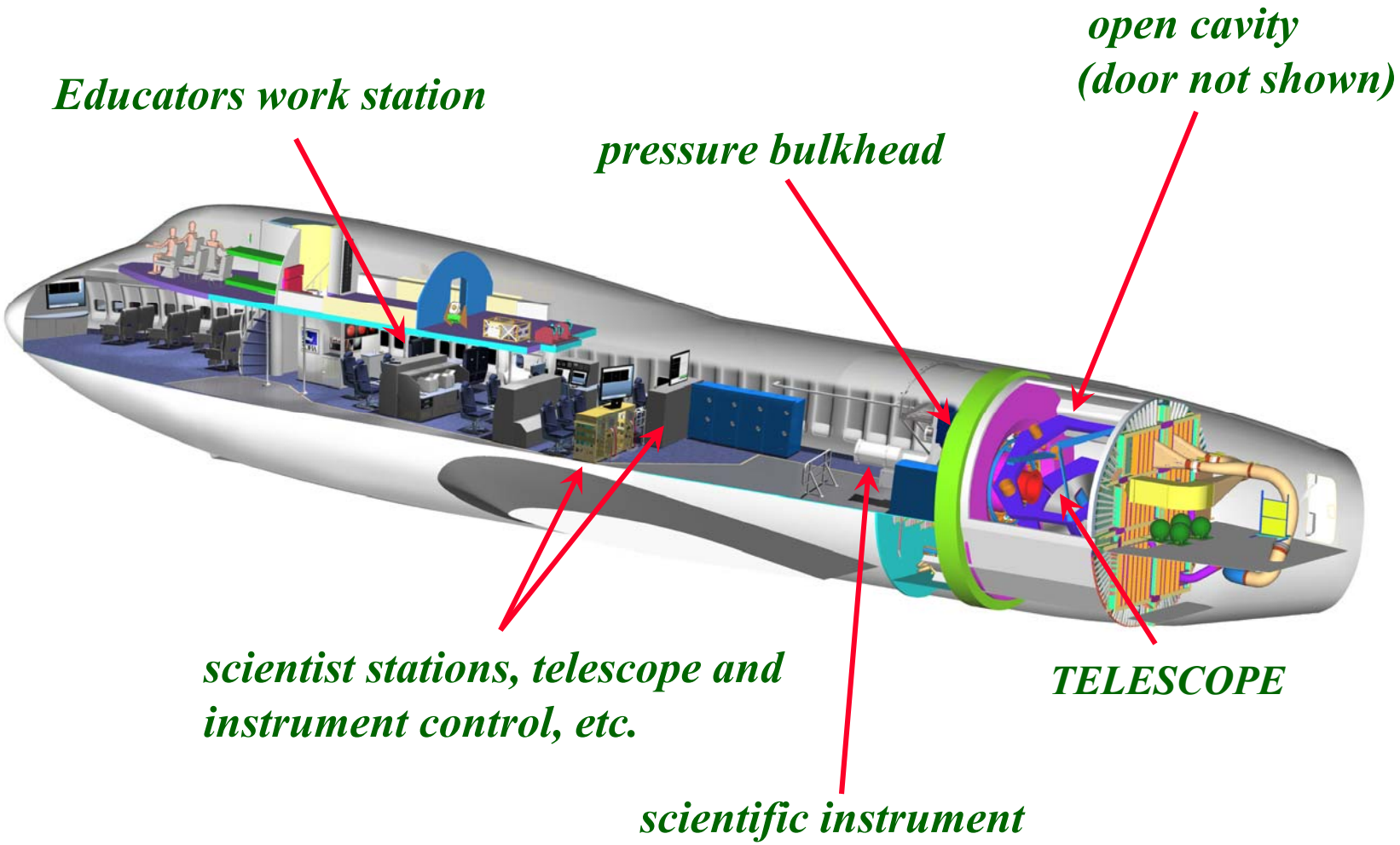
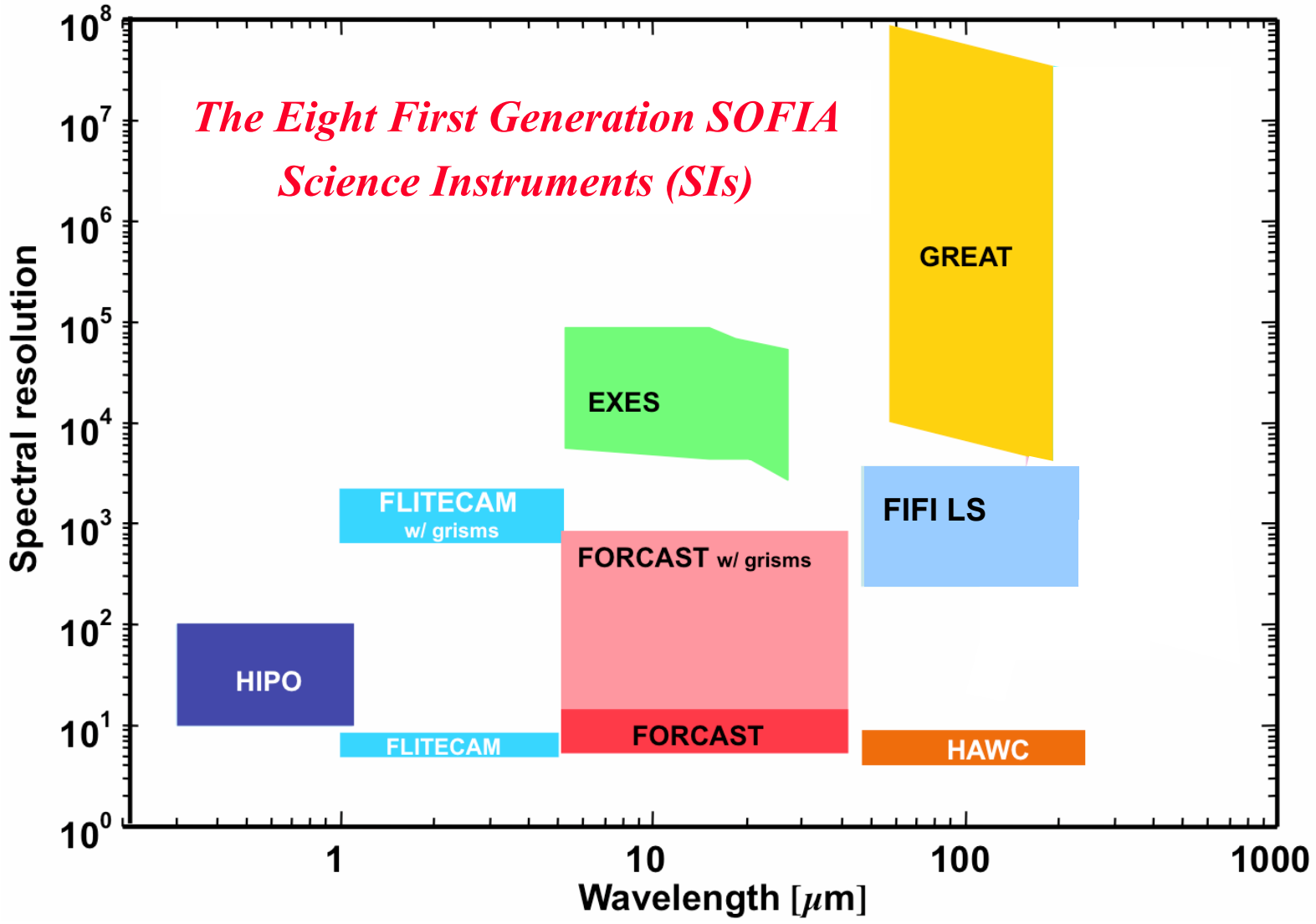
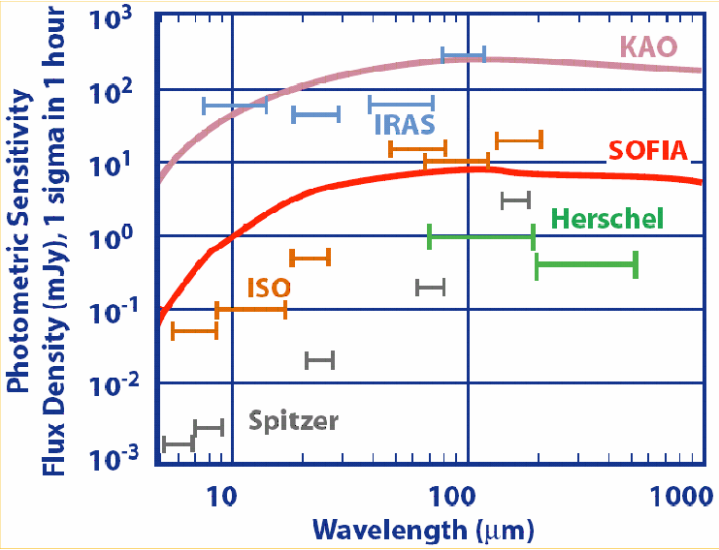
The SOFIA Observatory

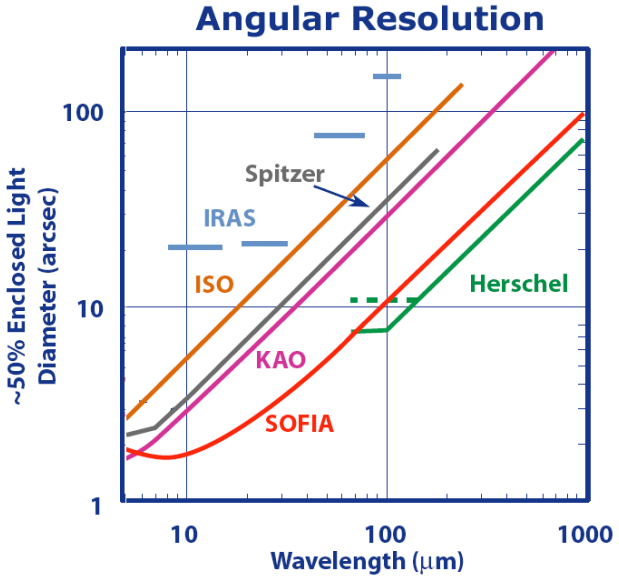


SOFIA First Generation Spectroscopy



Photometric Sensitivity and Angular resolution





SOFIA is as sensitive as ISO

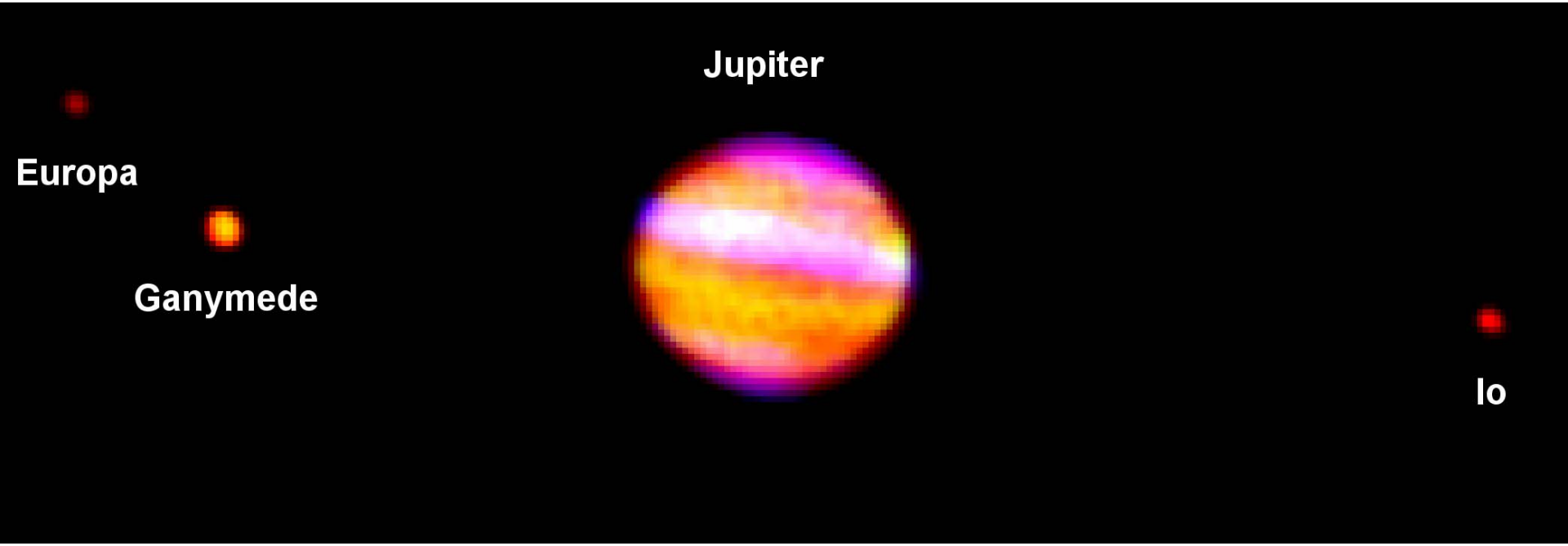
SOFIA is diffraction limited beyond 25 μm (θ min ~ λ/10 in arcseconds) and can produce images three times sharper than those made by Spitzer

The First Light Flight on May 26, 2010 UT

The FORCAST Team

The FORCAST Team in action during the First Light Flight

We have demonstrated imaging capability from 5 to 37 microns with 3-4 arcsecond FWHM



Red = 37.1 μm, Green = 24.2 μm, Blue = 5.4 μm

Red = 37.1um, Green = 24.2um, Blue = 5.4um

SOFIA Studies of Extrasolar Planetary Systems

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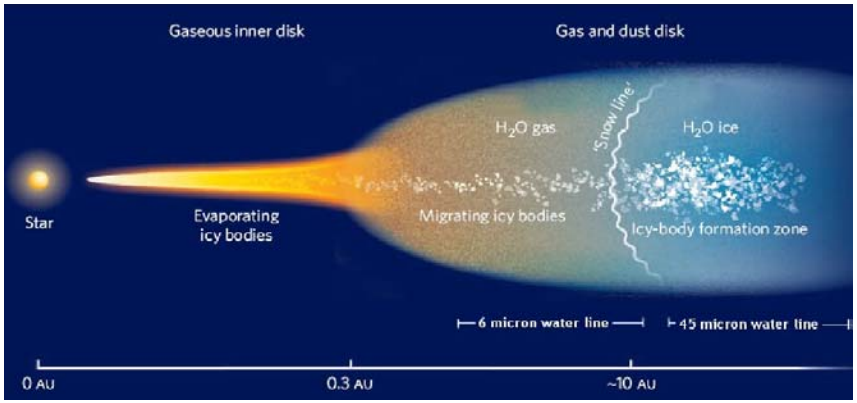
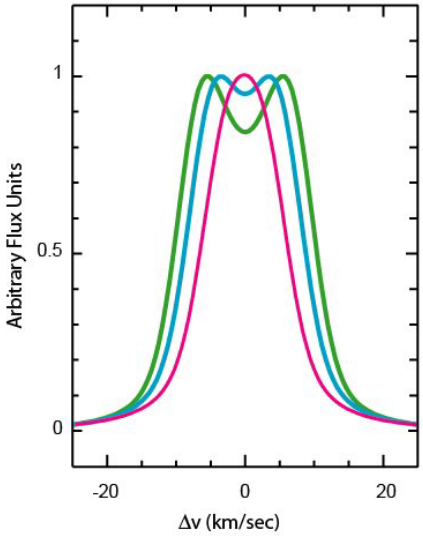
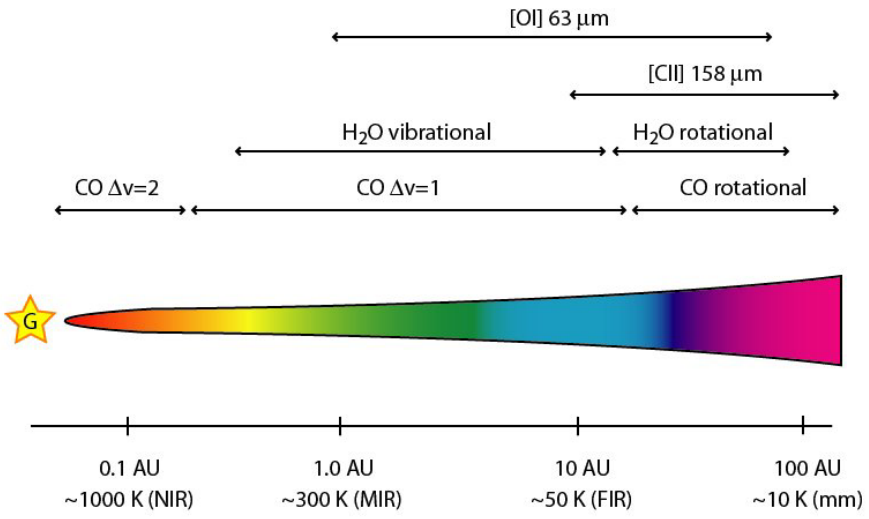
The Physics and Chemistry of Protoplanetary Disks

- *High spectral resolution enables dynamical studies and can establish where different atomic, molecular, and solid state species reside in the disk*
- *small stellar-centric radii are associated with wide, double-peaked line profiles; large radii with narrow line profiles*
- *Observing many disks of different ages will trace the temporal evolution of disk dynamics and chemistry*

Simulations from N. J. Evans et al. 2009







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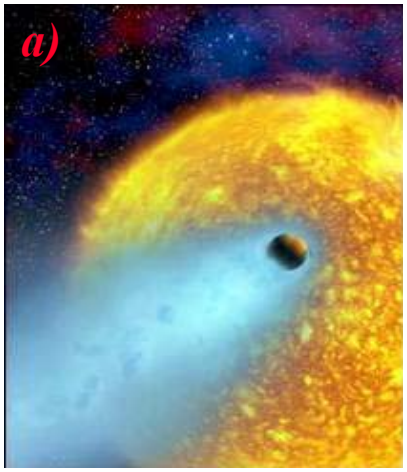
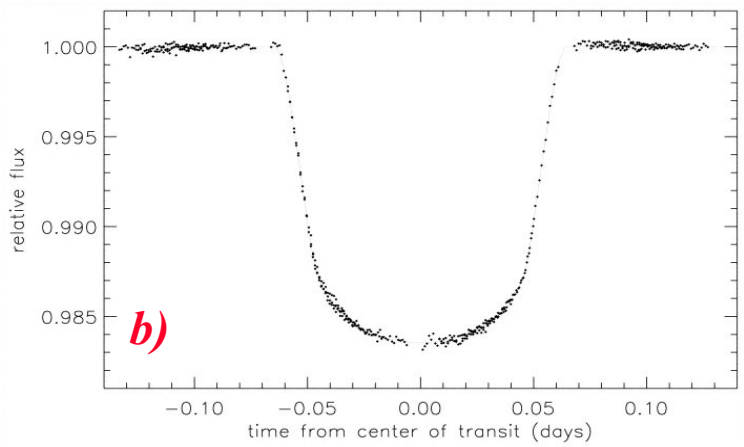
R. D. Gehrz

SOFIA and Extra-solar Planet Transits

- *There are 358 extra-solar planets; more than 59 transit their primary star*
- *SOFIA flies above the scintillating component of the atmosphere where it can detect transits of planets across bright stars at high signal to noise*





HD 209458b transit:

a) artist's concept and

b) HST STIS data

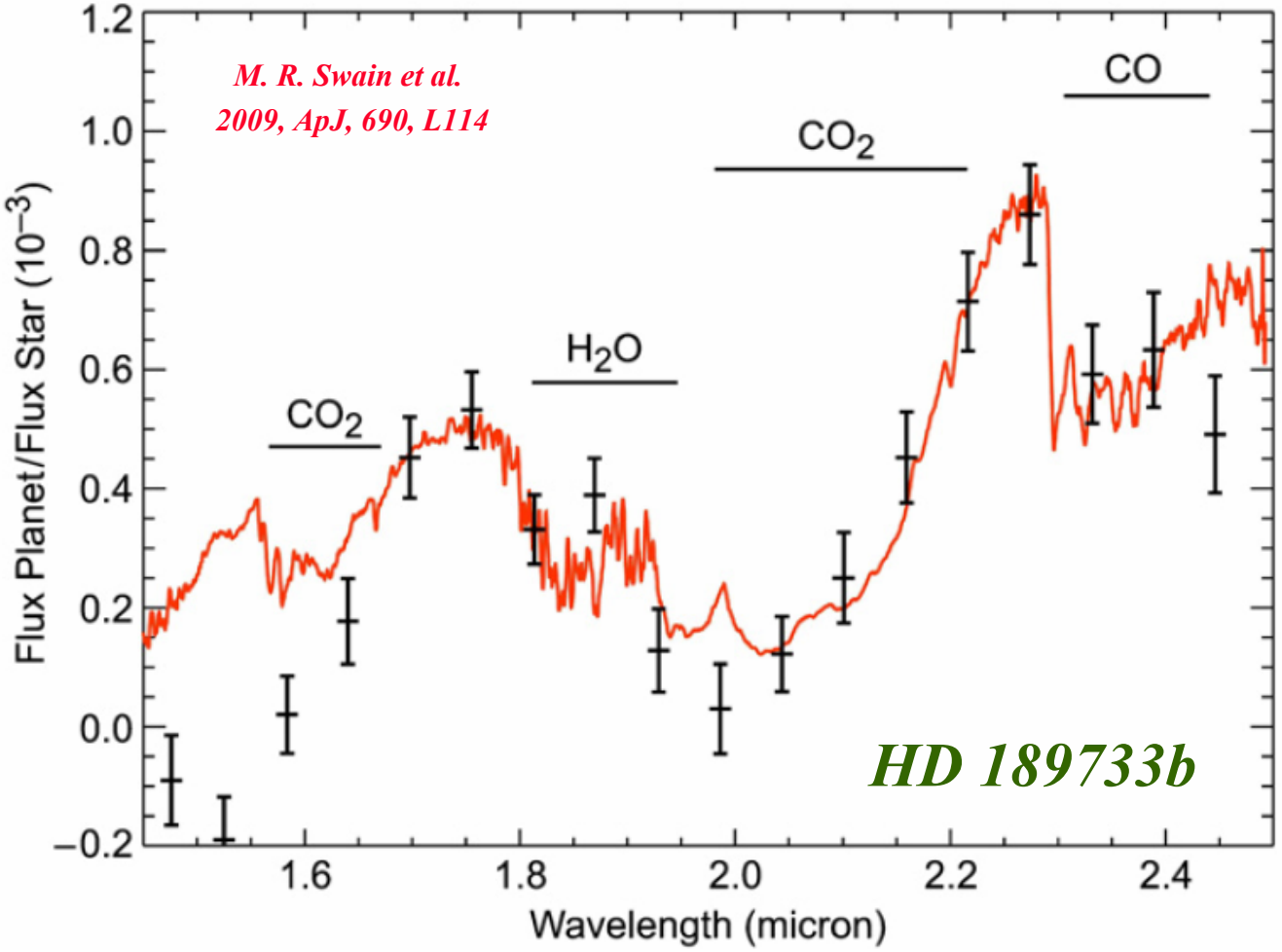
- *Transits provide good estimates for the mass, size and density of the planet*
- *Transits can reveal the presence of, satellites, and/or planetary rings*
- *Spectroscopic observations can reveal the presence and composition of an atmosphere*

Using HIPO and FLITECAM for Observations of Exoplanet Transits

- ***HIPO: Fast Imager; operates from 0.3 to 1.1 μm with interference filters, spectral resolution TBD by application***
- ***FLITECAM: Imager; operates from 1.0 to 5.5 μm with interference filters and grisms; spectral resolutions as high as $R = \lambda/\Delta\lambda = 2000$***
- ***HIPO and FLITECAM can observe simultaneously using a dichroic beam splitter***

We will also evaluate the FORECAST Imager for doing exoplanet transit observations: operates from 5.6 to 38 μm with interference filters and grisms; spectral resolutions as high as $R = \lambda/\Delta\lambda = 2000$

Detection of Biogenic Molecules in Extrasolar Planetary Atmospheres by the transit Method



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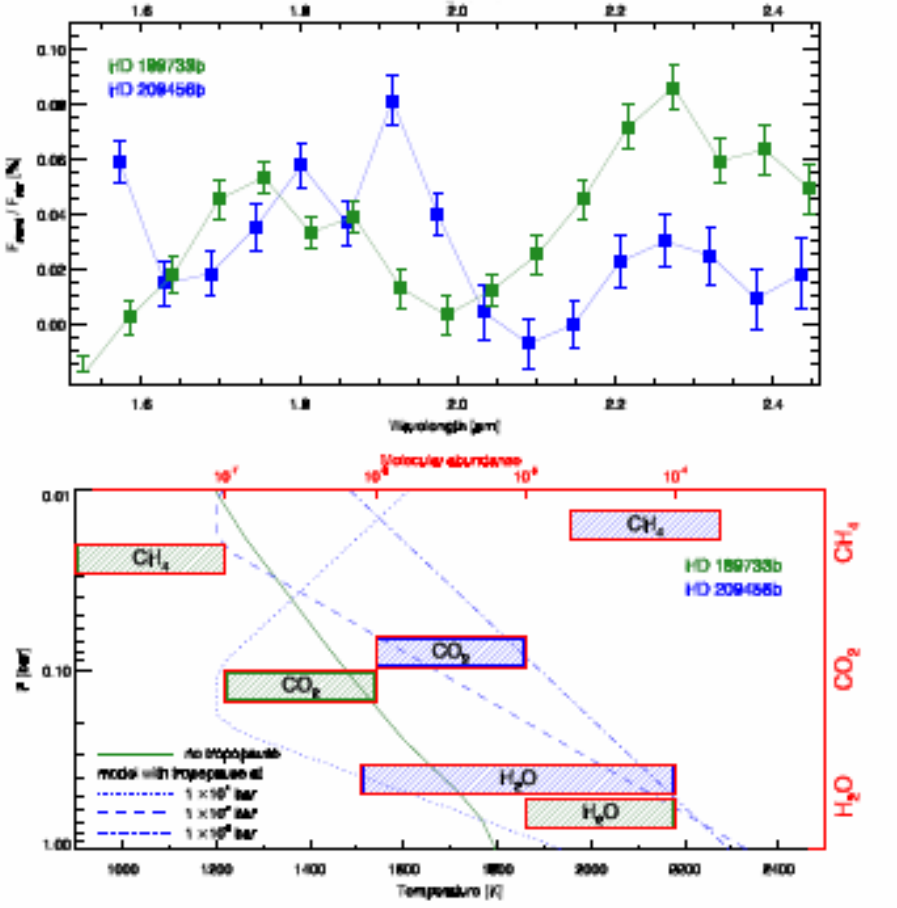
First Direct Spectroscopic Comparison of two Exoplanet Atmospheres



M. R. Swain et al. 2009, ApJL, in press

Comparison of dayside emission spectra of HD 189733b and HD 209458b, shows:

- ***Significant CH_4 enhancement in HD 209458b***
- ***Suggestion of enhancement in the abundance of CH_4 and H_2O in HD 209458b***

Early General Observer and Instrumentation Development Opportunities

- **Basic Science for GOs in 2011 with FORCAST and GREAT**
  - Proposals were ingested on July 30, 2010
  - ~15 Flights starting in in Spring, 2011
- **General Observer (GO) Science**
  - The next call for science will be in late 2011 for flights in 2012
  - Planning for 30 flights in 2012, 60 in 2013, and 100 in 2014
- **Next Call for New Instruments in FY 2011**
  - One new instrument or instrument upgrade per year
  - New calls every three years
  - Funding for new instruments is ~$5-$10 M/yr

Summary

- *SOFIA will be a premier facility for far-IR and submillimeter spectroscopy for many years*
- *It will be especially effective for spectroscopic studies of the physics and chemistry of:*
  - *Proto-planetary disks*
  - *The atmosphers Extrasolar planets*
  - *Special emphasis will be given to biogenic molecules*

Our Web site: ***http://www.sofia.usra.edu/***

This talk: ***http://www.sofia.usra.edu/Science/speakers/index.html***