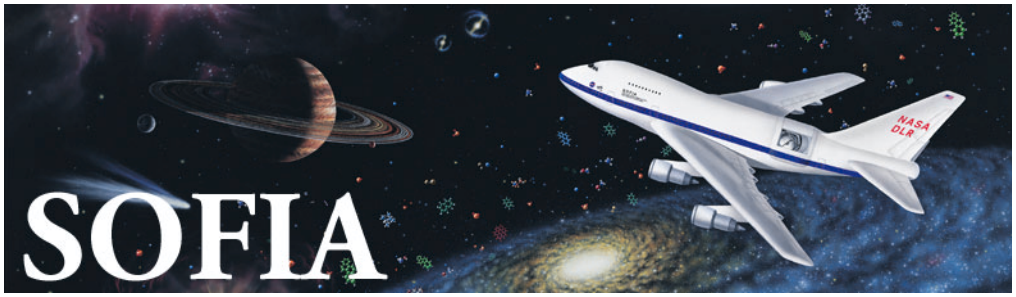
EXES:

The Echelon-Cross-Echelle Spectrograph



SOFIA will have a unique potential for high-resolution spectroscopy in the mid-infrared. To take advantage of this potential, we are building EXES, a PI-class spectrograph optimized for high spectral resolution at 5-28.5 μm. EXES will operate in three spectroscopic modes: high-resolution ($R=\lambda/\Delta\lambda\sim10^5$) cross-dispersed; medium-resolution ($R\sim10^4$) long-slit; and low-resolution ($R\sim3000$) long-slit. There will also be an imaging mode suitable for target acquisition.

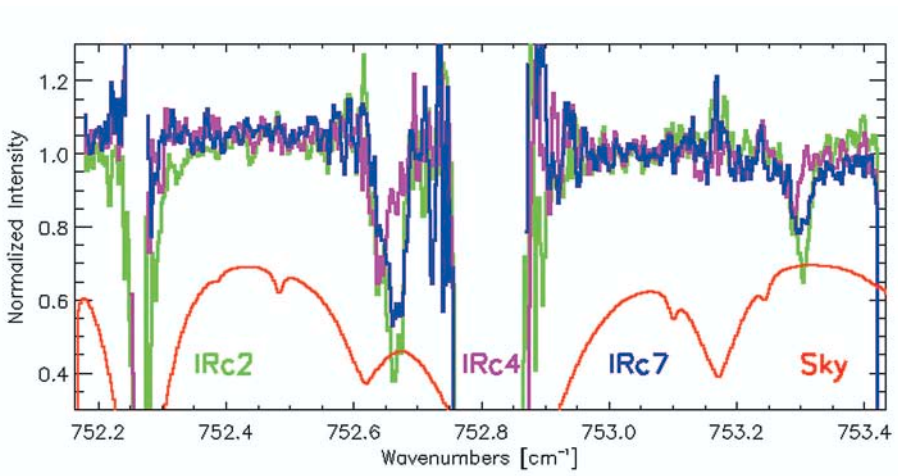
EXES will use a 256^2 Si:As IBC detector. High dispersion is provided by an echelon, a coarsely-ruled, steeply-blazed aluminum reflection grating. We use an echelle grating to cross-disperse the spectrum, resulting in continuous wavelength coverage of ~6 cm^{-1} and a slit length of ~10".

One of the greatest advantages of SOFIA will be the ability to study molecules that are blocked by the Earth's atmosphere. In particular, high spectral resolution enables the study of molecular hydrogen, water vapor, and methane from sources such as molecular clouds, protoplanetary disks, interstellar shocks, circumstellar shells, planetary atmospheres, and comets. For narrow lines associated with point sources, EXES on SOFIA will achieve comparable sensitivity to infrared satellite missions such as ISO and Spitzer.

We currently are observing with a ground-based instrument, TEXES, which is very similar to EXES. TEXES also features an echelon to achieve a resolving power of $R=10^5$. The two instruments will share a detector and associated electronics and all the associated software. With TEXES, we are already exploring the mid-infrared at high resolution.

The EXES echelon grating was diamond-machined by Hyperfine, Inc. from a single piece of 6061 Aluminum. It measures 4" x 4" x 40" and weighs 25 lb.

A closeup of the EXES echelon grating. The groove spacing is 7.6 mm and the angle of incidence is 84.3 degrees. The design of EXES is based upon our successful TEXES spectrograph (see http://arXiv.org/abs/astro-ph/0110521).



Spectra of sources in the BN-KL region of Orion taken with TEXES, a ground-based spectrograph on which EXES is based. The figure shows 2 of the 7 orders obtained simultaneously, including the C_2H_2 R(9) line near 752.65 cm^{-1} and the HCN R(13) line near 753.3 cm^{-1}. At this wavelength, the orders are larger than the detector, causing gaps in the wavelength coverage. The gap between the two orders is near 752.8 cm^{-1}. Velocity structure is clearly evident with the line-width for IRc2 encompassing velocity components evident in IRc4 and IRc7. Earth's atmospheric transmission, shown in red, is responsible for the apparent feature at 752.27 cm^{-1} and regions of increased noise. From SOFIA, the transmission, and emission, will be substantially better, allowing observations of molecular lines and other spectral features that are currently inaccessible with ground-based facilities.

EXES Specifications

- Wavelength Range: 5 to 28.5 μm The short wavelength limit is a function of the echelon grating performance and the detector response. The long wavelength limit depends on the detector response.
- Detector: 256^2 pixel Si:As array optimized for low background.
- System Throughput: 5-10% depending on mode and wavelength.
- Platescale on SOFIA: 0.4"/pixel
- High Resolution Mode:
  - Resolving Power: 1000,000 for $\lambda < 10$ μm; $10^6/\lambda$ for $\lambda > 10$ μm
  - Spectral Coverage: 1500 km/s
  - NEFD (10σ:100s): 10 Jy @ 10 μm; 20 Jy @ 20 μm
  - NELB (10σ:100s): 1.4×10^{-6} W m^{-2} sr^{-1} @ 10 μm; 7×10^{-7} W m^{-2} sr^{-1} @ 20 μm
  - Slit length: 5 to 20"
- Medium Resolution Mode:
  - Resolving Power: 10,000 (depending on grating angle, order, and slit width)
  - Spectral Coverage: 1500 km/s
  - NEFD (10σ:100s): 3 Jy @ 10 μm; 6 Jy @ 20 μm
  - NELB (10σ:100s): 4×10^{-6} W m^{-2} sr^{-1} @ 10 μm; 1.1×10^{-6} W m^{-2} sr^{-1} @ 20 μm
  - Slit length: 40 to 90"
- Low Resolution Mode:
  - Resolving Power: ~3000 (depending on grating angle, order, and slit width)
  - Spectral Coverage: 6000 km/s
  - NEFD (10σ:100s): 1.5 Jy @ 10 μm; 3 Jy @ 20 μm
  - NELB (10σ:100s): 7×10^{-6} W m^{-2} sr^{-1} @ 10 μm; 4×10^{-6} W m^{-2} sr^{-1} @ 20 μm
  - Slit length: 40 to 90"
- Time to switch modes: 1-3 minutes

EXES will be available for Guest Investigator use on a collaborative basis. Potential Guest Investigators should contact Matt Richter (information below) prior to proposing to ensure that the proposed observations are feasible and make the best use of EXES's capabilities.

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For more information, visit:

http://www.sofia.usra.edu/Science/instruments/sci_instruments.html