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An open-source library for performance-portable neutrino reaction rates and Applications to neutron star mergers

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A realistic and detailed description of neutrinos in binary neutron star (BNS) mergers is essential to build reliable models of such systems. To this end, we present BNS_NURATES, a novel open-source numerical library designed for the efficient on-the-fly computation of neutrino interactions, with particular focus on regimes relevant to BNS mergers. BNS_NURATES targets a higher level of accuracy and realism in the implementation of commonly employed reactions by accounting for relevant microphysics effects on the interactions, such as weak magnetism and mean field effects. It also includes the contributions of inelastic neutrino scattering off electrons and positrons and (inverse) nucleon decays. Finally, it offers a way to reconstruct the neutrino distribution function in the framework of moment-based transport schemes. As a first application, we compute both energy-dependent and energy-integrated neutrino emissivities and opacities for conditions extracted from a BNS merger simulation with M1 transport scheme. We find some qualitative differences in the results when considering the impact of the additional relevant reactions and of microphysics effects. For example, neutrino-electron/positron scattering reactions are important for the energy exchange of heavy-type neutrinos as they do not undergo semileptonic charged-current processes, when μ are not accounted for. Moreover, weak magnetism and mean field effects can significantly modify the contribution of β processes for electron-type (anti)neutrinos, increasing at the same time the importance of (inverse) neutron decays. The improved treatment for the reaction rates also modifies the conditions at which neutrinos decouple from matter in the system, potentially affecting their emission spectra.

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