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Infrared astronomy in India with balloons

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Abstract. An historical account of developments related to balloon borne Far Infrared astronomy programme at TIFR, spanning over three decades has been presented. Recently, the main work-horse, TIFR 100 cm telescope (T100) completed 25 years of successful operations. A few interesting examples of technical innovations as well as scientific results from T100 are briefly described.

1. Introduction

Most of the infrared waveband is inaccessible from ground based astronomical observatories, primarily due to atmospheric absorption. The balloon borne platform provides a cheaper and less risky alternative to the satellite based ones. Less stringent technical specifications necessary for balloon payloads (e.g. mechanical structures are less demanding due to moderate qualification levels for vibration & shock), result in a shorter developmental turn-around time when compared to space projects. However, some special environmental situations need to be addressed by the balloon payloads, viz., stronger perturbing forces to the orientation & platform stabilization system and wider range of operating temperature. Still, they provide a niche for carrying out high quality scientific research (e.g. in the area of Far Infrared Astronomy), particularly when a balloon fabricating & launching facility is available in-house. In addition, such experiments act as the initial steps towards manpower training for space technology. Here, we describe the developments related to the balloon borne Far Infrared Astronomy programme at the Tata Institute of Fundamental Research (TIFR), which also owns and operates the TIFR Balloon Facility at Hyderabad in central India.

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2. Far-infrared telescopes built at TIFR

The balloon borne Far Infrared (FIR) Astronomy programme was initiated during the early 1970's. At the beginning a relatively smaller telescope, Mark I (Cassegrain system, Primary aperture 30 cm), was planned with a moderate pointing accuracy and a single band (50-300 μm) FIR photometer. Later, larger and more sophisticated balloon borne FIR telescopes were developed, which involved several innovations, viz., Star tracker (electro-optical system as a two axis angular position sensor using a guide star), 3-axis orientation system, versatile telecommand system, improved aspect from focal plane optical imager (Ghosh & Tandon 1982; Almeida et al 1983; Daniel et al 1984; D'Costa, Ghosh & Naik 2000; Naik et al 2000). The real work horse has been the most recently built 100 cm FIR telescope (T100). Along with the telescopes, the focal plane instruments have also improved. Initially two-band photometers using single bolometers cooled by liquid ^{4}He ($\sim$ 1.8 K) and finally using bolometer arrays (3×2) cooled by closed cycle liquid ^{3}He (0.3 K) dilution refrigerator, PHT-12 (Ghosh 1991; Verma, Rengarajan & Ghosh 1993). Currently, a high resolution ($\lambda/\Delta\lambda \sim 1800$) scanning Fabry Perot Spectrometer tuned to the 158 μm fine-structure line of [C II] developed at ISAS, Japan, is in use alongwith the T100 telescope. A summary and time line of the various FIR telescope systems developed at TIFR and used for astronomy is presented in Table 1.

Table 1. Balloon-borne Far-Infrared Telescopes built at TIFR.

Telescope (launches)	Primary diameter	Pointing accuracy	Waveband(s)	Payload mass	Years of operation
Mark I (5)	30 cm	6 arc min	50–300 μm	450 Kg	1975–79
Mark IIa (1)	75 cm	0.5 arc min	70–120 μm	800 Kg	1980
Mark IIb$^\bullet$ (21)	100 cm	$\sim$0.3 arc min	(a) 120–300 μm	850 Kg	1983–86
			(b) 45–70 μm 110–160 μm		1987–90
			(c) 120–160 μm† 180–300 μm		1993–98
			(d) 158 μm*		1999+

$^\bullet$ TIFR 100 cm balloon borne telescope : T100.
†Two-band 12-channel FIR Photometer : PHT-12.
*Scanning Fabry Perot Spectrometer : FPS.

The location of TIFR's balloon launch facility allows easy access to the southern sky (observation at very low elevation is possible unhindered from

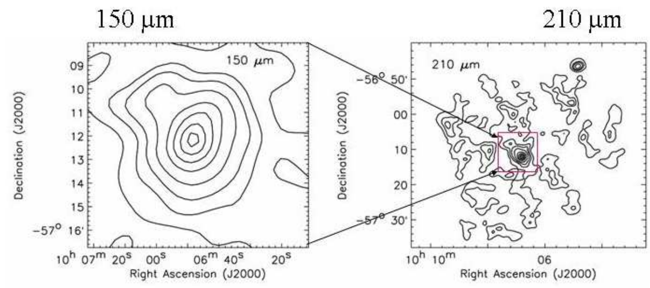

Figure 1. Intensity map for the region around IRAS 10049-5657 at 150 μm (left) and 210 μm (right). While the 150 μm map shows an expanded view of the emission from the central region, the 210 μm map shows a much larger region mapped by the T100 telescope. Contour levels are at 1, 5, 10, 20, 40, 60, 80, and 95% of the peak intensity of 624 Jy arcmin^{-2} (left) and 292 Jy arcmin^{-2} (right).

balloon altitudes) where the lesser explored inner Galactic plane lies. This has been the major focus of the T100 based observations.

The two band Far Infrared photometer (PHT-12) alongwith the TIFR 100 cm balloon borne telescope (T100) has been successfully flown regularly for astronomical studies. The combined strengths of high angular resolution, use of longer wavebands beyond the limit of even stressed photoconductors ($\sim$ 200 micron, using bolometers), and robust image de-convolution schemes have created a niche and ensured quality science (Ghosh et al 1988). This has been demonstrated in numerous studies of Galactic star forming regions (GSFRs), leading to a better understanding of physical conditions and processes in the interstellar medium. Nearly identical beams in the two FIR bands of PHT-12 (150 & 210 μm) has led to reliable measurement of temperature and optical depth of the cooler dust in the regions studied (Ghosh 2000; Ghosh 2005). These studies have led to results related to the interstellar medium in general. Some of results include : emissivity properties of interstellar dust in molecular cloud complexes; structure, energetics and fragmentation in young as well as evolved star forming regions; resolution of several compact H II regions into multiple components; detection of cold dust (T_d < 20 K) and their spatial distribution; determination of radial density distribution and dust composition (using radiative transfer modeling).

3. Flavour of scientific results

The Galactic Star forming region IRAS 10049-5657 (G282.0-1.2) is an example from the southern sky, which has been studied using the T100_PHT-12 system (Vig et al 2008). High resolution intensity maps at 150 & 210 μm are shown

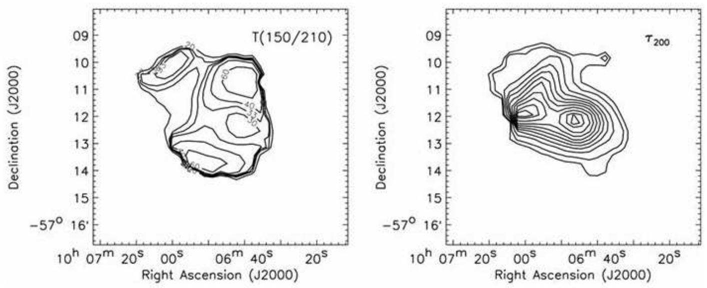

Figure 2. Distribution of dust temperature T(150/210) (left), and optical depth at 200 μm, τ_{200} (right) from the region around IRAS 10049-5657. The isotherms of T(150/210) correspond to 20, 27, 30, 33, 40, and 60 K. The τ_{200} contours represent 5, 10, 20, 30, 40, 50, 60, 70, 80, and 90% of the peak value of 0.007.

in Fig. 1. Taking advantage of the nearly identical beams at both these bands, reliable spatial distribution of temperature and optical depth of the cool dust has been obtained (Fig. 2).

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