Mid-infrared imaging of AGB Star Envelopes

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Abstract.

The recent development of bi-dimensional detectors operating in the mid-infrared has opened new possibilities for the observation and analysis of the high mass loss processes in the last stages of stellar evolution. Radio (CO) and maser (OH) observations show that an important rôle is played by intermediate and low mass stars (1-8 $M_\odot$) in the TP–AGB phase, and by their circumstellar envelopes of gas and dust. We analyse the problem of characterizing the chemical nature of the AGB envelopes (C-rich or O-rich) through mid-infrared observations by means of a suitable photometric system.

Key words: Stars: evolution — Stars: circumstellar shells — Infrared: sources

1. INTRODUCTION

Intermediate and low mass stars (1-8 $M_\odot$) in Asymptotic Giant Branch (AGB) stage are characterized by the formation of an optically opaque, circumstellar envelope of gas and dust, which will later evolve into a planetary nebula. Nucleosyntesis and mixing processes (third dredge-up) occuring in the star during the thermal pulsing phase (TP–AGB) involve also the external layers (Iben, 1981) and can cause the transition from oxygen- to carbon-rich envelope (Willems and deJong, 1988) as a consequence of the large variations in mass loss rates triggered by the thermal pulses themselves.

This transition is a consequence of the periodic C enrichment in the star convective envelope; observational and theoretical evidences (Kwok and Chan, 1989) show that stars in a mass range between 3 $M_\odot$ (or less) and 5 $M_\odot$ experience a sufficient number of dredge-up events to reach an abundance ratio [C]/[O]>1 before the expulsion of the convective envelope is completed. The stars in such a range of masses will lose their O-rich circumstellar envelope, developing a new one rich of carbon.

An oxygen excess in the envelope locks all carbon atoms in CO and allows the formation of silicate dust grains, which are globally responsible for a broad emission/absorption band at 9.7 μm, and an emission feature at 20 μm. On the other hand, an excess of carbon would form dust rich in graphite, amorphous carbon and a small but significant amount of SiC, which is detectable at 11.3 μm. The determination of the dust chemical abundances is thus favoured in the mid-infrared.

2. AGB ENVELOPES OBSERVATIONS

A collaboration between the Astronomical Observatory of Torino (OATo), the Department of Experimental Physics of the University of Torino, and the Institute for Space Astrophysics (IAS) of CNR, has made available a mid-infrared camera (TIRCAM, Tirgo InfraRed CAMera, Persi et al., 1994). The camera is equipped with a 10×64 Si:As array sensitive in the 5–25 μm wavelength range.

The photometric system of the camera is specifically designed for the observation of interstellar and circumstellar dust, providing the spectral resolution necessary to detect the known emission and/or absorption features of O-rich and C-rich dust grains.

Filters	Band (μm)	λ_{eff} (μm)	$\Delta\lambda$ (μm)	Chemical characteristics
F3	8.4–9.2	8.81	0.87	Dust continuum
F4	9.3–10.3	9.80	0.99	Silicates emission features (9.7 μm)
F5	9.8–10.8	10.27	1.01	Dust continuum
F6	11.2–12.3	11.69	1.11	SiC emission feature (11.3 μm)
F7	11.9–13.1	12.49	1.16	Dust continuum

Table 1: TIRCAM photometric system

The TIRCAM camera has been used in a few observing runs at the National Mexican Observatory of San Pedro Martir (Baja California) and at the Italian Infrared Telescope (TIRGO), in 1992–1994 years, for imaging of circumstellar envelopes around AGB stars.

The observed sources have been selected from a statistically complete sample of AGB stars extracted from the IRAS Point Source Catalogue (1985), in order to satisfy the observational constraints for an infrared camera like TIRCAM. The spatial extension of each source has been previously evaluated by a model developed on the basis of the radial brightness distribution computed by Martin and Rogers (1987) for the C-star CW Leonis.

A total number of 16 AGB stars with circumstellar envelopes (9 O-rich and 7 C-rich), and one post-AGB object have been observed. For each source the images were collected in the available photometric system and at a spatial resolution substantially limited by the telescope diffraction (2.4 and 3.4 arcsec at San Pedro Martir and at TIRGO, respectively). The complete results of the observations and the data analysis will be published in a forthcoming paper.

The obtained mid-infrared photometry was compared with the Low Resolution Spectra (LRS, 1986) measured by IRAS in the wavelength range 8–23 μm and a general good agreement was found. In Figure 1 the case of CW Leonis is shown. Besides, two of the sources (CW Leonis and R Leonis) after deconvolution with the instrumental Point Spread Function (using the iterative algorithm by Lucy, 1974), seems to be extended as a consequence of a possible spatially resolved envelope.

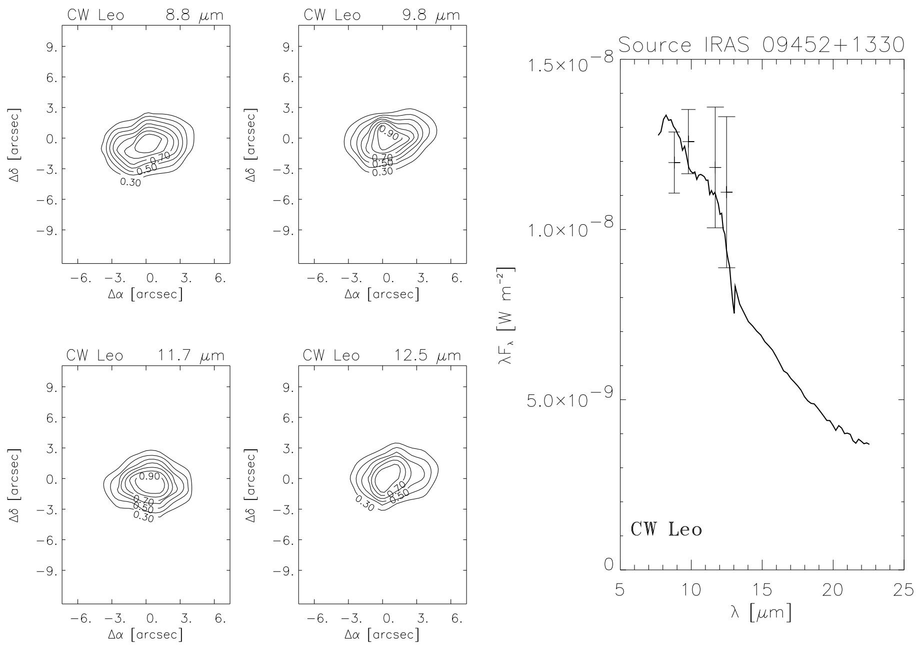

Fig. 1.— The C-rich source CW Leonis (IRC+10216) observed at 8.8, 9.8, 11.7 and 12.5 μm. The photometry of the source is compared with the IRAS LRS spectrum in the wavelength range 7–23 μm.

3. CHEMICAL CLASSIFICATION OF AGB ENVELOPES

Color-color diagrams in mid- and far-infrared allow to classify AGB and post-AGB sources on the basis of their evolutionary stage. Evolutionary sequences for O-rich, C-rich and transition objects can be drawn on the IRAS color-color diagram (van der Veen and Habing, 1988), based on the IRAS fluxes at 12, 25 and 60 μm. AGB stars in different evolutionary stages are located in different regions on the diagram, but there is not a complete separation between sources with C-rich or O-rich envelopes.

In order to obtain a chemical classification of the observed objects we have constructed a suitable color-color diagram in the TIRCAM photometric system The [8.8]$-$[12.5] color appears mainly related to the chemical nature of the dust in the envelope, being less than 0.6 for all O-rich envelopes, and greater than 0.6 for the C-rich sources. The only post-AGB object observed has the reddest color ($\sim$1.5) and is located in a separate region of the diagram. There are also some evidences that the [8.8]$-$[9.8] color can be associated with the evolutionary stage of the envelopes.

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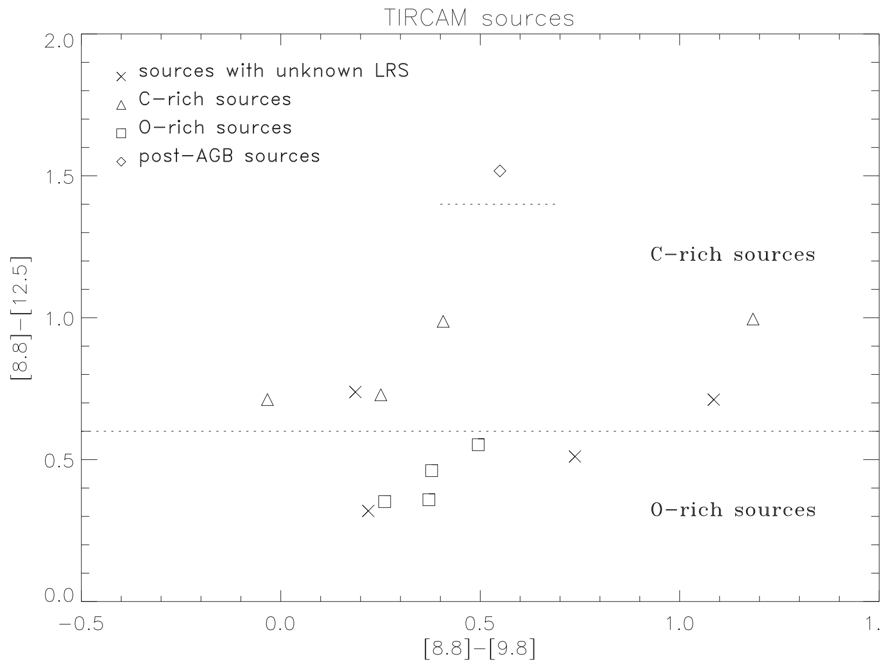

Fig. 2.— The TIRCAM color-color diagram of the observed sources

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