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A Canadian IFTS for the NGST

S. L. Morris, J. Ouellette

Herzberg Institute of Astrophysics, NRC, Victoria, BC, Canada V8X 4M6

A. Villemaire, F. Grandmont, L. Moreau

ABB Bomem, Québec, Qc, Canada G2E 5S5

Abstract. It is shown that an IFTS is a very attractive instrument to tackle the DRM. Breadboarding activities also demonstrate that the innovations necessary to bring standard IFTS to an NGST type instruments are within reach using current technology.

1. Introduction

Bomem and the Herzberg Institute of Astrophysics (HIA) studied an Imaging Fourier Transform Spectrometer (IFTS) as the main ISIM instrument for NGST. The work undertaken is complementary to the effort of the IFIRS Team (Graham et al. 1999). While the IFIRS Team looked at the end-to-end applicability of an IFTS for NGST, the technical work done by our team focused on the technological feasibility of the Michelson interferometer sub-system, which is the spectral engine of an IFTS. The IFTS holds the promise of being the only truly integrated science instrument module (ISIM) and consequently an instrument more effective in terms of mass, volume, cost and scientific return.

As demonstrated in Graham et al. (1999, 1998) and Section 2 of the Canadian Final report (Morris et al. 1999), an IFTS can carry out the entire NGST DRM in significantly less time (69%) than the estimated time for the yardstick ISIM. It is also argued that while doing so, the IFTS provides, at no extra instrument cost, a wealth of scientific data not obtainable with any other instruments.

The advantages of IFTS are numerous:

1. They provide unrivaled spectroscopy with the lowest level of radiometric errors and absolutely calibrated spectral scales

2. They provide the best imaging quality, i.e. equivalent to imagers with filters, because a FTS is only composed of three plane-parallel optical elements.

3. They are a relatively mature technology. Several FTS have flown successfully on various space platforms.

4. They require a relatively small number of actuators since the number of moving elements is very limited compared to a multi-object spectrograph (MOS), for instance.

5. They provide broadband coverage, from the visible to the thermal infrared, at adjustable spectral resolution (Panchromatic, $R = 1$, to $R > 10000$).

6. They have a light gathering advantage over most other types of spectrometers because they do not rely on energy limiting slits.

7. By combining spectral and spatial measurements over a wide field of view, IFTS can simultaneously carry out different science projects.

8. Last, but most important, They can survey the complete field of view of NGST and acquire a spectra for every pixel, making them especially appropriate for the unbiased study of uncharted (spectrally and spatially) areas of the sky and making them ideal for fortuitous discoveries.

Most of the above advantages are described in detail in Graham et al. (1998, 1999). By contrast, the perceived weaknesses of the IFTS are not as numerous:

1. Less sensitivity at high spectral resolution than dispersive spectrometers.

2. High technological risk, especially in a space environment.

3. Unproven performances.

Our analyses show (Morris et al. 1999) that the last two arguments are unfounded and that the first one can be overcome with less effort than is likely to be required to fix other instrument's shortcomings.

FTS is a mature technology widely used for IR measurement. Current space qualified designs are applicable for the NGST instrument with few modifications. The trade space differs mainly in the time scales involved, as shown in Figure 1. The long integration times required to produce an interferogram sample with sufficient SNR (10^3 sec typical) suggest a stop and stare approach in operating the interferometer moving mirror.

The faintness of the scene also sets constraints on the type of metrology system used. In order to eliminate any possibility of stray light on the detector, a temporally separated metrology system is proposed.

These two items have been studied in details with breadboarding activities conducted at Bomem and have demonstrated their expected performance.

2. Sciences Case

In order to address the science goals of the Galaxy Evolution part of the Design Reference Mission (GDRM), a Camera+Multil-Object Spectrograph (MOS) combination will require separate imaging, followed by object selection and then a (probably large) number of MOS mask observations in order to build up a large enough sample of galaxies and also to cover each of the different science goals. In Morris et al. (1999), we have tried to show that many of the GDRM science goals can be met with a single (or a small number) of IFTS data cubes. This will

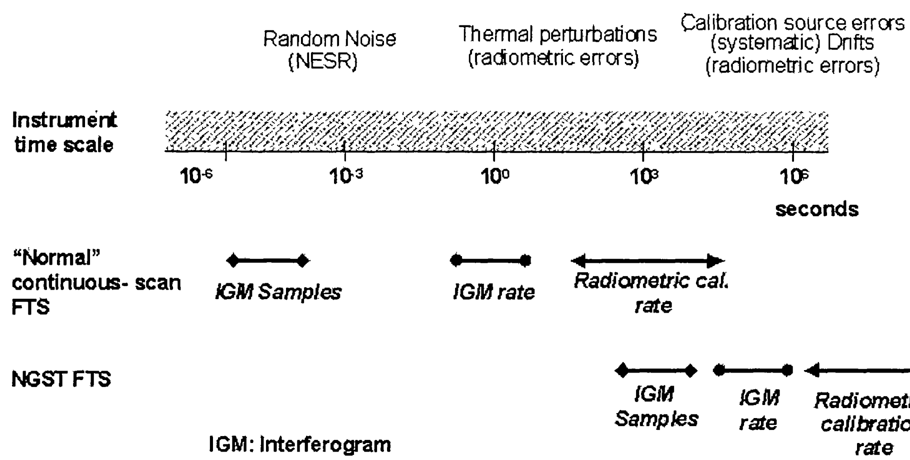

Figure 1. NGST FTS time scale.

both enable the primary goals of the GDRM, and also add considerable value, permitting science that would not be possible with only the Camera+MOS data. An IFTS on NGST would be a 'serendipity machine' churning out unexpected and exciting results on top of the very important goals of the GDRM.

Areas within the GDRM we have identified where a spectrum for every pixel produces clear science advantages include:

- Evolution of structure in the Universe
- Location of merging fragments of galaxies
- Studying the effects of environment on galaxy formation
- Spatially resolved star formation histories of galaxies
- Any study in which the galaxy sample has to be broken into multiple bins (e.g. luminosity, color, redshift, morphology, environment, ...)

In Morris et al. (1999), we also compare in detail the S/N and data achieved from two different approaches to deep imaging and spectroscopy with NGST. In particular, we compare what one obtains from observations with a camera+MOS combination, with what one can get with an IFTS. The total exposure time is held constant for the comparison ($\sim$ 51 days). This comparison makes the IFTS look very good. The more investment you put into a deep IFTS survey the more you get because the slope of the integral galaxy number counts is very steep. In particular the IFTS is very good at finding rare types of faint galaxies (perhaps these will be the most distant objects). Considerably more information, along with a S/N calculator is available on the WWW at http://www.hia.nrc.ca/STAFF/slm/ifts.

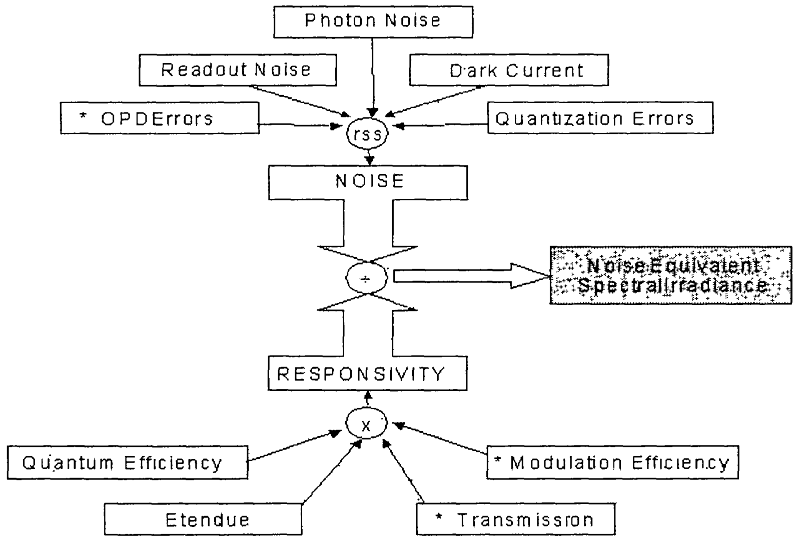

Figure 2. SNR evaluation for FTS.

3. Breadboarding Activities

The SNR of the spectra produced with a FTS is governed by the factors shown in Figure 2. Asterisks mark the items specifically related to FTS. Requirements on the FTS have been set to prevent them from becoming the limiting factors. We derive a requirement for OPD stability of 1%.

The breadboard has demonstrated compliance with this requirement using the temporally separated metrology system. Also tested with the breadboard was the ability to maintain interferometric alignment of the two mirrors and the beamsplitter while scanning the full OPD.

Figure 3 shows the major components of the interferometer. The complete ISIM for NGST could include two or more of these FTS depending on the wavebands and associated detectors chosen. It is proposed to cover the full 0.6 to 30 μm with two separated instruments. The actual set-up has dimensions of 50 $\times$ 40 $\times$ 35 cm and an overall weight of 50 pounds. To support the full throughput and 8k $\times$ 8k detectors of NGST, an increase of about 50% in the size and weight of this breadboard would be necessary. However, A full IFTS also includes I/O collimating optics and detectors that are not shown on the picture. The size of TMA required to bring an 8m telescope primary into an 15 cm aperture FTS easily takes as much space as the interferometer itself.

4. Conclusion

An IFTS that meets most of the DRM requirement for NGST has been designed. Major innovations proposed have been tested in breadboarding activities. Readers are invited to read and comment on the full report which this brief paper summarizes (Morris et al. 1999).

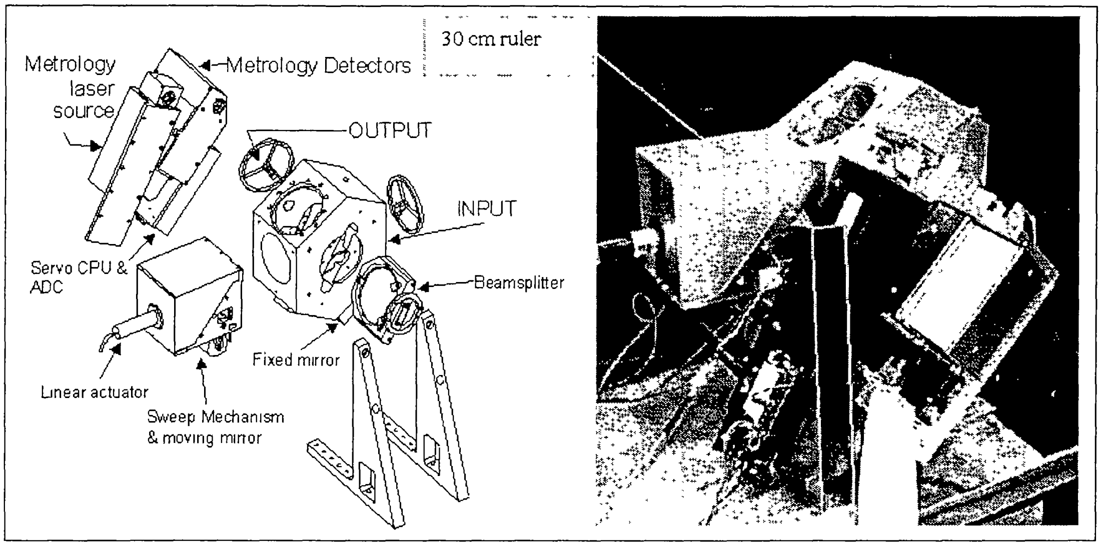

Figure 3. Breadboard CAD & Picture

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Simon Morris