
SOFIA
NASA
DLR
N747NA
NASA

The Early Years of Developing SOFIA—1996 to 2011 & The Science Future

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Lake Arrowhead: Our Galactic Ecosystem

After Dinner Talk

March 1, 2022

Outline of Material

- Thank you
- The USRA proposal
- The German telescope
- The aircraft modification and moving to Dryden (Armstrong)
- The Fabulous Door
- First Flight and Science
- Key Science and the future

Thank you &
Key People Early in the Program

NASA in the USA	DLR in Germany
Jackie Davidson	Hans Peter Roeser*
Ed Erickson	Alois Himmes
Larry Caroff	
Nans Kunz*	Hans Kuercher
Terry Herter	Rolf Guesten

*passed away

The Proposal in 1996

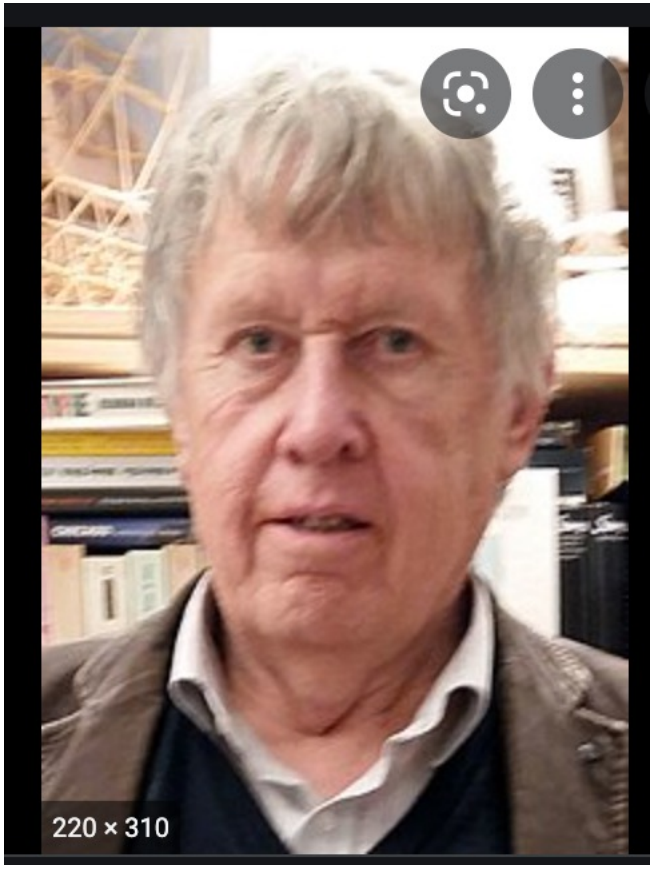
- SOFIA was selected in the 1990 decade astronomy report as one of two IR missions (Spitzer)
  - 4 teams competed: USRA, AURA, U Arizona, UT Austin
  - USRA teamed with United Airlines and an aircraft modifying team in Waco TX. We also worked closely with NASA Ames
- Jackie Davidson of NASA Ames was a key player in the proposal.
- Bill Howard of USRA, Paul Coleman President of USRA and Jackie convinced me to work with them on the proposal
- Key elements were United Airlines and Chipper Lindberg 747Sp, NASA work products including the design/ construction of the door and the mirror coating facility.
- First Science team was myself, Jackie Davidson, Mark Morris, James Graham, Ian McLean, and Sean Colgan.

Jackie Davidson now in Australia

The SOFIA Telescope

- The SOFIA telescope was built by two very good German industrial teams:
  - MAN had experience building large telescopes (Hans Kuercher)
  - KT was very good in optics
- The overall management was an early problem and was quickly solved by DLR.
- Telescope was delivered to Waco in 2002 in a EURO Guppy
- By 2004 it was working in SOFIA.
- No Oil has ever been detected from the 1.2 meter bearing!!

Hans Kuercher

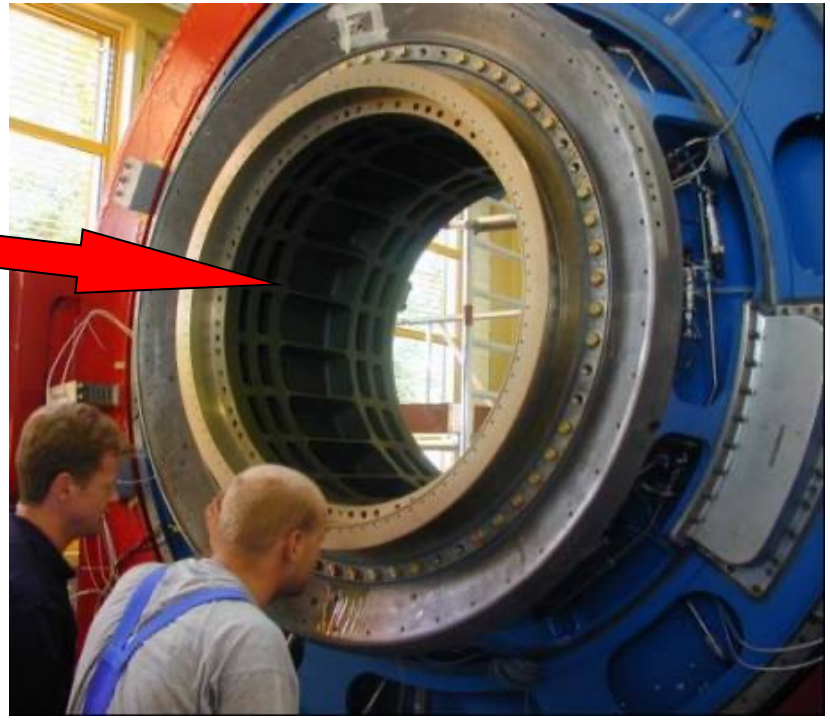


Rotation Isolation Subsystem

Spherical Bearing

The Bearing Sphere on the Nasmyth Tube

“First Oil“



Telescope Tests 2004

The Aircraft Modification was very slow

- SOFIA was the largest modification the Waco team (now L3Harris) had ever carried out:
  - Most 474 type modifications were for wealthy “heads of state”
  - USRA and NASA oversite was subpar
- A well designed modification was completed, (with NASA’s help, Nuns Kunz et al) but was 6 years late and way over budget.
- In 2006 NASA Headquarters decided to cancel SOFIA.
- The Germans, US political action in congress, and most important NASA Dryden stepping up with a proposal to run the program saved SOFIA.
- Bob Meyer was the key to this new proposal.

SOFIA Makes Its First Flight April 2007!

SOFIA First Flight April 2007

Bob Meyer SOFIA P.M. 2006-2012

Robert R. Meyer Jr.

Program Manager, SOFIA

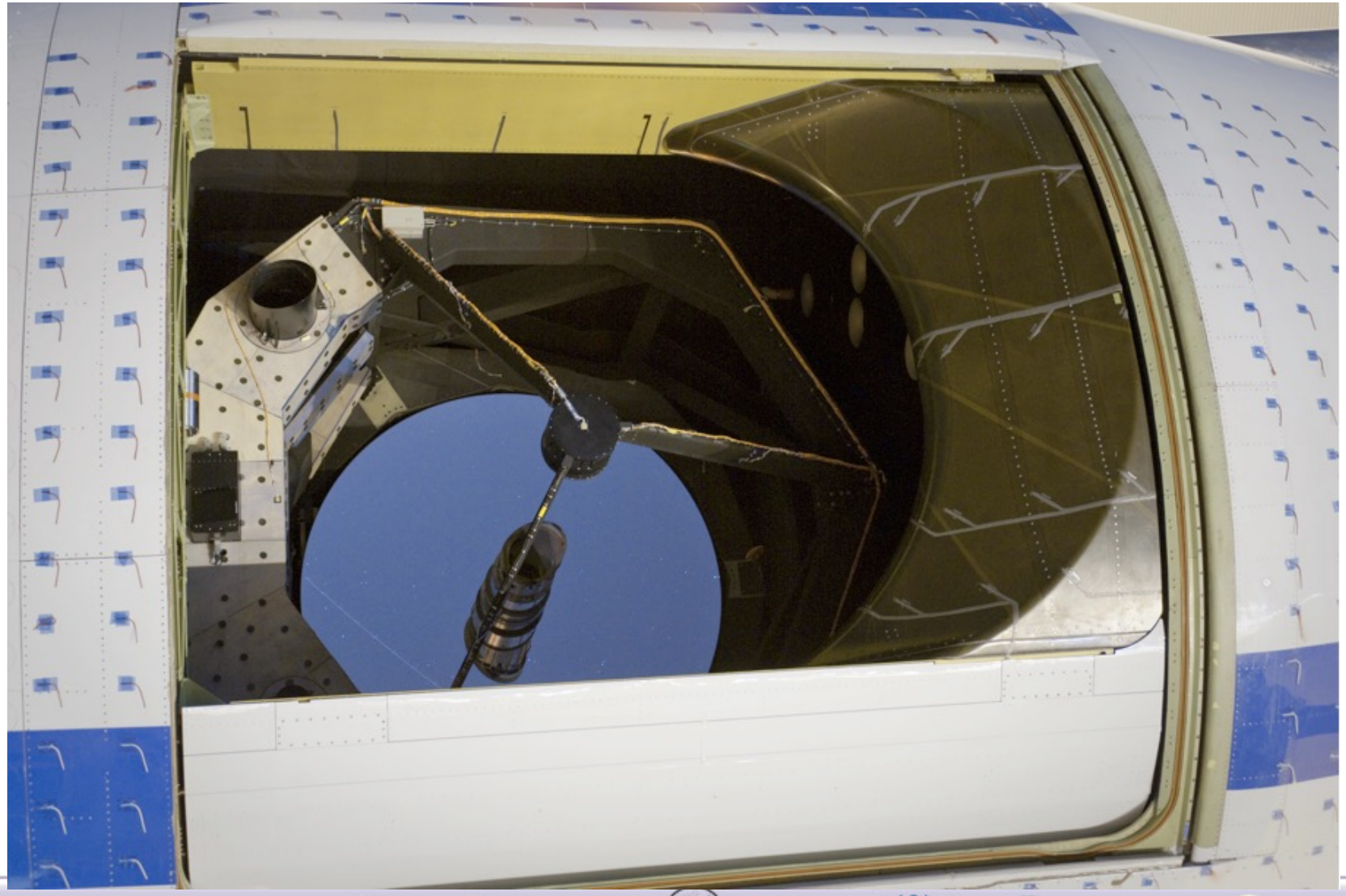
Clad in full pressure suits, flight engineers

The Fabulous SOFIA Door

- In the original USRA SOFIA proposal, the door was a NASA Ames work package.
  - For $1 Million Ames would produce a working door.
  - The design, construction and materials cost closer to $100 Million Dollars
- It was put on SOFIA in Waco ~2005, but with no drive motors.
- Drive motors and testing on the ground and in flight occurred in ~2009
- The door has opened and closed over 800 times without a major problem!!
- Paul Fusco is the key engineer on the door.

SOFIA Open Door Tests 2009

Coated Mirror and Aperture on SOFIA



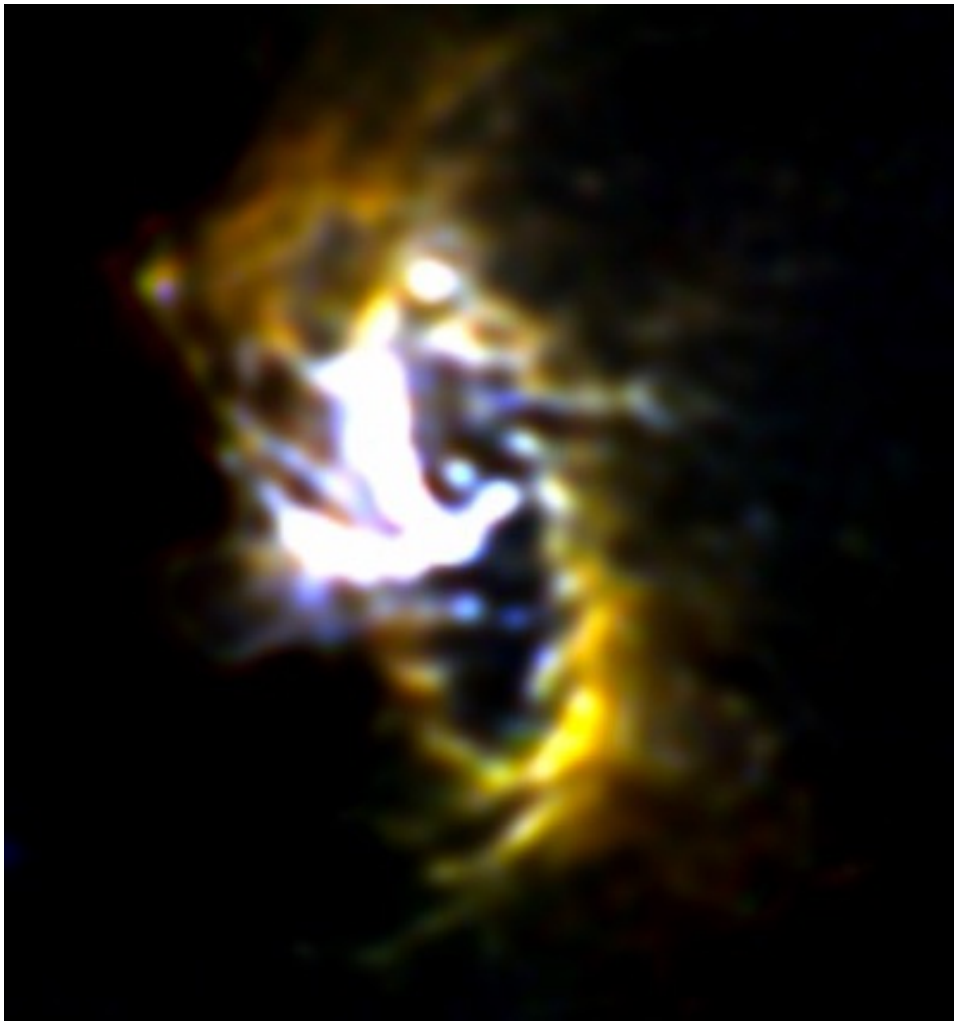
Early Science with SOFIA

- In 2008, Bob Meyer asked Tom Roellig and myself to select two instruments to conduct first light Science with SOFIA
  - FORCAST mid-IR imager was select from the US
  - GREAT Heterodyne Spectrometer was selected from the Germany
- Both had a successful series in 2010 and 2011.
- These flights demonstrated that SOFIA worked and could do science.
- 25 Science papers resulted from these flights.

Galactic Center Circumnuclear Ring With FORCAST

This is the highest resolution image of the Circumnuclear ring ever obtained with ~3 arcsec FWHM. (Lau etal 2013)

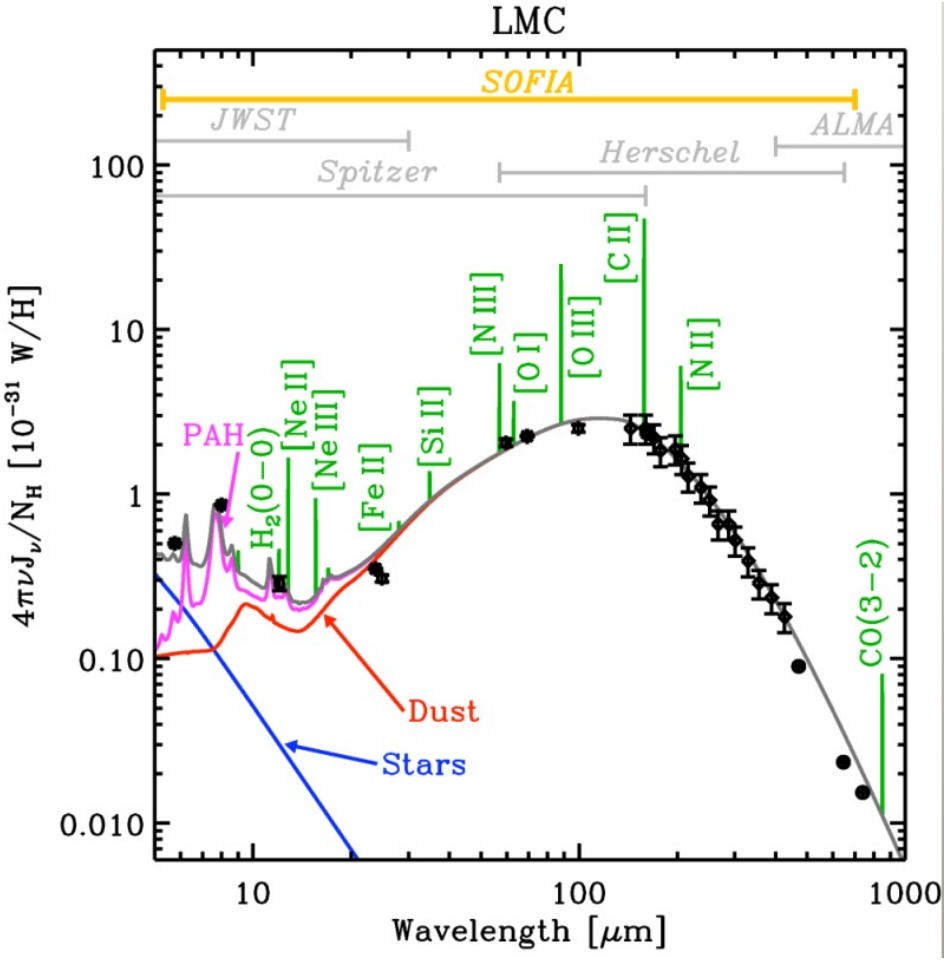
- The yellow almost perfect 4 light year radius ring is seen in cooler dust (T~100K) centered on a Massive Black Hole. (4 Million Suns).
- It is tipped 67 degrees from the plane of the sky.
- The ring is resolved with a width of about 1 ly and shows much structure.
- The white is hot dust falling on to the Black Hole



Future Science with SOFIA

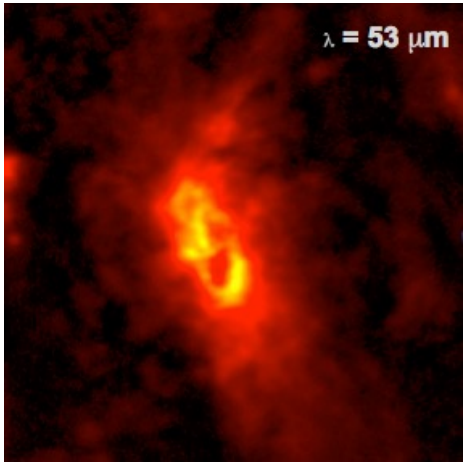
- SOFIA will do Unique Science for the next 10 to 15 Years
  - It will be the only operational Observatory in the 28 to 300 micron region of the spectrum.
  - This is the region where most the thermal luminosity in our Galaxy and other nearby Galaxies radiate.
  - Important atomic and molecular lines in the interstellar medium radiate in this region. For example the strong cooling lines of [C II] at 168 microns and [O I] at 63 microns and the molecular lines CO, OD, SH, HD, H2D+, HeH+, just to name a few.
- SOFIA has the instrumentation to make both the continuum and line observations.
- It can also make polarization measurements of the magnetically aligned grains for regions of Star Formations and the Nuclear Region of the Milky Way and other nearby Galaxies.

Future Science from 28 to 300 microns



SOFIA Summary

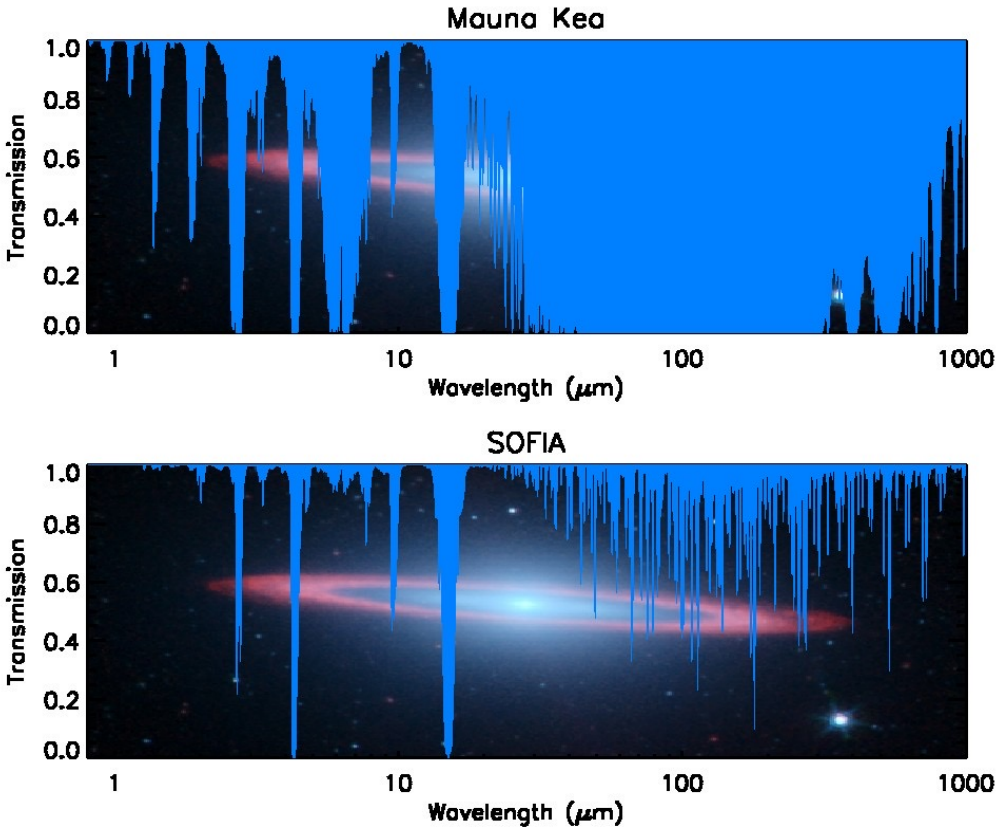
- SOFIA has produced outstanding science with 300 published papers
  - Spectacular Galactic Center results.
  - Discovery of many chemical and astrophysical lines.
  - HAWC+ with Polarimetry is making fabulous discoveries
  - Two Pluto, Triton, MU69, and Titan Occultations have been a great success!
  - Over 50 PhDs and increasing
- SOFIA is now the only observatory offering routine use by the community from 28 to 300 microns for the next decade.



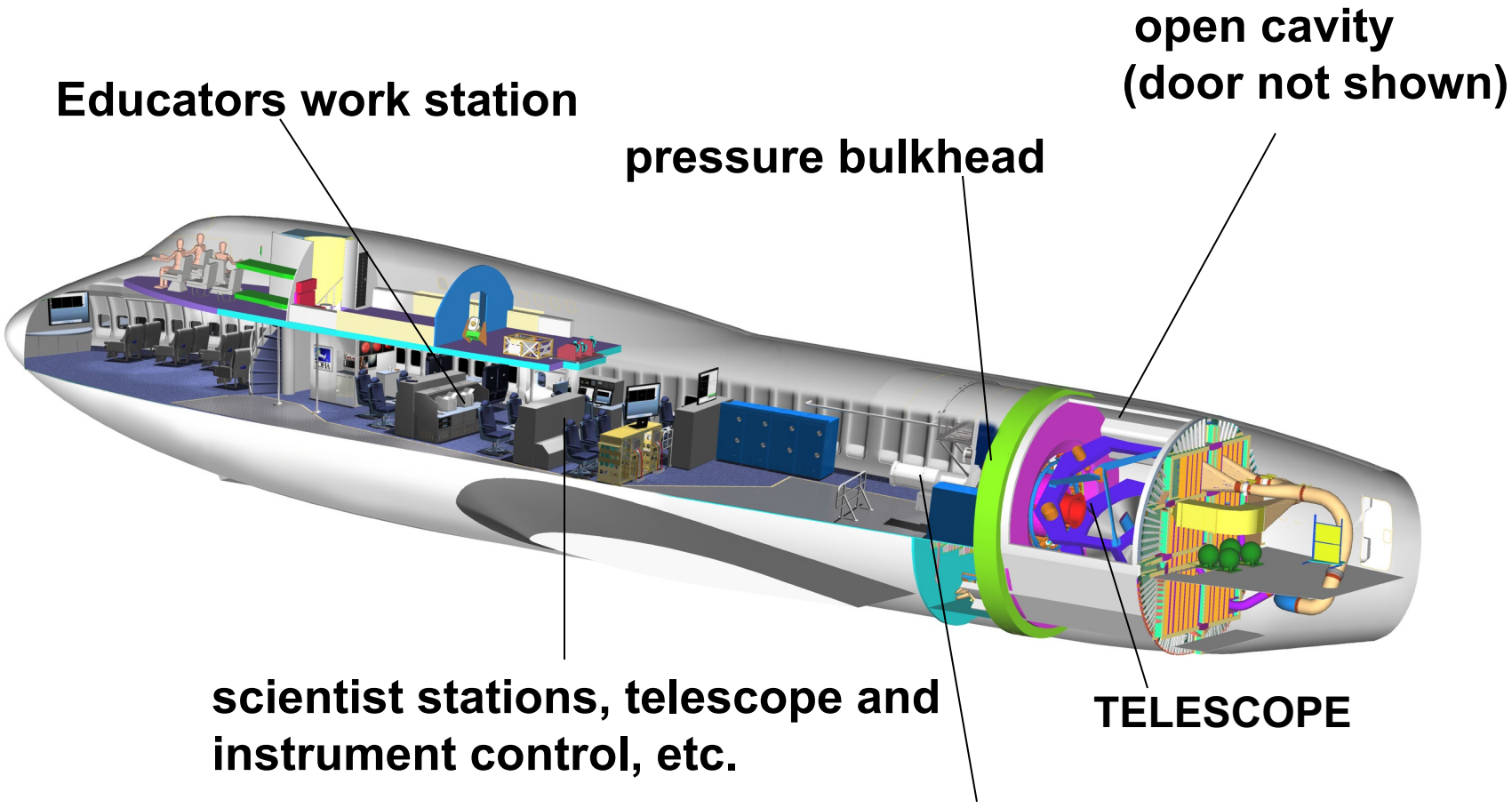
Backups

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



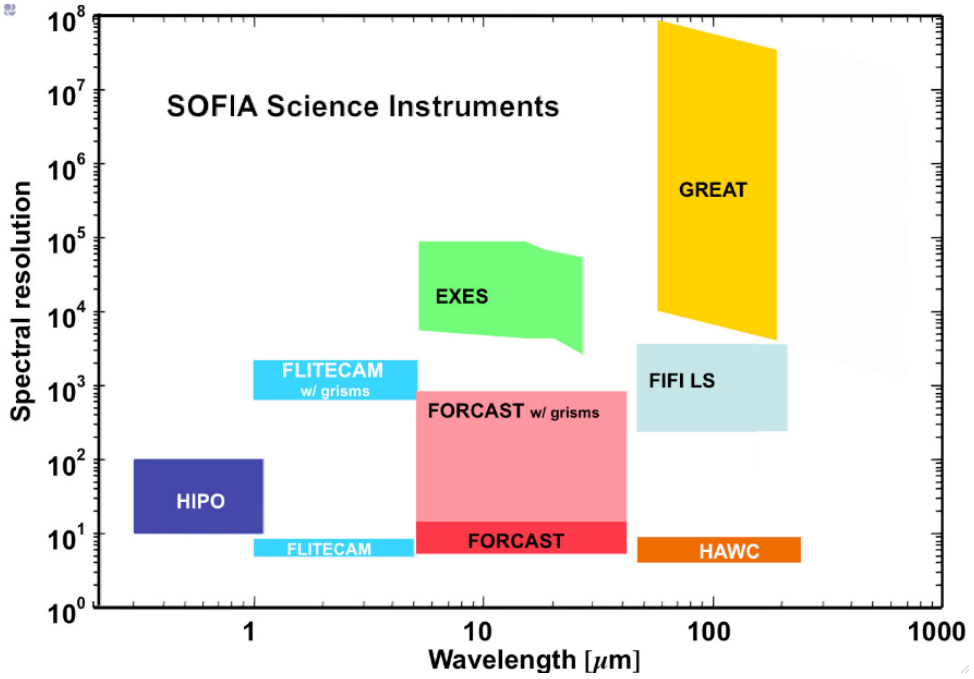
SOFIA — The Observatory



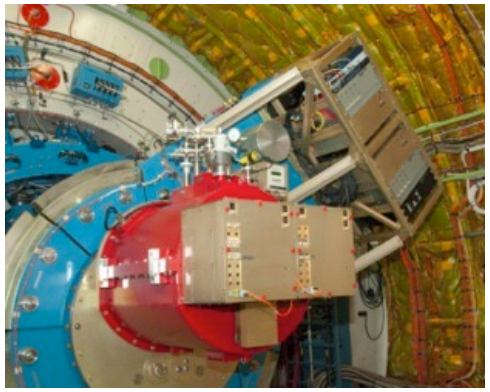
SOFIA's Instrument Complement

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
- 6 instruments now in Operation including FPI+
- 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

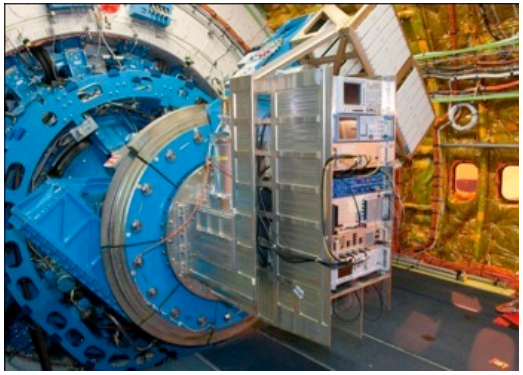


Current Instrument Complement

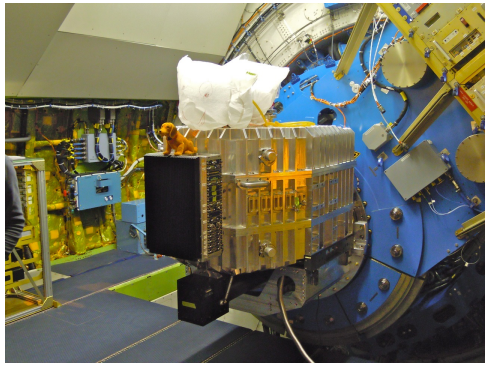


FORCAST
Mid-IR Camera

GREAT
Heterodyne
spectrometer



HAWC+
Far-IR Bolometer Camera
and Polarimeter



FIFI-LS
Integral Field
Spectrometer

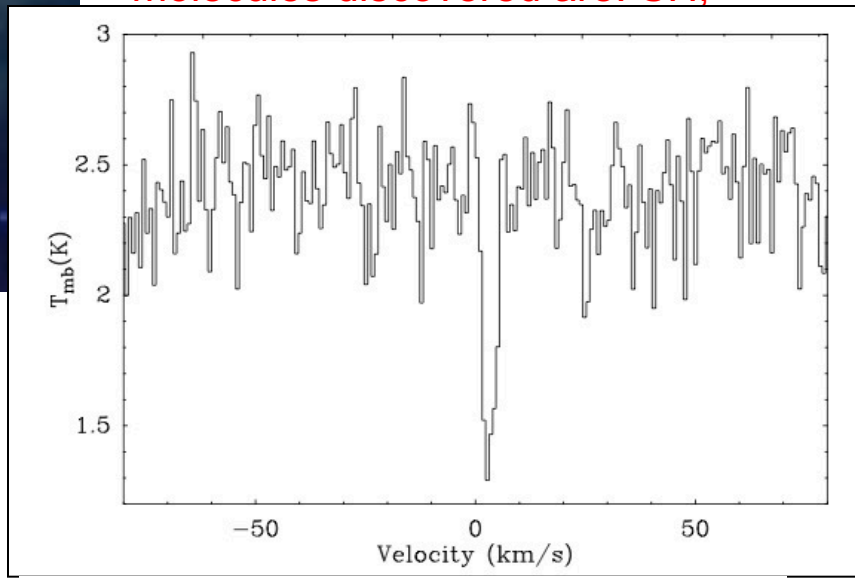
EXES
High Resolution
IR Spectrometer

Focal Plane Imager

Detection of OD Toward the Low-Mass Protostar IRAS16293

Detection of the OD ground state line at 216 microns in absorption toward the line-of-sight of a low-mass protostar.

First detection of OD outside of the solar system. Other Simple molecules discovered are: SH,

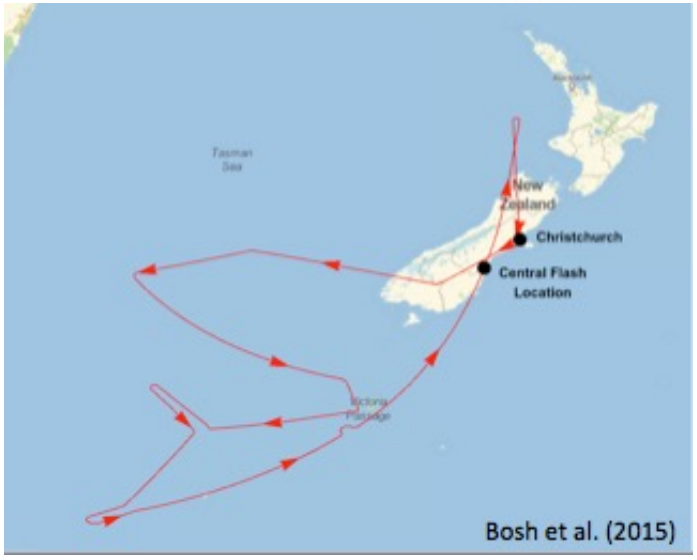


Analysis is ongoing, but high OD abundance suggests a higher than predicted OH fractionization

Work of B. Parise and the GREAT Team

Pluto Occultation on 29 June 2015

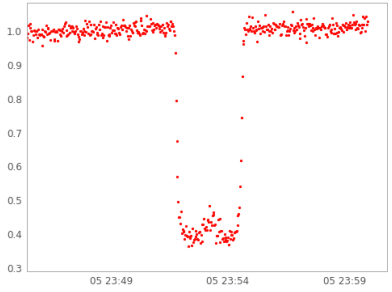
- Occultation of 12-mag star by Pluto on 2015 June 29 in support of New Horizons.
- Goal was to be within 25 km of center of Pluto shadow of 2400 km. (1 milli-arcsec and 100 milli-arcsec)
- Ground shadow moves 90,000 Km/hr. Plane 900 Km/hr.
- Final ground-based shadow updates required course adjustments of 230 km (7 milli-arcsec)
  - Updates to shadow path kept coming even after the plane took off.
  - Mobility of SOFIA was key to getting the observation

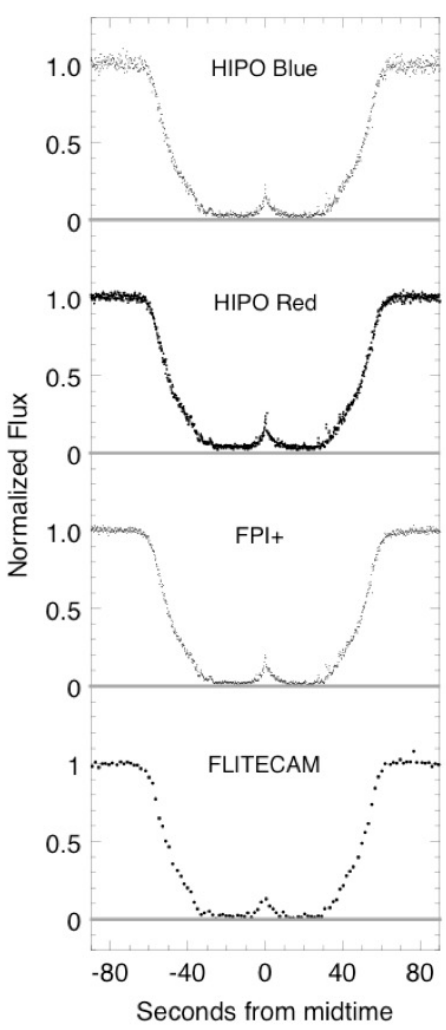


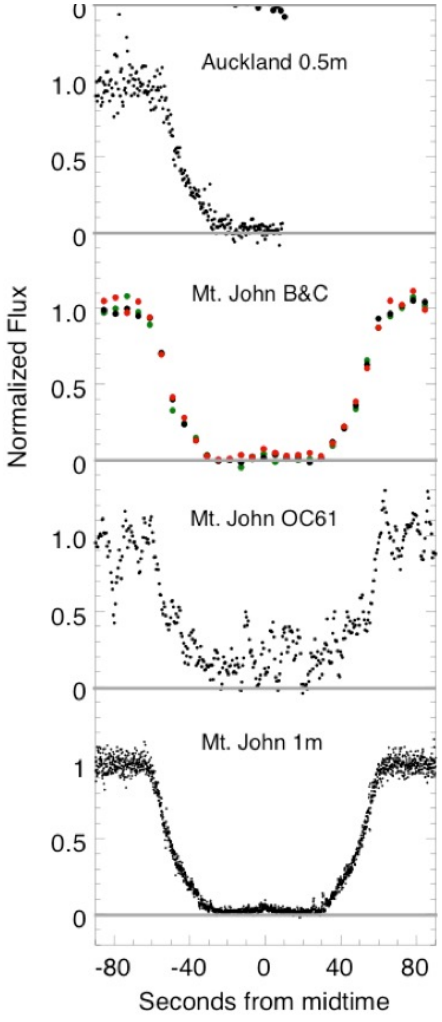
FliteCam team during Occultation

Science Highlight: Pluto Occultation

- Detection of strong “central flash” confirms accuracy of course corrections (within ~20 Km of Pluto center)
- Light curves show effect of mostly refraction in the atmosphere.
- Stability of Pluto’s atmosphere over last 15 years determined. Change had occurred between 1988 and 2000.
- Comparison of multi-wavelength observations allows detailed analysis of atmospheric profiles and aerosol or haze content. The haze results agree with the New Horizon’s images.
- The same team observed Triton, the moon of Neptune, with the same instrumentations in 6 October 2018 from Dayton FL. !.8 micron data shown red data below.
- In the future only can use FPI+ at 0.4 to 1.1 microns







30 Dor at 154 microns with HAWC+ in polarization: lines are direction of Magnetic Fields