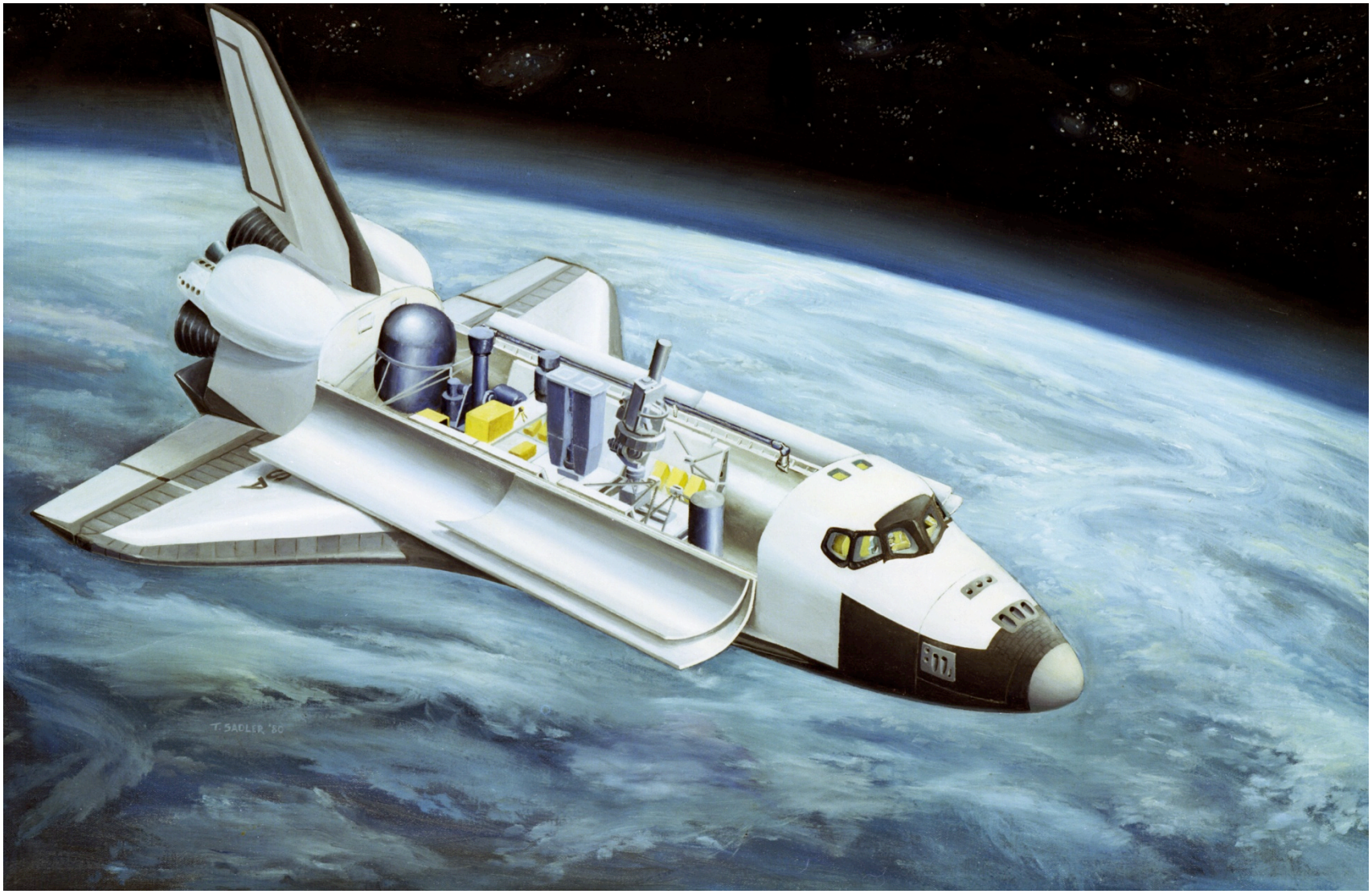
SOFIA: The Stratospheric Observatory for Infrared Astronomy

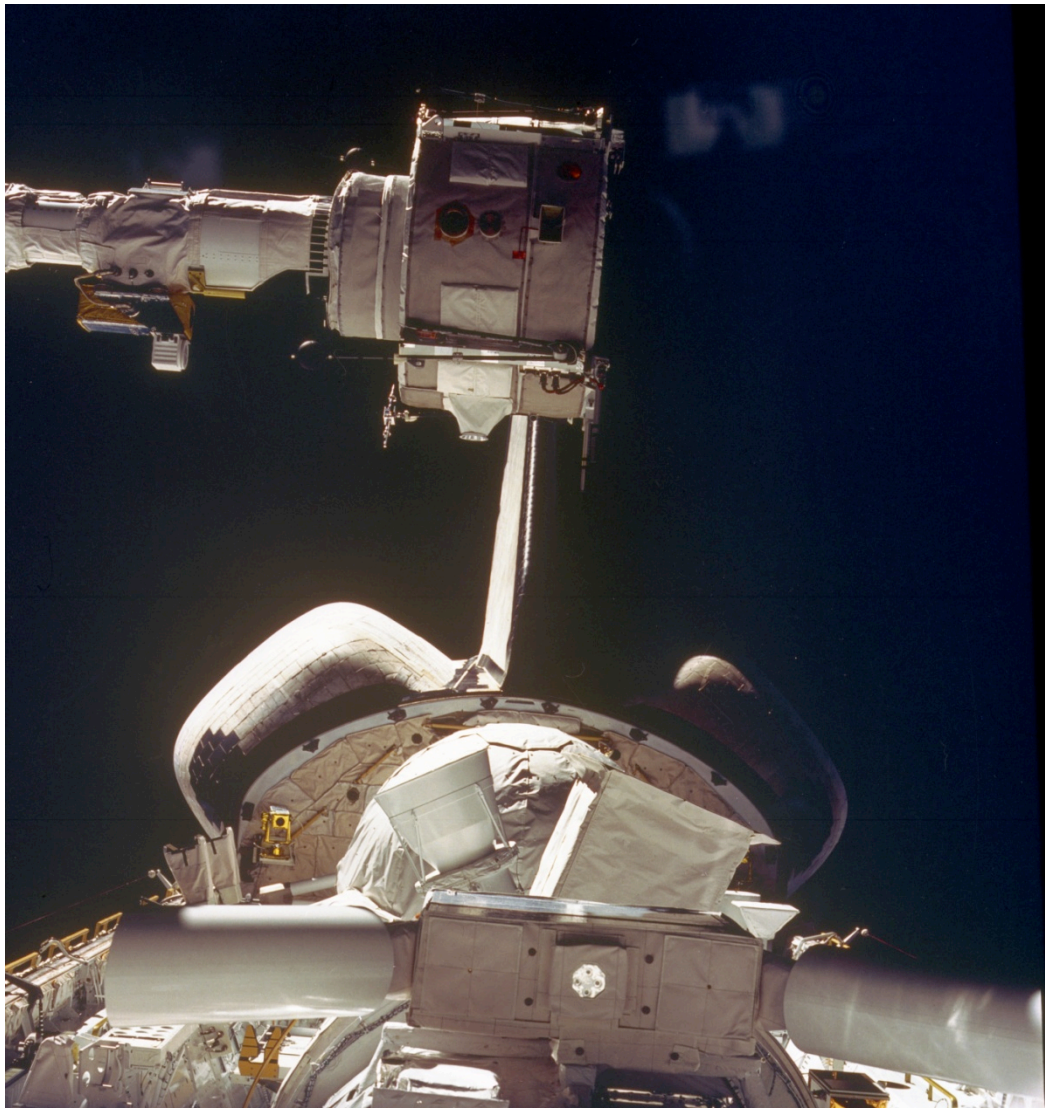
Erick Young (University of Arizona, for a few more months)
Eric Becklin (USRA)

Giovanni Fazio Symposium May 27-28, 2009

Spacelab 2



SL-2 In Orbit



Instrument Station in Houston


SOFIA
NASA
DLR
N747NA
NASA
850

Overview of SOFIA

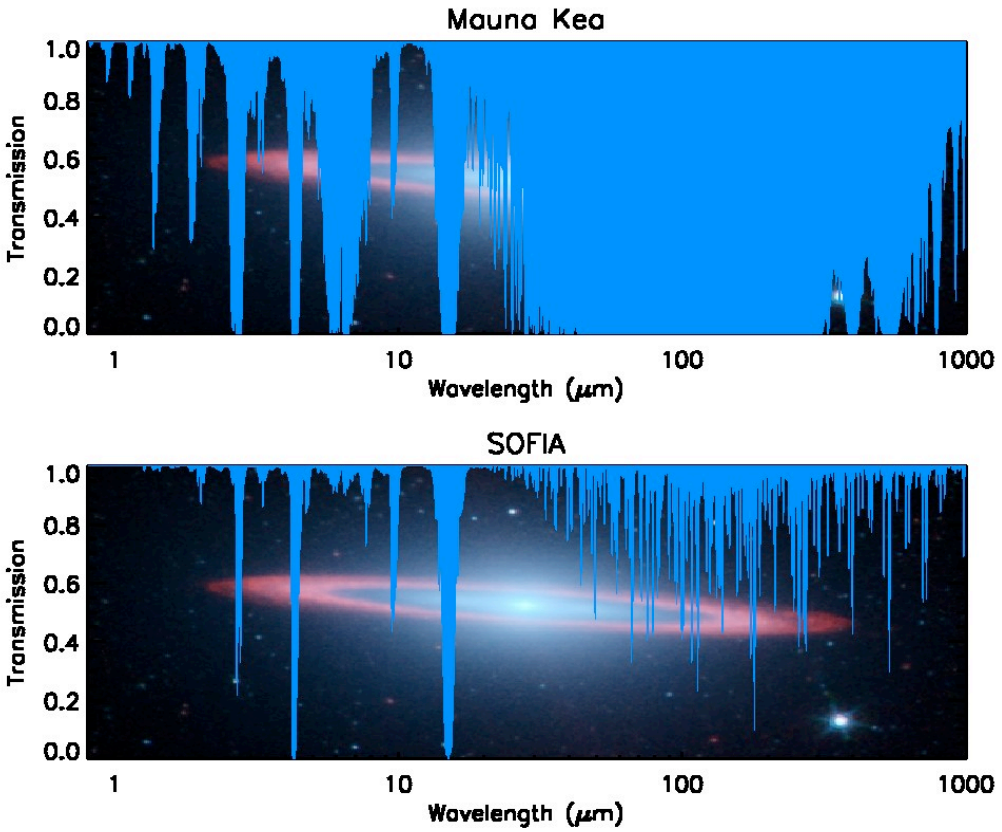
- SOFIA is 2.5 m telescope in a modified B747SP aircraft
  - Optical-mm performance
  - Obscured IR (30-300 μm) most important
- Joint Program between the US (80%) and Germany (20%)
- Operating altitude
  - 39,000 to 45,000 feet (12 to 14 km)
  - Above > 99% of obscuring water vapor
- First Science 2010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

SOFIA Operations

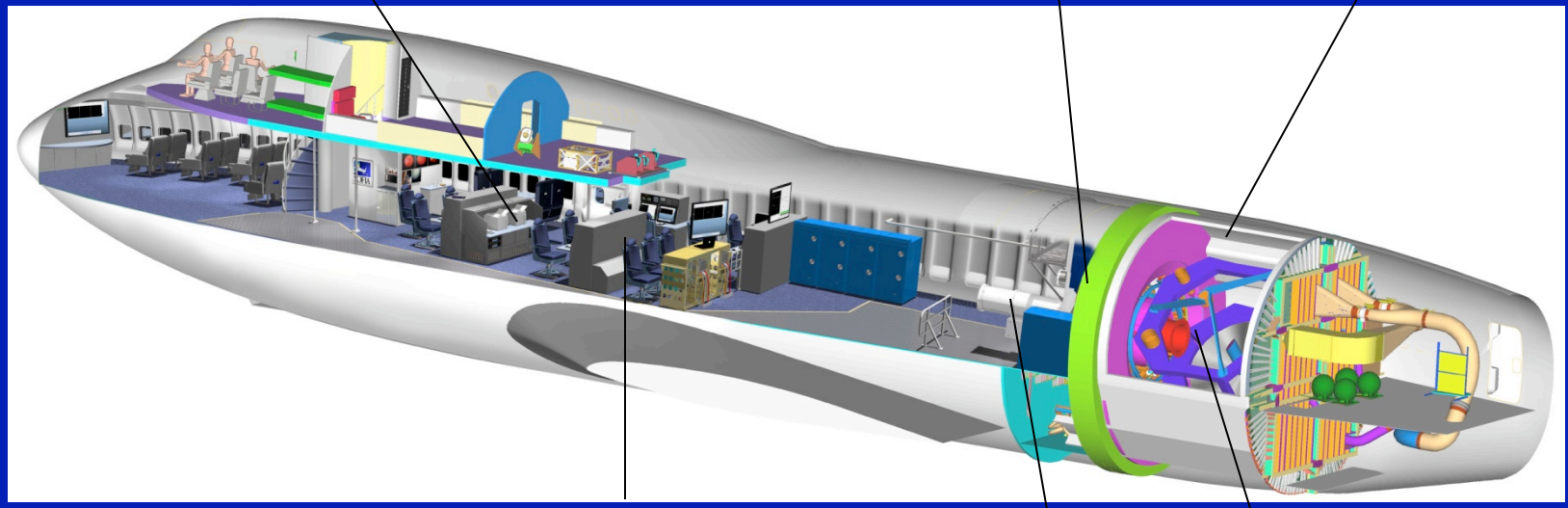
- Science flights to originate from Palmdale California
  - Aircraft operation by NASA Dryden Research Center from the Dryden Aircraft Operations Facility (DAOF)
- Science Center is located at NASA Ames Research Center
- World Wide Deployments
- Ramp up to ~1000 science hours per year
- SOFIA will support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

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

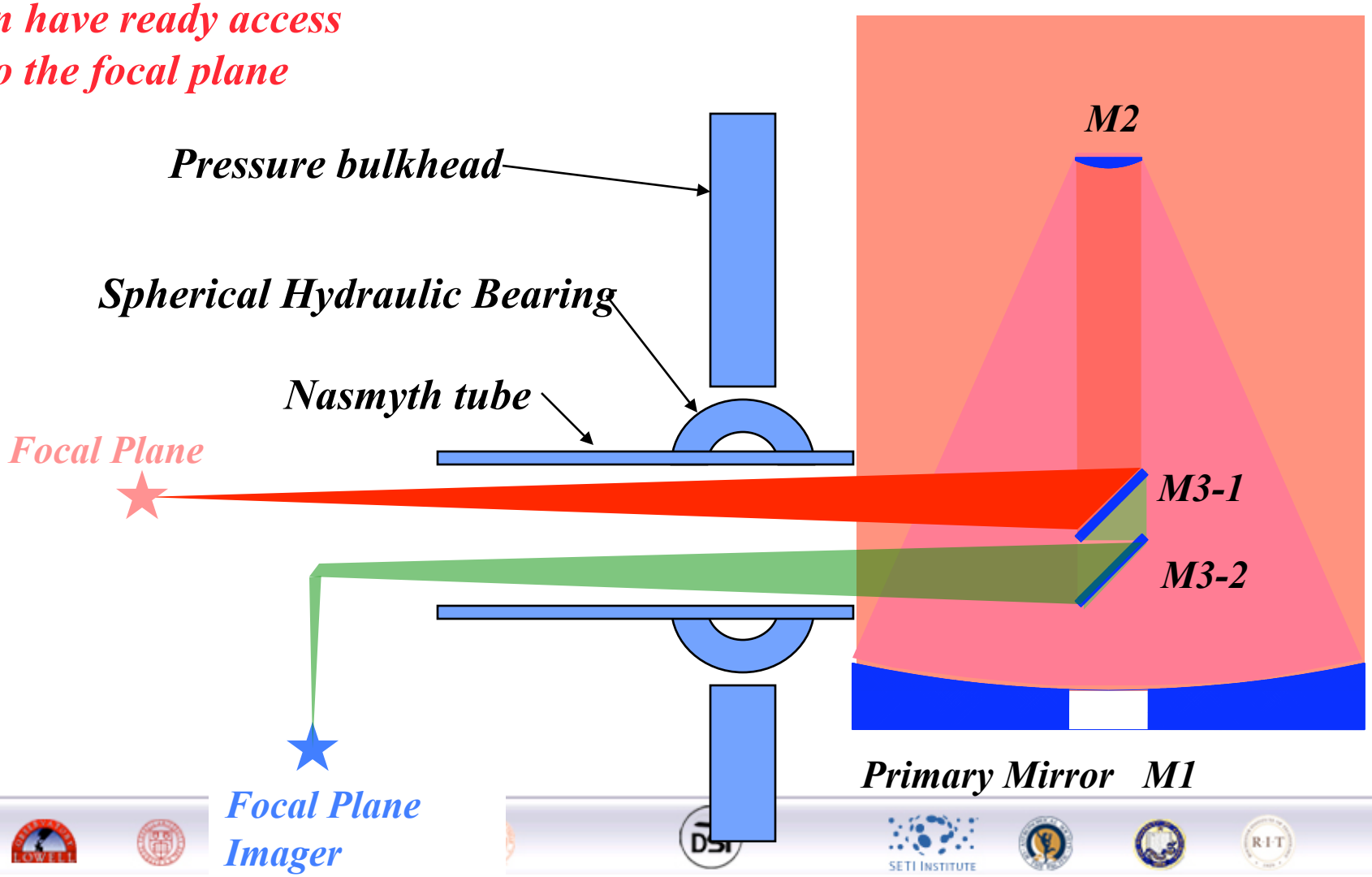


SOFIA — The Observatory



Nasmyth: Optical Layout

Observers in pressurized cabin have ready access to the focal plane

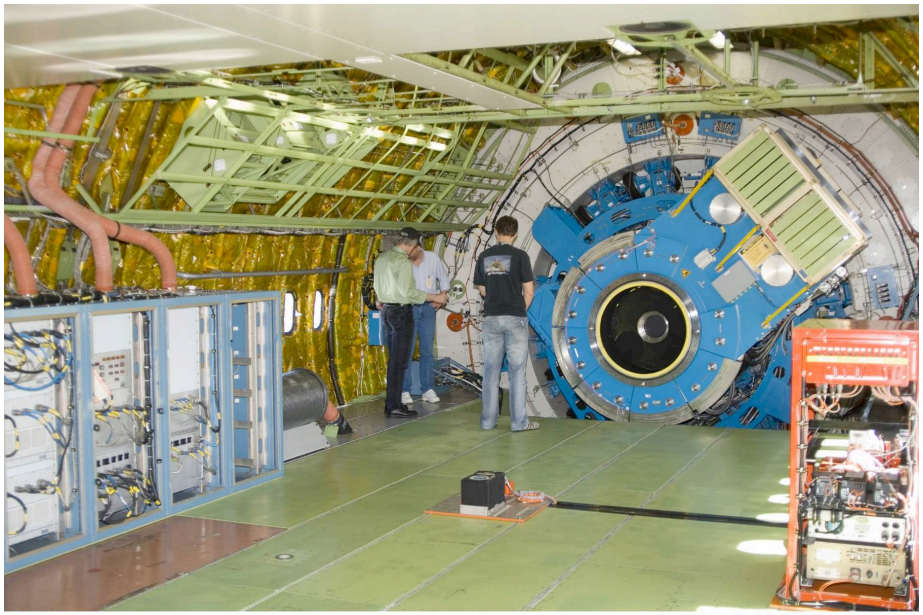


SOFIA Makes Its First Flight!

SOFIA in the Palmdale Hanger

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

March 2008 Ground Test in Palmdale

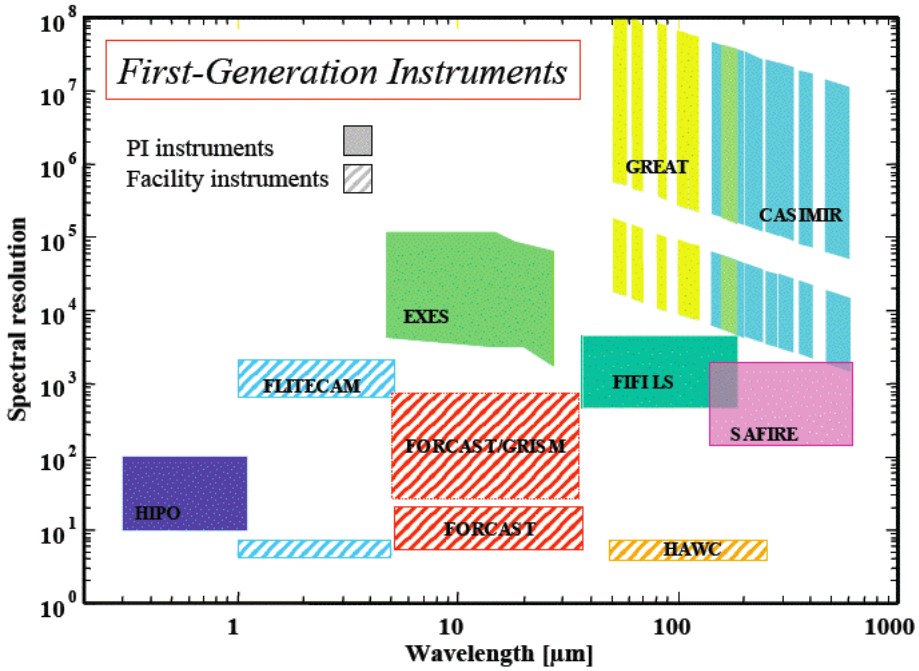
Science Capabilities

- Because of large aperture and better detectors, sensitivity for imaging and spectroscopy similar to the space observatory ISO
- 8x8 arcmin Field of View allows use of very large detector arrays
- Image size is diffraction-limited beyond 25 μm, making it 3 times sharper than the space observatory Spitzer at these wavelengths

SOFIA's Instrument Complement

As an airborne mission, SOFIA supports a unique, expandable instrument suite

- SOFIA covers the full IR range with imagers and low to high resolution spectrographs
- 5 instruments at Initial Operations; 9 instruments at Full Operations.
- SOFIA will take full advantage of improvements in instrument technology. There will be one new instrument or major upgrade each year.
- Will support both Facility Instruments and PI Class Instruments



FORCAST: Mid-IR Imager

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

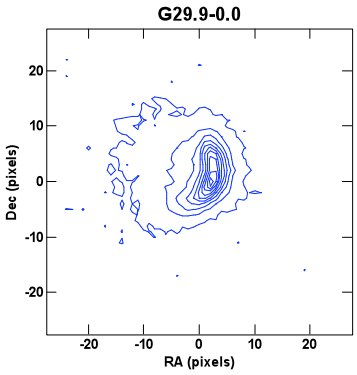
Detectors: Dual channel
256 x 256 arrays;
5 – 25 μm (Si:As)
20 – 40 μm (Si:Sb)
Field of View: 3.2' x 3.2'

Science: Thermal and narrow band imaging

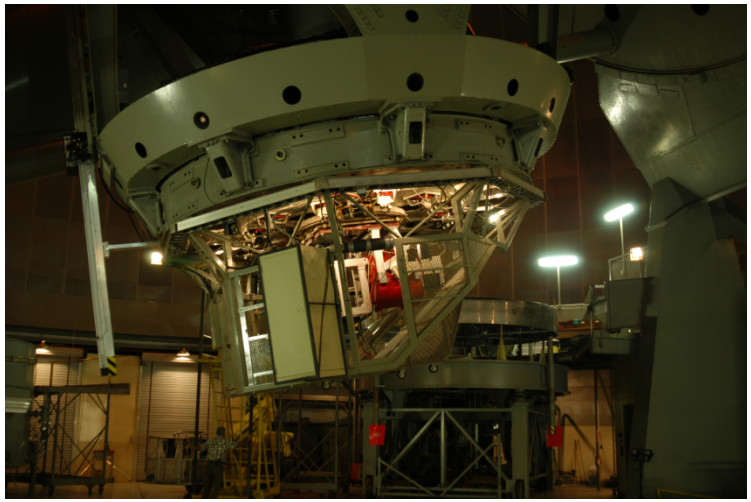
Targets: Circumstellar disks, Galactic Center, Galactic and extragalactic star formation

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

G29.9-0.0



10.6 μm ($\Delta\lambda$ = 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).



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

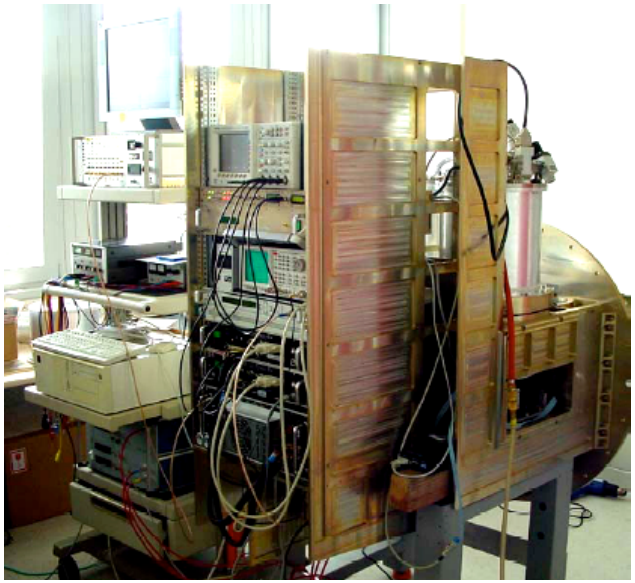
R= 10^6 -> 10^8

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

Targets: Galactic and extragalactic ISM, circumstellar shells

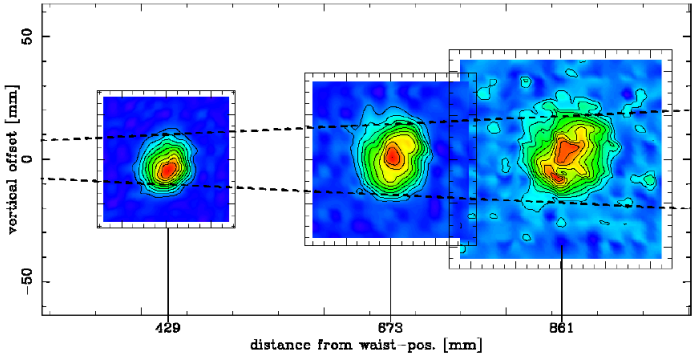
NB: T_S ~ 2500 K at 158 μm

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

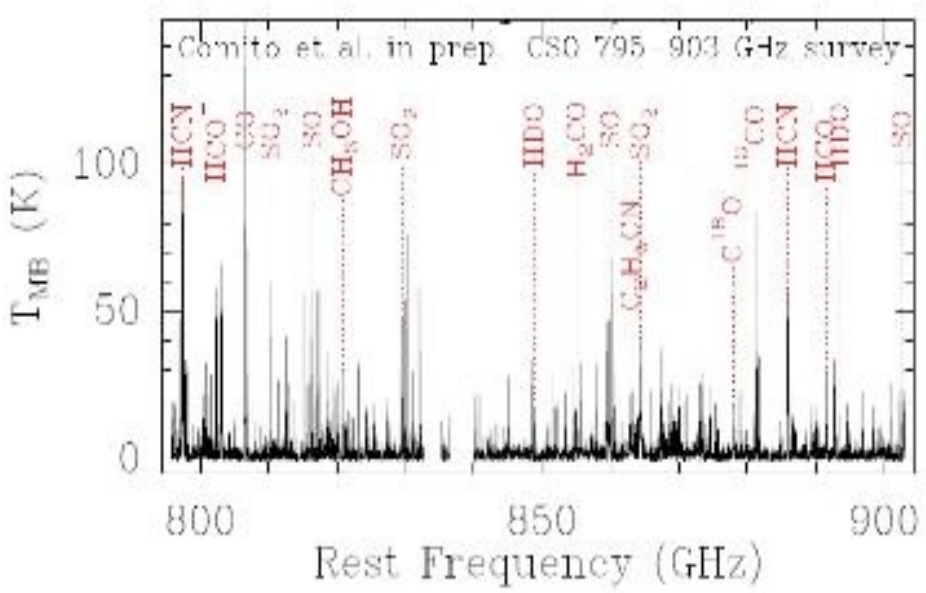
New Science Vision for SOFIA

- Over the past year, the extended SOFIA science team has been working to update the SOFIA science case to incorporate the many developments of the past decade
  - Spitzer and Herschel follow-up
  - Effort was led by Eric Becklin and Tom Roellig
  - Participation by many members of the community
    - Bob Gehrz, Dan Lester, Neal Evans, James de Buizer, Margaret Meixner, Xander Tielens, Jesse Dotson, Gordon Stacey, William Vacca, Jeff Cuzzi, & Dana Backman were lead editors
- Science Vision is at the printers and will be available in its full 136 page glory at the AAS meeting.

Astrochemistry

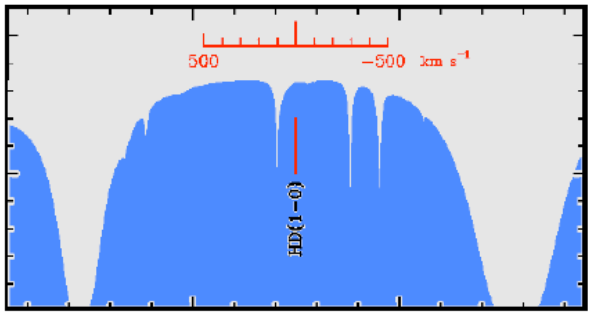
The broad spectral coverage of SOFIA makes it a powerful observatory to study chemistry in space

- Most ground state molecular lines in IR or submillimeter
- Need high spectral resolution throughout which SOFIA has.
- As sensitive as CSO, but much larger wavelength range is accessible
- Light molecules: Molecular hydrogen, HD, water, other hydrides in IR and submillimeter
- The fullerene, C_{60}, has 4 IR lines in SOFIA's bands



Cold Molecular Hydrogen using HD

SOFIA will study deuterium in the galaxy using the ground state HD line at 112 microns. This will allow determination the cold molecular hydrogen abundance.



Atmospheric transmission around the HD line at 40,000 feet

Deuterium in the universe is created in the Big Bang.

Measuring the amount of cold HD (T<50K) can best be done with the ground state rotational line at 112 microns.

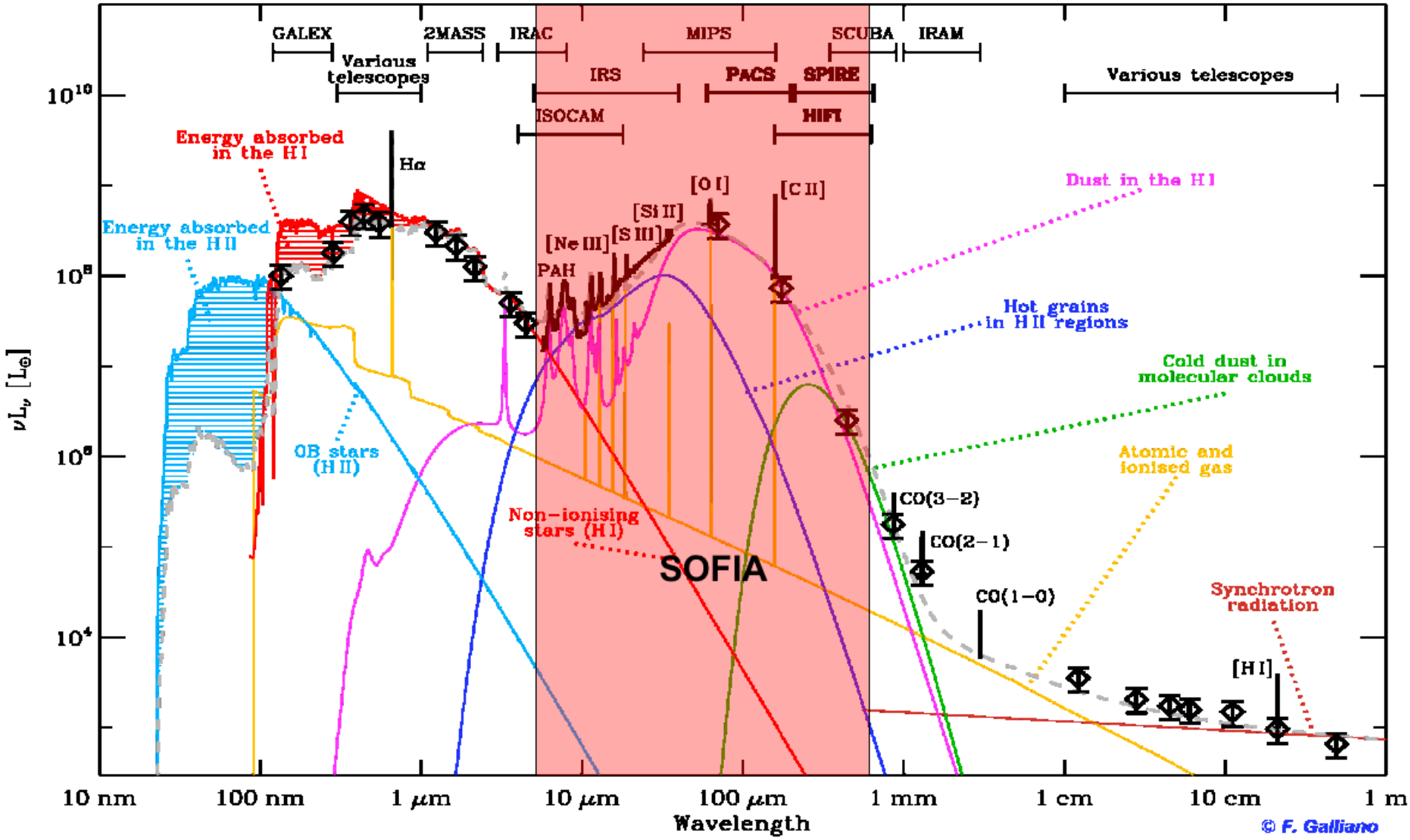
Detections with ISO means a GREAT high resolution spectrometer study possible.

As pointed out by Bergin and Hollenbach, HD gives the cold molecular hydrogen.

HD has a much lower excitation temperature and a dipole pole moment that almost compensates for the higher abundance of molecular hydrogen.

In the future could be used much like the HI 21cm maps but for cold molecular gas.

Galaxy Spectral Energy Distribution (SED)



SOFIA Schedule (Major Milestones)

• First Re-Flight	Occurred April '07
• Closed Door Testing	Finished Jan 08
• Door Drive Delivered	Summer 08
• Mirror Coated	Summer 08
• Open Door Flights at Palmdale	Fall 09
• New USRA Science Director	September 09
• First Science Flights	2010
• Next Instrument call	2011

Observer Opportunities

- Selection for Community support of Early Short Science with FORCAST and GREAT has been made. Paul Harvey (UC Boulder), Mark Morris (UCLA) for FORCAST, David Neufeld (JHU)

- The Call for more extended observing (~15 Flights) in Basic Science in CY 2010 with FORCAST and GREAT will occur after first open door flights.

- Future call every year with additional instruments

- Will have Financial Support and Support Scientists to aid with Data Reduction

- Open Observatory with Facility Instruments

Next Call for New Instruments

- The next call for instruments will be after First Science in the Spring of 2011
- We are considering:
  - New Science Instruments both FSI and PSI
  - Studies of instruments and technology
  - Upgrades to present instruments
- There will be additional calls every 3 years
- There will be ~one new instrument or upgrade per year
- Approximate funding for new instruments and technology is ~ $10 M/yr
  - Now part of Cosmic Origins Technology Program
- Personal Observation: For the new instrument vision (and SOFIA) to be really successful, we need to enable more rapid instrument development

Summary

- Program is making real progress
  - Aircraft structural modifications complete
  - Telescope installed, several instruments tested on ground observatories.
  - Full envelope flight testing closed door finished. Aircraft at Palmdale.
  - Several subsystems are installed (Door motor drive, coated primary mirror)
  - First Door Open Fall 09
  - First science in 2010
- SOFIA will be one of the primary facilities for far-IR and sub-millimeter astronomy for many years