Interstellar Matter and Star Formation:
A Multi-wavelength Perspective
ASI Conference Series, 2010, Vol. 1, pp 171–175
Edited by D. K. Ojha

Infrared Spectroscopic Imaging Survey (*IRSIS*) payload for an Indian satellite

S. K. Ghosh*
Tata Institute of Fundamental Research, Homi Bhabha Road,
Mumbai 400 005, India

Abstract. The Infrared Spectroscopic Imaging Survey (*IRSIS*) experiment, targeted for the Small Satellite Mission of the Indian Space Research Organization (ISRO), will carry out spectroscopic measurements in the wavelength range 1.7 to 6.4 μm seamlessly for the first time, covering a large fraction ($\sim$ 50%) of the sky (including the Galactic Plane), with a reasonable sensitivity (completeness at 2.2 μm, K = 14 mag.). The planned Spectral Resolution is $\sim$ 100. Primary science goals include : (i) Discovery & classification of Brown Dwarfs, M-L-T Dwarfs (faint end of Initial Mass Function); (ii) Large scale mapping in emission features; e.g. Polycyclic Aromatic Hydrocarbon (PAH) at 3.3 μm, 6.2 μm, etc. (Galactic Plane survey); (iii) Minor bodies of Solar System : Asteroids, Comets, Inter- Planetary Dust; Origin, evolution & types of Organics; History of Solar System; and (iv) Asymptotic Giant Branch (AGB), Red-Super-Giant (RSG), Carbon-rich stars; (Galactic Bulge survey). In addition, it will support studies of time critical phenomena like novae, comets etc, under Targets of Opportunity (ToO) observations. The *IRSIS* database is expected to provide better understanding of energetics and composition of the ISM, infrared characterisation of stars, and various types of Solar system bodies.

Keywords : instrumentation: spectrographs – techniques: spectroscopic – stars: low-mass, brown dwarfs – ISM: lines and bands

*e-mail: swarna@tifr.res.in

1. Introduction

Astronomical measurements from ground based observatories in the Near Infrared waveband are restricted to a few selected windows in the Earth's atmosphere (viz., J, H, K, L, M, etc). Space borne observatories however have unhindered access to the entire range of wavelengths in a seamless manner. In spite of the fact that astrophysically unique and important information in the form of detectable spectral lines / features are expected in the wavelength range $\sim$ 2–6 μm, a crucial gap has been left in the astronomical spectroscopic capabilities of current / planned (near-future) international space missions. Even though $\sim$ 30% of this waveband is accessible from a few special sites atop high ($>$ 4,000 amsl) mountains, the challenges posed by : temporal fluctuations of the atmospheric transparency, high thermal background and airglow emission severly restrict their utility for astronomical observations of the kind proposed here. In order to bridge this wavelength gap a simple yet versatile instrument, viz., *Infrared Spectroscopic Imaging Survey, IRSIS*, onboard an Indian satellite in Low Earth Orbit, has been proposed by a consortium of Institutions (IUCAA, PRL, IIA, ARIES, Paris Observatory, IAS-Orsay), led by TIFR (Ghosh et al, 2007). The primary mission goal is to carry out a Spectroscopic Survey at 1.7 − 6.4 μm covering $>$ 50% of the full sky (within 2 years) including the Galactic plane. The overall scientific potential of *IRSIS* is very significant, capable of addressing a wide variety of interesting and contemporary astrophysical problems, viz., Interstellar Medium and stellar populations in our Galaxy, Circumstellar solid matter, Low mass stars and small bodies in the solar neighbourhood, etc. The large spectroscopic database with wide sky coverage and identical depth will be used to study : spectral classification of Brown Dwarfs, M-L-T dwarfs and sub-dwarfs; spatial distribution of emission features in the Galactic plane; classification & census of Solar system bodies; AGB stars etc. A list of important spectral features accessible to *IRSIS* is presented in Table 1.

2. Description of *IRSIS*

The major baseline concept design for IRSIS has been driven by the constraints of the Small Satellite Mission of ISRO, viz., size, mass & power. The basic scheme of the *IRSIS* instrument is as follows. A medium size telescope (paraboloid of aperture $\sim$ 25 cm dia; passively cooled to $\sim$ 120 K) will collect and focus infrared radiation entering its field of view (FoV) from astronomical objects in the sky and feed (at its Cassegrain focal plane) an array of microlenses coupled to infrared optical-fiber bundles. The other end of the fiber bundles terminate into multiple slits of a 2-channel spectrometer (Channel SW : 1.7–3.4 μm, & Channel LW : 3.2–6.4 μm). Each Channel of the spectrometer places the dispered images of the multiple slits onto one cooled detector

Table 1. Astrophysically important spectral bands / features accessible to *IRSIS*, which are inaccessible/difficult to observe from the ground.

Wavelength (μm)	Band identifier	Type of target
1.8	C_2	Carbon stars
1.9	H_2O	M stars
2.4	CH_4	Brown Dwarfs
2.7	OH in Silicates	ISM
3.05	Ice (H_2O)	ISM
3.1	C_2H_2, HCN	Carbon stars
3.3	PAH (in emission)	ISM
3.5	nano-diamonds	stars
4.2	Ice (CO_2)	ISM
4.6	CO	M/C Stars
5.2	C_3	Carbon stars
6.0	Ice (H_2O)	ISM
6.2	PAH (in emission)	ISM

Figure 1. The miniature low power mechanical cooler (RICOR K-508) with space heritage, integrated with a test dewar in TIFR laboratory.

array (HgCdTe @ 80 K; 1024×1024 pixels). Fiber-optic coupling allows for rearrangement of topology of the focal plane into several simultaneously dispered spectra filling up the entire square shaped detector array. The most crucial specifications for the *IRSIS* experiment are presented in Table 2.

The *IRSIS* will be a complete satellite, albeit of small category ($\sim$ 120 kg). The proposed orbit is a polar Sun-synchronous one ($\sim$ 900 km) as dictated by the thermal issues. The entire spacecraft will form a 3-axis stabilized platform with inertial pointing. The spatial resolution of *IRSIS* is consistent with the expected spacecraft drift in 10-sec integration per unit observation for the sky survey. While the infrared detector arrays will be cooled actively by mechanical coolers, the telescope will be cooled passively using a radiator (pointing towards anti-Sun direction).

Table 2. Crucial specifications for the Infrared Spectroscopic Imaging Survey (IRSIS) payload.

Parameter		Specification
Wavelength coverage		1.7-6.4 μm
	Short-Wave. (SW) chan.	1.7 – 3.4 μm
	Long-Wave. (LW) chan.	3.2 – 6.4 μm
Spectral Resolution		
	R = $\lambda/(\Delta\lambda)$	100 – 120
Angular resolution		18 arc-second
Telescope optics		Cassegrain system
Primary mirror		250 mm (dia)
Secondary mirror		35 mm (dia)
Instantaneous FoV		$\sim 9' \times 9'$
Sensitivity :		
(3-σ; 10 sec.)	Point-like source -	$K = 14$ mag.
	Diffuse emission (SW) -	1.3×10^{-7} W m^{-2} μm^{-1} sr^{-1}
		(0.4 MJy sr^{-1})
	Diffuse emission (LW) -	1.5 MJy sr^{-1}
Confusion limit		$\sim$ 2500 stars deg.$^{-2}$
Average Data Rate		3.2 mbps
Raw input power		$\sim$ 22 Watt
Mission Life		$>$ 2 years

3. Status of *IRSIS*

The major technical challenges faced in implementing *IRSIS* are as follows : (i) thermal background originating within the payload, impinging on the infrared detectors, depending on the success of the passive cooling; (ii) mechanical properties of the cryogenic infrared fibers & micro-lens array system (surviving vibration & shock tests); (iii) optical design of the anamorphoser-spectrometer system to accommodate the targeted field-of-view and the spectral resolution within the available dimensions. As per ISRO's directive, a complete plan for the Phase-1 activities as a first step towards realizing the IRSIS payload, has been prepared (Ghosh, 2008). This includes : developmental plan for the telescope, infrared fiber-bundle with micro-lens array, two channel Czerny-Turner spectrometer, infrared detector arrays with read-out electronics, thermal control system, mechanical structures, signal processing and standard interfaces to the spacecraft bus sub-systems (telecommand, telemetry, power, etc).

Among the activities in the laboratory - the procurement, assembly and testing of the miniature cryo-coolers identified for *IRSIS* has been completed (see Fig. 1). A 100 fiber infrared anamorphoser micro-lens array system has been developed by the French team led by Paris Observatory.

References

Ghosh S. K., Ojha D. K., et al., 2007, "Infrared Spectroscopic Imaging Survey (IRSIS) payload for an Indian Satellite" TIFR Tech. Rep. No. /TIFR/DAA/IRA/07-2/

Ghosh S.K., 2008, "Infrared Spectroscopic Imaging Survey (IRSIS) payload for an Indian Satellite : Phase-1 Proposal", TIFR Tech. Rep. No. /TIFR/DAA/IRA/08-2/