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Neutrino Flavor Transformations with Emu: A New Particle-in-Cell Code for Quantum Kinetics[1]

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Neutrino flavor transformations occurring in neutron star mergers and core collapse supernovae may significantly modify the amount of electron flavor content and thus the nucleosynthesis outcomes of these events. Especially important to determining the neutrino flavor in such events is the fast-growing neutrino flavor instability driven by neutrino-neutrino interactions. However, solving the equations of neutrino quantum kinetics has remained a challenge because capturing the neutrino self-interaction potential requires resolving small length, time, and angular scales in the neutrino distribution. We present Emu, a particle-in-cell simulation code implementing the neutrino quantum kinetics equations that enables arbitrary angular resolution by representing the neutrino distribution with a set of computational particles, each with unique position, momentum, and quantum state. Emus C++ kernels for computing the evolution of each particles quantum state are all symbolically generated from the quantum kinetics equations using Sympy. Emu is based on the AMReX computational framework for its scalable, domain-distributed particle-mesh routines and is performance portable on CPUs and GPUs. Emu thus enables detailed multidimensional studies of the neutrino fast flavor instability, resolved in space, angle, and time. We will discuss Emus design and its scalability on modern supercomputing platforms along with our ongoing simulation explorations of the fast flavor instability and its astrophysical implications.

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