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Astrophysical and Nuclear Uncertainties of the r-Process

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The rapid neutron capture (r-) process is responsible for producing half of the elements heavier than iron in the Universe. Significant uncertainties remain in understanding the astrophysical environments capable of generating the necessary intense neutron fluxes. Detailed hydrodynamical simulations of proposed astrophysical scenarios (e.g. binary neutron star mergers, magneto-hydrodynamical supernovae, and collapsars) are computationally intensive and subject to various uncertainties, including the nuclear equation of state, neutrino interactions, and initial conditions.
To address these challenges, we adopt an alternative approach that is instead based on a site-independent parametric density profile. Our nuclear network calculations explore a wide range of initial electron fractions, entropies, and expansion timescales. The results align well with those of simulations and extend beyond conditions currently found in them.
Another important source of uncertainties arises from poorly constrained nuclear properties: Most nuclei along the r-process path are currently not experimentally accessible, making theoretical predictions essential, e.g. for nuclear masses, reaction rates, and fission properties. Here we show the impact of nuclear masses on r-process predictions and compare the results to observational data.

Author: Mr KUSKE, Jan (TU Darmstadt)

Co-authors: Prof. ARCONES, Almudena (TU Darmstadt, GSI, MPIK Heidelberg); Dr MIYAGI, Takayuki (CCS, University of Tsukuba); Dr REICHERT, Moritz (University of Valencia); Prof. SCHWENK, Achim (TU Darmstadt, MPIK Heidelberg)

Presenter: Mr KUSKE, Jan (TU Darmstadt)