From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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Abundances of *s*-elements in Extragalactic Carbon Stars

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Abstract. Carbon stars found in the Small Magellanic Cloud and the Sagittarius Dwarf Spheroidal galaxy have been chemically analysed. We found that the abundance ratios derived between elements belonging to the first and the second s-process abundance peaks agree remarkably well with the theoretical predictions of low mass metal-poor AGB nucleosynthesis models. Together with their estimated luminosities, their derived abundances and their carbon isotopic ratio we speculate on the evolutionary status of these carbon stars.

Keywords. Stars: carbon, stars: abundances, galaxies: abundances, nuclear reactions, nucleosynthesis, abundances

1. Introduction

AGB stars are believed to be the main producers of *s*-elements in the Universe. However, their effective production of these chemical elements and its dependence with the stellar metallicity and mass is still rather poorly constrained by observations. On another hand, current models are rather well advanced. They predict that the relative abundances of the *s*-peak nuclei (Zr, Ba and Pb) vary according to the stellar metallicity (the larger Pb/Ba/Zr ratios the lower [M/H]). By deriving the chemical abundances of 3 extragalactic carbon stars with low metallicity, we provide constraints to the evolutionary status of these stars and discuss our results in the framework of AGB nucleosynthesis models. This work is presented with more details in de Laverny *et al.* (2005).

2. Chemical analysis

From VLT/UVES spectra, we have performed the chemical analysis of one carbon star in the SMC (BMB-B 30) and two stars of the Sagittarius Dwarf Spheroidal galaxy (IGI95-C1 and IGI95-C3). For this analysis, we have used new carbon-rich MARCS model atmospheres and specific atomic and molecular linelists. We have been able to derive the C/O (assuming solar scaled O and N abundances) and $^{12}C/^{13}C$ ratios, and abundances of some metals, of low (Sr, Y, Zr) and high (La, Nd, Sm) mass *s*-elements. The stellar parameters and some derived abundances are reported in Tab. 1. In this table, the C/O ratios indicate the range of values estimated from the analysis of the different spectral ranges. Regarding the bolometric magnitude, the first value indicates the luminosity obtained from M_K according to the calibration by Alknis *et al.* (1998) and the second one was derived after the bolometric correction by Wood *et al.* (1983).

Table 1. Stellar parameters, metallicity and the s-process indices of the extragalactic C-stars studied. [M/H] is the derived mean metallicity, s, ls and hs refer to s-elements, light and heavy s-elements, respectively.

Star	$T_{\rm eff}$(K)	[M/H]	C/O	ϵ(C)−ϵ(O)	^{12}C/^{13}C	$M_{\rm bol}$	[s/M]	[ls/M]	[hs/M]	[hs/ls]
IGI95-C1	3 300	−0.80	1.18-1.06	7.23	25	−3.1, −3.3	1.07	0.63	1.50	0.88
IGI95-C3	2 900	−0.50	1.10-1.05	7.33	40	−4.5, −4.5	0.95	0.95	0.95	0.00
BMB-B 30	3 000	−1.00	1.20-1.09	7.35	> 300	−5.6, −5.1	0.90	0.50	1.30	0.80

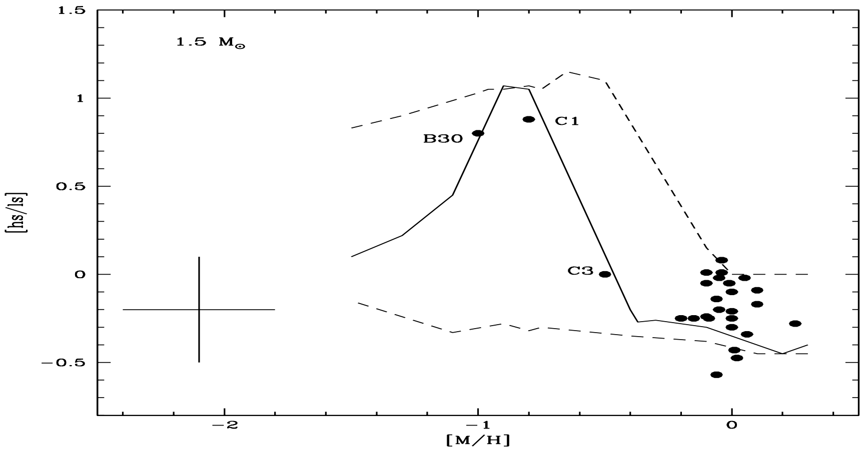

Figure 1. Comparison of the observed mean of heavy (Ba, La, Nd and Sm) to light-mass (Sr, Y and Zr) s-element [hs/ls] enhancement against metallicity with theoretical prediction for a 1.5 $M_\odot$ TP-AGB from Gallino *et al.* (1998). Continuous line represents the ST (standard) choice of the ^{13}C-pocket while dashed lines limit the area allowed by the choices from STx2 to ST/12. The location of the stars studied here are marked. At near solar metallicity, the Galactic carbon stars studied in Abia *et al.* (2002) are shown for comparison.

3. Discussion

The chemical analysis of these three extragalactic carbon stars gives new constraints for stellar evolution models. Indeed, rather low C/O ratios and large s-elements enhancements are found as in Galactic carbon stars. Furthermore, abundance ratios of light and heavy s-elements are in good agreement with theoretical predictions of low mass (<3 $M_\odot$) metal-poor AGB nucleosynthesis models (see Figure 1). We thus suggest that the main source of neutrons might be the ^{13}C(α,n)^{16}O reaction. However, the C/O and ^{12}C/^{13}C ratios are more difficult to reconcile with theoretical expectations. Finally, since the distance of these extragalactic carbon stars are rather well known, we have estimated their total luminosity. We then propose that BMB-B 30 and IGI95-C3 are intrinsic carbon stars whereas IGI95-C1 might be extrinsic.

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