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Advanced evolution and final fate of Super-AGB stars

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Abstract. Based on two grids (with and without overshooting) of stellar models we have investigated the role of initial composition, core overshooting and interplay between mass loss and core growth on the final fate (neon-oxygen white dwarf or electron-capture supernova) of Super-AGB stars. We find that the supernova-channel for these stars exists, but the initial stellar mass range for this evolutionary channel is $\sim 1.5 M_{\odot}$ at the most. The possible link between the final fate and the second dredge-up phenomenon is also briefly discussed.

Key words. Stars: AGB - Stars: evolution

1. Introduction

Stellar evolution reveals the existence of two critical initial masses referred to as M_{up} and M_{mas} and defined respectively as the critical initial mass above which C-burning (CB) ignites and the minimum initial mass for the completion of all the nuclear burning phases (e.g. Woosley et al. 2002). So-called Super-AGB (SAGB) stars fill the gap between M_{up} and M_{mas} (e.g. Pumo & Siess 2007). Their post-He-burning evolution is characterised by an off-centre CB ignition in condition of partial degeneracy and the formation of a neon-oxygen core. Thereafter the SAGB stars will evolve either to a neon-oxygen white dwarf (NeO WD) or to a neutron star if a supernova event triggered by electron-capture reactions (EC SN) occurs (e.g. Ritossa et al. 1999). What fraction of these stars evolve into each of these "final evolutionary channels" is still an unclear question (e.g. Siess & Pumo 2006). We investigate the role of initial composition, core overshooting and interplay between mass loss and core growth on the final fate of SAGB stars, pointing our attention also on the possible link between the final fate and the second dredge-up phenomenon (2DUP).

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2. Stellar evolution code and models

Our models are calculated using the stellar evolution code STAREVOL in the version described in Siess (2006), with the differences reported in Siess & Pumo (2006). Starting from the pre-main sequence, we have computed a grid of 70 stellar models without overshooting having initial masses (M_{ini}) between 7 and $13 M_{\odot}$ with 5 different values of the initial metallicity (Z) in the range 10^{-5} to 0.04,

Table 1. M_N obtained for different ζ values as a function of Z, for the models without (upper panel) and with (lower panel) overshooting respectively. For comparison M_{mas} is reported in the last column (see Pumo 2007 in this volume for details). The masses are in solar units.

Z	M_N					M_{mas}
	ζ=−35	ζ=−70	ζ=−350	ζ=−700	ζ=−4000	
0.00001	8.36	9.06	9.58	9.66	9.74	9.75
0.0001	8.28	9.02	9.53	9.59	9.65	9.66
0.001	8.33	9.06	9.60	9.66	9.71	9.72
0.004	8.75	9.48	10.13	10.19	10.25	10.26
0.008	9.39	9.99	10.52	10.59	10.65	10.66
0.02	9.65	10.44	10.83	10.85	10.90	10.93
0.04	9.66	10.20	10.77	10.83	10.88	10.89
0.0001	6.77	7.20	7.55	7.59	7.62	7.63
0.02	7.89	8.39	8.77	8.81	8.83	8.83

and a grid of 20 stellar models with overshooting having $5 \leq M_{ini}/M_\odot \leq 10.5$ for $Z = 10^{-4}$ and 0.02.

3. Results and discussion

After the CB phase, the outcome of SAGB evolution is dependent on the remaining neon-oxygen core mass ($M^{\rm f}_{\rm NeO}$) when all the stellar envelope is removed by the mass loss. According to Nomoto (1984), if $M^{\rm f}_{\rm NeO}$ reaches a critical value of $\sim 1.37M_\odot$, the star ends its life as an EC SN and it becomes a neutron star. Using a procedure based on the fact that $M^{\rm f}_{\rm NeO}$ can be evaluated as in the following (Pumo 2006):

$$M^{\rm f}_{\rm NeO} = M_{\rm NeO} + \frac{M_{\rm env}}{1-\zeta}$$

where $M_{\rm NeO}$ and $M_{\rm env}$ are the neon-oxygen core mass and the envelope mass at the end of the CB phase respectively, while ζ is the ratio of mass loss rate to core growth rate after CB phase, we have calculated the minimum initial mass (M_N) to have an EC SN as a function of Z for different values of ζ (namely $\zeta = -35$, -70, -350, -700 and -4000). Our results (see Table 1) show that: (*i*) setting the ζ value, M_N presents non-linear behaviour with Z due to opacity effects; (*ii*) changing ζ, M_N ranges between $\sim$ 8.3 to $10.9M_\odot$, indicating that the supernova-channel is possible but the range of M_{ini} for this channel is $\sim 1.5M_\odot$ at the most; (*iii*) the insertion of core overshooting in the calculations reduces the M_N values by $\sim 2M_\odot$, showing a non-negligible role of the mixing treatment. It is also to stress that the 2DUP is linked to the fate of SAGB stars, because it is able to hamper a possible EC SN event by reducing the core mass below the Chandrasekhar mass limit (Pumo & Siess 2007). According to this link, to occur an EC SN, $|\zeta|$ must be $\lesssim 70-100$.

In the light of results, we believe it is worthwhile to point our attention on the nucleosynthesis during the advanced evolution (post-CB phases), in particular investigating the possibility of s-nuclei nucleosynthesis during the thermally pulsing Super-AGB phase.

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