Heavy Element Synthesis in Type II Supernovae: Sensitivity to Nuclear Equation of States [1]

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A phenomenological model has been developed in which the enrichment of light r-process elements (relative to heavy r-process elements) in metal-poor and extremely-metal-poor stars (EMPs) is found to depend on the stiffness of the nuclear equation of state. Here, an r-process is assumed in which an explosion scenario is halted due to an accretion-induced collapse and a subsequent failed or partial explosion, followed by partial ejection of r-process material. Nucleosynthesis then results in an abundance distribution enriched in the light r-process elements. Initial results suggest that a possible upper limit on the stiffness of the EOS may be constrained by observations, which could complement results of neutron star masses which place lower limits on the EOS stiffness.

We have explored a previously-proposed model, referred to as the tr-process [1], which assumes an r-process in a core-collapse scenario which is halted due to an accretion-induced collapse into a BH or a stalled shock. The model attempts to explain the maximum [Sr/Ba] ejected in a single r-process event; we note that reductions in this ratio may result from mixing between outer and inner ejecta in the explosion or from asymmetric explosion mechanisms. We also note that the observed large values of [Sr/Fe], [Ba/Fe], and [Eu/Fe] (so-called r-II stars) can be reproduced by turbulent ejection (as suggested in [2]). The results presented here represent one potential avenue for producing these extremes.

The calculated [Sr/Ba] values are also shown in Figure 1 compared to observed values in the galaxy. The significant changes in the Ba ejection in a collapse scenario results in a dramatic change in the [Sr/Ba] (and [Sr/Eu]) ratios. In a previous paper [2], changes in [Sr/Ba] were suggested to be caused at least in part by turbulent ejection of material in a collapse scenario. It is seen that for a softer EOS, the maximum values in [Sr/Ba] as a function of metallicity can be achieved in a tr-process for partial enrichment of r-process elements in a GCE model. As noted above, the GCE results shown in these figures represent extremes in these ratios as they are produced in collapse scenarios corresponding to the minimum collapse time to a BH. In examining the abundance ratios of [Sr/Ba] as they relate to the EOS, one sees that these ratios generally increase as the EOS softens. However, at some point, the EOS becomes so soft that the collapse time becomes early enough to prohibit Sr ejection, and the ratios of [Sr/Ba] begin to decrease with the softness of the EOS. This may occur for an EOS with a softness somewhere between the Shen EOS and the LS220 EOS, as one sees that the [Sr/Ba] ratios calculated using an LS220 EOS drop below those calculated using a Shen EOS at metallicities $-2.5 < [Fe/H] < -2$.

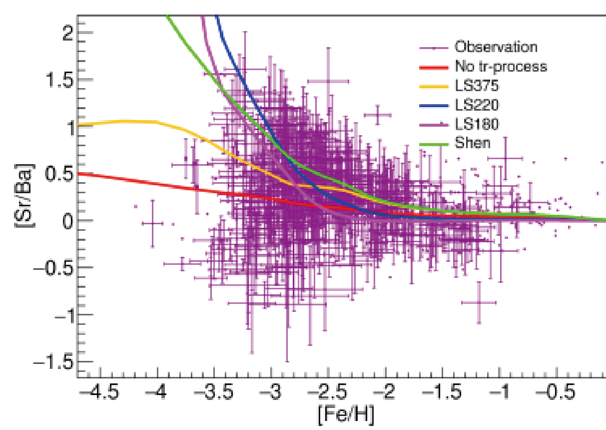

Figure 1: [Sr/Ba] as a function of [Fe/H] for several EOS assumptions compared to observation.

References

[1] Famiano, M. A., et al.: 2016, *ApJ*, **830**, 61.
[2] Aoki, W., et al.: 2013, *ApJ*, **766**, L13.