H-He Shell Interactions and Nucleosynthesis in Massive Population III Stars

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Interactions between H- and He-shell convection layers have been seen in 1D stellar models of massive Pop III stars [1, 2] but until recently have not been investigated in detail. Using the 1D stellar evolution code MESA, we find that when this event occurs in a $45\,\mathrm{M}_\odot$ Pop III model, it leads to H-burning luminosities of $\log \mathrm{L_H}/\mathrm{L}_\odot \sim 13$ due to convective-reactive mixing at the interface between the two shells. These conditions render 1D models unreliable and we will report on initial results of our new project to investigate the hydrodynamic nature of mixing at the interface between the H- and He-convection zone (Fig. 1). This mixing is similar to H-ingestion events found in other environments, such as He-shell flashes in low-mass stars [3, 4] and may lead to the *i*-process with neutron densities of $\approx 10^{13}\mathrm{cm}^{-3}$, reproducing the nucleosynthetic abundance patterns (Fig. 2) existing in some of the most metal-poor stars [5]. We have now also investigated in more detail the conditions for Ca production in Pop III stars, and specifically the role of the $^{19}\mathrm{F}(p,\gamma)^{20}\mathrm{Ne}$ reaction. Using default rates, we find that unless mixing between H-and He layers is involved Ca is produced at a level at least a factor 10 below the value observed in the most Fe-poor star.

References

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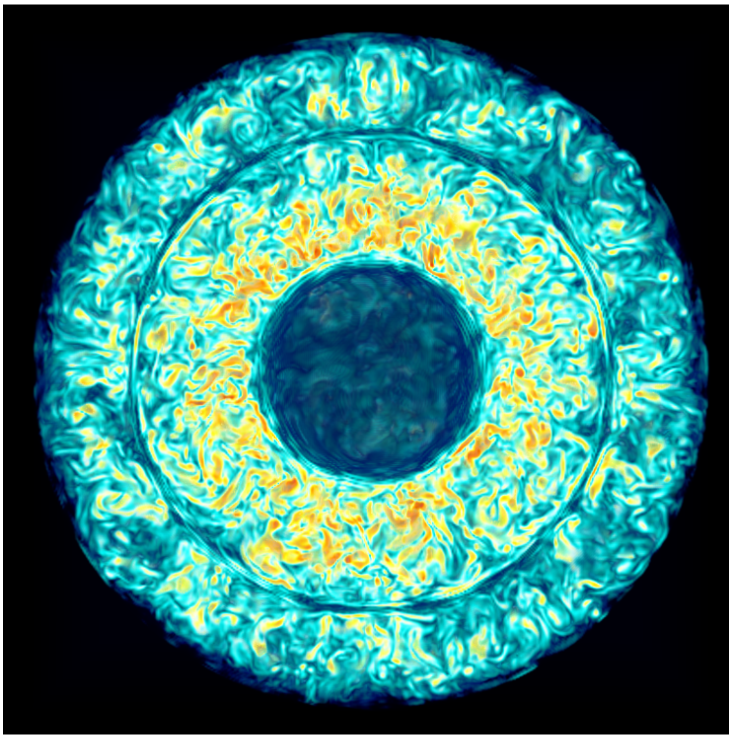

Figure 1: Preliminary 3D simulation on a low resolution 384^3 grid of double-shell convection conditions similar to those encountered when convective H- and He-shells are right on top of each other in a massive Pop III star. The color scale represents the vorticity as calculated with our new hydro code version PPMstar2.0.

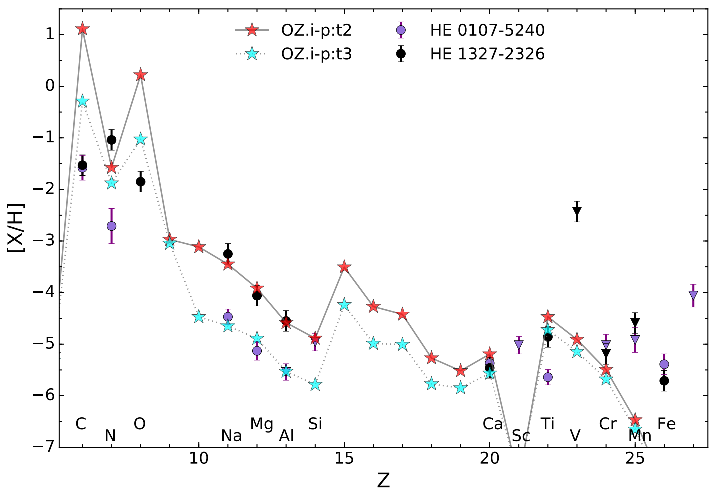

Figure 2: Single-zone calculations of Pop III *i*-process nucleosynthesis shown with two UMP stars for comparison. [5]