From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
Proceedings IAU Symposium No. 228, 2005
V. Hill, P. François & F. Primas, eds.

doi:10.1017/S1743921305006290

Chemical evolution of the Galactic halo and the Origin of Precious Metals

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Abstract. Observed large scatters in abundances of neutron-capture elements in metal-poor stars may suggest incomplete mixing of the interstellar medium at the beginning of the Galaxy. Comparing predictions by an inhomogeneous chemical evolution model and new observational results with *Subaru* HDS, we attempt to constrain the origins of r-process elements.

Keywords. Nuclear reactions, nucleosynthesis, abundances, stars: abundances, Galaxy: evolution, Galaxy: halo

1. Introduction

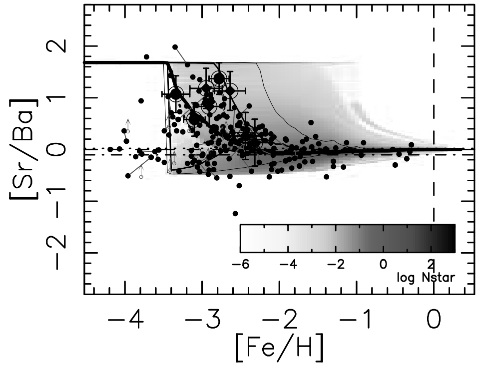
Abundance analysis of metal-poor stars reveals large dispersions in r-process elements (e.g., Ryan, Norris, & Beers 1996, Honda *et al.* 2004). This may be interpreted as a result of incomplete mixing of the interstellar medium (ISM) at the beginning of the Galaxy. If metal-poor stars contain products of a single or a few supernovae (SNe), huge dispersions in abundances of r-process elements possibly imply that their yields are highly dependent on SN progenitor mass. However, no consensus about the origins of r-process elements has been achieved, although a few scenarios show some promise (Woosley *et al.* 1994, Wanajo *et al.* 2003). In particular, observed enhancement of Sr comparing to Ba in metal-poor stars suggests the presence of the 'weak' r-process which produce mainly lighter r-elements. In this study, we discuss the enrichment of Sr, Pd, Eu, and Ba, using an inhomogeneous chemical evolution model, and attempt to constrain the origin of r-process.

2. Bimodal r-process

In our previous study, the observed wide spread of Eu in metal-poor stars are shown to be well-reproduced by an inhomogeneous enrichment scenario. In particular, sub-solar values of [Eu/Fe] in stars of [Fe/H]~ -3 can restrict the site of r-process as SNe of low-mass end stars such as $8 - 10M_\odot$ (cf. Ishimaru *et al.* 2004). The distribution of the [Ba/Fe] abundance ratio also supports this result.

While Ba and heavier elements seem to fit the solar r-process pattern, lighter elements show wide varieties (e.g., Hill *et al.* 2002, Sneden *et al.* 2003). In particular, a large dispersion has been found in [Sr/Ba] at low metallicity (e.g., Ryan, Norris, & Beers

1996, Honda *et al.* 2004), suggesting that lighter elements such as Sr does not come from a universal process, which produces Ba and Eu, but from "weak" r-process. As shown in fig. 1, this scenario can well explain the observational distribution of [Sr/Ba], when weak r-process produces ∼60% of Sr but only ∼1% of Ba in metal-poor stars.



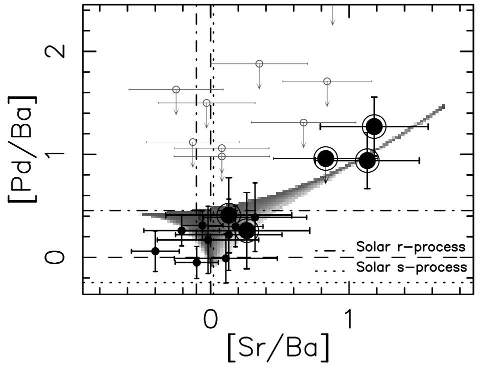


Figure 1. *(left panel)* [Sr/Ba] as a function of [Fe/H]. Gray-scale indicates predicted distribution of stellar fraction. Weak r-process fraction for Sr and Ba are assumed as 60% and 1%, respectively. The average stellar distributions are indicated by thick-solid lines with the 50% (solid lines) and 90% confidence intervals (thin-solid lines). The observational data of this study are given by large circles, with other data (small circles).

Figure 2. *(right panel)* Same with Fig. 1 but for [Pd/Ba] vs. [Sr/Ba]. Weak r-process fraction for Pd is assumed to be 10%.

3. Origin of palladium and 'weak' r-process

Intermediate mass elements between Sr and Ba must provide clues to understand the nucleosynthesis of weak r-process. Therefore, we have estimated Pd abundance of very metal-poor stars, using *Subaru* HDS. Fig. 2 shows [Pd/Ba] as a function of [Sr/Ba]. By definition, [Sr/Ba] should increase with the fractional contribution of weak r-process to the stellar abundances. If Pd originates from weak r like Sr, [Pd/Ba] must show a correlation with a slope of unity to [Sr/Ba]. If Pd comes from main r like Ba, [Pd/Ba] must be constant. New data show a mild correlation with a slope less than unity, suggesting that the weak r-process fraction for Pd takes intermediate value between those of Sr and Ba; ∼ 10%. Therefore, this result possibly implies that the weak r-process fraction decreases with atomic mass from Sr to Ba. One of the evidence for such nucleosynthesis of weak r-process is obtained from our latest result of *Subaru* observation. The abundance pattern of HD122563 shows over-production in lighter elements around Sr. But the over-production decreases towards heavier elements (cf. Honda *et al.*, in this proceedings). HD 122563 is possibly enriched by SNe which produce weak r-elements.

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https://doi.org/10.1017/S1743921305006290 Published online by Cambridge University Press