

When binaries keep track of recent nucleosynthesis

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Abstract. We determine Zr and Nb elemental abundances in barium stars to probe the operation temperature of the s-process that occurred in the companion asymptotic giant branch (AGB) stars. Along with Zr and Nb, we derive the abundances of a large number of heavy elements. They provide constraints on the s-process operation temperature and therefore on the s-process neutron source. The results are then compared with stellar evolution and nucleosynthesis models. We compare the nucleosynthetic profile of the present sample stars with those of CEMP-s, CEMP-rs and CEMP-r stars. One barium star of our sample is potentially identified as the highest-metallicity CEMP-rs star yet discovered.

Keywords. stars: AGB, stars: binaries, stars: abundances

1. Introduction

Barium stars are s-process enriched giants; they owe their chemical peculiarities to a past mass transfer, during which they were polluted by their binary companion, which at the time was an asymptotic giant branch (AGB) star, but now an extinct white dwarf. Hence barium stars are ideal targets to understand and constrain the s-process in AGB stars. Actually, since the $^{93}\text{Zr}/\text{Zr}$ isotopic ratio is a sensitive function of the s-process operation temperature (independently of stellar evolution models), and since, in extrinsic stars, ^{93}Zr has fully decayed into mono-isotopic ^{93}Nb , we can use the Nb/Zr abundance ratio to constrain the s-process operation temperature. Adopting a recent methodology (Neyskens *et al.* 2015), we analyze a sample of highly-enriched barium stars observed with the high-resolution HERMES spectrograph (Raskin *et al.* 2011) mounted on the MERCATOR telescope (La Palma). Atmospheric parameters for the majority of the programme stars are derived using the BACCHUS pipeline (Masseron *et al.* 2016). Abundances for all the elements are derived by comparing observed spectra with synthetic spectra generated by the Turbospectrum radiative transfer code using MARCS model atmospheres.

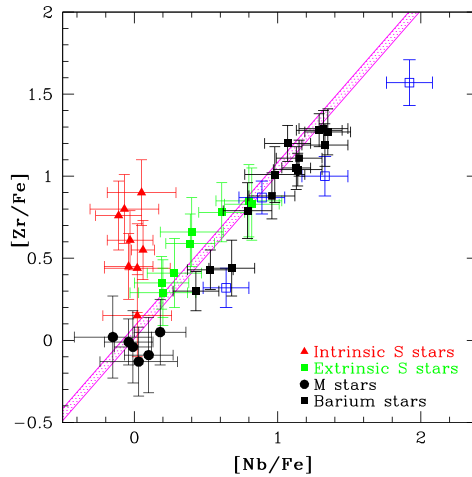


Figure 1. Distribution of $[Zr/Fe]$ vs. $[Nb/Fe]$ for our target stars.

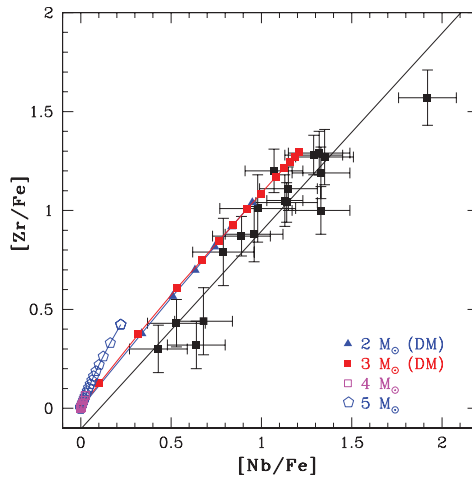


Figure 2. Predictions from the STAREVOL code for extrinsic stars.

2. Results and Discussions

Four objects in our sample are found to be nitrogen rich (blue squares in Fig. 1). Among these four objects, three are found to be Nb-rich (see Fig. 1) with high Nb/Zr ratio. Also, these three objects are found to be Na-rich indicating possible hot bottom burning (HBB) in their companion. We could not derive Mg abundances in all these objects, hence we were not able to test the HBB occurring in massive AGB stars. Most of the objects are falling in the magenta shaded band in Fig. 1, which indicates the expected location of stars polluted by material resulting from the s-process operating at temperatures between 10^8 K (upper line) and $3 \cdot 10^8$ K (lower line) for $^{13}\text{C}(\alpha, n)^{16}\text{O}$ neutron source. Moreover, Zr and Nb predictions from the STAREVOL code for 2, 3, 4, or 5 M_{\odot} stars with $[\text{Fe}/\text{H}] = -0.5$ (Fig. 2) rule out the operation of a high temperature s-process in the former companion AGB stars that polluted our programme stars.

Possible i-process candidates

Among the three N- and Nb- rich objects, two objects, HD 100503 and HD 121447 are found to be also enriched with r-process elements and show high [hs/lr] ratios. HD 121447 is highly s-process enriched which is consistent with its short orbital period of 185 days. We have compared the abundance patterns in these objects with CEMP-s, CEMP-r and CEMP-rs stars from [Masseron *et al.* \(2010\)](#). HD 100503 is found to be in the CEMP-rs group and is identified as a potential analogue of CEMP-rs star at higher metallicity; if its abundance pattern originates from the i-process, it could help constraining this process at higher metallicities.

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References

- Masseron, T., Johnson, J. A., Plez, B., Van Eck, S., Primas, F., Goriely, S., & Jorissen, A. 2010, *A&A*, 509, A93
- Masseron, T., Merle, T., & Hawkins, K., 2016, *ascl*, 1605.004
- Neyskens, P., Van Eck, S., Jorissen, A., Goriely, S., Siess, S., Plez, B. 2015, *nature*, 517, 174
- Raskin, G., van Winckel, H., Hensberge, H., Jorissen, A., Lehmann, H., Waelkens, Avila, G., de Cyper, J.-P., *et al.* 2011, *A&A*, 526, A69