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Observing the signatures of the r-process in metal-poor stars[1]

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In their atmospheres, old metal-poor Galactic stars retain detailed information about the chemical composition of the interstellar medium at the time of their birth. Extracting such stellar abundances enables us to reconstruct the beginning of the chemical evolution shortly after the Big Bang. About 5% of metal-poor stars with [Fe/H] < -2.5 display in their spectrum a strong enhancement of neutron-capture elements associated with the rapid (r-) nucleosynthesis process that is responsible for the production of the heaviest elements in the Universe. This fortuity provides a unique opportunity of bringing together astrophysics and nuclear physics because these objects act as "cosmic lab" for both fields of study. The so-called r-process stars are thought to have formed from material enriched in heavy neutron-capture elements that were created during an r-process event in a previous generation SN. It appears that the few stars known with this rare chemical signature all follow the scaled solar r-process pattern (for the heaviest elements with $56 < Z < 90$ that is). This suggests that the r-process is universal – a surprising empirical finding and a solid result that can not be obtained from any laboratory on earth. It is thus a crucial constraint for theoretical nuclear physices models. Among the heaviest elements are the long-lived radioactive isotopes ^{232}Th (half-life 14 Gyr) and ^{238}U (4.5 Gyr). While Th is often detectable in these stars, U poses a real challenge because only one, extremely weak line is available in the optical spectrum. In comparison with stable r-process nuclei, such as Eu, stellar ages can be derived from abundance ratios involving Th and/or U. Through individual age measurements, these objects become vital probes for observational "near-field" cosmology by providing an independent lower limit for the age of the Universe.

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