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Collective neutrino oscillations and the heavy-element nucleosynthesis in supernova

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In high energy astrophysical processes involving compact objects, such as core-collapse supernovae or neutron star mergers, neutrinos are likely to play an important role in the synthesis of nuclides. Neutrinos in these environments can experience collective flavor oscillations driven by neutrino-neutrino coherent forward scattering. Recently, there has been interest in exploring potential beyond-the-mean-field effects in the collective oscillations of neutrinos. Here, we seek to explore possible implications of these effects for the heavy-element nucleosynthesis yields in supernova environments with different astrophysical conditions and neutrino inputs. We find that collective oscillations can impact the operation of the νp-process and r-process nucleosynthesis in supernovae. The potential impact is particularly strong in high-entropy, proton-rich conditions, where we find that neutrino interactions can nudge an initial νp process neutron rich, resulting in a unique combination of proton-rich low-mass nuclei as well as neutron-rich high-mass nuclei. We describe this neutrino-induced neutron capture process as the "νi process". In addition, nontrivial quantum correlations among neutrinos, if present, could lead to distinctly different nucleosynthesis results compared to the corresponding mean-field treatments, by virtue of modifying the evolution of the relevant one-body observables.

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