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Stellar evolution and the 'O-rich AGB sequence'

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Abstract. The 'O-rich AGB sequence' is a well defined area occupied by oxygen-rich AGB stars (OH/IR) in the IRAS two-colour diagram [12]-[25] vs [25]-[60] (Fig. 1). This sequence is interpreted in terms of evolutionary stage and/or progenitor mass with the aim to link observed classes of AGB stars and Planetary Nebulae (PNe).

Key words. Stars: OH/IR – Stars: AGB and post-AGB – Stars: circumstellar matter – Stars: variable – Stars: evolution – Infrared: stars

1. Introduction

One of the most fundamental questions that still remains open in the understanding of AGB stellar evolution is the interpretation of the 'O-rich AGB sequence'. It has been shown by several authors that this sequence reflects the increase of optical thickness of the circumstellar envelope as the star evolves along the AGB (e.g. Bedijn 1987; Volk & Kwok 1988).

However, this increase can be interpreted in two different ways:
i) **evolutionary sequence**: every star would start the AGB phase at the blue end of this sequence, and would later move while increasing its mass-loss rate until reaching the red extreme at the end of the AGB;
ii) **mass sequence**: their different location would be just a consequence of their different initial mass, which would determine the mass-loss rate;
iii) A third interpretation was proposed, which is a combination of the previous ones: all AGB stars would move towards redder colours as they increase their mass-loss rate, but only the more massive stars would be able to reach the reddest end of the sequence.

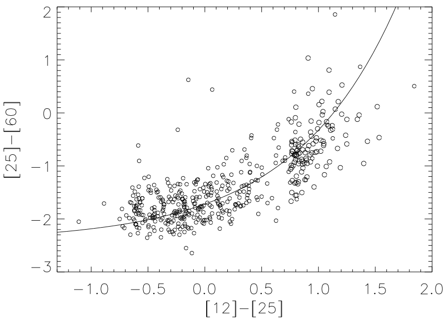

Fig. 1. The position in the IRAS two-colour diagram of OH/IR stars in the sample. The solid line is the 'O-rich AGB sequence' (see text), and the IRAS colours are defined as: $[12]-[25] = -2.5 \log \frac{F_\nu(12)}{F_\nu(25)}$ and $[25]-[60] = -2.5 \log \frac{F_\nu(25)}{F_\nu(60)}$.

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In two previous works (Jiménez-Esteban et al. 2005a,b), we have studied a very large sample of OH/IR stars with a very good coverage of the whole ‘O-rich AGB sequence’ (Fig. 1). We also have photometric information not only in the mid- and far-infrared but also in the near-infrared where the bluer objects have the maximum of their spectral energy distribution.

2. Luminosity, distance and galactic height

Bolometric fluxes were obtained by integrating the photometric data available from the near infrared to the far infrared domain (2MASS, own photometry, MSX and IRAS data), and extrapolating both toward shorter and longer wavelengths. The typical uncertainty is $\approx 40\%$.

We selected from our sample 41 extremely red OH/IR stars detected in the direction of the Galactic Bulge, and assumed a common distance (8 kpc) to all them. The range of absolute luminosities obtained (Fig. 2) is strongly peaked around $3\,500\,L_\odot$, in agreement with those found by other authors using different OH/IR star samples in the bulge with very different (bluer) colours (e.g. Wood et al. 1998; Blommaert et al. 1998) or using samples located in different parts of the Galaxy (Knauer et al. 2001). Then we conclude that the luminosity function may be similar throughout the Galaxy and not very dependent on the colours of the stars selected. Our subsample of OH/IR stars in the Galactic Bulge is dominated by relative low mass stars, so, these stars can also reach the red part of the ‘O-rich AGB sequence’.

We estimated the galactic height for the rest of OH/IR stars by simply assuming a common and constant luminosity $L_{OH/IR}$ of $3\,500\,L_\odot$ for all them.

3. Interpretation of the ‘O-rich AGB sequence’

In order to have a good descriptor for the whole ‘O-rich AGB sequence’, we have used the parametrization introduced by the following equations:

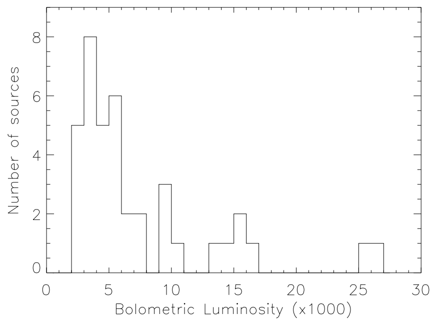

Fig. 2. Absolute bolometric luminosity in thousands of $L_\odot$ of the OH/IR stars belonging to the Galactic Bulge population.

$$\left.\begin{aligned}[12]-[25] &= 0.912\,\mathrm{Ln}\,\lambda \\ [25]-[60] &= -2.42 + 0.72\,\lambda\end{aligned}\right\}$$

Each point of the ‘O-rich AGB sequence’ can then be associated with a given value of λ, and each star is then assigned a λ value which corresponds to the nearest point in the ‘O-rich AGB sequence’.

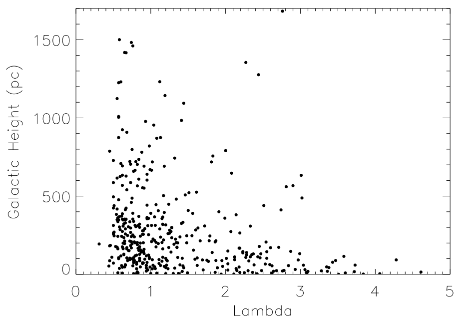

Fig. 3. Galactic height distribution as a function of λ derived for all the sources in the sample, excluding the Galactic Bulge OH/IR stars ($L_{OH/IR} = 3\,500\,L_\odot$ assumed).

Fig. 3 shows the galactic height in absolute value derived as a function of the λ parameter. We found a very clear correlation, which implies that the redder part of the ‘O-rich AGB sequence’ must be populated mainly with objects of higher mass. In addition, we found a similar correlation between v_{exp} and λ. Note that assuming a different luminosity would just change the scale of the y-axis.

The above results are only consistent with an evolutionary scenario in which all OH/IR stars would start the AGB phase, independent of their progenitor mass, in the bluer part of the 'O-rich AGB sequence' and then they would evolve toward redder colors, although only the more massive stars would reach the very end of the sequence.

In order to further characterise the stars populating the 'O-rich AGB sequence', we have divided the sequence in bins of λ and determined the galactic scale height H associated (Fig. 4). Then we have classified all the OH/IR stars in our sample in 5 main groups.

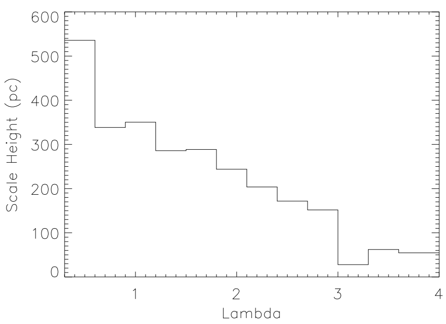

Fig. 4. Galactic scale height distribution as a function of the λ parameter for all the sources in the sample, excluding the Galactic Bulge.

The *'extremely blue subsample'* ($\lambda < 0.6$; H = 536 pc) is dominated by OH/IR stars that can be identified as the result of the evolution of low mass optically bright short period ($\lesssim$ 300 days) Miras (Jura 1994). These OH/IR stars should be the progenitors of so-called Type III PNe (Maciel & Dutra 1992).

The *'blue subsample'* ($0.6 < \lambda \leq 1.2$; H = 344 pc) is mainly formed by OH/IR stars identified as the result of the evolution of intermediate period ($\approx$ 300 days) Miras (Wood & Cahn 1977). These OH/IR stars should be the progenitor of low mass (O-rich) Type II PNe (Maciel & Dutra 1992).

The *'transition subsample'* ($1.2 < \lambda \leq 1.8$; H = 287 pc) populates the region in which OH/IR stars become optically thick. These OH/IR stars are the result of the evolution of intermediate period (300 - 500 days) Miras (Jura et al. 1993), will probably transform into C-rich AGB stars (Groenewegen et al. 1992), and must be the progenitors of high mass (C-rich) Type II PNe (Maciel & Dutra 1992).

The *'red subsample'* ($1.8 < \lambda \leq 3.0$; H = 193 pc) is formed by OH/IR stars with optically thick circumstellar envelope. These stars are probaly undergoing Hot Botton Burning proces, and should be the progenitors of Type I PNe (Maciel & Dutra 1992).

The *'extremely red subsample'* ($3.0 < \lambda$; H = 48 pc) is identified as the group containing the most massive OH/IR stars in our sample. They should be the precursors of the so-called OHPNe, heavily obscured OH/IR stars with radiocontinuum emission that have been proposed to be infrared PNe.

References

Bedijn, P. J. 1987, A&A, 186, 136

Blommaert, J.A.D.L., van der Veen, W.E.C.J., van Langevelde, H. J., Habing, H. J., & Sjouwerman, L. O. 1998, A&A, 329, 991

Groenewegen, M. A. T., de Jong, T., van der Bliek, N. S., Slijkhuis, S., & Willems, F. J. 1992, A&A, 253, 150

Jiménez-Esteban, F. M., Agudo-Mérida, L., Engels, D., & García-Lario, P. 2005a, A&A, 431, 779

Jiménez-Esteban, F. M., García-Lario, P., Engels, D., & Perea-Calderon, J. 2005b, A&A, submitted

Jura, M., Yamamoto, A., & Kleinmann, S. G. 1993, ApJ, 413, 298

Jura, M. 1994, ApJ, 422, 102

Knauer, T. G., Ivezić, Ž., & Knapp, G. R. 2001, ApJ, 552, 787

Maciel, W. J. & Dutra, C. M. 1992, A&A, 262, 271

Volk, K., & Kwok, S. 1988, ApJ, 331, 435

Wood, P.R., & Cahn, J.H. 1977, ApJ, 211, 499

Wood, P. R., Habing, H. J., & McGregor, P. J. 1998, A&A, 336, 925