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R-Process Alliance: unveiling the abundance patterns of ten r-II stars through homogeneous spectral analysis

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The rapid neutron capture process, known as the r-process, is responsible for producing approximately half of the elements heavier than iron, including Ag, Au, Th and U, among others. Despite its fundamental role in nucleosynthesis, the astrophysical sites and conditions of the r-process remain an open question. Metal-poor stars serve as exceptional
laboratories for studying this process, as their chemical compositions reflect that of the cloud in which they were born.
Among them, r-II stars, which are characterized by strong enhancements in r-process elements with [Eu/Fe] > 0.7, offer key insights into the nature of the astrophysical events responsible for heavy element production. However, previous studies have focused on individual r-II stars rather than performing a homogeneous analysis of a larger sample.

In this work, we present the first homogeneous chemical abundance analysis of a sample of ten r-II stars, expanding upon the discoveries from the R-Process Alliance's first data release by Hansen et al. (2018) and Sakari et al. (2018). We derive abundances for 28 neutron-capture elements, covering the full r-process pattern from Sr to U. A central objective of this study is to determine whether the observed star-to-star variations in r-process abundances originate from intrinsic astrophysical differences, such as variations in the progenitor events, or from observational uncertainties.

Our analysis highlights two key elemental regions. (i) the Ru-Ag region, where recent studies suggest signatures of fission fragment deposition (Roederer et al. 2023), and (ii) the third r-process peak elements, Os and Ir, which remain poorly explored.

By applying a uniform methodology, we provide the most comprehensive abundance analysis of r-II stars to date, enabling a direct comparison across the sample. This approach is essential for bridging observations with theoretical nucleosynthesis models and advancing our understanding of the astrophysical sites of the r-process.

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