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 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.

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, $\epsilon(\text{Li}) > 1.5$, which is sometimes associated with an enhanced mass loss rate. We have recently estimated 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

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

(1)

The mass loss rate is given in $M_\odot$/yr, and the $\eta$ 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

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

(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 $\gamma = -6.3 \pm 1.2$. 

159
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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