**First results and current development of SpIOMM: an imaging Fourier transform spectrometer for astronomy**

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### Imaging Spectrometer concept

Most, if not all, imaging spectrometers used on astronomical telescopes are based on dispersive approaches. These must inevitably trade detector pixels (image sampling points) for spectral points. The number of pixels available for imagery is, at best, the total amount of detector pixels divided by the numbers of spectral points. For example, a 1K by 1K detector will only allow 1000 image points if 1000 spectral points are to be collected. Various concepts have been developed over time to make the best use of the available image points. Coarse sampling may be used, for example, by imaging a monochromatic source and by sampling the full FOV. In addition to this, some concepts use complex processing software to reconstruct the images. The imaging FTS and the Fabry-Perot tunable filter are the only concepts that do not compromise the imaging capacity offered by the detector (Fov andIFOV). However, the latter one is unfortunately limited to a relatively small spectral range. Hence the IFTS stands in a class of its own. If the two output ports of the interferometer are used, it can collect all photons from the full FOV, in the whole sensitivity waveband of the detector for the total measurement time. It has a tremendous light collecting power.

Before the advent of imaging detectors, the FTS was renowned for its multiplex advantage. The IFTS now brings the multi-channel advantage, the imaging equivalent of the former one.

### SpIOMM Results

SpIOMM is attached to the 1.6-m telescope of the Mont Méridien Observatory, in Québec. A complete spectral map with a resolution of 175 cm⁻¹ (about 10 nm in the red region) of the planetary nebula NGC 6543 was established by the Fourier transform of an interferogram containing 328 images, each exposed for 7 seconds. These results are compared with previous spectroscopic observations. Although some discrepancies are noted, the general picture is in very good agreement and shows how powerful such a wide field (12 arc minutes in diameter) spectrograph can be.

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**The SpIOMM IFTS**

Our IFTS is based on the classical Michelson interferometer with flat mirrors used at 30° angle of incidence. This design only adds 2 reflection and 2 transmission/reflection (beam splitter) to the optical path of a classical camera (not prime focus). A four port design (2 inputs/2 outputs) is obtained by the insertion of the science beam 8° off-axis to the interferometer. The single moving mirror is placed on a parallelogram three-wing mechanism which offers frictionless displacement. It is actuated by a piezo-based stepper motor mounted in series with a small range high frequency piezoelectric (hence the efficiency of the Optical Path Difference (OPD)).

The passive alignment offered by this moving mirror system is however unable to reach the 0.25" requirements on the science beam at a distance of about 1 km. Hence a piezo based dynamic alignment system was added to the moving mirror mechanics. The alignment and OPD positioning are reached at a rate of 2000 Hz in accordance with the feedback provided by an expanded IR laser beam running with the science beam in the interferometer. The laser creates a fringe pattern at the output observed by two linear arrays. A C code running on a dedicated PC analyzes the digitization of fringe pattern and computes new commands for all pixels at each servo loop turn. A control PC with a telecommand-based user interface communicates with the dedicated PC to sequence datacube acquisition.

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**Instrument specifications & performance**

One of the striking parameters of this instrument is its high efficiency. In addition to being unaffected by slit losses (the so-called throughput advantage) the IFTS does not suffer the typical 30% efficiency of gratings. The light is lost between the CCD and the telescope output. However, the amount of light that enters the spectrum also involves another multiplicative parameter: the modulation efficiency. This is the ability of the interferometer to make light interfere. Any unmodulated part is rejected in the FFT computation and does not contribute to the interferometric spectrum. The ME is the ratio of the interferometric spectrum to the individual spectra of the two parallaxes. We have demonstrated its variation is relatively small around 70%, about ±6% which allows us to be confident about the servo control precision. Unfortunately, we have noticed a considerable decrease of its performance in the observatory environment. SpIOMM is attached to the telescope and is subject to the wind, local temperature gradients (which change the refractive indices of the environment in the science or metrology beam optical paths, thus wavelength phase errors), and, more importantly, constant vibrations from the telescope which could not be completely compensated by the servo system. We have demonstrated that the old method leads to correction values biased because of the calculation from an IR fringe pattern (containing around 4-5 fringes) produced by intentional misalignment of the metrology beam. We are currently investigating this feedback loop.

The old system of control that regularizes the alignment of the mirror was based on a fringe pattern of reference. The correction to be applied on the mirror was calculated 2000 times per second with this pattern. Due to the large variability of the reference fringe pattern with the conditions of operation, a new control system was elaborated based on the fact that perfectly aligned mirrors show a flat fringe pattern (uniform intensity) on the detector. To remove the ambiguity in the direction of the correction, a ±1 fringe was inserted on the metrology pattern. Technically, this upgrade allows us to reach a precision of 0.05" on the alignment angle and increases the frequency of the algorithm (hence the efficiency of the system).