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Near- and Mid-Infrared Observations of Late-type Stars by the IRTS

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Abstract. The Infrared Telescope in Space (IRTS) was a cryogenically cooled space infrared mission carried out in March and April 1995. Four instruments on board the IRTS surveyed about 7% of the whole sky. Two spectrometers covering the range between 1.4 and 11.7 μm detected thousands of point sources, which are mostly late-type stars. Infrared spectra of these stars show significant variation depending on chemical composition, effective temperature, and mass-loss rate of the star.

1. The IRTS Mission

The IRTS (Murakami et al. 1994, 1996) was the first Japanese orbital infrared space mission in collaboration with U.S. groups, aiming to observe diffuse radiation in the universe. The telescope was a 15 cm F/4 Ritchey-Chretien design. Four focal plane instruments, a Near-InfraRed Spectrometer (NIRS; Noda et al. 1994), a Mid-InfraRed Spectrometer (MIRS; Roellig et al. 1994), a Far-Infrared Line Mapper (FILM; Shibai et al. 1994), and a Far-InfraRed Photometer (FIRP; Lange et al. 1994) covered the wavelength range from 1.4 to 700 μm. They simultaneously observed slightly different part of the sky. The telescope and the instruments were placed in a cryogenic system and cooled by super-fluid liquid-helium. The IRTS was implemented on board of a general purpose spacecraft, called the Space Flyer Unit (SFU).

The IRTS was launched on March 18, 1995 by a H-2 rocket developed by Japanese National Space Development Agency (NASDA). The observations started on March 30, and lasted until April 24 when the liquid-helium ran out. About 7% of the whole sky were surveyed during the 26-day observation. The surveyed areas are shown in Figure 1. In the first 7 days of the mission, the telescope scanned the low-galactic latitude region (N-scan), grazing the Galactic

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Center. On April 5 the satellite changed its spin direction, and later on it scanned through the high-galactic latitude areas (S-scan). The scan path crossed the galactic plane near the star forming region W51. The SFU was retrieved by the Space Shuttle Endeavor in January 1996. The instruments are now in the laboratory of ISAS (Institute of Space and Astronautical Sciences) for the post-flight calibrations. The position reconstruction has been primarily performed by IPAC (Infrared Processing and Analysis Center). The current accuracy of the position is typically about $1'$ for the scanning direction and $2-3'$ for the perpendicular direction.

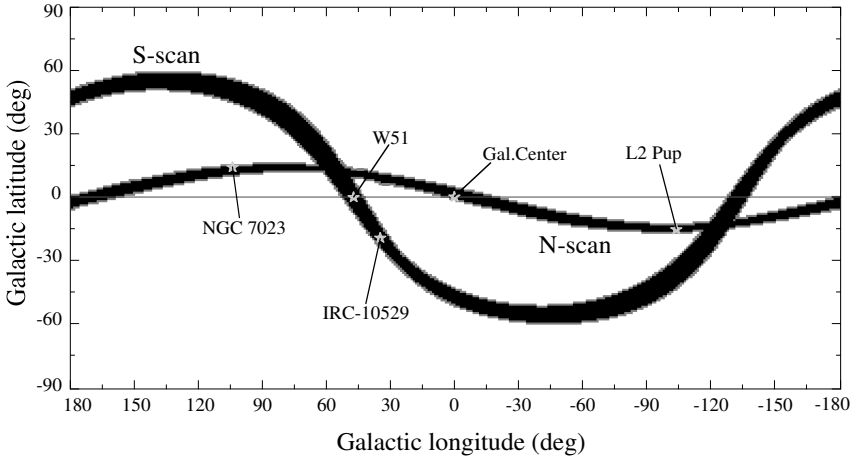

Figure 1. The areas surveyed by the IRTS on the Galactic coordinates. Major observed objects are indicated.

Point sources were detected by the two spectrometers, the NIRS and the MIRS. Table 1 summarizes the characteristics of the instruments. The two spectrometers were placed on the focal plane in the scanning direction, so that they observed the same part of the sky with a time difference of 30 seconds. The spectral responsivity of each detector has been calibrated using the "infrared spectral template" stars provided by Martin Cohen (Cohen et al. 1996; see also Freund et al. this issue), which have been observed by the IRTS (Tanabé et al. 1997). Asteroid Ceres was also used for wavelengths longward of 7 μm of the MIRS detectors (Cohen et al. 1997).

Table 1. Characteristics of the NIRS and the MIRS.

	NIRS	MIRS
Detector	24-ch InSb	32-ch Si:Bi
Aperture size	$8' \times 8'$	$8' \times 8'$
Wavelength (μm)	$1.4-4.0$	$4.5-11.7$
Resolution ($\lambda/\Delta\lambda$)	$10-33$	$20-33$
Detection Limit (Jy)	$0.04-0.2$	~ 10

2. Point Source Observation by the IRTS

In the photosphere and circumstellar of late-type stars, various molecules and dust grains form and contribute to the physical conditions of these regions. These molecules and dust grains often have spectral features in the near- and mid-infrared regions, which are good probes to inquire the chemical and physical environments of these stars. The NIRS and MIRS cover these important wavelength range, part of which cannot be observed from ground-based facilities. Thousands of uniformly sampled infrared spectra are valuable for studies of properties of the stars and stellar population in the Galaxy (Freund et al. this issue). However, because of the large aperture, it is difficult to distinguish stars in crowded areas near the galactic plane. Even for such case, the averaged spectrum of stars in the aperture provides useful information about stellar populations in these regions (Chan et al. this issue).

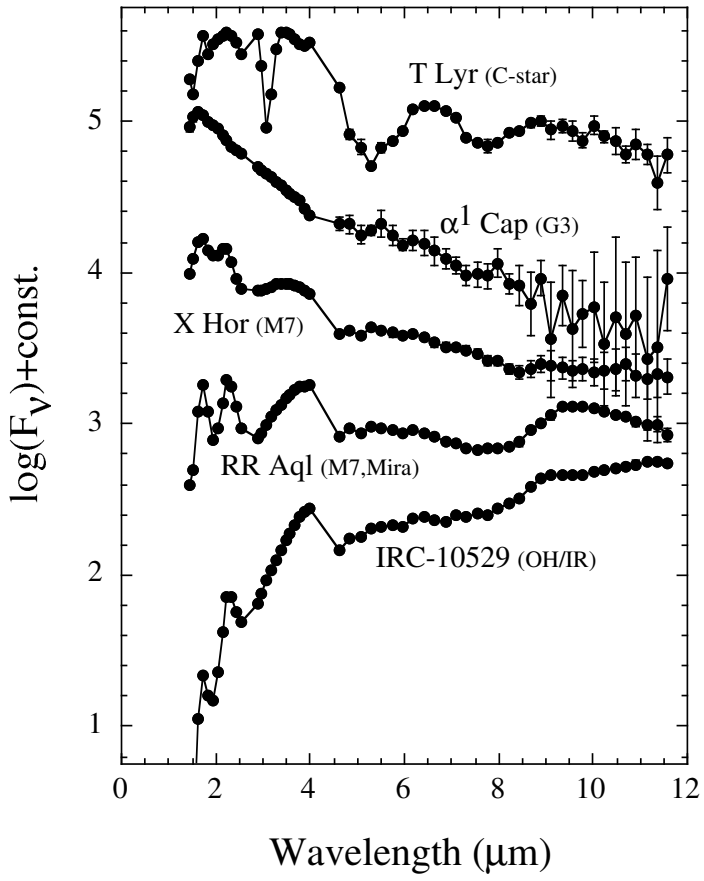

Figure 2. IRTS spectra of bright stars. T Lyr is a carbon star, and the remaining four stars are oxygen-rich stars.

We have extracted and catalogued point sources detected by the two spectrometers. Details of the extraction procedures are described by Yamamura et

al. (1997) and Freund et al. (1997, also this issue). The MIRS detected about 1,000 sources during the whole mission, while the NIRS is expected to have detected about 50,000 objects. The majority of the detected objects are late-type stars. The classification and identification of the sources observed by the MIRS are reported by Yamamura et al. (1996). About 80% of the objects have associations in the IRAS point source catalogue and are stars later than K. The remaining 20% are compact H II regions and solar system objects. Some may be space debris moving nearby the satellite. The NIRS observed more stars of earlier spectral-types (Freund et al. 1997, this issue).

The infrared spectra of late-type stars reflect their chemical composition, effective temperature (T_{eff}), and mass-loss rates (Yamamura et al. 1997). Spectra of five bright stars are shown in Figure 2. T Lyr is a carbon star — stars in which carbon is more abundant in the photosphere than oxygen. The spectrum shows several deep absorption bands, which are due to carbon bearing molecules, namely C_2H_2 and HCN at 2.6, 3.1 and 7.5 μm, C_3 at 5.2 μm, C_2 at 1.5 and 2.5 μm and CN at 1.5 and 1.9 μm. The other four stars in Figure 2 are oxygen-rich stars with different T_{eff} and mass-loss rates. It is clear that the features seen in these spectra are different from the carbon-rich case. The spectrum of the earliest type star, α^1 Cap, shows little absorption because of high T_{eff}. The remaining three late-M stars show significant absorption features of H_2O (1.5, 1.9, 2.7 and 6.2 μm; see Matsuura et al. 1997, this issue), CO (1.5, 2.3, and 4.6 μm), and SiO (8.1 μm). They also show silicate dust emission around 10 μm. The feature is most prominent in RR Aql, and is less visible due to self-absorption in the thick envelope of IRC$-$10529.

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