s-process production in rotating massive stars at solar and low metallicities

Urs Frischknecht (1,2), Raphael Hirschi (1,3,8), Marco Pignatari (4), André Maeder (5), George Meynet (5), Cristina Chiappini (6), Friedrich-Karl Thielemann (2), Thomas Rauscher (2,7,8), Cyril Georgy (1), Sylvia Ekström (5)

(1) Keele Uni, (2) Uni Basel (3) Kavli IPMU (4) Konkoly Obs (5) Geneva Obs (6) AIPotsdam (7) Uni Hertfordshire (8) BRIDGCE UK network

Rotation was shown to have a strong impact on the structure and light element nucleosynthesis in massive stars. In particular, models including rotation can reproduce the primary nitrogen observed in halo extremely metal-poor (EMP) stars. Additional exploratory models showed that rotation may enhance s-process production at low metallicity.

Here we present a large grid of massive star models including rotation and a full s-process network to study the impact of rotation on the weak s-process. We explore the possibility of producing significant amounts of elements beyond the strontium peak, which is where the weak s-process usually stops.

We used the Geneva stellar evolution code coupled to a large reaction network with 737 nuclear species up to bismuth to calculate 15-40 M_☉ models at four metallicities (Z=0.014, 10⁻³, 10⁻⁵, and 10⁻⁷) from the main sequence up to the end of oxygen burning.

We confirm that rotation-induced mixing between the convective H-shell and He-core enables an important production of primary ¹⁴N, ²²Ne and s-process at low metallicity.
At low metallicity, even though the production is still
limited by the initial number of iron seeds, rotation enhances the s-process
production, even for isotopes heavier than strontium, by increasing the neutron
to seed ratio. The increase in this ratio is a direct consequence of the primary production of ²²Ne.
Despite nuclear uncertainties affecting the s-process production and stellar uncertainties affecting the rotation-induced mixing, our results show a robust production of s process at low metallicity when rotation is taken into account. Considering models with a distribution of initial rotation rates enables to reproduce the observed large range of the [Sr/Ba] ratios in (carbon-enhanced and normal) EMP stars.

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Email: r.hirschi@keele.ac.uk