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The importance of infrared observations for AGB star luminosities

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Abstract. The evolutionary properties of the Asymptotic Giant Branch stars (hereafter AGB) are still not fully understood. Some relevant problems debated today are the uncertainties in nuclear cross sections, the poor knowledge of the mixing mechanisms, the evolution of the stellar luminosity and the amount (and origin) of the mass loss phenomena. Stars in the final stages of the AGB phase present large circumstellar envelopes that need Infrared (IR) and radio observations to be analyzed. Inclusion of photometric data, especially from space-borne experiments, up to at least 30 μm is necessary to reconstruct properly the AGB emission. I present here a study of the IR properties of AGB stars, based on the whole existing database extending to mid-far infrared. In this review I discuss only some preliminary results about the C-rich and S-type stars, focusing on the topics for which future Infrared surveys from Antarctica could be crucial. This kind of surveys could be of great help in making our knowledge of the physical parameters of evolved stars more quantitative.

Key words. Stars: AGB and post-AGB – Luminosity – Mass Loss – Infrared Photometry

1. Introduction

Stars of low and intermediate mass ($M < 8M_{\odot}$) in the final stages of their life evolve through the AGB phase (Busso et al. 1999,and references therein). Here they experience extensive phenomena of mass loss that affect deeply their evolution. These processes are also fundamental for the enrichment of the Interstellar Medium, that is replenished by these stars with about 70% of all the matter returned after stellar evolution (Sedlmayr 1994). Moreover, AGB stars are the progenitors of planetary nebulae.

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The mass loss phenomena cause the formation of extended circumstellar envelopes (Winters et al. 2002). The radiative emission of the cool dust in the infrared dominates the energy distribution of the most evolved AGB stars, but is not negligible also for the less evolved ones. Until recently, the bolometric magnitudes of the evolved AGB stars were difficult to derive, mainly due to the insufficient photometric coverage of the mid-far IR range of the electromagnetic spectrum and to the difficulties in measuring the distances of such single, strongly variable stars.

Only in the last fifteen years, the availability of large IR databases from space-borne telescopes like ISO, IRTS, MSX, SPITZER and the increased quality and amount of ground-

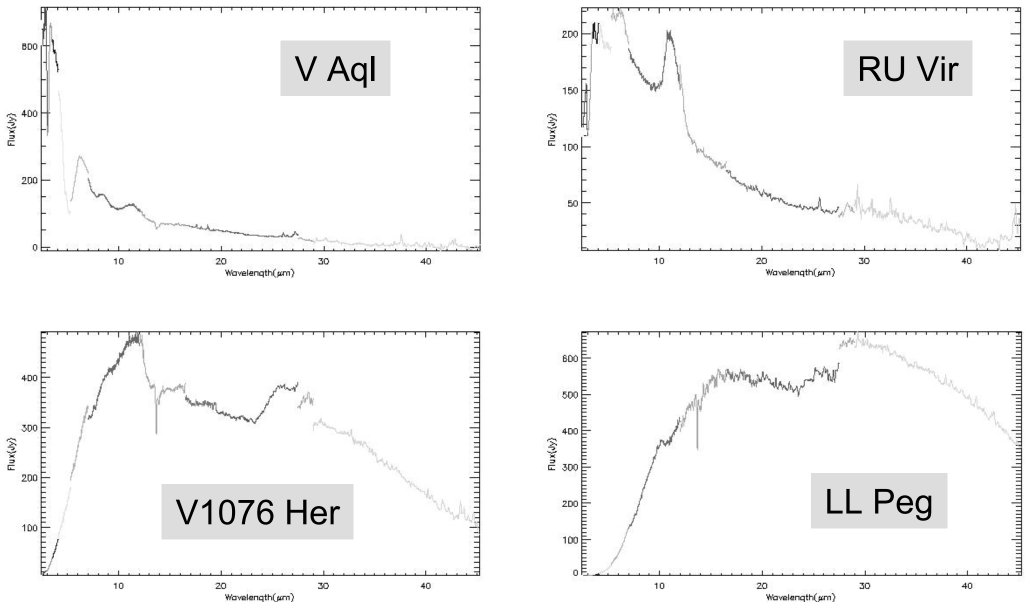

Fig. 1. SWS1 spectra for a semiregular variable (V Aql), two Mira variables (RU Vir and V1076 Her) and one post-AGB star (LL Peg). The dominant role of IR emission longward of 20 μm for Miras and post-AGB sources seems to be a general property for C-rich AGB stars.

based mid-IR observations has substantially improved the situation. Moreover, the estimates of the distances for AGB stars are now more reliable than before. Hipparcos distances have been corrected from various biases, mainly caused by the variability of the AGB sources (see Bergeat & Chevallier 2005), while the period-luminosity relations found for Mira sources have been thoroughly analyzed and refined (as can be seen e.g. in Whitelock et al. 2006,and references therein). The study of the fundamental physical parameters of these stars can now be performed in a rather quantitative point of view.

However, observations from space-borne telescopes in the IR present also disadvantages. In particular, the duration of the operational period is quite limited and AGB stars are generally studied with a single-epoch observation (a critical point considering their variability). In this way, our understanding of several basic physical parameters, which are fundamental in the study of AGB stars, is hindered. A complementary (but fundamental) role in solving these problems could be played by ground-based observations at IR wavelengths made from well-chosen locations, especially from Antarctica. In fact, the Antarctic Plateau presents the best conditions available on Earth from the point of view of infrared observations; actually, Antarctica should be the best place where ground-based observations in the (mid-)IR can be performed.

Our efforts are addressed to the preparation for IR observations of AGB stars from Antarctica through the IRAIT telescope (Tosti et al. 2007). With this aim we are trying to understand which kind of observations from Antarctica is most promising from the point of view of AGB stars. This contribution will stress only some selected topics of our analysis; a complete discussion about this study of Galactic C-rich and S-type AGB stars can be found in Guandalini et al. (2006); Busso et al. (2007); Guandalini & Busso (2007).

In this note, in particular, we address two main issues: in Section 2 we discuss some not–so–clear topics about AGB stars that could be

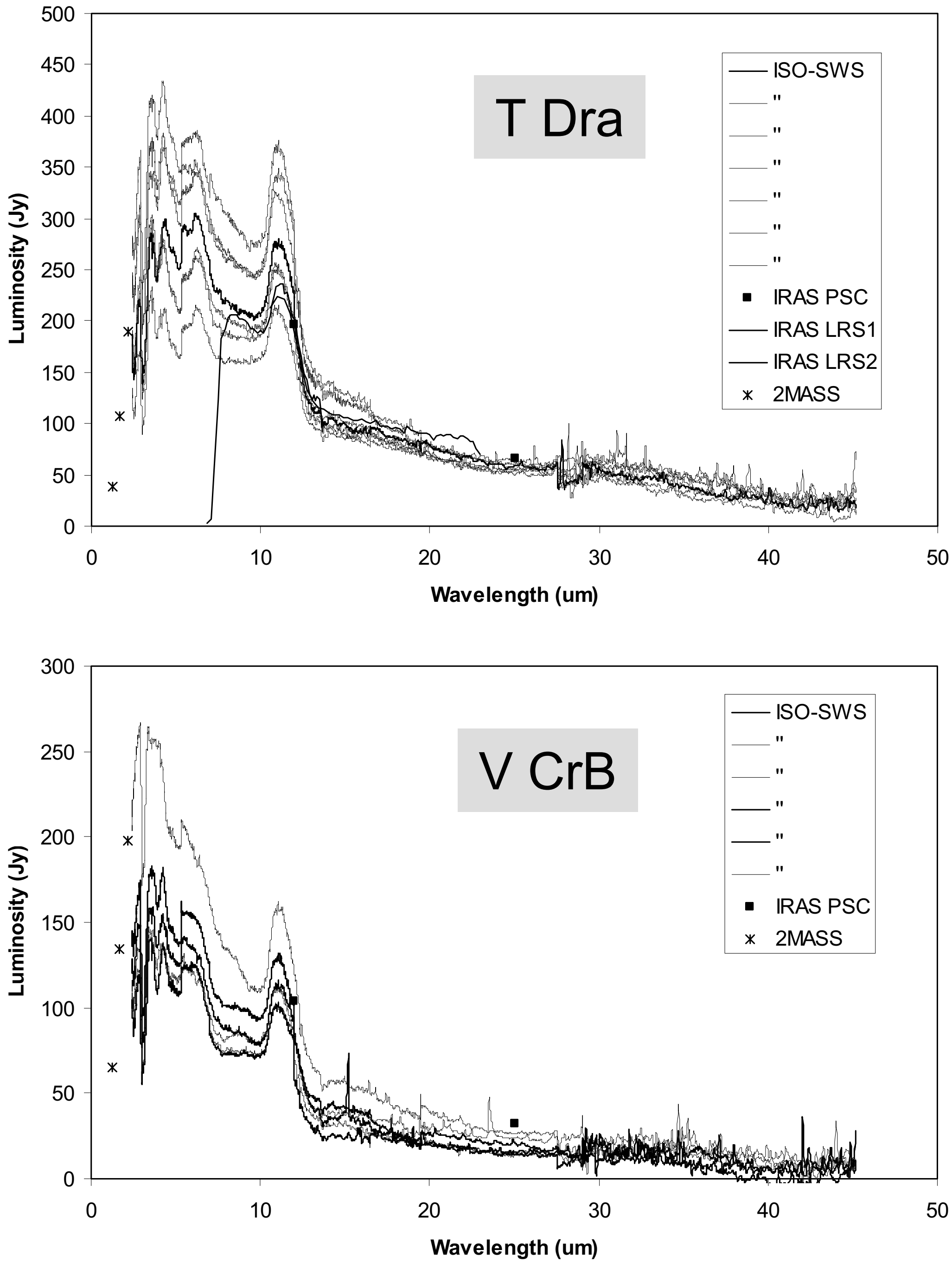

Fig. 2. Spectral Energy Distributions of two C-rich Miras that show significant variability over the time elapsed between the different observations. Data available from IRAS PSC, IRAS LRS, ISO-SWS, and 2MASS are included. Only sources with Mira-type variability appear to be variable, independent on their chemical composition (Busso et al. 2007).

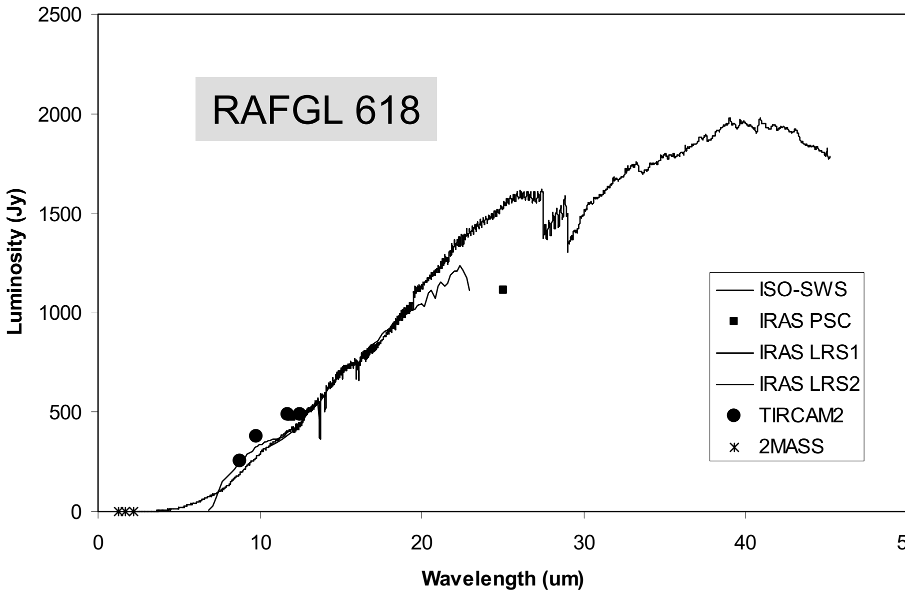

Fig. 3. The Spectral Energy Distribution of a non-variable Post-AGB source, as available from IRAS PSC, IRAS LRS, ISO-SWS, TIRCAM2 and 2MASS (for more details see Busso et al. 2007).

studied through ground-based observations. In Section 3 we present few preliminary results of our analysis.

2. Importance of Mid-IR and variability for AGB stars

There are several types of analysis, fundamental for our comprehension of AGB stars, that can be performed through observations at (mid-)IR wavelengths, both from space telescopes and ground-based facilities. Some examples are:

- accurate study of the photometric properties in the mid-IR region of the electromagnetic spectrum;
- analysis of light curves and therefore of variability;
- extension of variability studies to long wavelengths up to at least 40μm.

An extended wavelength coverage is fundamental in the study of the final evolutionary phases of stars of low and intermediate mass. Indeed, Figure 1 clearly shows that evolved AGB stars (Mira and post-AGB) emit a large part of their flux at mid-IR wavelengths (in particular for the region >15 μm). Therefore, observations in this region of the electromagnetic spectrum are necessary to improve our comprehension of several basic parameters of AGB stars and particularly of stellar luminosity that otherwise could be heavily underestimated.

Another "not–so–clear" problem of AGB stars is the bolometric variability. This phenomenon can be clearly distinguished in the region of the mid-IR of AGB star spectral energy distributions, as observed at different epochs (Fig. 2 and 3). From such observations we learn that, during the variability period, the luminosity is not only shifted at different wavelengths, but also subject to intrinsic variations, probably related to the addition of non-thermal sources of energy. There isn't still an agreement on the origin of these variations in the bolometric magnitude; they could be perhaps generated by shock waves caused by dynamic events in the photosphere or by

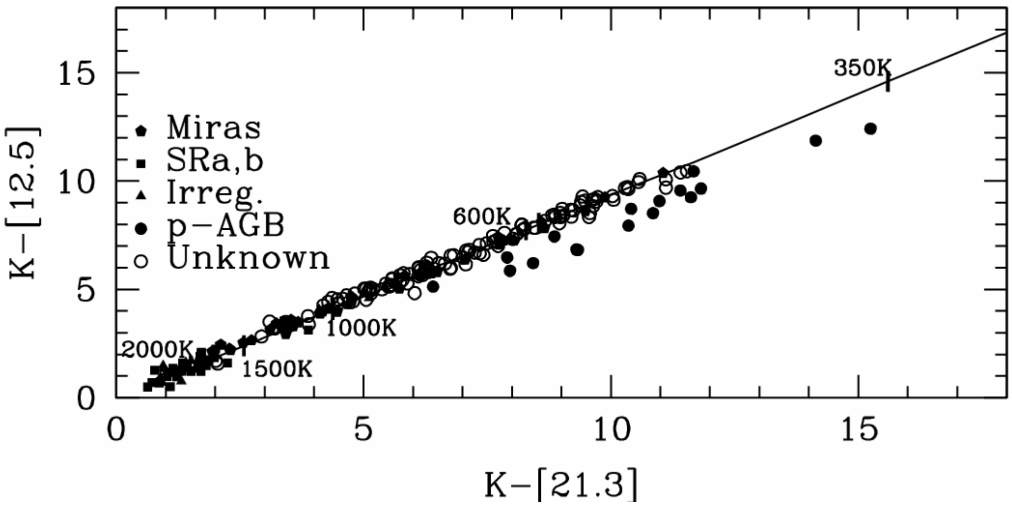

Fig. 4. An example of colour-colour diagram in the IR for C-rich AGB and post-AGB stars (Guandalini et al. 2006).

magneto-hydrodynamical (MHD) modes and magnetic storms. We notice that the best way to examine this variability is by observing AGB stars at different epochs also in mid-IR and this task could be performed in the best way by a ground-based telescope placed in Antarctica. At the same time, simultaneous observations in near- and mid-IR and correlations with optical variability could be extremely important.

3. Results with Mid-IR observations

In this section we briefly present a few preliminary results of our analysis on the evolutionary properties of galactic AGB stars that have been obtained through the use of both space-borne and ground-based (TIRCAM2) observations in mid-IR (for more details see Guandalini et al. 2006; Busso et al. 2007; Guandalini & Busso 2007). This analysis could further progress through new well-chosen ground-based observations in the mid-IR, that could be performed from Antarctica with the IRAIT telescope.

3.1. Post-AGB Stars

Excess emission at 21 μm is known to be a distinctive property of post-AGB C stars and C-rich pre-planetary nebulae (Kwok et al. 1999,Figure 3). However, so far the number of known sources with this feature was very limited: in our data this property seems to be shared by several objects.

Indeed, Figure 4 shows that, in a sample of galactic C-rich AGB sources observed by space-borne telescopes, only the post-AGBs (but also almost every post-AGBs) present an excess emission at 21 μm; this feature is confirmed also by the ground-based observations of TIRCAM2 (see Busso et al. 2007). Filters centered at 21 μm could be suitable to discover and examine post-AGB C-rich sources.

3.2. Bolometric corrections and bolometric magnitudes

The bolometric corrections presented in Figure 5 are fundamental tools to extend the number of sources for which precise bolometric magnitudes are known, thus including stars that have not been fully covered by observations. In panel *a)* a bolometric correction that we have calculated from a sample of galactic C-rich AGB stars is shown; in the bottom panel instead, a different bolometric correction obtained from a sample of S-type stars can be

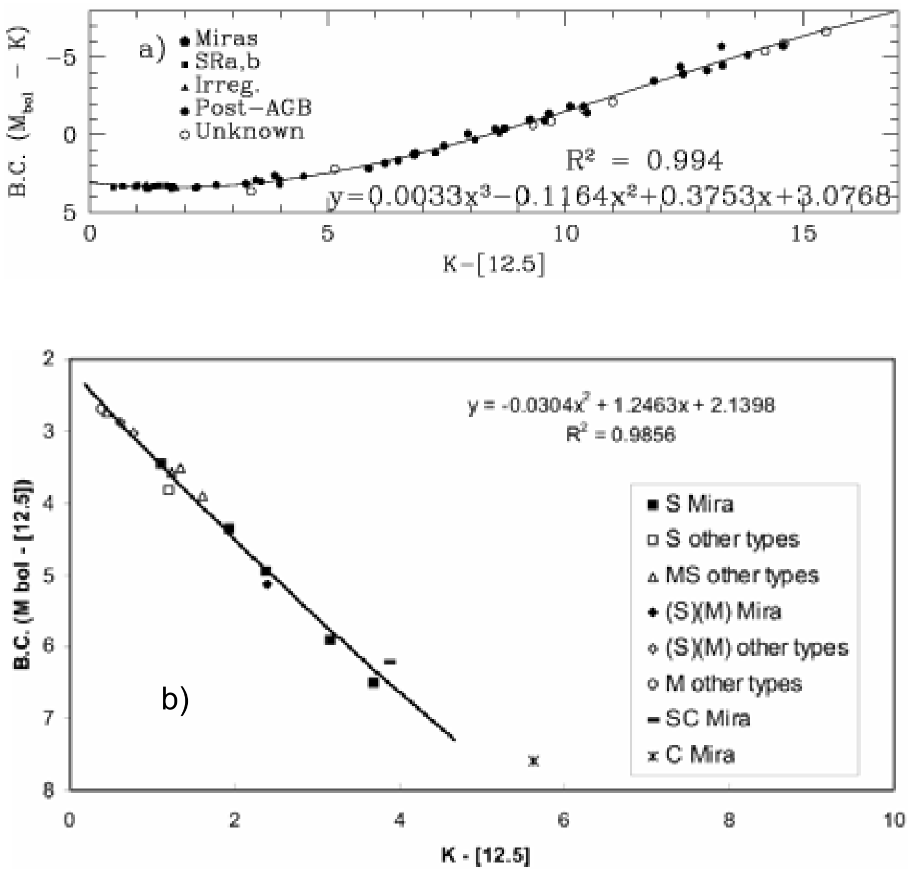

Fig. 5. Panel a): C-rich stars → Bolometric correction for the K magnitude as a function of the K–[12.5] colour. It was derived for AGB C-stars with complete SEDs, from 2MASS and ISO-SWS, up to 45 μm (from Guandalini et al. 2006). Panel b): S-type stars → Bolometric correction for the [12.5] magnitude as a function of the K–[12.5] colour. It was derived for AGB S stars with complete SEDs, from 2MASS and ISO-SWS, up to 45 μm (for more details see Guandalini & Busso 2007).

seen. Bolometric magnitudes can be estimated using these relations.

Histograms of the bolometric magnitude for samples of C-rich and S-type stars can be found in Guandalini et al. (2006) and Guandalini et al. (2007). The estimates of the luminosity that we derive for our sample of galactic C-rich stars agree well with the predictions of theoretical models, contrary to previous suggestions indicating the existence of under-luminous C stars. This problem in our work does not appear to exist. The expectations of the theoretical models are confirmed by our estimates because our luminosities are brighter than previously estimated due to a proper inclusion of the stellar emission up to 45 μm, whenever possible,

In general, bolometric magnitudes of AGB stars can definitely be improved though ground-based observations of their emission in the mid-IR.

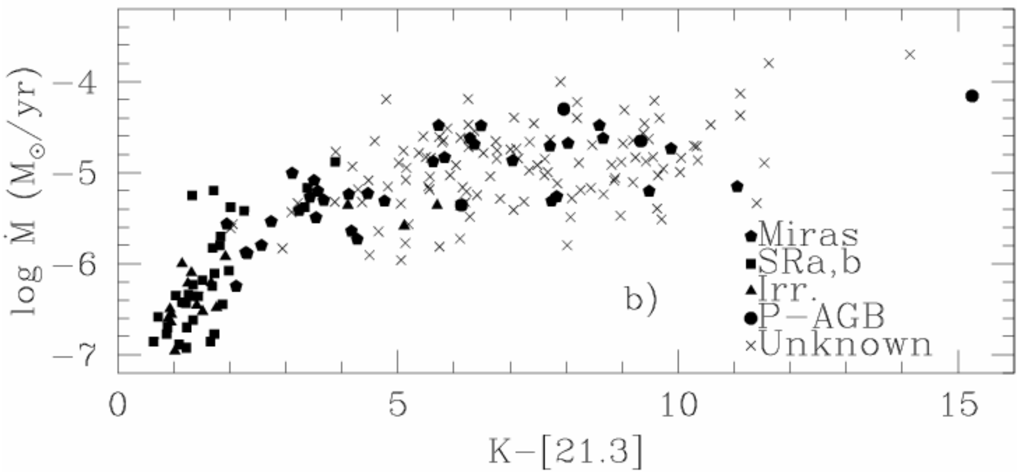

Fig. 6. Mass loss rate as a function of the K – [21.3] infrared color (from Guandalini et al. 2006).

3.3. Mass loss and IR colors

It is evident from Figure 6 that well-defined relations between mass loss and infrared colors can be found for C-rich stars (in this case for K -[21.3]). However, O-rich sources behave differently: the relation between (O-dominated) dust opacities and mass loss rates for M and S stars has to be quite different from that of C-stars. We shall verify this in a dedicated work on a larger database of S stars (Guandalini & Busso 2007). On the basis of the data available so far, it is not yet possible to state whether there exists any quantitative and usable relation between IR colors and mass loss for M and S giants.

4. Conclusions

There is a pressing need of understanding the final evolutionary phases of AGB stars, with a particular interest in the knowledge of the evolution of crucial physical parameters like i.e. the stellar luminosity and the rate of mass loss. In this way we could make quantitative assessments on:

- the amount of the matter returned to the InterStellar Medium;
- chemical evolution during the AGB phase;
- mass of the White Dwarfs that are the final remnants of the AGB evolution.

An update of the photometric analysis of AGB stars up to 40 μm is necessary to complete the analysis about these topics. This could be done e.g. from a ground-based Antarctic location. In this way we could also improve the preliminary results shown in this note with:

- light curves and therefore an improved knowledge of variability;
- an accurate study of the luminosity variations over a wide region of the electromagnetic spectrum, including optical and IR;
- a thorough analysis of the photometric properties in the mid-IR region of the electromagnetic spectrum;
- finally, a reliable comparison between observations and theoretical models of AGB stars.

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References

Bergeat, J., & Chevallier, L. 2005, A&A, 429, 235

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

Busso, M., Guandalini, R., Persi, P., Corcione, L., & Ferrari-Toniolo, M. 2007, AJ, 133, 2310

Guandalini, R., Busso, M., Ciprini, S., Silvestro, G., & Persi, P. 2006, A&A, 445, 1069

Guandalini, R., Busso, M., & Cardinali, M. 2007, in Why Galaxies care about AGB Stars, in press in ASP Conference Series

Guandalini, R., & Busso, M. 2007, in preparation

Kwok, S., Volk, K., & Hrivnak, B.J. 1999, IAUS, 191, 297

Sedlmayr, E. 1994, Lecture Notes in Physics, 428, 163

Tosti, G., et al. 2007, in 1st ARENA Conference, in press in EDP Sciences (EAS Publications Series)

Whitelock, P.A., Feast, M.W., Marang, F., & Groenewegen, M.A.T. 2006, MNRAS, 369, 751

Winters, J.M., Le Bertre, T., Nyman, L.-Å., et al., 2002, A&A, 388, 609