
SOFIA
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SOFIA

Stratospheric Observatory For Infrared Astronomy

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ISSTT 2008

April 28, 2008

Outline of Material

- Overview of SOFIA
- Progress to Date
- Science
- Schedule and Future Opportunities

OVERVIEW

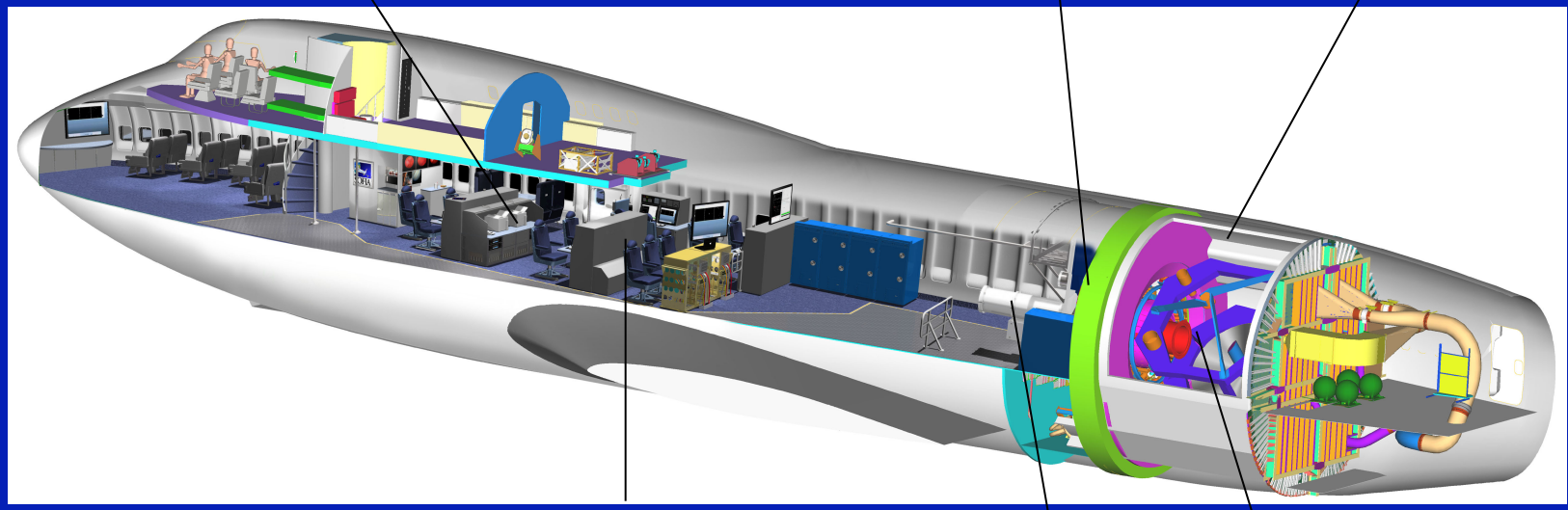
Overview of SOFIA

- SOFIA is 2.5 m telescope in a modified B747SP aircraft
  - Optical-mm performance
  - Can obtain obscured IR (30-300 μm), most important
- Joint Program between the US (80%) and Germany (20%)
- First Science 2009 (NASA, DLR, USRA, DSI)
- Designed for 20 year lifetime

Overview of SOFIA (Cont)

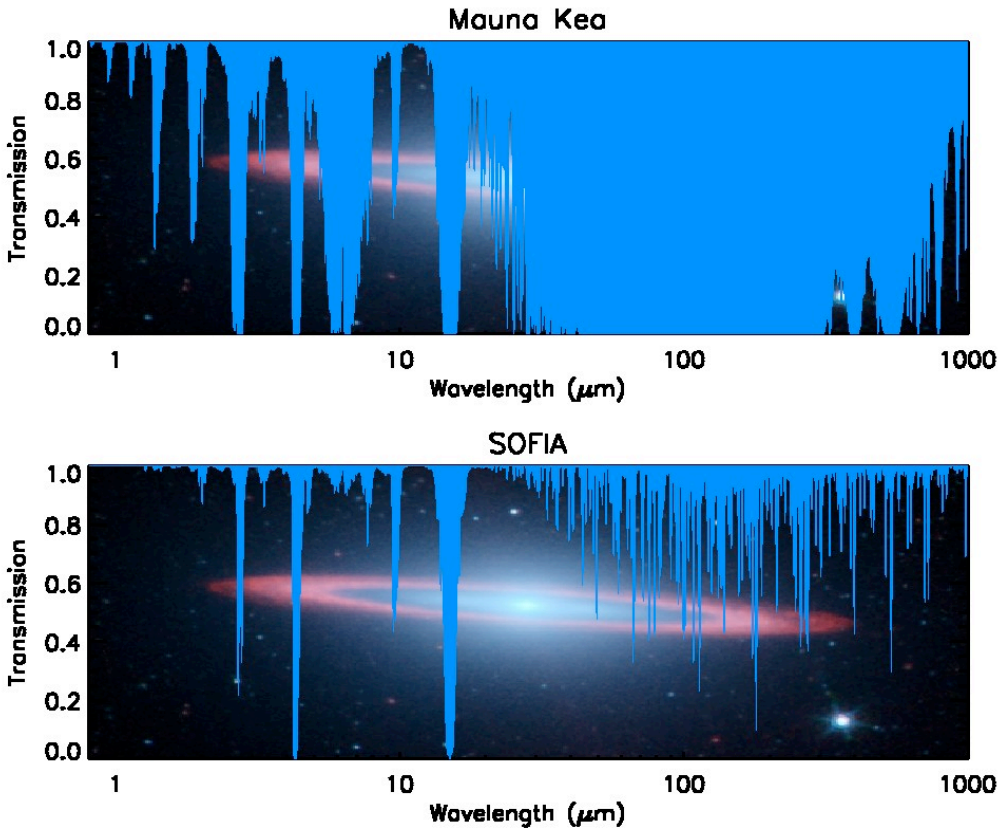
- Operating altitude
  - 39,000 to 45,000 feet (12 to 14 km)
  - Above > 99% of obscuring water vapor
- World Wide Deployments
- Ramp up to ~1000 science hours per year
- Build on KAO Heritage with improvements (Facility Inst., Science Support)
- Science flights to originate from Palmdale ….Aircraft operation by NASA Dryden Research Center (DFRC)
- Science Center is located at NASA Ames Research Center

SOFIA — The Observatory



Why SOFIA?

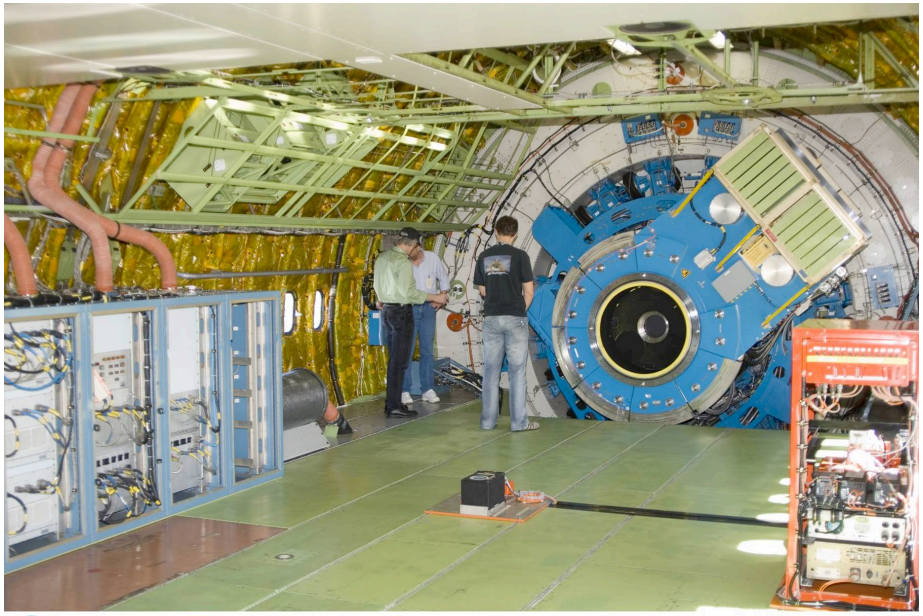
- Infrared transmission in the Stratosphere very good: >80% from 1 to 1000 microns
- Instrumentation: wide complement, rapidly interchangeable, state-of-the art
- Mobility: anywhere, anytime
- Long lifetime



PROGRESS TO DATE

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

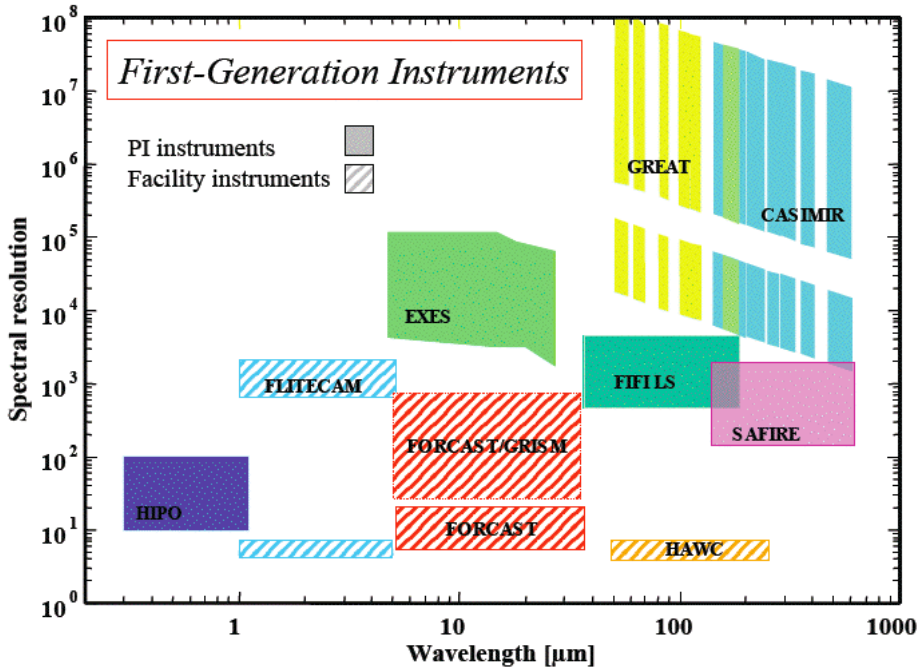
Telescope in Action

SOFIA Makes Its First Flight!

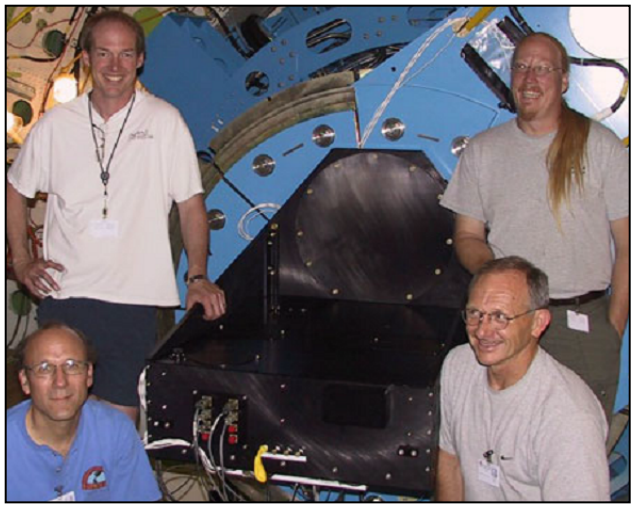
SOFIA's Instrument Complement

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
- 4 instruments at Initial Operations; 9 instruments at Full Operations.
- SOFIA will take fully advantage of improvements in instrument technology. There will be one new instrument or major upgrade each year.

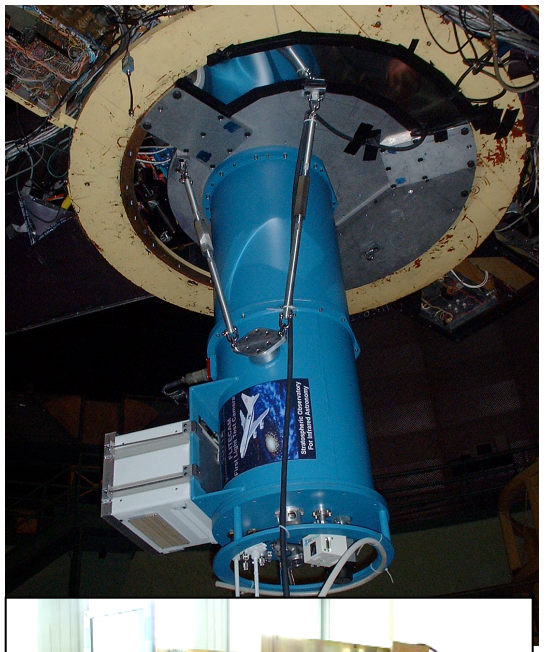


Four First Light Instruments



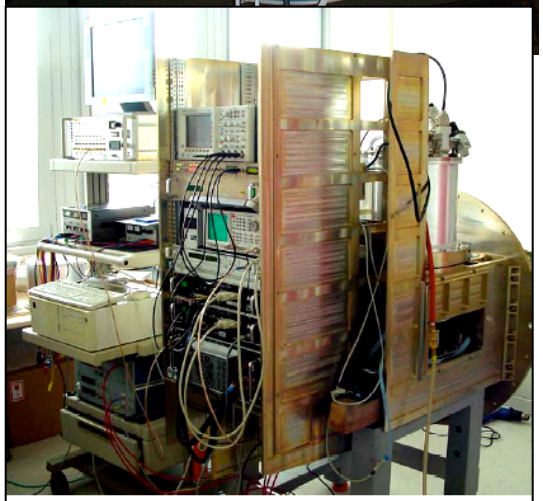
Working/complete HIPO instrument in Waco on SOFIA during Aug 2004

Working/complete FLITECAM instrument at Lick in 2004/5



Working FORCAST instrument at Palomar in 2005

Successful lab demonstration of GREAT in July 2005



Lab-picture of GREAT equipped with the KOSMA 1.9THz channel

SCIENCE

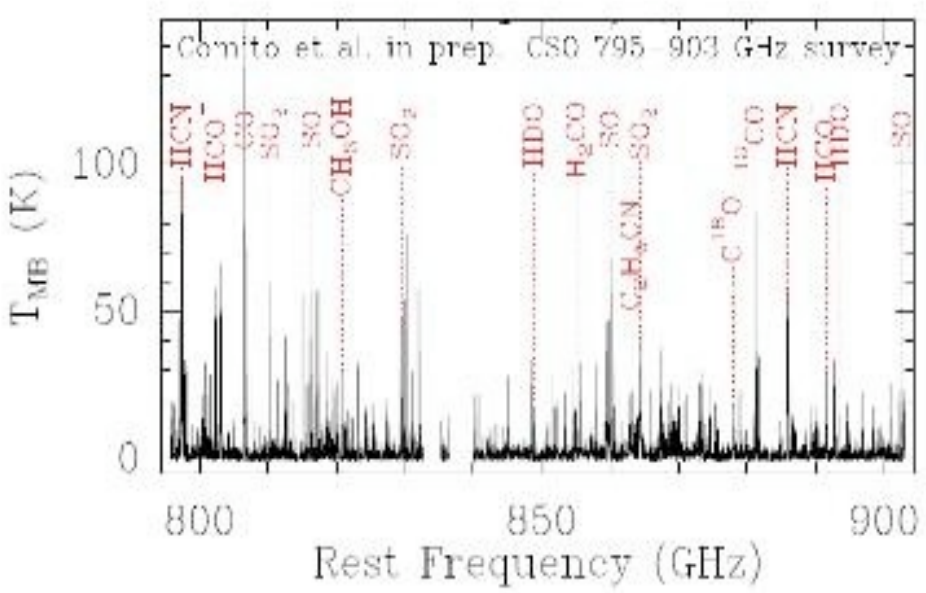
Science Capabilities

- 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

Astrochemistry

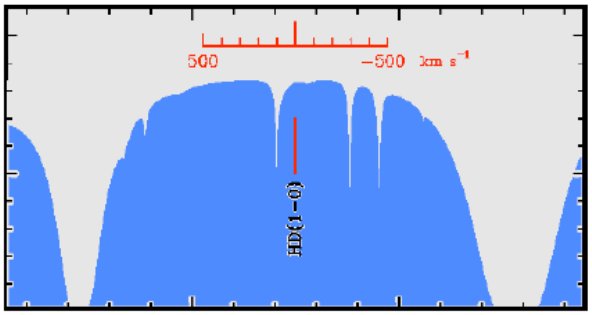
SOFIA is a good observatory to study chemistry in space

- 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.

Schedule & Future Opportunities

SOFIA Schedule (Major Milestones)

• First Re-Flight	Occurred April '07
• Closed Door Testing	Finished Jan 08
• Door Drive Delivered	Spring 08
• Mirror Coated	Summer 08
• Open Door Flights at Palmdale	Winter 08-09
• First Science	09
• Next Instrument call	10

US General Observer Opportunities

- First call for science proposals in ‘09
- Future calls every 12 months
- First General Observers 2010
  - Expect ~ 20 General Observer science flights
  - Shared risk with Instrument PI’s
- Open Observatory with Facility Instruments

Next Call for New Instruments

- The next call for instruments will be at first Science ~FY10
- There will be additional calls every 3 years
- There will be one new instrument or upgrade per year
- Approximate funding for new instruments $8 M/yr

Summary

- Program making progress!
  - Aircraft structural modifications complete
  - Telescope installed, several instruments tested on ground observatories
  - Completed first flight and ferry flight to NASA Dryden
  - Full envelope flight testing closed door finished. Aircraft at Palmdale.
  - Several subsystems will be installed fall 08 (Door motor drive, coated primary mirror)
  - First science in ’09
- SOFIA will be one of the primary facilities for far-IR and sub-millimeter astronomy for many years

Back-up

Instrument/ Location	PI	Instrument Type
HIPO/Lowell	Dunham	.3-1.1 μm High Speed Occultation Camera
FLITECAM**/ UCLA	McLean	1-5.5 μm Infrared Camera and IR channel for HIPO
FORCAST**/ Cornell	Herter	Faint Object Infrared Camera. Simultaneous Dual channel observations (5-25 μm & 25-40 μm)
GREAT/MPI-Bonn	Güsten	Hi resolution (R> 10^6) Heterodyne Spectrometer 3 bands - 1.6-1.9 THz; 2.4-2.7 THz; 4.7 THz
FIFI-LS**/ MPI Garching	Poglitsch	Dual Channel (42-110 μm ; 100-210 μm) Grating Spectrometer
HAWC**/ UChicago	Harper	High Angular resolution 4 channel Camera @ 50 μm, 100 μm, 160 μm, 200 μm
CASIMIR/ Caltech	Zmuidzinas	Hi resolution (R~ 10^6) Heterodyne Spectrometer 500-2000 GHz
EXES/UTexas	Lacy	5-28 μm-High resolution grating spectrometer (R>100,000)
SAFIRE/GSFC	Moseley	Fabry-Perot Spectrometer 100-655 μm (2000<R<10^4)

** Facility Instruments

SOFIA and Spitzer

- SOFIA will become operational near the time that Spitzer runs out of cryogens. The science impact of not being contemporary is small: Spitzer is a high sensitivity imaging and low resolution spectroscopy mission. SOFIA is a high spectral and high angular resolution mission
- As it now stands, the two observatories are very complementary and when Spitzer runs out of cryogens in early FY09, SOFIA will be the only observatory working in the 25 to 60 micron region for over 10 years: Comets, Supernovae, Variable AGN, other discoveries.

SOFIA and Herschel

- Herschel and SOFIA will now start at about the same time
- Joint calibration work is on going
- For the years of overlap, SOFIA will be only program
  - with 25 to 60 micron capability
  - with high resolution spectroscopy in the 60 to 150 micron region
- When cryogens run out in Herschel in ~2011 SOFIA will be only NASA mission in 25 to 600 micron region for many years
  - Important follow-up
  - Advanced instrumentation will give unique capabilities to SOFIA: Polarization, Heterodyne Arrays, Heterodyne Spectroscopy at 28 microns (ground state of molecular hydrogen), and other interesting astrophysics lines
- Both missions are critically important and complementary

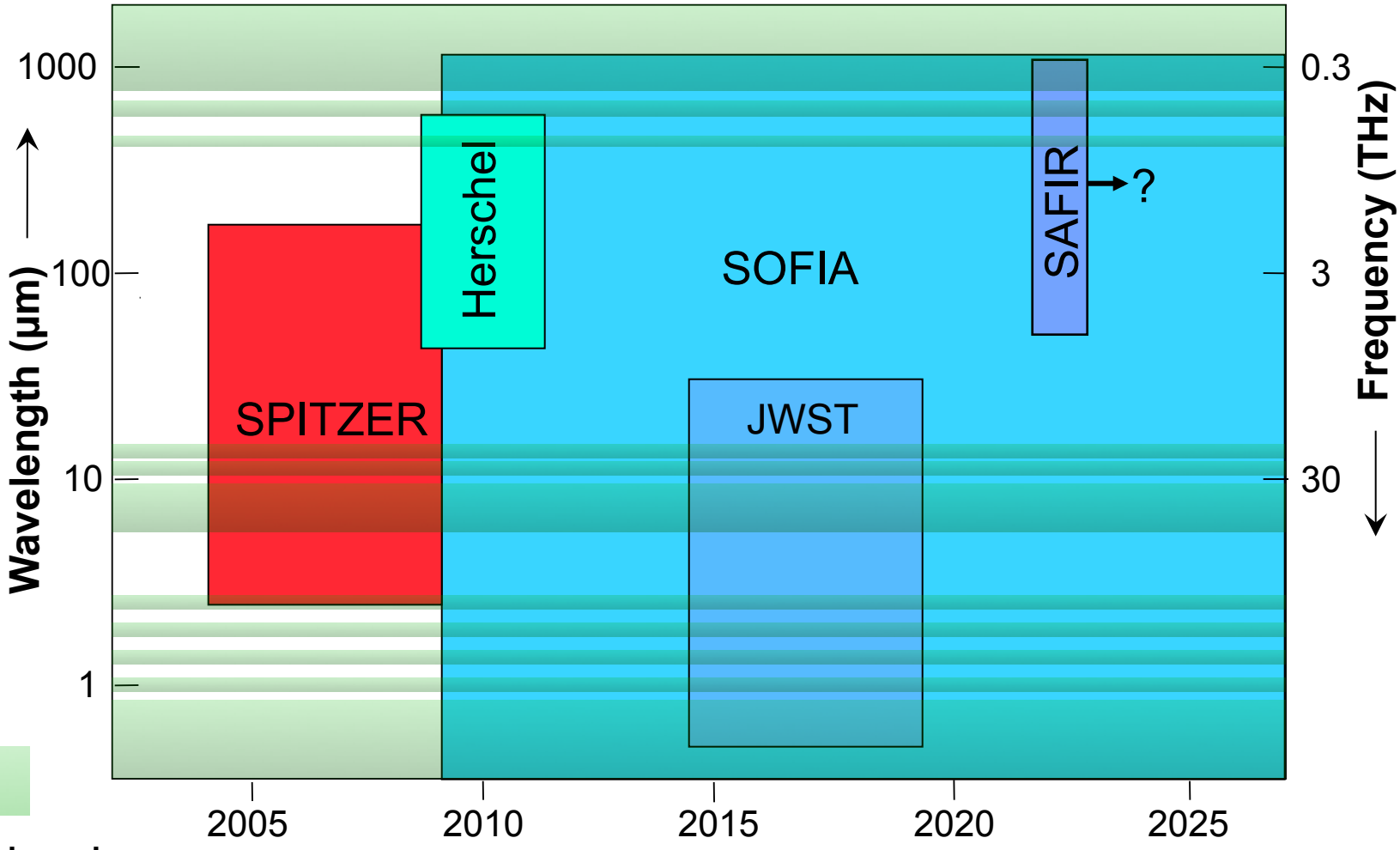
SOFIA and JWST

- SOFIA is very complementary to JWST
- Before JWST is deployed and after Spitzer cryogens run out , SOFIA is only mission with 5 to 8 micron capabilities
  - important organic signatures
- After JWST is launched SOFIA is the only mission to give complementary observation beyond 28 microns and high resolution spectroscopy in 5 to 28 micron region

SOFIA and WISE

- WISE is a very sensitive all sky survey in the 3.3 to 23 micron region. It is expect to launch just as SOFIA begins operations.
- SOFIA can provide a number of important follow up observations.
  - Very red sources seen only at 23 microns can be followed up at 38 microns with FORCAST on SOFIA and spectra can be obtained with EXES on SOFIA for the brightest 23 micron sources not seen by IRAS.
  - Nearby cold Brown Dwarfs discovered by WISE can be followed up with the FLITECAM GRISM and EXES.

Infrared Space Observatories



SOFIA provides temporal continuity and wide spectral coverage, complementing other infrared observatories.

Partnership Opportunity on SOFIA

- ***The NASA Science Mission Directorate is providing an opportunity for domestic and international governments, agencies, universities, organizations, and research foundations to participate as a partner in SOFIA operations.***

- ***Currently, NASA is funding 80% of the program and the German space agency, DLR, is funding 20%. A substantial long-term opportunity exists for a new partnership agreement of between 3 and 10 years duration. In exchange for their support, the new partner would receive up to 20% of NASA's share of the observatory time (≥ 150 observation hours per year at full operational capability).***

The Benefits of Partnership

The new partner will have access to flight and science operations and infrastructure, including:

- *World-wide deployment capability*
- *Fully operational and maintained aircraft and telescope assembly with aircrew and support staff*
- *Ground-based labs at NASA Dryden and NASA Ames, and project data archiving and storage infra-structure*
- *Existing instruments and/or use of partner-supplied instruments*
- *Access and use of SOFIA as an instrumentation flight test bed (detectors, focal planes, read-out electronics, cooling) in support of future instrument technology development and testing. (A detailed instrument interface control document (ICD) is available).*