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Mass loss rates of Li-rich AGB/RGB stars from GAIA data

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Abstract. A recent determination of the mass loss rates of Li-rich AGB/RGB stars based on two independent methods suggests that their luminosities as well their mass loss rates are much lower than in the case of Li-poor stars, which form the majority of AGB/RGB stars. This is in contrast with some suggestions in the literature that the Li enrichment phenomenon may be associated with enhanced mass loss rates. In this work, we determine the mass loss rates of Li-rich AGB/RGB stars based on recent GAIA DR2 data. We consider two methods, the first one based on a correlation between the Li abundances and the stellar luminosity, and the second based on a correlation between the mass loss rate and some stellar parameters. These methods are applied to GAIA data, which include new results for some of the physical properties of the stars. As a result, some differences are observed relative to the results based on earlier distances and luminosities, in particular a somewhat broader luminosity range is derived. It can be concluded that the new GAIA data confirm the previous results on the mass loss rates and luminosities of Li-rich stars, in the sense that both the average luminosities and mass loss rates of these stars are usually lower than the corresponding values of Li-poor objects. A comparison can then be made between the new results for Li-rich stars and the well determined mass loss rates and luminosities of Li-poor stars available in the literature.

Resumo. Uma determinação recente das taxas de perda de massa de estrelas AGB/RGB ricas em Li baseada em dois métodos independentes sugere que suas luminosidades e taxas de perda de massa são muito mais baixas do que no caso de estrelas pobres em Li, que formam a maioria das estrelas AGB/RGB. Isto contrasta com algumas sugestões na literatura de que o fenômeno de enriquecimento de Li pode estar associado a taxas de perda de massa acentuadas. Neste trabalho, determinamos as taxas de perda de massa de estrelas AGB/RGB ricas em Li com base em dados recentes do levantamento GAIA DR2. Consideramos dois métodos, o primeiro baseado em uma correlação entre as abundâncias de Li e a luminosidade estelar, e o segundo baseado em uma correlação entre a taxa de perda de massa e alguns parâmetros estelares. Estes métodos são aplicados aos dados do GAIA, que incluem novos resultados para algumas propriedades físicas das estrelas. Como resultado, algumas diferenças são observadas com relação aos resultados baseados em determinações anteriores das distâncias e luminosidades, em particular um intervalo mais largo das luminosidades é determinado. Pode ser concluído que os novos dados do GAIA confirmam os resultados anteriores sobre as taxas de perda de massa e as luminosidades das estrelas ricas em Li, no sentido de que tanto as luminosidades médias como as taxas de perda de massa destas estrelas são geralmente mais baixas que os valores correspondentes para os objetos pobres em Li. Uma comparação pode então ser feita entre os novos resultados para as estrelas ricas em Li e as taxas de perda de massa e luminosidades mais bem determinadas para as estrelas pobres em Li disponíveis na literatura.

Keywords. Stars: AGB and post-AGB – Stars: mass-loss – Stars: abundances

1. Introduction

It is well known that there is a sample of AGB/RGB stars with an excess of Li abundances, $\epsilon(\mathrm{Li}) > 1.5$, which is sometimes associated with an enhanced mass loss rate. We have recently estimated of the mass loss rates of a large sample of AGB/RGB stars using two different methods. The first one is based on a correlation between the stellar luminosity and the Li abundances, making use of a newly calibrated Reimers formula; the second method was originally proposed by van Loon et al. (2005), and is based on a direct determination of the mass loss rates as a function of some stellar parameters (Maciel & Costa (2018)). We have found that both the luminosities and the mass loss rates of the stars in our sample are consistently smaller than the corresponding values for Li-poor stars, for which much better determinations of the mass loss rates are available. The luminosity is a key parameter in the determination of the mass loss rates, as the mass ejection is probably due to the action of the stellar radiation pressure on atoms and ions in the stellar outer atmosphere. In the present work we consider again both methods, using the data recently released by the GAIA project (Brown et al. (2018)). We have found GAIA data for 115 stars, out of our previous sample of 159 stars.

The sample considered in this work is discussed in detail in Maciel & Costa (2018) and the full table containing the previous results and input data can be found in http://www.astro.iag.usp.br/~maciel/research/articles/art170-table.pdf.

2. Determination of the mass loss rates

As discussed in detail by Maciel & Costa (2018), we have adopted two different methods to estimate the mass loss rates of Li-rich giant stars. The first method uses a modified Reimers formula that can be written as

$$\frac{dM}{dt} = 4 \times 10^{-13}\, \eta\, \frac{(L/L_\odot)\,(R/R_\odot)}{(M/M_\odot)} \tag{1}$$

The mass loss rate is given in $M_\odot$/yr, and the η parameter was found to be $\eta = 5.7$. The second method was proposed by van Loon et al. (2005), based on the modelling of the spectral energy distributions of a sample of red giants in the Large Magellanic Cloud. The formula can be written as

$$\log \frac{dM}{dt} = \alpha + \beta\, \log\left(\frac{L}{10000\, L_\odot}\right) + \gamma\, \log\left(\frac{T_{eff}}{3500\,\mathrm{K}}\right) \tag{2}$$

where the mass loss rate is given in $M_\odot$/yr, and the constants are $\alpha = -5.64 \pm 0.15$, $\beta = 1.05 \pm 0.14$ and $\gamma = -6.3 \pm 1.2$.

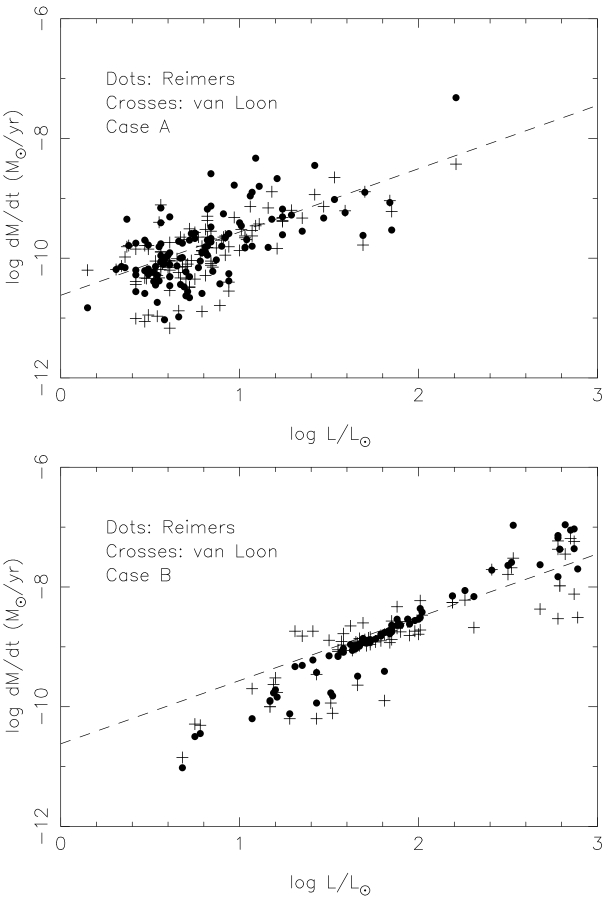

FIGURE 1. Mass loss rates of Li-rich AGB/RGB stars as a function of the stellar luminosity. (a) Results using the modified Reimers formula (dots) and the van Loon approximation (crosses) for Case A. (b) The same for Case B.

3. Results and Discussion

We have considered two cases, namely Case A and Case B, defined on the basis of the data selected from the GAIA archive.
Case A - A preliminary approach consists in adopting the GAIA effective temperature and modifying the stellar luminosity accordingly. We assume that the distances and radii are not significantly modified by the new data. In this case, the mass loss rates can be written as a function of the previously obtained rate and the new effective temperatures, both for the modified Reimers formula and the van Loon formula.
Case B - As a second and more reliable approach, we have adopted the new values of the effective temperature, luminosity and radius as given in the GAIA archive, assuming that the stellar mass does not change appreciably. In this case the mass loss rates can be obtained directly from eqs. (1) and (2), using the new GAIA values.

The main results are shown in figure 1, where the mass loss rates are given as a function of the luminosity. The dots represent Method 1 (Reimers) and the crosses are for Method 2 (van Loon), both for Case A and Case B. The dashed line shows the least squares fit for Li-rich stars from our previous work and is included for comparison.

Case A displays essentially the same distribution obtained in our previous work, since the main differences arise from the new values of the effective temperatures, which do not present large discrepancies relative to our previous values. For Case B we notice that the luminosities and mass loss rates are usually larger and spread over a larger range, presenting a smaller dispersion relative to the average relation for Li-rich stars. This implies a more realistic distribution of the stellar luminosities, providing a smoother connection with the high luminosity Li-poor stars. In fact, in our previous work (Maciel & Costa (2018)) we have compared the mass loss rates and luminosities of Li-rich stars with the corresponding quantities for Li-poor objects, and found that the latter have typical luminosities in the range $3 \leq L/L_\odot \leq 5$, therefore higher than the values shown in figure 1. The mass loss rates for the Li-poor stars show a larger range, $-10 \leq \log dM/dt \leq -5$, again reaching higher values than Li-rich stars. It can be concluded that the mass loss rates and especially the luminosities reach somewhat higher values than in the previous determination, but these quantities are still much lower than for Li-poor stars, as confirmed by some estimates by Groenewegen and collaborators (Groenewegen et al. (2009), Groenewegen & Sloan (2018)) and Gullieuszik et al. (2012).

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