

# EXES:

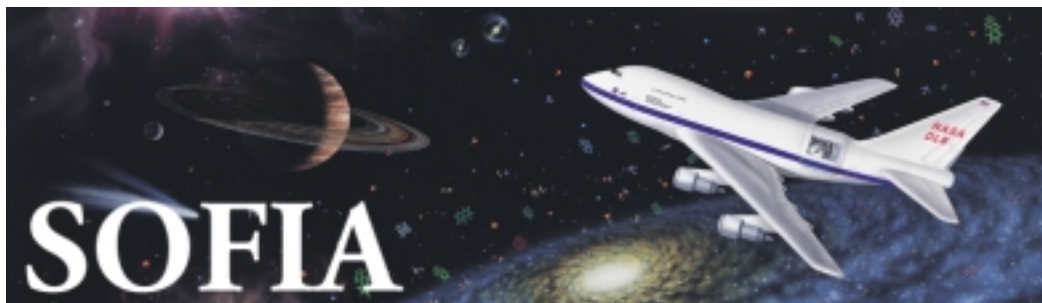
## The Echelon-Cross-Echelle Spectrograph

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  $\mu\text{m}$ . EXES will operate in three spectroscopic modes: high-resolution ( $R=\lambda/\Delta\lambda\sim 10^5$ ) cross-dispersed; medium-resolution ( $R\sim 10^4$ ) long-slit; and low-resolution ( $R\sim 3000$ ) 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  $\sim 6\text{ cm}^{-1}$  and a slit length of  $\sim 10''$ .

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 SIRTf.

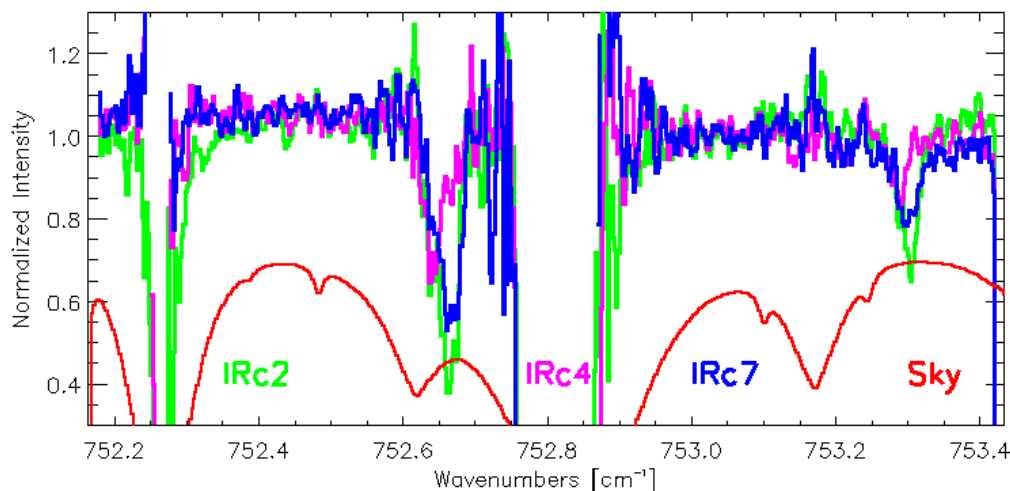
We currently are observing with a ground-based instrument, TEXES, which is very similar to EXES. TEXES also features an echelon to achieve a resolving power of  $R=10^5$ . The two instruments will share a detector and associated electronics and all the associated software. With TEXES, we are already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



The EXES echelon grating measures 4" x 4" x 40". It is made from a single piece of Aluminum 6061 tooling plate diamond-machined by Hyperfine Inc.



A portion of the EXES echelon grating. The grooves are separated by 7.5 mm and the angle of incidence is approximately 84.3 degrees. The EXES design 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 similar to EXES. The figure shows 2 of the 7 orders obtained simultaneously, including the  $\text{C}_2\text{H}_2$  R(9) line near  $752.65\text{ cm}^{-1}$  and the  $\text{HCN}$  R(13) line near  $753.3\text{ cm}^{-1}$ . At this wavelength, the orders are larger than the detector, causing gaps in the wavelength coverage. The gap between the two orders is near  $752.8\text{ cm}^{-1}$ . 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  $752.27\text{ cm}^{-1}$  and regions of increased noise. From SOFIA, the transmission, and emission, will be substantially better, allowing observations of molecules and lines currently unavailable from the ground.

# EXES Specifications

- Wavelength Range: 5 to 28.5  $\mu\text{m}$ . 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. These numbers are uncertain at this time.
- 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: 100,000 for  $\lambda < 10 \mu\text{m}$ ;  $10^6/\lambda$  for  $\lambda > 10 \mu\text{m}$
  - Spectral Coverage: 1500 km/s
  - NEFD (10 $\sigma$ :100s): 10 Jy @ 10  $\mu\text{m}$ ; 20 Jy @ 20  $\mu\text{m}$
  - NELB (10 $\sigma$ :100s):  $1.4 \times 10^{-6} \text{ W m}^{-2} \text{ sr}^{-1}$  @ 10  $\mu\text{m}$ ;  $7 \times 10^{-7} \text{ W m}^{-2} \text{ sr}^{-1}$  @ 20  $\mu\text{m}$
  - 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 (10 $\sigma$ :100s): 3 Jy @ 10  $\mu\text{m}$ ; 6 Jy @ 20  $\mu\text{m}$
  - NELB (10 $\sigma$ :100s):  $4 \times 10^{-6} \text{ W m}^{-2} \text{ sr}^{-1}$  @ 10  $\mu\text{m}$ ;  $1.1 \times 10^{-6} \text{ W m}^{-2} \text{ sr}^{-1}$  @ 20  $\mu\text{m}$
  - Slit length: 40 to 90"
- Low Resolution Mode:
  - Resolving Power:  $\sim 3000$  (depending on grating angle, order, and slit width)
  - Spectral Coverage: 6000 km/s
  - NEFD (10 $\sigma$ :100s): 1.5 Jy @ 10  $\mu\text{m}$ ; 3 Jy @ 20  $\mu\text{m}$
  - NELB (10 $\sigma$ :100s):  $7 \times 10^{-6} \text{ W m}^{-2} \text{ sr}^{-1}$  @ 10  $\mu\text{m}$ ;  $4 \times 10^{-6} \text{ W m}^{-2} \text{ sr}^{-1}$  @ 20  $\mu\text{m}$
  - Slit length: 40 to 90"
- Time to switch modes: 1-3 minutes

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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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## The EXES Team

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For more information, visit: <http://www.sofia.usra.edu/observatory/instruments/>  
<http://nene.as.utexas.edu/exes/>