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Using nucleosynthesis calculations to illuminate astrophysical actinide production

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Fingerprints of the properties of exotic nuclei on nucleosynthesis observables have been used for decades to frame our picture of how the heaviest elements in our Solar System came to be. The abundance of elements in our Sun, as well as nearby metal-poor stars, hints at multiple neutron capture nucleosynthesis processes, the slow (s), intermediate (i) and rapid (r) neutron capture processes. While the s-process terminates its heavy element production at Pb-208, we know that the r-process or i-process must be capable of going beyond since we observe long-lived actinides like U-238 in stars and traces of Cm-247 in meteorites. However which astrophysical site(s) are responsible for actinide production, and how heavy of actinides ultimately can be produced, remains unclear. The path forward relies heavily on computational calculations, with nucleosynthesis network solvers which post-process output from large scale hydrodynamics simulations. These networks make use of thousands of pieces of nuclear data, from separation energies of isotopes across the nuclear chart, to their capture, decay, and fission rates and branchings. The need to navigate large data can continue after the network run as well, for example further post-processing utilizing databases of emission spectra are required to predict light curves and gamma-rays. It is via such efforts to combine results from leading hydrodynamics simulations of proposed sites with carefully considered nuclear data libraries that we can make meaningful comparisons to astrophysical observables. For instance, in this talk I will discuss how utilizing observations of metal-poor stars rich in r-process elements, our calculations suggest the presence of fission fragments from isotopes with A˜260 [1]. Then, utilizing MeV gamma-rays, I will discuss how our nucleosynthesis predictions point to a 2.6 MeV emission line of Tl-208 that could be used to hunt locally for in situ neutron capture nucleosynthesis, from both i-process and r-process sources [2].

[1] Roederer, Vassh, et al. Science 382, 6675, 1177-1180, Dec 2023

[2] Vassh, Wang, Lariviere, et al. Phys.Rev.Lett. 132, 052701, Jan 2024

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Keyword-2

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Keyword-3

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