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The impact of individual nuclear properties on *r*-process nucleosynthesis

The detailed pattern of isotopic abundances produced in rapid neutron capture, or r-process, nucleosynthesis depends upon the nuclear physics properties of thousands of unstable neutron-rich nuclear species, as illustrated, for example, in Fig. 1. While some properties of neutron-rich nuclei near stability are known, experimental data is currently unavailable for most of the required masses and β-decay properties and essentially all of the needed neutron capture rates. However, the situation is evolving rapidly. Radioactive isotope facilities are expanding experimental reach into previously unknown regions of the nuclear chart, and new techniques are being developed to fully exploit the capabilities of current and upcoming facilities. A pressing question therefore emerges—which of the thousands of isotopes potentially involved in an r-process are most important to measure?

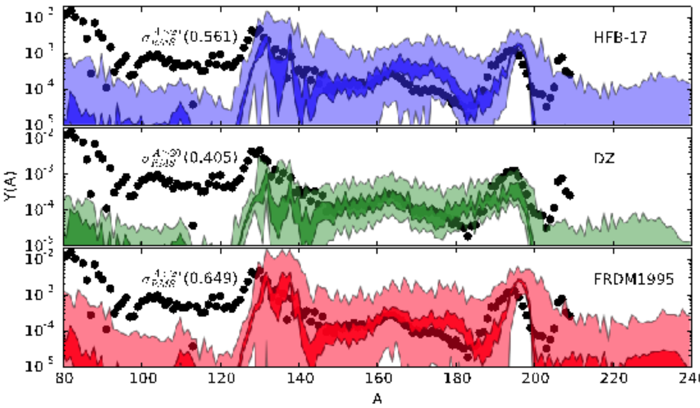

Fig. 1: Monte Carlo variances in isotopic abundance patterns from three nuclear mass model predictions compared to the solar data (dots). The uncorrelated mass variations are consistent with the mass model rms for the light shaded bands, while the darker shaded bands show the improvements that result if the mass model rms error can be reduced to 100 keV.

One approach to this question is to directly examine the influence of individual nuclear properties on r-process abundance predictions via sensitivity studies. In an r-process sensitivity study, a baseline astrophysical trajectory is chosen and then run thousands of times, each with one piece of nuclear data systematically varied. Results of the simulations are then compared to the baseline simulation with no data changes, to highlight the nuclei whose properties have the greatest leverage on the final abundance pattern in that particular environment. Sensitivity studies of this type have been performed for nuclear masses (Fig. 2), β-decay rates, neutron capture rates, and β-delayed neutron emission probabilities. JINA-CEE postdoc Matthew Mumpower along with JINA-CEE researchers Rebecca Surman, Gail McLaughlin, and Ani Aprahamian have spearheaded many of these studies and have now published a review of this work [1]. Detailed tables of the results are available at www.matthewmumpower.com.

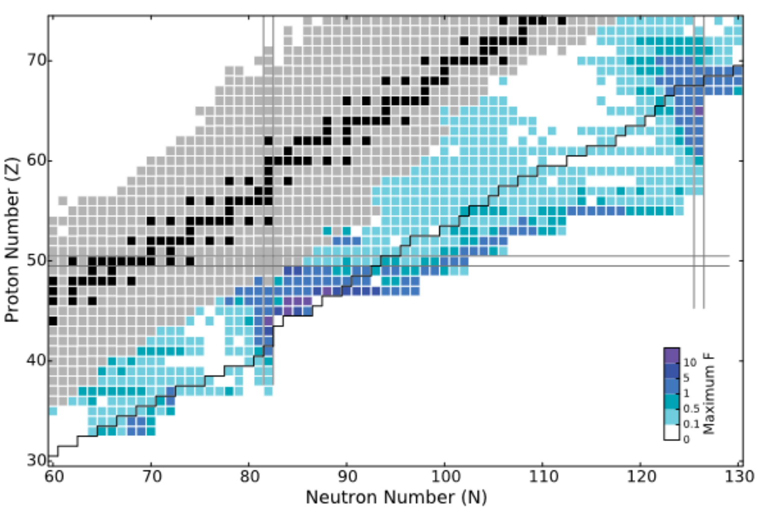

Fig. 2: Individual nuclear masses that significantly impact abundances for a neutron star merger r process.

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[1] M. Mumpower, R. Surman, G.C. McLaughlin, A. Aprahamian, Progress in Particle and Nuclear Physics, **86**, 86-126 (2016)