SOFIA : follow-up opportunities for Herschel

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ABSTRACT

SOFIA, the Stratospheric Observatory for Infrared Astronomy, is a Boeing 747-SP airplane with a 2.5 m telescope, designed to operate at altitudes from 12 to 14 km and wavelengths from 0.3 μm to 1.6 mm over a 20 year lifetime. The telescope will be diffraction limited at wavelengths beyond ~ 15 μm. At 100 μm the resolution is ~ 10", which is comparable to the angular resolution of large groundbased telescopes in the mm/sub-mm such as IRAM, JCMT, and CSO. **SOFIA is ideal for follow-up of Herschel observations.** Several of our instruments are very complementary, others extend the wavelength range to shorter wavelengths or provide higher spectral resolution. GREAT (German PI instrument) is a heterodyne receiver similar to HIFI, which fills the gap between band 5 and 6L and will also have a mixer covering 110 μm. FIFI-LS is an integral field spectrometer built by MPE, the same group that built PACS, but which goes to somewhat shorter wavelengths (42 μm) than PACS. SOFIA has seven instruments and is expected to add or upgrade instruments every few years during its lifetime. The next call for new instruments will be issued early next year.

SOFIA has finished its flight testing and the first science flights will begin this fall. First light was obtained on May 26, 2010 with FORCAST images of Jupiter and the starburst galaxy M82. For basic science, which will take place next spring, we received 59 proposals, corresponding to an over-subscription rate of 3.4:1. Basic science consists of 12 US flights and three German flights with FORCAST and GREAT. This is the first real opportunity for the astronomy community to use SOFIA. SOFIA will be fully operational in 2014.

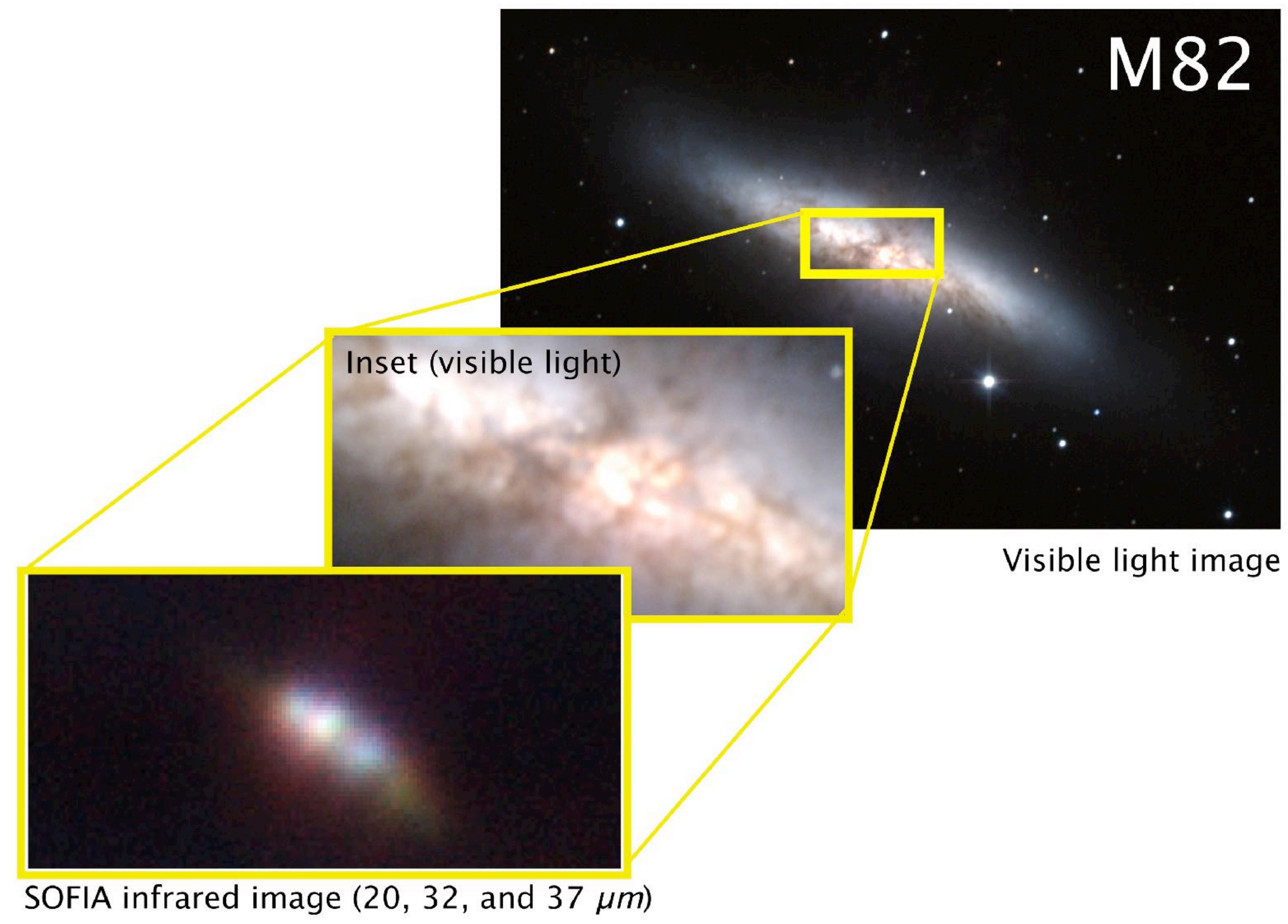
Introduction

SOFIA is now airborne. Limited science observations are starting in the fall of 2010 and will ramp up to full capability by 2014. Even with the first generation instruments, SOFIA can do unique observations from near- to far-infrared wavelengths, which we summarize briefly below.

SOFIA is the only FIR mission available to the astronomy community after Herschel !!

Below we list our first generation instruments that can be used for follow-up of Herschel projects (see Table) and give a few examples of what kind of studies could be done with each instrument. We are sure that you will quickly find your own application of one or several of these unique SOFIA instruments.

- FORCAST:
  Followup of PACS and SPIRE imaging. At 38 μm FORCAST provides similar spatial resolution as the PACS blue channel. FORCAST will also have spectroscopic capabilities (grisms), but not for basic science.
- HAWC:
  Provides FIR images with narrower filters and better SED sampling than PACS. Ideal for studying star formation in our galaxy and nearby galaxies. A polarimetry module, independently funded, is being developed for HAWC.
- FLITECAM:
  Can do fast surveys in narrowband filters (e.g. Pα, Brα, the 3.1 μm "ice", and the 3.3 μm PAH band) due to it's large field of view (8'), allowing us to see the interaction between the hot stars and the surrounding molecular cloud. FLITECAM is also equipped with grisms, which enable medium resolution (R ~ 2000) spectroscopy of lines not observable from the ground.
- EXES:
  Ideal for studying the chemistry and kinematics of protostellar disks. EXES can reach all the pure rotational lines of H_2 from S(0) to S(9) as well as many transitions of H_2O, providing a unique probe of the hot inner parts of protoplanetary disks and the outflows powered by the accretion disks.
- GREAT:
  Studies of hot dense gas in hot cores, accretions disks and outflows. GREAT covers the HIFI gap between Band 6 & &, i.e. 1.27 - 1.41 THz. the mid-frequency channel covers the J = 1 - 0 transition of deuterated H_2 (HD) at 2.7 THz and ground state rotational transition of OH. It will also have a high frequency channel which targets the [OI] line at 63 μm.
- FIFI-LS:
  An Integral field spectrometer for the FIR similar to PACS. On SOFIA it can be uniquely study solar system objects like Venus or planetary moons like Titan. Can be used to study star formation in our and nearby galaxies.

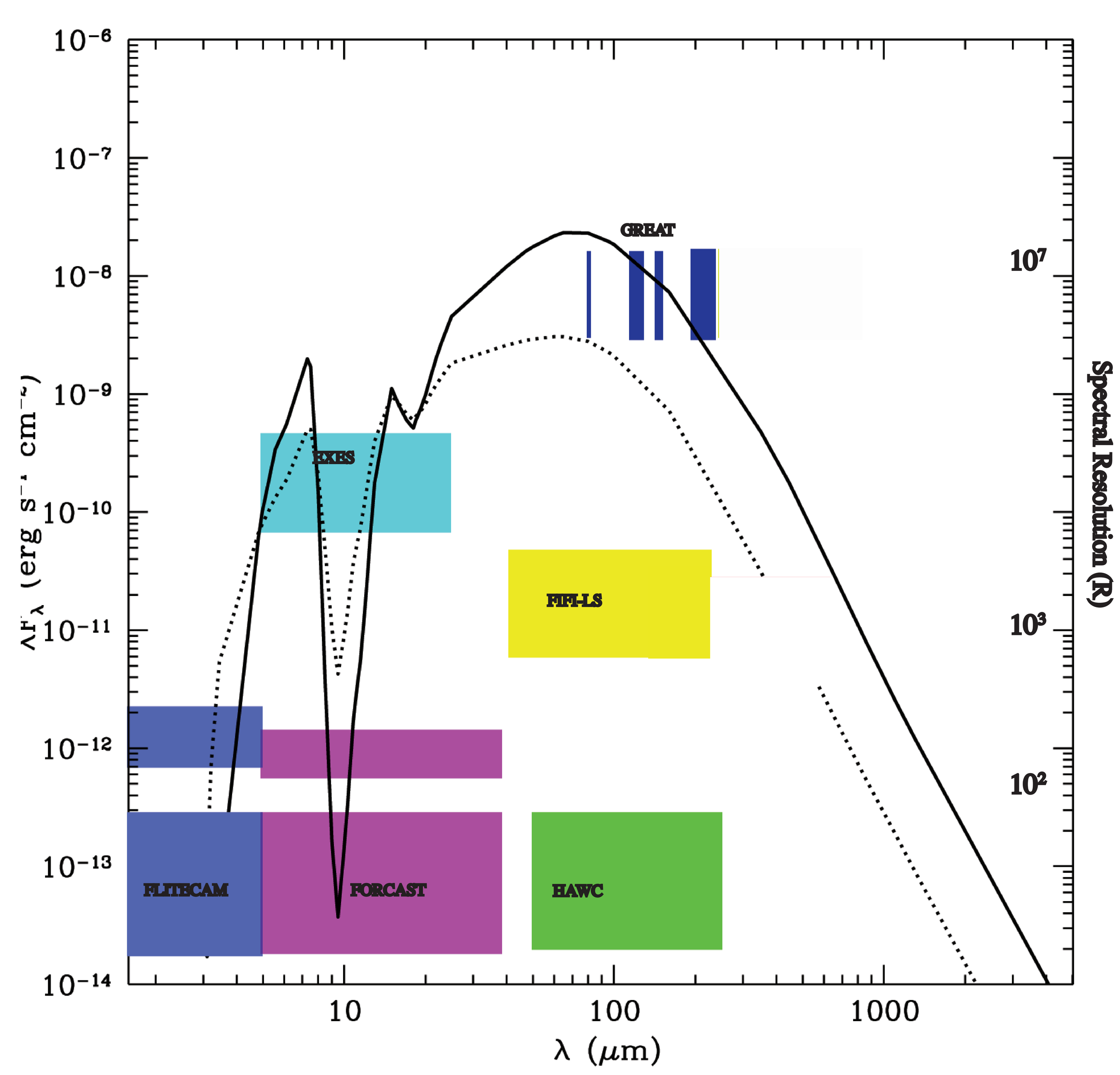


Composite infrared image of the central portion of M82 from SOFIA's first light flight at wavelengths of 20 (blue), 32 (green), and 37 μm (red).

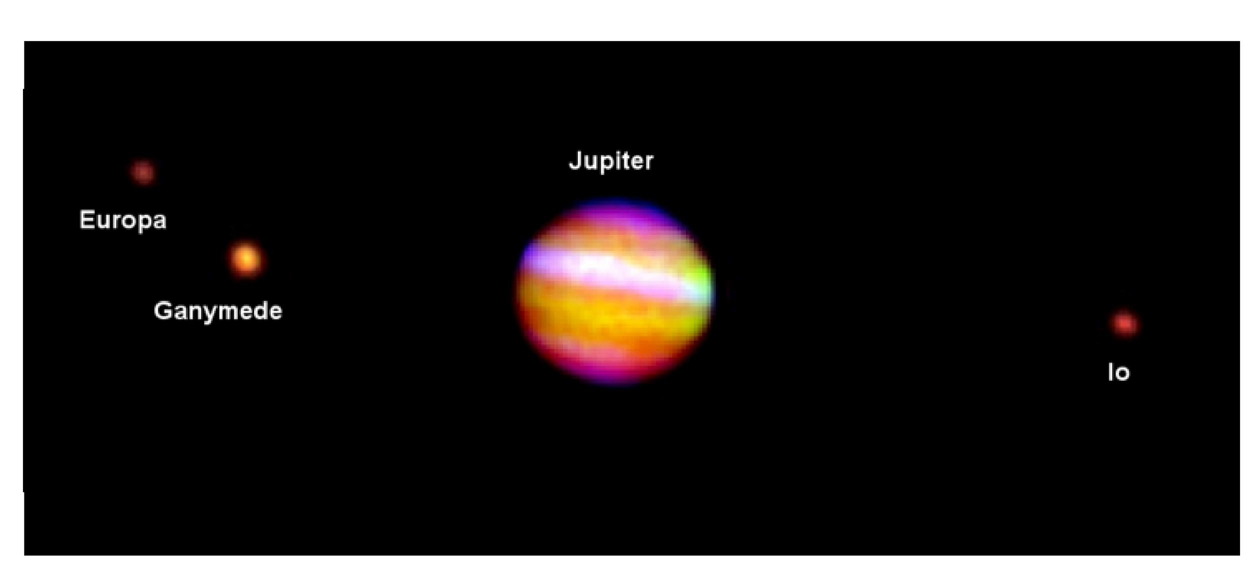
SOFIA FIRST GENERATION INSTRUMENTS

Instrument name	Type	Array & pixel size	Wavelength coverage & resolution
Facility Instruments			
HAWC	Far Infrared Bolometer Camera	12 x 32, 2.3″ - 8″/pixel	40 - 300 μm
FORCAST	Mid IR Camera	256x256 , 0.75″/pixel	5 - 40 μm
FLITECAM	Near IR Test Camera	1024x1024, 0.48″/pixel	1 - 5 μm
PI Instruments			
EXES	Echelon Grating Spectrometer	1024x1024, 1″ - 4″ slit	5 - 28 μm, R=3 10^3 - 10^5
FIFI-LS	Image Sliced Grating Spectrometer	5x5 (x2), 7″ &14″/pixel	42-110, 110-210 μm R= 2000
GREAT	Heterodyne Spectrometer	Single, diff.limited	63,110-125,156-240 μm R=10^6-10^8

The table above gives a very short summary of the main characteristics of each intrument. The figure below shows that these instruments essentially cover the whole SED of a young protostar. The intensity axis of the SED is used to approximately illustrate the spectral resolution of each instrument.



In addition to the first generation instruments, SOFIA will upgrade or add a new instrument every few years, which will enhance or enable new capabilities. The next instrument call will be issued early next year.



SOFIA image of Jupiter and three of the Galilean moons composed of multiple frames taken at wavelengths of 5.4, 24 and 37 μm with the FORCAST infrared camera (P.I. Terry Herter, Cornell University; image layout by James De Buizer)