

Rb and Zr abundances in massive Galactic AGB stars revisited

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Abstract. We report new abundances of Rb and Zr in a sample of massive Galactic asymptotic giant branch (AGB) stars that were previously studied with hydrostatic models by using more realistic dynamical model atmospheres. We use a modified version of the spectral synthesis code Turbospectrum, and consider the presence of a circumstellar envelope and a radial wind in the modelling of these Galactic AGB stars. The Rb and Zr are determined from the 7800 Å Rb I resonant line and the 6474 Å ZrO bandhead, respectively, and they are compared with the AGB nucleosynthesis theoretical predictions. The derived Rb abundances are much lower ($\sim 1-2$ dex) with the new dynamical models, while the Zr abundances, however, are closer to the hydrostatic values. The new model atmospheres can help to resolve the problem of the mismatch between the observations and the nucleosynthesis theoretical predictions of massive AGB stars.

1. Observational data and models

We have used high-resolution optical echelle spectra ($R \sim 50,000$) in a sample of 21 massive Galactic AGB stars (see [1, 2]). The S/N ratios achieved in the reduced spectra strongly vary from the blue to the red orders (typically $\sim 10-20$ at 6000 Å and >100 at 8000 Å). By using new dynamical model atmospheres recently developed by us [3], we obtain reliable Rb (and Zr) photospheric abundances for 12 stars in our sample. The rest of stars displayed more than one circumstellar contribution, which cannot be reproduced by our present modified version of the Turbospectrum spectral synthesis code.

2. Results

The new Rb abundances derived from our dynamical models display an average decrease of 1 dex with respect to the static case. Fig. 1 shows that our dynamical atmosphere models reproduce the observed 7800 Å Rb I line much better than the classical hydrostatic models. However, the Zr abundances derived from dynamical models are similar to those obtained with



the hydrostatic models because the 6474 Å ZrO bandhead is formed deeper in the atmosphere and is less affected than the Rb I line [3].

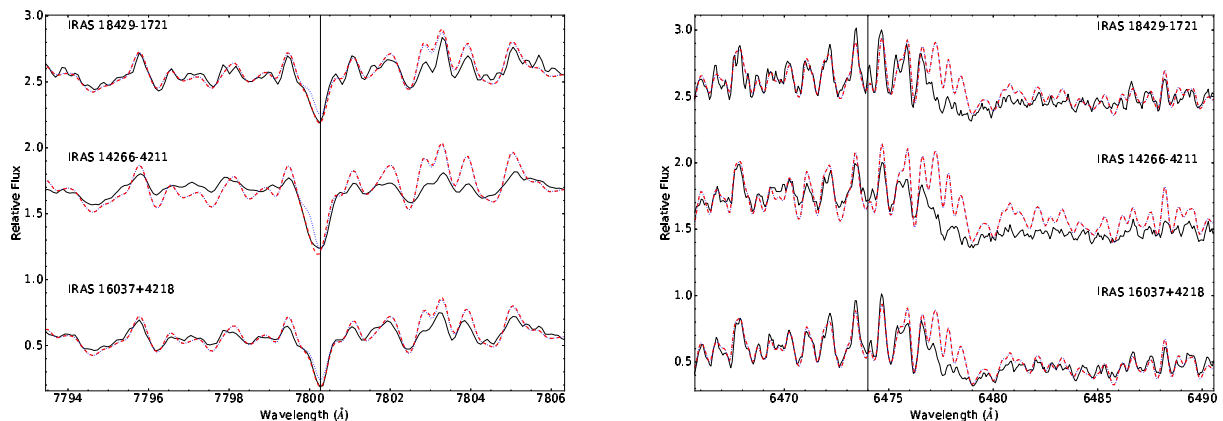


Figure 1. The Rb I 7800 Å (left panel) and ZrO 6474 Å (right panel) spectral regions in three massive Galactic AGB stars. The dynamical model best fits (dashed lines) to the observations (solid lines) in three sample stars are shown. For comparison, the hydrostatic models are also displayed (dotted lines). Note that the dynamical and hydrostatic models are identical in the right panel.

A comparison with standard nucleosynthesis models for massive AGB stars shows that the predicted Rb abundances range from $[\text{Rb}/\text{Fe}] \sim 0.00$ up to 1.04 dex for solar metallicity stars as those studied here; the maximum Rb is found for a $6.5 M_{\odot}$ star [4]. On the other hand, Karakas et al. [5] delayed the beginning of the superwind phase in massive AGB models and this increases the Rb production up to $[\text{Rb}/\text{Fe}]=1.34$ dex (for the $6 M_{\odot}$ case).

The Rb abundances and $[\text{Rb}/\text{Zr}]$ ratios previously derived with hydrostatic models [1, 2] represented a challenge for the theoretical models because both quantities are much larger than theoretically predicted values. The Rb abundances were correlated with the OH expansion velocity in the static case, while the Rb- $V_{exp}(\text{OH})$ distribution is now more flatter in the dynamical case. In short, the Rb abundances and $[\text{Rb}/\text{Zr}]$ ratios derived here could resolve the previous mismatch between the observations of massive Galactic AGB stars and the theoretical predictions.

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3. References

- [1] García-Hernández D A, García-Lario P, Plez B, D’Antona F, Manchado A and Trigo-Rodríguez J M 2006 *Science* **314** 1751
- [2] García-Hernández D A, García-Lario P, Plez B, Manchado A, D’Antona F, Lub J and Halbing H 2007 *Astron. Astrophys.* **462** 711
- [3] Zamora O, García-Hernández D A, Plez B and Manchado A 2014 *Astron. Astrophys.* **564** L4
- [4] van Raai M A, Lugaro M, Karakas A I, García-Hernández D A and Yong D 2012 *Astron. Astrophys.* **540** 44
- [5] Karakas A I, García-Hernández D A and Lugaro M 2012 *Astrophys. J.* **751** 8