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Astrophysics with Infrared Surveys: A Prelude to SIRTF

IRTS/MIRS Observations of Point Sources

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Abstract. The Mid-Infrared Spectrometer (MIRS) on board the Infrared Telescope in Space (IRTS) detected about 1000 point sources in a surveyed area of about 7% of the whole sky. The spectra provide unique information of these objects in the spectral range between 4.5 and 11.7 μm, part of which is inaccessible from the ground-based facilities. The data reduction procedures of the MIRS and the characteristics of the detected objects are described.

1. The IRTS Mission

The Infrared Telescope in Space (IRTS) was a 15 cm cryogenically cooled infrared telescope system designed to observe diffuse infrared radiation (Murakami et al. 1994, 1996). Four focal plane instruments covered a broad wavelength range from 1.4 to 700 μm, and observed slightly different parts of the sky. The IRTS was launched on 1995 March 18. The survey operation started on March 30, and lasted for the following 26 days until the liquid-helium ran out. It surveyed about 7% of the whole sky in two individual strips, one in a low-galactic latitude region grazing the Galactic Center, and the other through high-galactic latitude areas. The accuracy of the position reconstruction is typically about $1'$ in the scanning direction and $2-3'$ for the perpendicular direction. The details of the instruments and the mission are described by Matsumoto (this issue).

In addition to diffuse radiation, the IRTS detected many point-like sources mostly by two spectrometers in the shortward wavelength ranges (Yamamura et al. 1997). In this article, we focus on the results by the Mid-Infrared Spectrometer (MIRS; Roellig et al. 1994). The results from the point source observations from the Near-Infrared Spectrometer (NIRS; Noda et al. 1994) are reported elsewhere (Freund et al. 1998; Matsuura et al. 1998).

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2. The MIRS observations

The MIRS was a grating spectrometer covering 4.5 – 11.7 μm with 32 discrete Si:Bi detectors. The spectral resolution was $\Delta\lambda = 0.23 - 0.36$ μm, depending on the wavelengths. The relatively large aperture size of $8' \times 8'$ did not cause a serious confusion problem except on the galactic plane.

The point sources are extracted in the following ways (see also Yamamura et al 1997). The signals brighter than 2σ of the local *rms* are identified in the time-sequence scanning data of each detector. In order to exclude spurious signals by cosmic-rays, the block of the data is regarded as a real signal and recorded as an "event" only when more than 1/4 of the detectors are identified as bright. The spectrum of each event is measured subsequently. The background diffuse radiation (mostly the zodiacal light) at the source position is evaluated from nearby ($\leq 40'$) data, and subtracted. The signals are integrated over the period of the source passage in the aperture and converted into a flux density. Events in different scans corresponding to the same object are identified by using their positions and the observed colors (see below). The final spectrum is created by averaging the spectra of these events. Throughout the whole IRTS mission, MIRS spectra of about 1000 objects were obtained from about 3300 events. About half of the spectra have a high enough quality that they can be used for scientific analysis. The detection of the point sources is complete to a flux level of about 20 Jy at any wavelengths (Yamamura et al. 1996).

The spectral responsivity of detectors have been calibrated using the "infrared spectral template" stars provided by Martin Cohen (Cohen et al. 1996). Four template stars were observed by the MIRS (Tanabé et al. 1997). The asteroid Ceres was also used for wavelengths longward of 7 μm (Cohen et al. 1998).

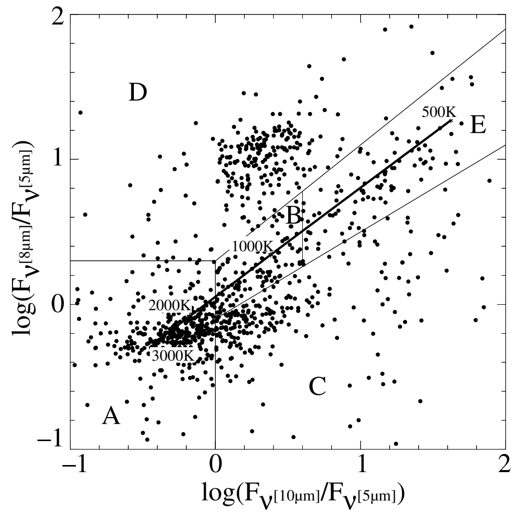

Figure 1. A MIRS two color diagram formed by the three representative wavelength bands described in the text. The thick line and numbers indicate the blackbody and temperatures. The sources can be classified into five different characteristic groups.

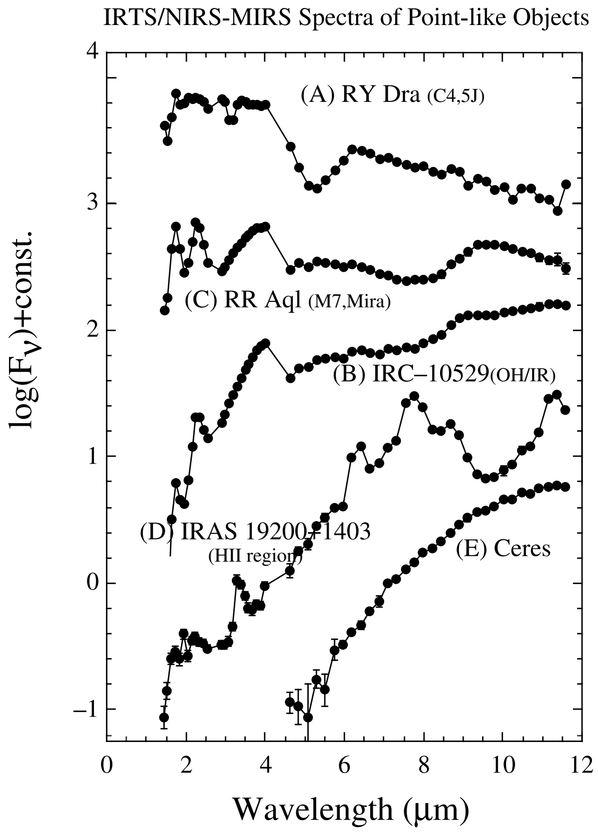

Figure 2. IRTS spectra of representative objects. Notations (A)–(E) correspond to the groups defined in Figure 1. The near IR part (1.4 – 4.0 μm) is provided by courtesy of the NIRS team.

3. Characteristics of the detected sources

We have defined three representative wavelength bands in the MIRS wavelength range. The averaged flux densities of four detectors, each of them centered at 5.0, 7.9, and 9.9 μm are denoted as 5, 8, and 10 μm band fluxes, respectively. The 5 μm band is representative of a represent the stellar continuum, while the 8 and 10 μm bands indicate the strength of the UIR band and silicate / SiC circumstellar dust features.

Figure 1 shows a two color diagram made from these three band fluxes. It is straightforward to draw lines on the diagram to separate the objects into different groups. We define five groups as indicated in Figure 1, and denote them as groups A – E. The characteristics of the objects in the different groups are investigated by their spectra and the cataloged data (Yamamura et al. 1996).
Group-A: This group is located near the blackbody line with temperatures higher than 2000 K. The objects in this group are stars with spectral types later than K, and do not have circumstellar envelopes. A bright carbon star, RY Dra, is shown in Figure 2A as a typical source in group A. Several photospheric absorp-

tion bands due to C_2H_2, HCN, C_3, etc. are recognized, while any circumstellar dust feature, namely 11.3 μm SiC feature is not seen in the spectrum.

Group-B: These are also late-type stars with circumstellar envelopes. The OH/IR star IRC−10529 (Figure 2B) shows a featureless but remarkably red spectrum. For this particular case the silicate feature is just on the border between emission and absorption.

Group-C: The objects in this group generally have strong excesses in the 10 μm band due to silicate dust emission, which shifts the object rightward of the blackbody line. A representative of this group, RR Aql (Figure 2C), also shows strong H_2O absorption bands which are characteristic of oxygen-rich stars.

Group-D: The spectra of this group are characterized by the strong UIR bands at 3.3, (3.4,) 6.2, 7.7, 8.6, and 11.3 μm, indicating their highly excited nature (Figure 2D). Many of them are identified with compact H II regions.

Group-E: The group-E objects are the most mysterious. Most of the sources in this category have similar, almost featureless and very red spectra, which are well represented by a blackbody at a few hundred K. Only one object in the group has been identified with a known object. It is the asteroid Ceres whose spectrum is shown in Figure 2E. Except for Ceres, all the objects were detected only once, and were not seen in the successive orbits. We suspect that these objects are mostly space debris around the Earth, although other possibilities cannot completely be ruled out.

4. Summary

The IRTS/MIRS spectral samples of point sources are quite unique in their numbers and the wavelength coverage, and provide a useful data base for studying the infrared properties of late-type stars and compact H II regions.

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References

Cohen, M., Witteborn, F. C., Carbon, D. F., et al. 1996, AJ, 112, 2274

Cohen, M., Witteborn, F. C., Roush, T., et al. 1998, AJ 115, 1671

Freund, M.M., et al., 1998, ASP Conf. Ser., 138, 101

Matsuura, M., et al., 1998, ASP Conf. Ser. 138, 237

Murakami, H., Bock, J., Freund, M. M., et al. 1994, ApJ, 428, 354

Murakami, H., Freund, M. M., Ganga, K., et al. 1996, PASJ, 48, L41

Noda, M., Matsumoto, T., Matsuura, S., et al. 1994, ApJ, 428, 363

Roellig, T.L., Onaka, T., McMahon, T.J., Tanabé, T. 1994, ApJ, 428, 370

Tanabé, T., Yamamura, I., Onaka, T., et al. 1997, ASP Conf. Ser., 124, 25

Yamamura, I. Onaka, T., Tanabé, T., et al. 1996, PASJ, 48, L59

Yamamura, I., the IRTS team 1997, ASP Conf. Ser., 124, 72