EXES: an echelon-cross-echelle spectrograph for SOFIA

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ABSTRACT
To study narrow features in quiescent molecular clouds, a high spectral resolution, high sensitivity instrument is required. We present the design and capabilities of a mid-infrared spectrograph being built as a PI instrument for the Stratospheric Observatory for Infrared Astronomy. The Echelon-Cross-Echelle Spectrograph (EXES) will operate from 5.5-28.5 μm in three spectroscopic modes: R~ 10^5, 10^4, and 1500. EXES is similar in concept to our ground based instrument, TEXES.

EXES consists of three chambers. The first chamber contains focal-reducing optics. The second chamber houses the high resolution grating, an echelon. Discussion of the echelon can be found elsewhere in this volume. The third chamber contains an echelle grating and a first order grating mounted back-to-back. A flip mirror selects operating mode by either directing light into the echelon chamber or allowing the light to pass through to the grating chamber. Reimaging optics upstream of the detector provide two plate scales. The detector, a 256 × 256 pixel Si:As IBC, is in a baffled subsection of the third chamber. Finally, the low resolution grating serves as a slit positioning camera when it is rotated face on.

Keywords: Infrared, Spectrograph, Interstellar Medium, SOFIA

1. INTRODUCTION
To understand the origin of the Sun and the Earth, we must understand how molecular clouds condense to form stars and planets. Molecular line observations allow us to follow the changes in density, temperature, bulk velocity, and chemical state as diffuse clouds evolve into stars with surrounding disks and planets. Much of our current understanding of star formation has come from the successful use of molecular line observations at millimeter and sub-mm wavelengths. However, constraints imposed by technology and by the transmission of the Earth's atmosphere have hampered our ability to study simple, abundant, and important molecules such as H_2 and H_2O.

We are building a mid-infrared spectrograph as a PI-class instrument for the Stratospheric Observatory for Infrared Astronomy (SOFIA) that will permit a more detailed look into how molecular gas turns into stars and planets. Because our instrument uses an echelon grating cross-dispersed by an echelle grating, we call it EXES (for echelon-cross-echelle spectrograph). EXES will operate at wavelengths from 5.5 μm to 28.5 μm, a region of the spectrum with many molecular transitions. At altitudes reached by SOFIA, the reduced water burden and atmospheric pressure will allow observations of H_2 and H_2O transitions that are totally blocked or heavily attenuated from the ground. EXES must have a resolving power of R ≥ 10^5 at 10 μm to maximize sensitivity to lines with widths of ~3 km s^{-1}, as appropriate for molecular clouds. The small wavelength separation of molecular ro-vibrational transitions, especially in Q-branches, means that continuous wavelength coverage of as large a spectral region as possible will greatly enhance the usefulness of a single observation. The key to achieving high spectral resolution and relatively large wavelength coverage is a 1 m long echelon grating as described elsewhere in this volume.\footnote{E-mail addresses: richter@astro.as.utexas.edu, lacy@astro.as.utexas.edu, dtj@astro.as.utexas.edu, marykay@astro.as.utexas.edu, yuwel@astro.as.utexas.edu}

Although our goals focus on high resolution observations, we have designed EXES to be a very versatile instrument. There will be three spectral modes: high spectral resolution in a cross-dispersed format, and medium and low spectral resolution in a long-slit format. There will also be a camera mode suitable for reliably positioning the slit on the target. The low and mid resolution capability of EXES will find a broad range of applications in studies of ionized nebulae, external galaxies, and late-type stars. The baseline detector is a Si:As IBC array with 256^2 pixels and suitable for low background operation.

In this paper, we will first describe some of the scientific goals behind the design of EXES presented in Sect. 3. We will give estimates of EXES's capabilities in Sect. 4.

For more information see http://nece.as.utexas.edu/exes