Origin of Xe-H Component in Presolar Diamond. K. Otsuki, Natural History of Science, Hokkaido University, Sapporo, Hokkaido, Japan (otsuki@ep.sci.hokudai.ac.jp).

Presolar diamond is known as the carrier of the isotopically anomalous Xe component Xe-HL. These are excess of p-process only isotopes ^{124}Xe, ^{126}Xe and rprocess only isotopes ^{134}Xe, ^{136}Xe. Since both process occur only in core-collapse supernovae, the Xe-HL component are thought to be from supernovae. It has been a mystery that the ratio of ^{124}Xe/^{126}Xe and ^{134}Xe/^{136}Xe are different from Solar system value (e.g., [1]).

On the other hand, recent observations of metalpoor halo stars revealed that two different process are contributed to solar r-process abundances, which is obtained via subtraction of theoretical s-process abundance from observed solar abundances. One process contribute to all r-process elements and sometimes called ’main r-process’ to distinguish from other one. Other one contribute only light r-process elements and usually called ’weak r-process’ or ’LEPP’. The r-process only Xe in Solar system are superposition of these two process. If Xe-H in the presolar diamond is originated in a core-collapsed supernova, the Xe-H isotope ratio, ^{134}Xe/^{136}Xe, should be same with one of the weak or the main r-process. The ratio can constrain on the astrophysical site for the r-process. The ratio of ^{134}Xe/^{136}Xe in theoretical r-process calculations in various environments are compared with observed quantity. Although no strong constraint for r-process sites are found in this study, another isotope for heavier pure r-process elements, such as ^{148}Nd and ^{150}Nd, may answer the question: which r-process contributed to Xe-H in presolar diamond?

Astrophysical site for the r-processes

Astrophysical site(s) for the r-processes are still unknown despite of decades of studies. Although corecollapse supernova is dominant candidate, physical environment for the r-process is not clear. This is partly because explosion mechanism of supernovae is poorly understood. In addition, r-process elements are formed via extremely neutron-rich unstable nuclei, which are unreachable by experiments. Theoretical r-process calculation always depend on which nuclear physics model is adopted. Hence, current r-process studies have huge uncertainties.

Observational studies with large aperture telescopes in past decades revealed several interesting features of rprocess elements. Starting detailed abundance study of CS 22892-052 [2], dozens of metal-poor stars are found to show same abundance distributions for the elements heavier than Ba(Z=56). The abundance pattern also coincide with solar r-process pattern which is obtained via a subtraction of theoretical s-process contribution from total abundances. The observational fact suggest that the r-process which contribute to the elements heavier than Ba are metallicity independent. The process always enriches the elements in the same abundance pattern since early epoch of Galaxy to solar formation period.

Although abundance ratio of r-process elements heavier than Ba are almost always same, the ratio of Fe to these elements vary among the metal-poor stars[3]. Since Type I supernovae contribute later stage of Galaxy, the Fe in these metal-poor stars are exclusively from Type II supernovae. The abundance scatter imply not all Type II supernovae contributed to r-process elements. For example, the scatter can be reproduced if only Type II supernovae of progenitor in narrow mass range contribute to the r-process [4, 5]. It is still marginal which progenitor mass contribute to the r-process, though.

It is also reported that the light r-process elements, such as Sr, Y, Zr vary among the metal-poor stars with same Ba abundances, although the origin of these heavy elements seems exclusively r-process [3]. The observational fact suggests that at least two different process has enriched these light r-process elements. One forms all rprocess elements, including Sr, Y, Zr, Ba, and actinide elements. Other forms only r-process elements lighter than Ba, without significant increase of Ba. For convenience’s sake, the former process is called main r-process, the latter is called weak r-process in this paper. This is because there is no unified name for the latter process. Note that weak r-process has been just a name, it did not have to be the rapid neutron-caprture process.

Honda et al. (2006, 2007) studied detailed abundances of two stars, HD 122563 and HD 88609 (see Fig. 1). In both stars, weak r-process elements are strongly enhanced while heavier elements are deficient. The abundances decrease with mass number increasing. The pattern has never been observed in previous studies. If this newly found abundance pattern is weak rprocess pattern, weak r-process also contribute to Xe abundances. The Xe-H anomaly in presolar diamond imply that weak r-process is actually r-process.

Xe isotopes in two r-processes

Figure 1 shows ^{134}Xe/^{136}Xe of theoretical calculations in various physical conditions. The ratio varies 0.18 to 9.67. Since physical condition for r-process in a single event varies by time, total yield from a singe r-process event is interpret as

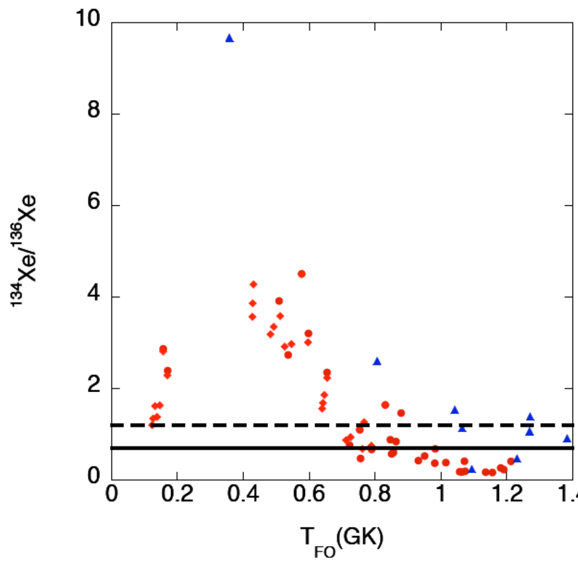

Figure 1: The isotope ration of $^{134}Xe/^{136}Xe$ in theoretical r-process calculations. The red circles are the cases with actinide elements, the red diamonds are the cases with significant fission cycling, the blue triangles are cases with no actinide elements.

superposition of these component. The weak r-process pattern should be reproduced only by blue triangle component while all component can contribute to main r-process pattern.

Although there are nuclear physics uncertainties, either main or weak r-process can reproduce the ratio of presolar diamond, 0.699. We could not find any clear correlations between freeze out temperature and the isotope ratio. This might be because of complicated behavior of two neutron separation energy of FRDM mass model, which is adopted to this work. Assuming that the nuclear physics model is correct, it seems that r-process should freeze out at higher temperature to reproduce Xe- H isotope ratio.

Discussion

It is difficult to clarify whether origin of Xe-H in diamond is weak r-process or not by theoretical studies. Although one can make so-called "best fit model" theoretically, it would not be the unique solution. There are large uncertainties of astrophysical environment and nuclear physics models.

If we assume the new abundance pattern of HD 122563 and HD 88609 is the weak r-process pattern, the contribution from weak r-process for Ba in solar abundance is more than three orders of magnitude less compare to the main r-process contribution. Therefore, we can assume Ba isotope ratio in solar r-process abundance is same with the ratio of main r-process pattern. The same interpretation could apply to heavy Xe isotopes since they are nuclei next to Ba. In that case, Xe-H is originated in weak r-process and use this quantities to constrain weak r-process site. However, we cannot discard the possibility that weak-r contribution for solar Xe is significant. The amount of Xe isotopes in the weak rprocess is still uncertain because Xe is unmeasurable in stellar atmosphere.

Heavier r-process only isotopes can answer the question. For example, $^{148}Nd/^{150}Nd$ could be a index. Nd is heavier than Ba. The ratio of $^{148}Nd/^{150}Nd$ in the solar system is about 1.02 and it should be the same or very close to the one in main r-process. Hence, $^{148}Nd/^{150}Nd$ in presolar diamond (if any) shows the anomaly, the origin of Xe-H component is the weak r-process and Xe-HL are from supernova in which weak r-process occur. So far, two of heaviest isotopes of Nd is only one combination which is able to avoid theoretical s-process uncertainties.

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