Early Galactic Chemical Evolution and *r*-Process Nucleosynthesis in Black-Hole Forming Supernovae [1]

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Extremely metal-poor (EMP) halo stars are early generations of stars whose elemental abundances reflect the interstellar gas compositions of the early Galaxy. Compilations of abundances of neutron-capture elements in EMP stars indicate that Sr and Ba show a clear cutoff in the distribution of [Sr/Ba] at [Fe/H] ~ −3.6 and an upper bound as a function of [Fe/H] as well as a lower bound at [Sr/Ba] ~ −0.5 as shown in the upper Fig. 1 [2].

Our recent model [3] was developed in which the collapses of type II supernovae (SNe) are found to reproduce many of these features seen in the data. We point out that the cutoff at [Fe/H] = −3.6 for [Sr/Ba] > 0.0 data can be explained by the truncated r-process, that is, by the collapses to black holes over a fairly wide mass range of progenitor stars. Furthermore, the results of our GCE calculations can predict the upper bound in [Sr/Ba] in these data. Effects of turbulence in an explosive site have also been simulated, and are found to be important in explaining the large scatter observed in the [Sr/Ba] data [1]. See the lower Fig. 1.

A fascinating aspect of this work is the possibility that observed minima in [Ba/Fe], [Sr/Fe], and [Sr/Ba] may be directly related to the stiffness of the nuclear EOS. The lower limit of [Ba/Fe] as a function of metallicity predicted in our model can be reproduced in a GCE model assuming a contribution to r-process elements from black holes produced in fallback SNe. The softer the equation of state (EOS), the lower the calculated [Ba/Fe] as a function of [Fe/H]. Thus the observed lower limit in [Ba/Fe] as a function of metallicity appears to constrain the lower limit of the stiffness of the EOS.

While astronomical observations of neutron star masses are able to predict a lower limit of the stiffness of the EOS, this model suggests a new method of determining the upper limit [4].

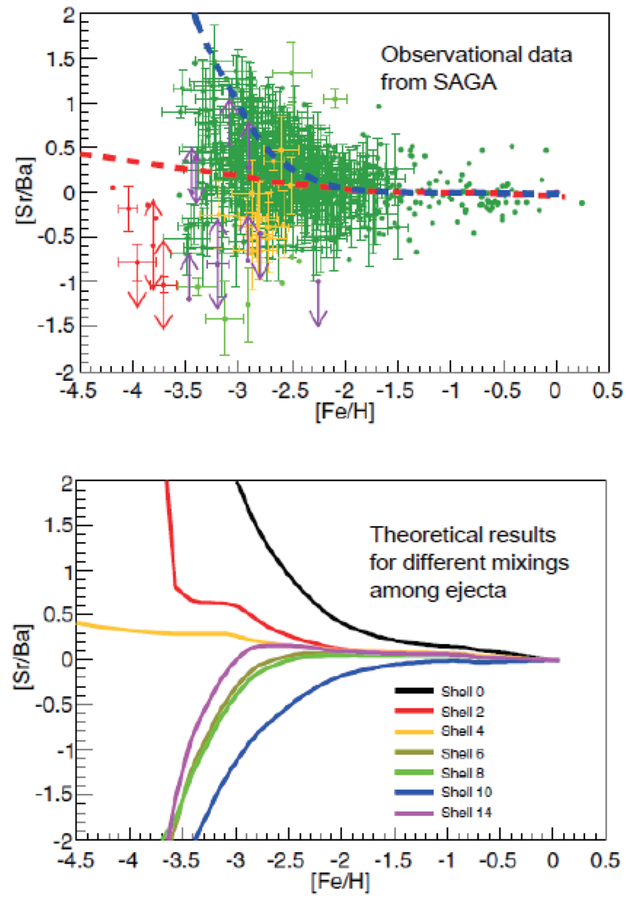

Figure 1: Upper: The calculated results for [Sr/Ba] assuming a truncated black-hole forming r-process. The red dashed line corresponds to a GCE model without production in a truncated r-process, while the blue dashed line corresponds to a GCE model with a primary production from this r-process for all stars with $M \geq 20\,M_\odot$. Lower: The GCE results for single-site truncated rprocess production for turbulent ejection of specific shells assuming only those shells are ejected. From shell 0 toward shell 14, each colored line indicates calculated [Sr/Ba] with the mixing for deeper shell.

References

[1] Aoki, W., et al.: 2013, *ApJ*, **766**, L13.
[2] Aoki, W., et al.: 2005, *ApJ*, **623**, 611.
[3] Boyd, R. N., et al.: 2011, *ApJ*, **744**, L14.
[4] Famiano, M. A., et al.: 2013, in preparation.