JINA: Center for the Evolution of the Elements

Connecting the Dots: From Nucleosynthesis in Early Massive Stars to the Elemental Abundances of the Most Iron-Poor Stars

Stellar astrophysicists believe that the elemental abundances they observe in the most iron-poor stars are the result of one, or perhaps a few sources of element synthesis originating within the first generations of stars. These ultra-metal poor (UMP) and carbon-enhanced metal-poor (CEMP) stars therefore act as extremely powerful verifiers of our understanding of both stellar evolution and nucleosynthesis, in the early universe. For example, we can probe, via simulations, what types of ancient astrophysical events caused the often unusual abundance patterns we observe today. This is precisely the impetus of a recent investigation into a new element synthesis mechanism, which may explain the chemical abundances observed some of the most iron-poor stars known.

The authors construct models of massive first generation Population III stars and explore the nucleosynthesis resulting from hydrogen mixing into the convective helium burning shell below. This is a phenomenon often found in stellar models of zero and very low metal contents. When this mixing event takes place in the model, large amounts of energy are released that is expected to cause hydrodynamic feedback may even trigger mass ejection.

Nucleosynthesis calculations for the conditions found in the stellar model reveal that the intermediate neutron capture process (i-process) is activated. The i-process is a neutron capture process with characteristic neutron densities between those of the well established slow- and rapid neutron capture processes and was originally proposed in the 1970's. The new study shows that it also operates in massive Pop III stars and can explain the abundance signatures of two out of the three most iron-poor stars known. This result could greatly affect our understanding of the evolution and nucleosynthesis of the first stars although many details require further investigation.

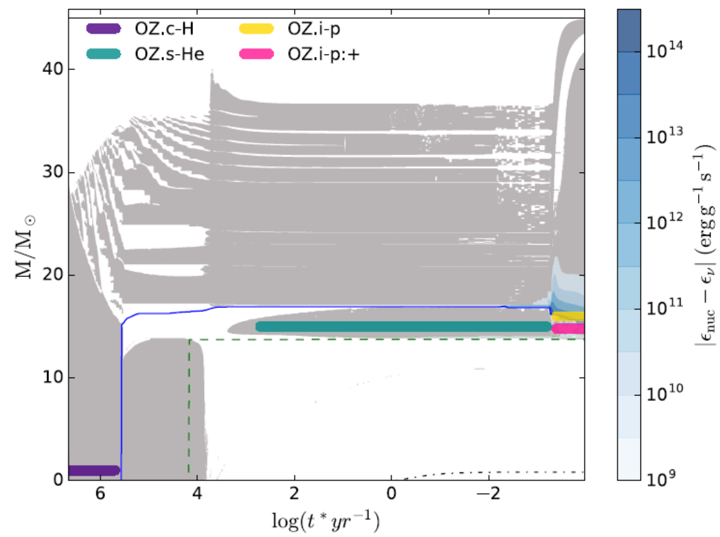

Figure 1.
Areas of convection (grey) and energy generation (blue contours) in a model of a massive Population III star as functions of radius from the center, measured as enclosed mass (vertical axis), and time (horizontal axis). The thick colored lines mark the stellar burning regimes used for detailed nucleosynthesis studies in separate single zone calculations.

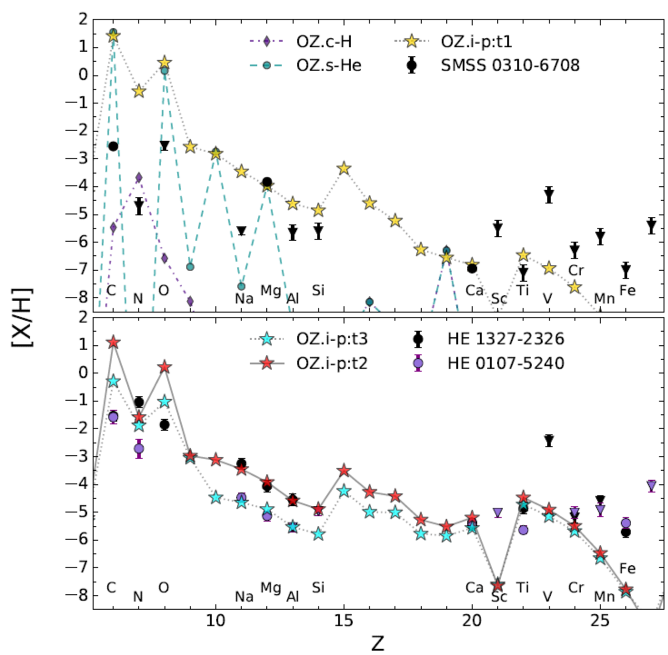

Figure 2.
Observed abundances of CEMP stars SMSS J0313-6708, HE 1327-2326, and HE 0107-5240 with abundances from single zone i process simulations.

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