Neutron-Capture Elements in Globular Cluster M15

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Abstract

We have observed six giants in the metal-poor globular cluster M15 using the Subaru Telescope to measure neutron-capture elemental abundances. There is star-to-star scatter in the heavy neutron-capture elements (e.g., Eu) but no significant s-process contribution as found in previous studies. We have found that there are anticorrelations between the abundance ratios of light to heavy neutron-capture elements ([Y/Eu] and [Zr/Eu]) and the abundance of heavy neutron-capture elements (e.g., Eu). Our results suggest that the light neutron-capture elements in those stars cannot be explained by only a single r-process. There was another process that contributed significantly to the light neutron-capture elements in M15. Our results also indicate that the heavy r-process elements were less dispersed than those light neutron-capture elements when M15 stars were formed.

Discussion

1There are star-to-star abundance variations in heavy r-process elements (e.g., Eu) in M15.
2There is an anti-correlation between the abundance ratio of light to heavy neutron-capture elements (e.g., [Y/Eu], [Zr/Eu]) and the abundance of heavy r-process elements.
3Two different sources of neutron-capture elements contributed to M15 progenitor.
4Heavy r-process elements show a larger scatter than light neutron-capture elements.
5Uniform contamination of light neutron-capture elements and insufficient mixing of main r-process elements.

If we assume a simple correlation between time and the degree of mixing, this scatter can be realized if light neutron-capture elements enriched the progenitor of M15 earlier than the main r-process elements which were not mixed completely before the star formation. In this case, the astrophysical origin of those light neutron-capture elements could be related to more massive stars than the main r-process.

Strongly concentrated main r-process elements (e.g., jet) could also explain our results. Since very little about mixing of SNe ejecta and ISM is known, it is difficult to reach a definitive conclusion. The theoretical studies of such dynamics are now ongoing.

neutron-capture elements in other metal-poor globular clusters

Our preliminary results ([Y/Eu] in M92 & M30) suggest that the abundance ratios of light to heavy neutron-capture elements vary in each GCs.

References

Honda et al. 2004, ApJ 607, 404
Otsuki et al. 2006, ApJ, L189 (closed circles), Cohen & Cohen 2003 (open circles), HD122563: Wolf et al. 1995 (black open triangle), simulated: Wolf et al. 1995, Our new data (squares), M68: Lee et al. 2005, M92: Our new data, M13 & M3: Sneden et al. 2004 (closed circles), M5: Ivans et al. 2001 (closed circles), Ramirez & Cohen 2003 (open circles), McKee et al. 2001 (closed circles), McKee et al. 2003 (open circles).

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We confirmed that there is the star-to-star abundance variation in heavy neutron-capture elements.

We adopted the latest line data for the abundance analyses.

<References>

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Sneden et al. 2000, ApJ, 536, L189
Sneden et al. 2003, ApJ, 591,936

Abundance distribution of [Ba/Fe] scatter in M15 stars

Previous studies (Sneden et al. 1997,2000)

[Ba/Fe] scatter in M15 stars

Chemical inhomogeneity of progenitor?

Abundance distributions for elements Z>56 agree with solar r-process abundance pattern. Pure r-process.

Observational uncertainties of Ba abundance.

Light neutron-capture elements has not been studied.

Examples of spectra

[(Eu/H) vs. [Fe/H]]

We confirmed that there is the star-to-star abundance variation in heavy neutron-capture elements.

((Up) [La/Eu] vs. [Eu/H])

There is no significant s-process contribution.

((Middle) [Y/Eu] vs. [Eu/H])

There are anticorrelations between [Y,Zr/Eu] and [Eu/H].

([Epsilon] (Up) [La/Eu] vs. [Eu/H])

There is no significant s-process contribution.

((Middle) [Y/Eu] vs. [Eu/H])

There are anticorrelations between [Y,Zr/Eu] and [Eu/H].

((Bottom) [Zr/Eu] vs. [Eu/H])

There are anticorrelations between [Y,Zr/Eu] and [Eu/H].