NUCLEAR ROBUSTNESS OF THE R PROCESS IN NEUTRON-STAR MERGERS

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We have performed r-process calculations for matter ejected dynamically in neutron star mergers based on a complete set of trajectories from a three-dimensional relativistic smoothed particle hydrodynamic simulation. Our calculations consider an extended nuclear network, including spontaneous, β- and neutron-induced fission and adopting fission yield distributions from the ABLA code. We have studied the sensitivity of the r-process abundances to nuclear masses by using different models. Most of the trajectories, corresponding to 90% of the ejected mass, follow a relatively slow expansion allowing for all neutrons to be captured. The resulting abundances are very similar to each other and reproduce the general features of the observed r-process abundance (the second and third peaks, the rare-earth peak, and the lead peak) for all mass models as they are mainly determined by the fission yields. We find distinct differences in the predictions of the mass models at and just above the third peak, which can be traced back to different predictions of neutron separation energies for r-process nuclei around neutron number $N = 130$. In all simulations, we find that the second peak around $A \sim 130$ is produced by the fission yields of the material that piles up in nuclei with $A \gtrsim 250$ due to the substantially longer β-decay half-lives found in this region. The third peak around $A \sim 195$ is generated in a competition between neutron captures and β decays during r-process freeze-out. The remaining trajectories, which contribute 10% by mass to the total integrated abundances, follow such a fast expansion that the r process does not use all the neutrons. This also leads to a larger variation of abundances among trajectories, as fission does not dominate the r-process dynamics. The resulting abundances are in between those associated to the r and s processes. The total integrated abundances are dominated by contributions from the slow abundances and hence reproduce the general features of the observed r-process abundances.