Non-standard s process in low metallicity massive rotating stars

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Context. Rotation is known to have a strong impact on the nucleosynthesis of light elements in massive stars, mainly by inducing mixing in radiative zones. In particular, rotation boosts the primary nitrogen production, and models of rotating stars are able to reproduce the nitrogen observed in low-metallicity halo stars.

Aims. Here we present the first grid of stellar models for rotating massive stars at low metallicity, where a full s-process network is used to study the impact of rotation-induced mixing on the neutron capture nucleosynthesis of heavy elements.

Methods. We used the Geneva stellar evolution code that includes an enlarged reaction network with nuclear species up to bismuth to calculate 25 solar mass models at three different metallicities (Z = 1e-3, 1e-5, and 1e-7) and with different initial rotation rates.

Results. First, we confirm that rotation-induced mixing (shear) between the convective H-shell and He-core leads to a large production of primary ^{22}Ne (0.1 to 1% in mass fraction), which is the main neutron source for the s process in massive stars. Therefore rotation boosts the s process in massive stars at all metallicities. Second, the neutron-to-seed ratio increases with decreasing Z in models including rotation, which leads to the complete consumption of all iron seeds at metallicities below Z = 1e-3 by the end of core He-burning. Thus at low Z, the iron seeds are the main limitation for this boosted s process. Third, as the metallicity decreases, the production of elements up to the Ba peak increases at the expense of the elements of the Sr peak. We studied the impact of the initial rotation rate and of the highly uncertain ^{17}O(α,γ) rate (which strongly affects the strength of ^{16}O as a neutron poison) on our results. This study shows that rotating models can produce significant amounts of elements up to Ba over a wide range of Z, which has important consequences for our understanding of the formation of these elements in low-metallicity environments like the halo of our galaxy and globular clusters. Fourth, compared to the He-core, the primary ^{22}Ne production induced by rotation in the He-shell is even higher (greater than 1% in mass fraction at all metallicities), which could open the door for an explosive neutron capture nucleosynthesis in the He-shell, with a primary neutron source.

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Comments:

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