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Predictions for low-metallicity s-process Lead stars showing peculiar r-process enhancements

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Abstract. Spectroscopic abundances of s- and r-process enriched very metal-poor stars are interpreted as the result of mass transfer in a binary system from an AGB companion assuming an initial composition of the parental cloud pre-enriched in r elements. The spectroscopic determination of [Na/Fe], [Mg/Fe] and [ls/Fe] permits an estimate of the initial AGB stellar mass, while a value [Zr/Nb] ≈ 0 is a nuclear indicator of an extrinsic AGB in a binary system.

Keywords. Nuclear reactions, nucleosynthesis, abundances, stars: abundances, stars: AGB, stars: binaries, stars: Population II, stars: individual(CS22948-027,CS31062-050)

We analyse a sample of very metal-poor stars, C-rich and s-process rich, using AGB nucleosynthesis models for different initial masses, metallicities and ^{13}C-pocket efficiencies (e.g., Gallino *et al.*, these Proceedings). An important fraction of these stars are strongly r-process enriched, with [Eu/Fe] = 1.5 to 2. In fact, while an s-process ratio $[\mathrm{La/Eu}]_s = +0.70$ dex is predicted at these metallicities, CS 22948-27 shows [La/Eu] = 0.44, (Barbuy *et al.* 2005), CS 31062-050 [La/Eu] = 0.33 (Johnson *et al.* 2004), CS 29497-030 [La/Eu] = 0.23 (Ivans *et al.* 2005), HE 2148-1247 [La/Eu] = 0.40 (Cohen *et al.* 2003), CS 22898-027 [La/Eu] = 0.25 (Aoki *et al.* 2002). A best fit for CS 22948-27 and CS 31062-050 is shown in Fig. 1, assuming an initial ratio $[\mathrm{Eu/Fe}]^{ini} = 1.5$, an AGB mass $M \approx 1.3 M_\odot$ and two different choices for the ^{13}C-pocket efficiency, ST/7.5 and ST/6 (the case ST corresponds to the choice of Arlandini *et al.* 1999). Given the adopted Eu enhancement, the initial abundance of all heavy nuclides was modified accordingly, on the basis of their solar system r-process contribution (Arlandini *et al.* 1999). Besides Eu, other r-elements observed are Gd, Tb, Dy, Ho, Er, Tm. In a preliminary study (Delaude *et al.* 2004) the r contributions were added to the initial composition of the observed star only. Predicted and observed elemental abundances are normalised to solar photospheric abundance values by Lodders (2003). The discrepancy between observed and predicted C and N in CS 22948-27 may be reconciled by the operation of an efficient cool bottom process during the TP-AGB phase (Nollett *et al.* 2003). In Fig. 2 (panel a) we compare the s-process predictions for an AGB model of $M = 1.3 M_\odot$ and case ST, using $[\mathrm{Eu/Fe}]^{ini}$ = 2, or $[\mathrm{Eu/Fe}]^{ini} = 1.5$, with the case with no r-enrichment. The pre-enrichment in r elements acts as a strong poison for the neutron exposure (see also Ivans *et al.*, these Proceedings). AGB models of very low metallicity predict an important production of primary Na and Mg, which may constrain the initial mass. In Fig.2 (panel b) we show the results of AGB models for different initial masses, the same ^{13}C-pocket and [Fe/H] = − 2.60. By increasing the initial mass, we obtain [Na/Fe] = 0.6 and [Mg/Fe] = 0.5

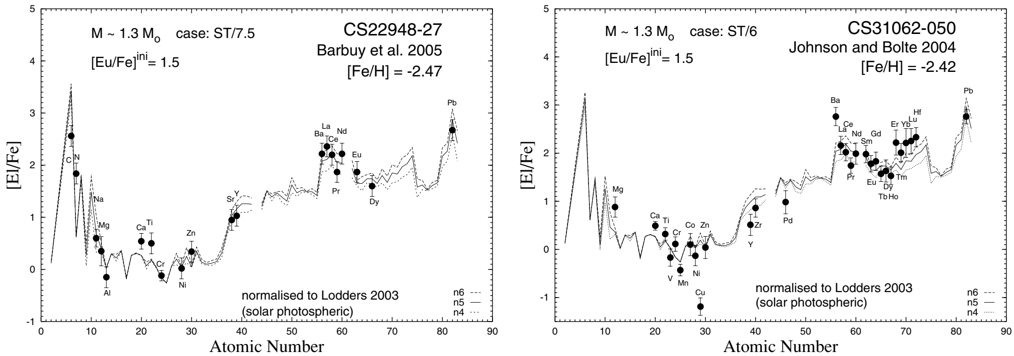

Figure 1. Panel a): Comparison between the [El/Fe] abundances in CS 22948-27 with s+r process predictions. Panel b): The same for the CS 31062-050. Symbols n_i indicate the number of thermal pulses with third dredge up.

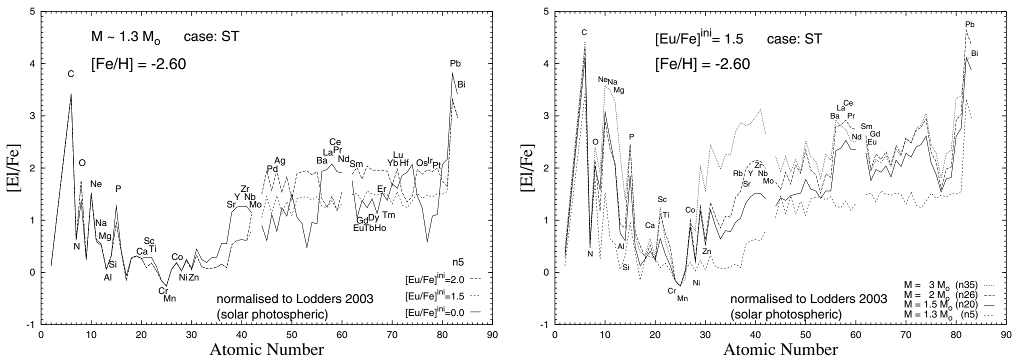

Figure 2. Panel a): Theoretical s+r-process predictions for different initial value of [Eu/Fe]. Panel b): Theoretical s-process predictions for different masses (case ST, [Fe/H] = −2.60). Dilution by 0.2 dex of C and s-elements by mass transfer are conceivable.

for $M = 1.3M_\odot$, [Na/Fe] $\simeq$ 2.4 and [Mg/Fe] $\simeq$ 2.0 in the range 1.5 to 2 $M_\odot$, and up to [Na/Fe] = 3.5 and [Mg/Fe] = 3.2 for $M = 3M_\odot$. A strong primary production of ^{22}Ne results in the advanced pulses, by the conversion of primary ^{12}C to ^{14}N in the H-burning ashes, followed by 2α captures on ^{14}N in the thermal pulses, implying a primary production of ^{23}Na via ^{22}Ne(n,γ)^{23}Na. Mg production derives from ^{23}Na(n,γ)^{24}Mg and from ^{22}Ne(α,n)^{25}Mg and ^{22}Ne(α,γ)^{26}Mg. Another signature of the initial mass is the large spread of [ls/Fe], with a minimum at $M = 1.3M_\odot$, compared with a much lower spread for [hs/Fe]. An expanded paper on these results is in preparation.

References

Aoki, W., *et al.* 2002, *ApJ* 580, 1149
Arlandini, C., *et al.* 1999, *ApJ* 525, 886
Barbuy, B., *et al.* 2005, *A&A* 429, 1031
Cohen, J.G., Christlieb, N., Qian, Y.Z., & Wasserburg, G.J. 2003, *ApJ* 588, 1082
Delaude, D., *et al.* 2004, *Mem. Soc. Astron. It.* 75, 706
François, P., *et al.* 2004, *A&A* 421, 613
Johnson, J.A. & Bolte, M. 2004, *ApJ* 605, 462
Ivans, I.I., Sneden, C., Gallino, R., Cowan, J.J., & Preston, G.W. 2005, *ApJ* 627, L145
Lodders, K. 2003, *ApJ* 591, 1220
Nollett, K. M., *et al.* 2003, *ApJ* 582, 1036