Imaging the Universe in Three Dimensions: Astrophysics with Advanced Multi-Wavelength Imaging Devices.
ASP Conference Series, Vol. xxx, 2000
W. van Breugel & J. Bland-Hawthorn (eds.)

SIMON: The Infrared Multi-Object Spectrometer of the Observatoire du Mont Mégantic

René Doyon, Daniel Nadeau, and Philippe Vallée

Département de Physique, Université de Montréal and Observatoire du Mont Mégantic, C.P. 6128, Succ. Centre-ville, Montréal, Qc, H3C 3J7, Canada.

Abstract. SIMON is a near-infrared (0.8–2.5 μm) 1024x1024 camera/spectrometer currently under development at the Université de Montréal. The instrument will be used on the 3.6 m Canada-France-Hawaii telescope (CFHT) and the 1.6 m telescope of the Observatoire du Mont Mégantic (OMM). The instrument features a separate cryogenic slit wheel unit that can be easily removed and warmed up rapidly for easy replacement of multi-object masks. This paper presents the optical/mechanical design and expected performance of the instrument.

1. Introduction

The availability of large-format infrared (IR) detectors has opened the way to the development of efficient three-dimensional spectrographs. Virtually all IR instrumentation development plans for large (and small) telescopes require their instruments to have either (if not both) multi-object and integral field spectroscopy capabilities. One of the projects at the OMM "Laboratoire d'Astrophysique Expérimentale" is the development of a near-IR (0.8-2.5 μm) multi-object spectrometer for use on the OMM 1.6 m telescope and CFHT, a project funded by grants from the Natural Sciences and Engineering Research Council of Canada. The design of the instrument (SIMON: "*Spectromètre Infrarouge de Montréal*") is presented in this paper.

2. General characteristics of the Instrument

The basic characteristics of SIMON are summarized in Table 1. The instrument houses a HgCdTe 1024×1024 detector sensitive between 0.8 μm and 2.5 μm and cryogenic (~80 K) reimaging optics. It has both imaging and spectroscopic capabilities and the required flexibility to be used on several telescopes (OMM 1.6 m, CFHT 3.6 m, Gemini) and configurations (direct f/8 or adaptive optics (AO) foci). A unique feature of SIMON is a separate focal plane cryostat used for rapid exchange of cold multi-object masks.

Table 1. Instrument Characteristics

Detector format:	HgCdTe 1024×1024			
Wavelength range:	0.8-2.5 μm			
Nominal slit width:	4 pixels			
Low resolution mode:	R∼400, 1.17 to 2.35 μm (1st order)			
Medium resolution mode:	R∼1500 covering, J,H or K			
	(R is doubled with a 2-pixel slit)			
	OMM	**CFHT**	**AOB**	**GEMINI**
Pixel scale ($''$):	0.46	0.20	0.08	0.045

3. Optical Design

A layout of the instrument, as mounted on the OMM, is presented in Figure 1. The f/8 beam enters the focal plane cryostat through a CaF_2 window and then crosses the CaF_2 window of the detector cryostat towards the collimator (BaF_2-IRG2 doublet). The beam then passes through a ten-position filter wheel followed by the Lyot wheel and the grism wheel. The Lyot wheel is mounted with several cold stops of different dimensions and locations for accomodating different telescope configurations. The nominal cold stop diameter at f/8 is 20 mm. The collimator is coupled with a f/5.3 quadruplet camera (BaF_2-IRG2-BaF_2-IRG2) providing pixel scales of $0.2''$ on the f/8 cassegrain focus of CFHT ($0.08''$ with AO), $0.46''$ on the OMM ($0.18''$ with AO) and $0.045''$ on GEMINI.

The optics is achromatic from 1.1 μm and 2.4 μm allowing the same focus set-up to be used for J, H and K, a crucial feature for acquiring good quality spectra over a wide spectral range (see below). Spot diagrams are shown in Figure 2. The nominal 80% encircled energy diameter is $<0.18''$ and $<0.30''$ when tolerances are taken into account. The geometrical distortion is only 0.1% in the corner of the array. With coating, the average throughput of the optics (lenses and windows) in imaging mode is expected to be 80-85%.

Spectroscopy is obtained by inserting a grism in the collimated beam with an appropriate slit in the focal plane cryostat. Two resolution modes are currently planned. The low-resolution grism, a 125 l/mm grating replicated onto a 33.5° IRGN6 prism, provides a 1st order spectrum from 1.17 μm to 2.35 μm with an average resolving power of 400 (4-pixel slit). An appropriate blocking filter must be used for this mode. The medium-resolution grism is a 130 l/mm grating ruled directly onto a 37.9° KRS-5 prism providing a resolving power of 1500 at J, (5th order), H (4th order) and K (3rd order) with a full wavelength coverage in each band. The low-resolution grism can also be used in combination with standard JHK filters for multi-object spectroscopy. For instance, used with the K filter, the low-resolution grism yields K-band spectra spanning 1/3 of a row on the array.

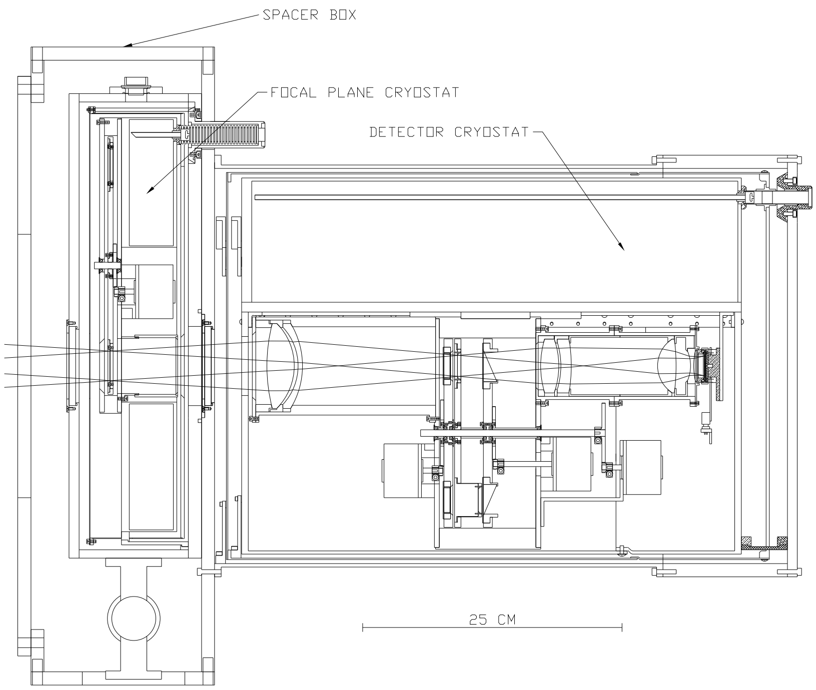

Figure 1. Layout of SIMON. The instrument is normally oriented with the optical axis pointing vertically.

4. Mechanical Design

The instrument comprises two cryostats: the detector cryostat and the focal plane cryostat (see Figure 1) both cooled with liquid nitrogen. The former includes all the optics and the three cryogenic mechanisms (filter, Lyot and grism wheels) operated with cryogenic motors. The main structure of the detector cryostat is a section of an aluminium cylinder constituting both the cryogen vessel and the cold surface. It is surrounded with a vapor-cooled radiation shield. Both the shield and the cold surface are attached at both ends of the cryostats by 3 G-10 tabs making the whole structure very stiff. The hold time of the detector cryostat is $\sim$50 hours.

The focal plane cryostat (FPC) is smaller and meant to be cycled frequently. It features a toric cryogen vessel, with a hold time of 25 hours at room temperature, mounted with an 11-position slit wheel driven by a cryogenic motor. One open position is used for imaging, three for long slit masks (2, 3 and 4 pixels width) and 7 positions for custom multi-object masks. The FPC has it own vacuum valve and getter and it is equipped with heating fingers mounted on the cold surface to reduce the warm-up time. Once warm, the vacuum of the FPC is broken and the unit is easily removed by removing one of the sides of the spacer box. The slit wheel has separate mounting cells for each mask that can be easily removed/replaced from the bottom hole of the FPC. The cool-down/warm-up time should each be less than 3 hours. We expect that less than 8 hours will be

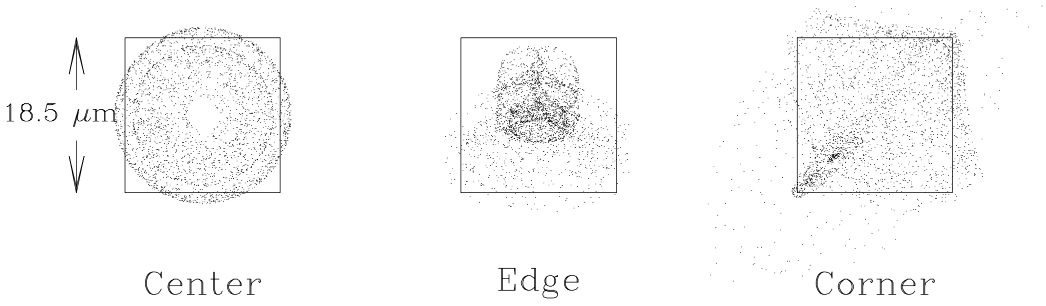

Figure 2. Polychromatic (1.1, 1.65 and 2.4 μm) spot diagram for the center, edge and corner of the array (on CFHT f/8). Each box is the size of a pixel.

needed to warm-up the FPC, service it and bring it back to operation. Mask replacement can take place during the day and will not affect observing time.

5. Expected Performance

The throughput of SIMON, from the top of the atmosphere to the detector, is predicted to be 35% in imaging and 20% in spectroscopy. On CFHT (without AO), this translates into a 3σ 1 hour sensitivity of $K = 21.9$ mag/arcsec^2 in broad band imaging and $K = 19.2$ mag/arcsec^2 in spectroscopy at $R = 500$. The optimum slit width should be about the same size as the seeing disk (3-4 pixels) wihout AO. With AO, the slit can be reduced to 2 pixels with little penalty on transmission to reach a resolving power of $\sim$3000. At such a resolution, 80% of the pixels of an H band spectrum are free of bright OH lines. Thus, SIMON combined with an AO sustem will have a very good software OH suppression mode. For this reason, SIMON represents a particularly good option for AO multi-object NIR spectroscopy on GEMINI.

The flexibility of SIMON to be operated on several telescopes will open a wide range of scientific programs: follow-up spectroscopic studies of very low mass star candidates from the DENIS and 2MASS survey, study of the initial mass function in young embedded star forming regions, high spatial resolution stellar kinematics and stellar population studies in the Galactic center, super star clusters studies of starburst galaxies, AGNs, studies of distant galaxy clusters, quasars and gravitational lenses.

6. Project Status

SIMON has entered the construction phase. All optical components will be in hand by the end of 1999. Prototypes for the various mechanisms have been built and tested. First light on the OMM is expected during the spring of 2000.