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Mass loss in AGB stars from infrared colors

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Abstract. We have selected a wide database of mid infrared observations for AGB stars from both ground-based and space-borne observatories, with the aim of characterizing the efficient mass loss mechanisms leading to the formation of their extended dusty envelopes and of planetary nebulae. Our sample includes more than 250 sources in our Galaxy, distributed along the evolutionary sequence that gradually changes the spectral characteristics of M giants, forming MS, S and then C-stars. Thanks to a re-analysis of existing estimates of mass loss at radio frequencies and to improved measurements of distance (often provided by the Hipparcos mission), we compile a homogeneous set of corrected mass loss rates and of mid-infrared colors. We show the existence of clear correlations suggesting that mass loss can be inferred from photometric colors in mid infrared, once these have been suitably calibrated. This provides a tool to predict the efficiency of stellar winds for other less known sources, and is a decisive step in view of the determination of observationally based criteria for including mass loss in stellar models. In this paper we discuss in particular, as an example, our sample of C-rich stars.

Key words. Stars: AGB and post-AGB – Mass loss – Mid infrared photometry

1. Introduction

Stars of low and intermediate mass (all those below M = 7-8 $M_\odot$) terminate their evolution through the so-called Asymptotic Giant Branch phase (Busso et al. 1999), in which they lose mass efficiently thanks to stellar winds powered by radiation pressure on dust grains Habing (1996). After this stage, they generate planetary nebulae and start a blueward path, which ultimately gives birth to a white dwarf. Moreover, winds from AGB stars replenish the Interstellar Medium with about 70% of all the matter returned after stellar evolution; this is done with the formation of circumstellar envelopes through the processes of mass loss (Winters et al. 2002).

One of the main open problems that still affect our knowledge of AGB stars and of their impact on galactic physics and evolution is the history of mass loss, whose efficiency controls the duration of the AGB phase and the amount of matter returned to the ISM. We do not have yet a quantitative description of stellar winds in AGB stars, though hydrodynamical modelling of pulsating stellar atmospheres and of the induced mass loss is undergoing important improvements (Winters et al. 2002, 2003). Also observational studies have become more

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and more quantitative, using new data at long wavelengths from space and from the ground (Le Bertre et al. 2001, 2003), as well as an improved knowledge of stellar distances Knapp et al. (2003).

We believe there is now a need to devise a quantitative basis for associating each phase of the physical-chemical evolution of an AGB star to a suitable mass loss efficiency estimated observationally. We intend here to perform an analysis of mass loss for AGB stars looking for quantitative correlations with their photometric properties. As a first step, we have collected a sample of 250 AGB stars of class 'C' (carbon-rich), for which we derive (from space-borne observations) the photometric properties in the mid infrared (in the 10 μm band), where cool dust normally dominates over the residual photospheric flux. We do this to the aim of verifying on wider statistics the criteria previously suggested by Busso et al. (1996), Marengo et al. (1997), Marengo et al. (1999), Corti et al. (2003). According to these authors the colors computed through moderate-width filters between 8.5 and 12.5 μm are good indicators of the mass loss efficiency, and also permit a first classification of the chemical properties of the circumstellar envelopes (see also Ciprini & Busso (2003)). We aim at using the results of this study to build observationally-based simple relations connecting the strength of the stellar winds to the photometric properties and then to the chemical properties (e.g. enhancement of newly produced carbon and s-elements in the photosphere) of AGB stars.

2. The sample

The sample of C-stars in this analysis is made of 249 sources and these have been divided in 5 classes, following the indications of several catalogues of variable stars: 1) Miras (36), 2) Semiregulars (26), 3) Irregulars (8), 4) PostAGB (20), 5) stars of unknown nature (159). As a general reference we used mainly the Combined Great Catalogue of Variable Stars (GCVS). From there, we selected AGB stars of C type with known mass loss rates at radio frequencies.

3. Mass loss rates

The estimates of mass loss that we adopt in this work are those derived from the models of Loup et al. (1993) (as used by Loup et al. (1993) themselves and by Winters et al. (2003)) and from Olofsson et al. (1993) (as used by Groenewegen et al. (1998)). We have also used raw data from Schöier et al. (2001), that we have processed through the method of Loup et al. (1993). Our upgrade of mass loss rates mainly concerns the use of improved and more recent measurements for the distance, which are provided through the Hipparcos mission or the period-luminosity relation given by Groenewegen et al. (1996). A detailed exposition of the methods used to obtain our revised estimates of mass loss can be found in Guandalini et al. (2004).

4. Mid infrared data

Our database of mid-infrared observations includes the measurements taken with 2 space-borne observatories, i.e. Infrared Space Observatory (ISO) and Midcourse Space eXperiment (MSX). As for ISO, we used the observations made with the Short Wavelength Spectrometer (SWS). We have reduced these observations by rebinning the spectra over the wavelength intervals corresponding to commonly-used photometric filters in the mid-infrared range. They are 1 μm wide and centered at 8.8, 11.7 and 12.5 μm. The rebinning is done through a convolution with the response of the filters. Concerning the photometric fluxes given by MSX, we have reprocessed them by correlating the A and C filters used in this experiment with the mentioned filters at 8.8 and 12.5 μm. In this case the flux at 11.7 μm cannot be derived because MSX did not observe at this wavelength. A detailed presentation of all the steps followed can be found in Guandalini et al. (2004).

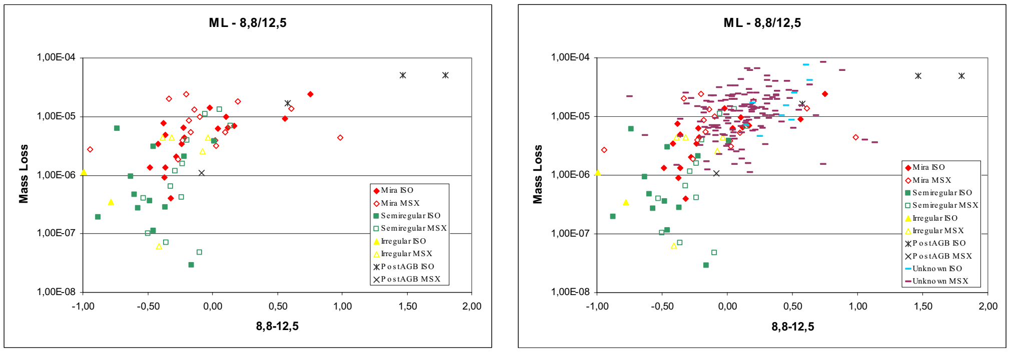

Fig. 1. Left panel: Relationship between mass loss and the mid-infrared color [8.8]-[12.5] using both ISO and MSX data. Right panel: same as left panel, but adding the C-rich stars of unknown evolutionary status.

5. Discussion

In this discussion the infrared *colors* are defined as, e.g.:

$$[8.8] - [12.5] = -2.5Log\frac{F_{8.8}}{F_{12.5}}$$

As mentioned above, these colors correspond to standard mid-IR filters, like e.g. mounted on the mid infrared camera TIRCAM at the TIRGO telescope.

In figure 1 (left) we can see how a correlation between mass loss and mid infrared color exists, although the different classes of C stars generate some scatter; in particular, some overlapping between Miras and Semiregulars can be seen, probably due to the uncertain limits between these two classes. Miras seem to dominate at higher values of mass loss while Semiregulars behave the same way for low mass loss rates. It is interesting to note how Post-AGB stars occupy region characterized by high mass loss rates and "redder" colors (this might be an indication that they are experiencing a superwind phase). They are relatively close to the Mira stars. One last thing to note in this relation is shown in figure 1 (right), where the unknown-type stars mainly occupy the area of Miras and PostAGB stars, probably because there is a certain selection effect in IR catalogues toward the reddest and brightest sources. More details on this topic can be found in Guandalini et al. (2004). In figure 2 we obtain a color-color relation for our sample of AGB stars and in this case we show that the different classes are quite clearly separated by their colors; in particular, a better distinction appears between Semiregulars and Miras and the same is true for Miras and Post-AGB objects. The unknown AGB stars tend again to cover the region of Miras and Post-AGB stars, confirming the previous indications, although the data for unknown stars are only a few for this case.

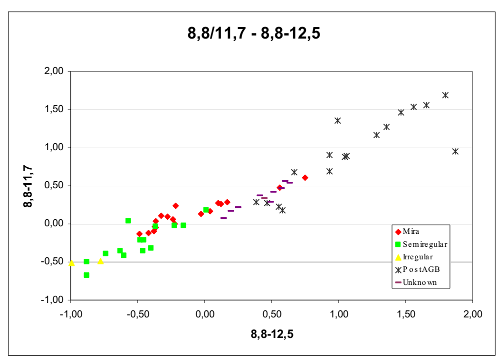

Fig. 2. A color-color diagram prepared using the ISO data only.

6. Conclusions

In conclusion we have found that the correlation between mass loss rates and the [8.8]-[12.5] color for C-stars has a good level of accuracy and can discriminate the different types of stars. The results also show that C stars as a whole are a quite homogeneous class. From both figures 1 and 2 the different classes of C-rich AGB stars appear to be roughly discriminated, especially for Semiregulars, Miras and Post-AGB objects. Finally, the unknown stars in our sample seem to be mainly attributable to the Mira and Post-AGB star classes.

References

Busso M., Origlia L., Marengo M., Persi P., Ferrari-Toniolo M., Silvestro G., Corcione L., Tapia M., Bohigas J., 1996, A&A 311, 253

Busso M., Gallino R., Wasserburg G. J., 1999, ARA&A 37, 239

Ciprini, S., & Busso, M. 2003, MmSAI Supplement 2, 233

Corti G., Risso S., Busso M., Silvestro G., Corcione L. 2003, MmSAI. 74, 205

Groenewegen M.A.T., Whitelock P.A., 1996, MNRAS 281, 1347

Groenewegen M.A.T., Sevenster M., Spoon H.W.W., Perez I., 2002, A&A 390, 511

Guandalini R., Ciprini S., Busso M., Silvestro G., 2004 submitted

Habing H.J., 1996, A&AR 7, 97

Knapp G.R., Pourbaix D., Platais I., Jorissen A., 2003, A&A 403, 993

Le Bertre T., Matsuura M., Winters J.M., Murakami H., Yamamura I., Freund M., Tanaka M., 2001, A&A 376, 997

Le Bertre T., Tanaka M., Yamamura I., Murakami H., 2003, A&A 403, 943

Loup C., Forveille T., Omont A., Paul J.F., 1993, A&AS 99, 291

Marengo M., Canil G., Silvestro G., Origlia L., Busso M., Persi P., 1997, A&A 322, 924

Marengo M., Busso M., Silvestro G., Persi P., Lagage P.O., 1999, A&A 348, 501

Olofsson H., Eriksson K., Gustafsson B., Carlstrom U., 1993, ApJS 87, 267

Schöier F.L., Olofsson H., 2001, A&A 368, 969

Winters J.M., Le Bertre T., Nyman L., Omont A., Jeong K.S., 2002, A&A 388, 609

Winters J.M., Le Bertre T., Jeong K.S., Nyman L., Epchtein N., 2003, A&A 409, 715