Nucleosynthesis beyond iron and the lighter element primary process
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Three observational findings for testing the theory

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I wish to draw the attention of the participants to three observational facts on the light trans-Fe elements in the very metal-poor (VMP) stars which could be useful for testing the nucleosynthesis theory.

1. The known r-II stars ([Eu/Fe] > 1, [Ba/Eu] < 0) have similar abundance pattern in the Sr-Hf range.

The first slide shows the element abundances of 8 strongly r-process enhanced stars with [Eu/Fe] > 1 which are referred to as r-II stars. For each star, its element abundances were scaled to match Eu-Tm in the benchmark r-II star CS 22892-052 which we call the Sneden's star. For better illustration, the abundance pattern of the Sneden's star is plotted by dotted curve. It can be seen that all these stars have very similar abundance pattern not only in the Ba-Hf range, as stated in the literature, but also in the Sr-Ag range. This is what should be expected because every r-II star experienced chemical enrichment from, most probably, a single r-process event. Therefore, the r-II stars provide empirical element production ratios for the r-process.

2. A clear distinction in Sr/Eu abundance ratios is found between the halo stars of different Eu enhancement.

Using the data from the literature, we selected the 53 halo stars with a dominant contribution of the r-process to the production of heavy elements beyond Ba, i.e., with [Ba/Eu] < -0.4. The Ba/Eu ratios are presented in the bottom panel. The stars are separable into 3 groups, depending on the observed Eu enhancement. The 9 r-II stars with [Eu/Fe] > 1 are shown by red circles, the 32 r-I stars with [Eu/Fe] = 0.2-1 by blue rombs, and the 12 Eu-poor stars with [Eu/Fe] < 0.06 by asterisks. In each of these stellar groups, the mean Ba/Eu ratio is close to the pure r-process production ratio. It should be stressed that an Eu-poor star does not mean a r-process poor star. In contrast, the Sr/Eu abundance ratios indicate a clear separation in the top panel between each of these 3 groups. The r-II stars contain low Sr/Eu at [Sr/Eu] = -0.92+-0.13, while the r-I and Eu-poor stars have 0.36 and 0.93 dex higher Sr/Eu values. This is indicative of different origin of Sr and also Y and Zr which show very similar behavior in the stars of different Eu enhancement.

3. At the same time, no distinction between the r-II, r-I, and Eu-poor groups is indicated by the abundance ratios among Sr, Y, and Zr.

In this slide, the r-II, r-I, and Eu-poor stars are shown by filled circles, asterisks, and open circles, respectively. Different colors are used to plot different element ratios. The obtained mean abundance ratios log(Sr/Y) = 0.83, log(Sr/Zr) = 0.09, log(Y/Zr) = -0.74 should serve to test the nucleosynthesis theory. One comparison with the HEW r-process model treated by Farouqi et al. (2009) is shown in this slide. You can see that the theory perfectly reproduces the observations of the old stars born before the onset of the main s-process.