SIFTIR: A Mid-IR Imaging Spectro-polarimeter

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Abstract. We are currently developing an instrument that mates TNTCAM2 (Klebe et al. 1998), an imaging polarimeter, with a Fourier transform spectrometer (FTS), that operates from 2 to 15 \(\mu\)m. The FTS component enhances TNTCAM2, giving the instrument a maximum resolution of 2000 at 10 \(\mu\)m, and 10^4 at 2 \(\mu\)m, while preserving the imaging capabilities. This enables both moderately high resolution imaging spectro-polarimetry of point sources, and the mapping of polarization vectors over an extended nebulous region as well. Potential scientific targets and discoveries will be discussed as well as the control of the FTS moving mirror as related to waveplate rotation and the observational technique of chopping & nodding necessary for ground based observations in the IR.

1. Scientific Prospects & Data Reduction

SIFTIR, the Spectro-polarimetric Imaging Fourier Transform spectrometer for the InfraRed, will build upon the results of TNTCAM2 (mid-IR polarimetry of NGC7027: Jurgenson et al. 2003). Imaging polarimetry has the potential to trace polarization magnitude and P.A. changes throughout an extended region of interest. TNTCAM2, though capable of a fair degree of spatial resolution, lacked spectral resolution needed to carry out the analysis for approximating grain shapes (e.g. Hildebrand & Dragovan, 1995). The resolution provided by the interferometer will be adequate for sampling of most IR resonance features to analysis.

Holloway et al. (2002), established correlations in polarization magnitude and position angle between the 10 \(\mu\)m silicate feature and the 3 \(\mu\)m water ice feature in a small sample of YSO’s. The existence of a correlation makes plausible the argument that silicate grains might provide nucleation sites for grain growth in a core-mantle arrangement. SIFTIR is designed to have the capability to cover both the near and mid-IR spectral regions to check for polarization correlations. This type of experiment can be extended to evolved stars, and cover other resonance features. Initially, point source targets, like evolved stars, will be observed before moving onto extended nebular regions. This serves a number of purposes, the first being that point source targets can be used to determine not only the instrument PSF, but develop the reduction technique as well. Point source targets will produce one interferogram for each of the four waveplate positions through aperture photometry, while extended sources produce multiple interferograms for a single waveplate position. In lab spectral and polarization calibration will be carried and is discussed in the next section.
2. Motion Control & Instrument Calibration

The FTS component will have the ability to operate in a step scan mode as well as in continuous scan with a maximum optical path difference (OPD) of 2 cm. The stepping mode will allow for background subtraction, whereby chopping and waveplate rotation is performed at each step of the scan. Once a single scan is performed, the telescope is nodded and the observation is repeated. This produces four background-subtracted interferograms for a given scan (for point sources, on extended sources each pixel will have four interferograms), one for each waveplate position. The number of steps over the course of a single scan is determined by the bandwidth of the observation and the desired resolution. The resolution is determined by the maximum travel of the moving mirror, and the bandwidths determined by TNTCAM2’s near/mid-IR filters. Quadrature encoder feedback, using two laser signals 90 degrees out of phase with one another is used to control the positioning of the moving mirror. This method enables distance between steps as well as direction to be measured, thus establishing the command input into the motion control algorithm.

Aside from the optical encoders for the laser/white light signals and an amplifying circuit, all signal processing and outputs to the motor is done via a Field Programmable Gate Array (FPGA). Through the FPGA, one can then program hardware using LabVIEW, being a product of National Instruments. All motion control of the interferometer, filter wheels, chopping mirror as well as array readout will be done through the FPGA. Initial results on the stepping of the moving mirror suggest a positional accuracy on the order of $\frac{1}{10}$ the HeNe laser wavelength. It has been observed that high frequency oscillations from the building, people walking, etcetera, introduces enough motion in the moving mirror to decrease the positional accuracy. Damping of external nt interface will only improve the positional accuracy between $\frac{1}{10}$ to $\frac{1}{100}$ of the HeNe laser wavelength. In lab spectra of known gases will be taken both of the FTS alone and then again when mated with TNTCAM2. The Dept. of Physics & Astronomy has an FTIR lab to assist with spectral calibration. Instrumental polarization will also be measured in the lab using a technique developed by Smith et al. (2000). An instrumental polarization Mueller matrix can be measured using this method, and then subtracted out during data reduction. The optical analysis software, Code V, will be used for the calculating telescope Mueller matrix. Sources like the BN object which have known polarization and constant P.A. across 10 $\mu$m can then be used for further calibration with telescope/FTS/TNTCAM2. We are grateful to Sigma Xi for a student grant, and to the estate of William Herschel Womble for partial support of this effort.

References

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