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The role of overshooting treatment in the s-process weak component efficiency

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Abstract. Using a new s-nucleosynthesis code simulations have been performed to study the impact of overshooting convective on the s-process during core He-burning of a 25 $M_{\odot}$ star (ZAMS mass) with initial Z = 0.02 metallicity. Attention has been devoted to the role played by the overshooting parameter value. The results show enhancements of about a factor 2-3 in s-process efficiency when overshooting is considered in the calculations, with overshooting parameter values in the range 0.01-0.035. The impact of these results on the p-process model based on type II supernovae is also discussed.

Key words. Nucleosynthesis – Convection: overshooting – Stars: evolution – Stars: interior

1. Introduction

It is well known that s-nuclei are formed via neutron exposures on iron-peak nuclei and that more than one "component" of s-process is necessary in order to explain the observed solar distribution of s-nuclei abundances. The "weak" component of s-process should give birth to s-species in the $60 \lesssim A \lesssim 90$ mass range during core He-burning of massive stars ($M_{ZAMS} \gtrsim 10 M_{\odot}$).

Although the general features of this component seem to be well established, there are still ambiguities and uncertainties coming from both the nuclear physics and stellar evolution modelling (see e.g. Arcoragi et al. 1991; Rayet & Hashimoto 2000; The et al. 2000; Hoffman et al. 2001; Woosley et al. 2002). Uncertainties due to nuclear physics have been examined by many authors (see e.g. Rayet & Hashimoto 2000; The et al. 2000; Costa et al. 2000, 2003; Rayet et al. 2001), but less work has been done on the impact of uncertainties due to stellar evolution modelling and, in particular, on the impact of uncertainties due to overshooting. So we believe it is worthwhile to study how much the overshooting affects the s-process weak component efficiency. In fact the increase of convective core due to overshoot-

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ing could to provide more "seed" material to He-burning.

2. The impact of overshooting

Using a new s-nucleosynthesis code coupled with the stellar evolution code Star2003 through the post-processing technique (see Weiss & Schlattl 2000 and Costa et al. 2005), we have performed s-process simulations with M_{ZAMS}=25$M_{\odot}$ stellar models having Z=0.02 initial metallicity, for mixing length parameter α=1.7, 2.0 and for overshooting parameter f=0.01, 0.015, 0.02, 0.025, 0.03, 0.035. Models without overshooting (f=10^{-5}) have been also calculated.

Our results (see table 1) show the following main features: a) models using overshooting give rise to a better s-process efficiency compared with "no-overshooting" models, with a sudden and significant enhancement of all the s-process efficiency indicators, especially the average overproduction factor F_0, even if the minimum adopted f value (f=0.01) is used; b) a slow nearly monotonic change of s-process efficiency as a function of the f value.

f	F_0	$\tilde{F}_0$	A_{max}	n_c
10^{-5}	99.88	6.57	91 – 96	4.24
0.01	246.13	11.16	94 – 104	5.22
0.015	216.74	10.13	94 – 104	5.09
0.02	257.81	11.57	94 – 104	5.32
0.025	236.40	10.82	94 – 104	5.20
0.03	304.17	13.20	96 – 104	5.55
0.035	310.39	13.49	96 – 104	5.58
10^{-5}	136.74	7.41	91 – 96	4.48
0.01	331.44	14.29	96 – 110	5.61
0.015	222.21	10.28	94 – 104	5.13
0.02	259.42	11.57	94 – 110	5.31
0.025	264.23	11.81	94 – 110	5.36
0.03	309.26	13.35	96 – 110	5.59
0.035	316.68	13.68	96 – 110	5.64

Table 1. Parameters describing the s-process efficiency, as defined in Costa et al. (2005), for stellar models with α = 1.7 (upper panel) and α = 2.0 (lower panel). The overshooting parameter value is reported in the first Col.

Concerning the link between s- and p- processes, a comparison of our results to those reported in Costa et al. (2000) shows that an enhancement of s-process efficiency due to overshooting together with a slightly enhanced ^{22}Ne$(\alpha, n)^{25}$Mg reaction rate (like the R_2 value reported in Costa et al. 2000) might bring the light p-isotopes abundances in a "solar like position", given that a possible further enhancement of the ^{22}Ne$(\alpha, n)^{25}$Mg reaction rate is still debated (Jaeger et al. 2001; Koehler 2002).

Our results show a not negligible impact of convective overshooting on the s- and p- processes outcome, but they might be strictly dependent on the details of the convective core evolution in the stellar models, so different stellar masses and initial metallicities could give rise to different results. Thus, as both p- and s-processes can occur on a wide range of stellar masses and metallicities, it might be worthwhile to extend the study described here to other stellar masses and initial metallicities in order to have a wider view on the subject.

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