Indications for a second r-process from Halo stars

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All elements heavier than Fe are synthesized by neutron-capture and subsequent β-decay, either by the s- or the r-process. Whereas the s-process is fairly understood, the r-process lacks a common consensus on the astrophysical conditions. Nevertheless, applying the model-independent ”waiting-point approximation”, the isotopic Solar system r-process abundances could be described by a superposition of components with weighting factors following power laws for A = 63 to 240 [1].

The recent discovery of the rare class of ultra-metal-poor (UMP) r-process element enriched Halo stars yielded a major step forward in the understanding of the r-process. These ancient stars were formed from the collaps of interstellar gas clouds which had been “contaminated” with heavy elements by only a few explosive events. The earlier determinations of elemental abundances in UMP stars as CS22892-052 or CS31082-001 seemed to demonstrate a unique pattern of r-process abundances from the very metal-poor, old stars up to the much younger Solar system over the whole range of elements from $_{32}$Ge up to $_{92}$U.

Extending the range of observed elements (by applying the Hubble Space telescope for UV spectroscopy) and studying more Halo stars spanning a wider range of metallicities, a more diverse picture emerged. The unique abundance pattern is confirmed for elements above the second r-process maximum. But elements in the range $_{32}$Ge to $_{50}$Sn exhibit a different behavior. They show underabundances of odd-Z elements compared to even-Z ones (see, e.g., [2]).

In order to see, if there is a scatter of the abundance patterns from star to star, in Fig. 1 ratios of elemental abundances normalised to $_{63}$Eu are displayed compared to the UMP star CS22892-052 with metallicity [Fe/H]=–3.1. CS31082-001 with the slightly higher metallicity of –2.9 shows the same pattern for light and heavy elements. In the less metal-poor stars BD+17°3248 and HD122563 with metallicities of –2.1 and –1.7, respectively, the lower-Z region is overabundant. And it seems that even the elements $_{56}$Ba to $_{60}$Nd above the second maximum are affected.

The total r-process abunance from just above the Fe-group elements up to the heaviest ones can be obtained by the operation of two processes: 1) the classical ”main” process with high neutron densities / entropies acting already in the UMP stars and 2) a new nucleosynthesis process with low neutron densities operating in less metal-poor stars producing low-Z elements. The LEPP (light element primary process) proposed in [6] is a possible candidate. Network calculations for low entropies are promising [7].

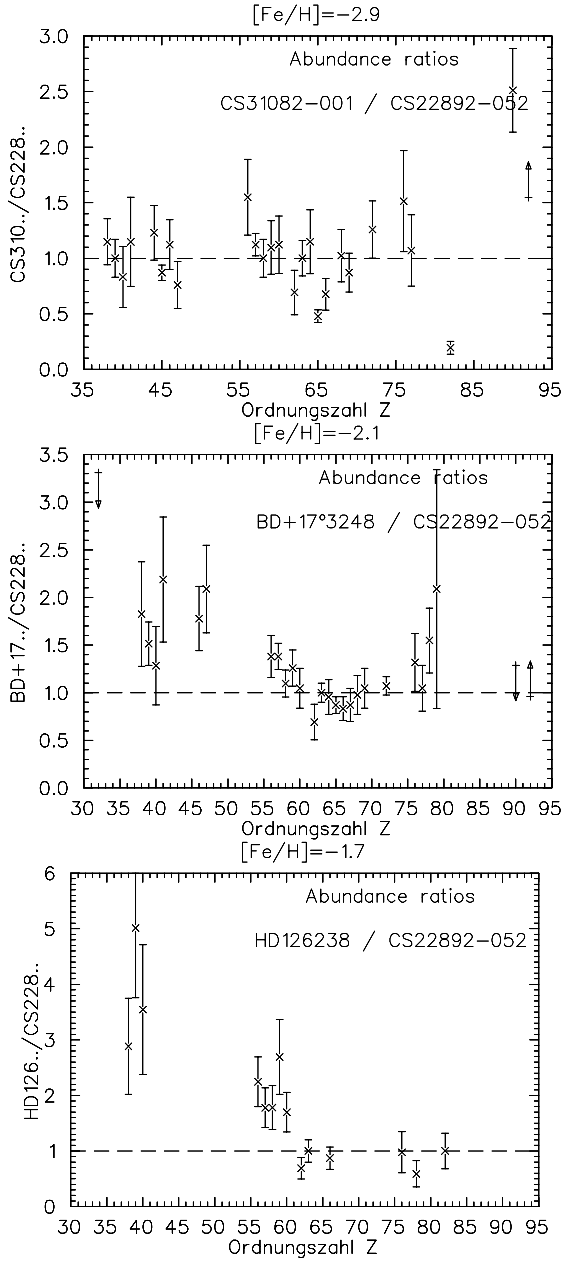

Figure 1: Elemental abundances in halo stars compared to CS22892-052. The ratios are normalized at $_{63}$Eu. The data are from [2] for CS22892-052, [3] for CS31082-001, [4] for BD+17^{o}3248, and [5] for HD126238.

References

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