Stratospheric Observatory For Infrared Astronomy (SOFIA)

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Abstract

The joint U.S. and German SOFIA project to develop and operate a 2.5-meter infrared airborne telescope in a Boeing 747-SP is now in the final stages of development. First science flights will begin in 2005. The observatory is expected to operate for over 20 years. The sensitivity, characteristics, science instrument complement, and examples of 1st light science are discussed.

Introduction

The Stratospheric Observatory For Infrared Astronomy (SOFIA) is NASA's and DLR's premier observatory for infrared and submillimeter astronomy. A Boeing 747-SP aircraft will carry a 2.5-meter telescope designed to make sensitive infrared measurements of a wide range of astronomical objects. It will fly at and above 12.5 km, where the telescope collects radiation in the wavelength range from 0.3 micrometers to 1.6 millimeters. SOFIA is being developed and operated for NASA and DLR by USRA.

The telescope and 20% of operations will be supplied by Germany through contracts with DLR (German Space Agency). The development of the science instruments to be attached to the SOFIA telescope will be the responsibility of the U.S. and German science communities. In the U.S., science instruments will be designed and built at universities and national centers through a USRA peer review process.

SOFIA First Light Instruments

A total of nine instruments have been selected and are now under development (see Table 1). The selection includes three Facility Class (FI) Science Instruments (HAWC, FORCAST, and FLITECAM) and six Principal Investigator Class (PI) Science Instruments. Two of the PI Class instruments are being developed in Germany.

SOFIA First Light Instruments

PI	Institution	Name	Type of Instrument	Instrument Class
E. Dunham	Lowell Observatory	HIPO	High-speed Imaging Photometer for Occultations 0.3 – 1.1 microns	Special Class (USA)
I. McLean	UCLA	FLITECAM	Near-IR Test Camera 1 – 5 microns	Facility Class (USA)
J. Lacy	Univ. of Texas	EXES	Echelon Spectrometer 5 – 28 microns; R = 10^5, 10^4, or 3000	PI Class (USA)
T. Herter	Cornell	FORCAST	Mid IR Camera 5 – 40 microns	Facility Class (USA)
D.A. Harper	Univ. of Chicago	HAWC	Far Infrared Bolometer Camera 50 – 240 microns	Facility Class (USA)
A. Poglitsch	MPE, Garching	FIFI LS	Field Imaging Far IR Line Spectrometer 40 – 210 microns	PI Class (German)
S. Moseley	NASA-GSFC	SAFIRE	Imaging Fabry-Perot Bolometer Array Spectrometer 145 – 655 microns; R = 1,000 – 1,900	PI Class (USA)
R. Guesten	MPIfR, KOSMA, DLR-WS	GREAT	Heterodyne Spectrometer 60 – 200 microns	PI Class (German)
J. Zmuidzinas	Caltech	CASIMIR	Heterodyne Spectrometer 250 – 600 microns	PI Class (USA)

First Light Expected in 2005

SOFIA will see first light in 2005, and is planned to make more than 140 scientific flights per year of at least 8 hours duration. SOFIA is expected to operate for at least 20 years, primarily from Moffett Field in California, but occasionally from other bases around the world, especially in the Southern Hemisphere. SOFIA will fly above 12.5 km, where the typical water vapor column density is less than 10 μm.

The SOFIA Science and Mission Operations Center (SSMOC), to be operated by USRA, will be located at NASA Ames Research Center at Moffett Field, in the same hangar housing SOFIA. The SOFIA Program will support approximately 50 investigation teams per year.

The finished telescope has been mated into the modified aircraft (Fig 1) and will be ready for testing in late ’03. First test flights will occur in mid ’04, and first science in ’05.

System Characteristics

Nominal Operational Wavelength Range	0.3 to 1600 microns
Primary Mirror Diameter	2.7 meters
System Clear Aperture Diameter	2.5 meters
Nominal System f-ratio	19.6
Primary Mirror f-ratio	1.28
Telescope's Unvignetted Elevation Range	20 to 60 degrees
Unvignetted Field-of-View Diameter	8 arcmin
Maximum Chop Throw on Sky	± 4 arcmin (unvignetted)
Image Quality of Telescope Optics at 0.6 microns	1.5 arcsec on-axis (80% encircled energy)
Diffraction Limited Image Size	0." 1 • λµm FWHM
Diffraction-Limited Wavelengths	≥ 15 microns
Optical Configuration	Bent Cassegrain with chopping secondary mirror and flat folding tertiary
Chopper Frequencies	1 to 20 Hz for 2-point square wave chop
Pointing Stability	= 1." 0 rms at first light = 0." 2 rms in operations
Pointing Accuracy	= 0." 5 with on-axis focal plane tracking = 3" with on-axis fine-field tracking
Total Emissivity of Telescope (Goal)	15% at 10 microns with dichroic tertiary 10% at 10 microns with aluminized tertiary
Recovery Air Temperature in Cavity (and Optics Temperature)	= 240K

Science Potential

With the parameters given under SOFIA Characteristics in Table 2, and the atmospheric transmission at flight altitudes given in Traub & Stier (1976) (see Figure 2) we calculate that the background limited NEFD at 100 µm in a 30% band should be about 400 mJyHz$^{-1/2}$ and at 450 µm about 300 mJyHz$^{-1/2}$. The corresponding 1-σ noise in an hour integration should be 7 mJy at 100 µm and 5 mJy at 450 µm. The 1-σ line flux limit in 1 hour should be about 4 x 10^{-18} Wm^{-2} at a resolution of 10^3 at 100 µm (see Figure 3).

Figure 1 A wide angle view of the SOFIA telescope through the aircraft opening. The Stratospheric Observatory for Infrared Astronomy is preparing for its first flights.

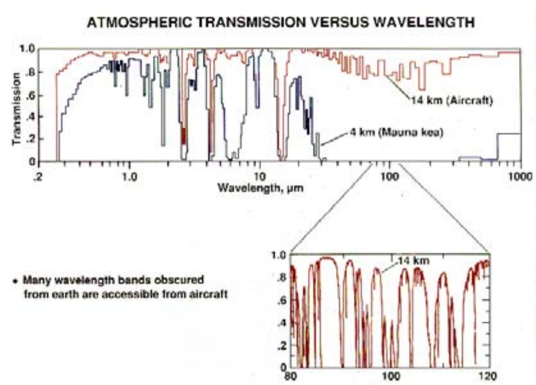

Figure 2 Atmospheric transmission as a function of wavelength for aircraft (14km) and mountaintop (4 km) altitudes. Absorption is largely due to water vapor; figure from Erickson (1995).

Examples of Submillimeter Science with SOFIA

Using the first light heterodyne instruments, spectra line surveys can be made to reveal many new lines in the broad atmospheric window. With spectral line sensitivities similar to the CSO, many new lines should be observed for the first time. Using the far infrared cameras, Galactic plane mapping will reveal structure never before observed at these wavelengths. Regions of high-mass and low-mass star formation can be imaged at 50, 100 and 200 µm.

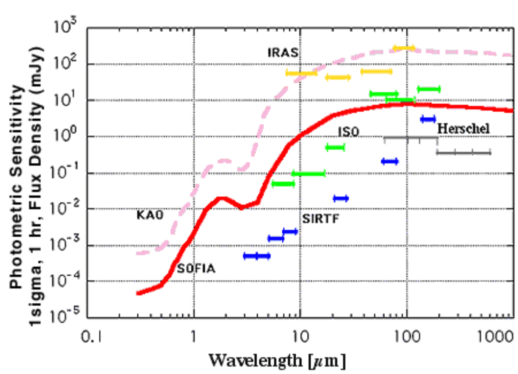

Figure 3
SOFIA photometric point source sensitivities are shown compared with Herschel, KAO, IRAS, ISO, and SIRTF. On source integration time is 1 hour.

References

Erickson, E.F. 1995, Space Science Reviews, 74, 91

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