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Infrared investigation from earth and space on the evolutionary state of a sample of LPV

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Abstract. We selected a sample of highly reddened AGB stars among the sources observed with the SWS instrument on the ISO satellite. These SWS data allow us to compute the source's photometry in the mid-IR filters of the camera TIRCAM at the TIRGO telescope. Our photometric data, supplemented with other measurements taken from the literature, permit to select the carbon-rich sources in the sample. For these stars, a linear relation holds between dust mass loss and the color index [8.8]-[12.5]. One may then, from photometric data alone, evaluate the total mass loss (for which we used the estimate of Loup et al. (1993), based on radio data). The oxygen-rich sources, on the other hand, are distributed in two branches, of which the upper one appears superimposed with carbon stars; the stars in this group have both high luminosity and high wind velocity and therefore higher masses. Finally S stars lie between the carbon-star branch and the low-mass oxygen-rich stars, in agreement with their intermediate evolutionary status.

Key words. AGB stars – mass loss – evolutionary state

1. The sample

A number of 45 very reddened AGB stars was first selected between the sources observed by the ISO infrared satellite. We made use of the Short Wavelength Spectrometer (SWS) data, having good accuracy. A few of sources were finally added in order to increase the statistics.

The sample includes sources with different types of envelope (Oxygen-rich, Carbon-rich and S stars) and different variability (Mira variables, Semi-Regular variables, other types).

2. Photometry

To each star we assign the [8.8]-[12.5] color index (see Table 1), which are calculated

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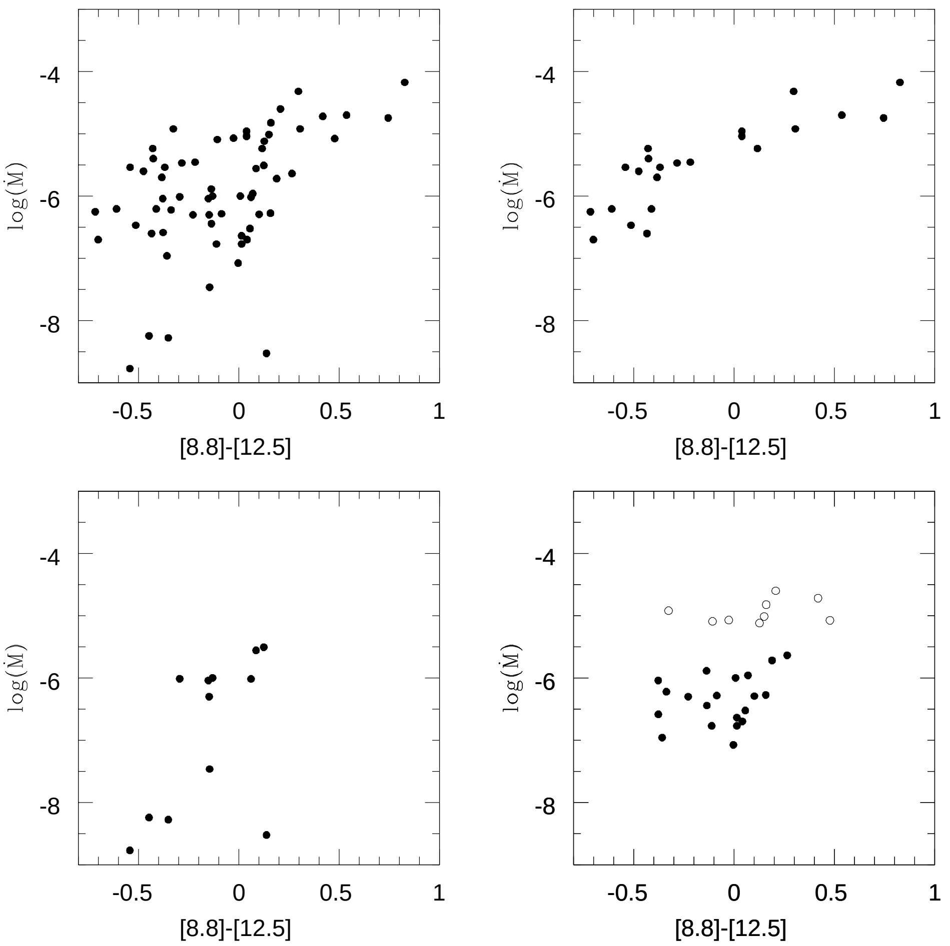

Fig. 1. Color index to mass loss diagrams: the whole sample (top left panel), C-rich stars (top right panel), S-stars (bottom left panel), O-rich stars (bottom right panel).

from the ISO-SWS data by integrating the flux over the filter profile according to:

$$F_j = \frac{1}{\Delta\lambda} \int_{\Delta\lambda} I_j(\lambda) f(\lambda) \mathrm{d}\lambda \qquad (1)$$

These colors correspond to the filters mounted on the mid-IR camera TIRCAM at the TIRGO telescope (see Persi et al. 1994), which were used by Busso et al. (1996).

We estimate for these colors an uncertainty ∼10%, as given by the spectrometer manual.

3. Color to mass loss relation

A [8.8]-[12.5] color index vs. $\log(\dot{M})$ diagram was constructed by using $\dot{M}$ data compiled by Loup et al. (1993), Fuente et al. (1998), Neri et al. (1998), Knapp et al. (1998).

Table 1. Photometric data calculated, or taken from: [a]Busso et al. (1996), [b]Marengo et al. (1997), [c]Marengo et al. (1999).

Name	Variable type	Spectral class	Envelope chemistry	$F_{8.8}$ (Jy)	$F_{12.5}$ (Jy)
AA CYG	SR	-	S	41.8	36.6
AFGL 1822[b]	?	M	O	138.0	167.0
AFGL 190	?	?	C	43.5	86.4
AFGL 2155	C	C	C	422.0	437.1
CHI CYG	M	S...	S	1395.8	1217.2
CRL 618[c]	?	B0	C	141.0	302.0
CW LEO[a]	M	Ce	C	28300.0	37200.0
EP AQR	v	M8III	O	481.1	487.0
FP AQR	p	M9	O	102.2	108.9
FX SER[a]	v	C	C	148.0	196.0
GZ PEG	-	-	S	91.0	55.2
HR PEG	-	-	S	27.4	19.8
IZ PEG	M	?	C	153.1	170.4
KU AND[c]	M	M9	O	433.0	497.0
LL PEG	M	?	C	285.0	467.1
LY MUS	-	-	S	28.9	19.1
NO AUR	-	-	S	34.5	39.2
NV AUR	v	M	O	238.9	268.4
NX SER	M	?	O	405.2	367.0
OH 44.8-2.3	?	?	O	150.8	111.6
PQ CEP	v	C...	C	155.1	94.1
RR AQL	M	M7e	O	441.7	311.5
RT VIR[a]	SRb	M8III	O	369.0	325.0
RU VIR	M	Rpe	C	164.7	126.7
RV BOO	SR	M6III:e	O	109.3	110.0
RX BOO	SR	M7.5	O	732.7	770.9
RY DRA	C	C...	C	127.5	72.7
R AND	M	Se...	S	201.5	213.1
R AQL	M	M7IIIe	O	312.3	275.4
R CAS	M	M7IIIe	O	1280.7	1182.3
R CYG	M	S...	S	79.5	69.2
R LMI[a]	M	M7e	O	331.0	268.0
SV PEG	SR	M7	O	168.2	200.1
SW VIR	SR	M7III	O	685.0	618.0
S CAS	M	Se	S	244.7	274.3
S CEP	M	CII...	C	501.4	323.6
S CRB[a]	M	M6,5e	O	183.0	134.0
S LYR	M	S	S	21.0	22.7
S VIR	M	M7IIIe	O	108.4	108.0
TX CAM	M	M8.5	O	578.1	737.4
TX PSC	C	CII...	C	170.8	88.3
T CAS	M	M7e	O	286.1	313.9
T CEP	M	M7IIIe	O	681.3	707.2
T DRA	M	Ne	C	218.0	155.1
U CAM	C	N...	C	120.4	84.6
U HER	M	M7III	O	222.0	156.7
V 1300 AQL	v	M:	O	6.8	10.6
V 384 PER	C	C	C	451.5	369.1
V 627 CAS	e	M4III:e	O	90.5	133.1
V 636 MON	v	C	C	160.2	107.8
V 821 HER[a]	M	Ce	C	782.0	810.0
V 833 HER	M	M2	O	466.8	540.6
V AQL	C	CII...	C	147.5	91.9
V CRB	M	N...	C	95.3	63.8
V CYG	M	N...	C	752.7	507.9
WX PSC	OH/IR	M9:	O	1072.0	1046.0
WX SER[b]	M	M8.5	O	141.0	163.0
W AND[b]	M	S8,2e	S	151.0	115.0
W AQL	M	S:...	S	949.9	841.6
W ORI	C	CII...	C	192.2	131.5
X HER	SR	M8	O	208.3	149.7
Y CVN	C	CIab:...	C	210.3	110.2
Y UMA	SR	M7II-III...	O	168.0	170.0

A diagram with inclusion of all sources in the sample appears to be rather spread out (Fig. 1, top left panel). As a matter of fact, our sample includes sources with different envelopes: (a) C-rich, (b) S-star, (c) O-rich. In our opinion, the three groups may differ in relation to their evolutive history. We are therefore led to consider each group separately:

(a) C-rich stars (Fig. 1, top right panel) have a parabolic distribution, in agreement with their well-defined evolutionary phase, which ensures homogeneous behaviour;

(b) S-stars (Fig. 1, bottom left panel) display a nearly linear behaviour. However, two sources appear not to fit the relation: the star NO Aur, of spectral class M2s, and the source AA Cyg, whose distance —on which depends the estimate for $\dot{M}$— is considerably uncertain;

(c) O-rich stars (Fig. 1, bottom right panel) are located in two distinct branches, according to their different luminosities and wind velocity. The upper branch stars have $L/L_4 \geq 0.9$ AND $v_e > 14$ km/s, and vice-versa for the lower branch. According to stellar evolutionary models (see Busso et al. 1999) the two groups include stars with different masses. In the lower branch lie stars with lower masses, which are unable to reach the thermal pulse phase.

4. Conclusions

In conclusion we found that the [8.8]-[12.5] color index, which can be obtained with simple photometric measurements, is related to the mass loss value only when one considers groups of sources which are homogeneous from an evolutionary point of view. The O-rich stars are further subdivided in two groups, which differ on the basis of both luminosity and wind velocity.

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