An Advanced Leakage Scheme for Neutrino Treatment in Astrophysical Simulations

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We present an Advanced Spectral Leakage (ASL) scheme to model neutrinos in the context of core-collapse supernovae (CCSNe) and compact binary mergers. Based on previous gray leakage schemes, the ASL scheme computes the neutrino cooling rates by interpolating local production and diffusion rates (relevant in optically thin and thick regimes, respectively) separately for discretized values of the neutrino energy. Neutrino trapped components are also modeled, based on equilibrium and timescale arguments. The better accuracy achieved by the spectral treatment allows a more reliable computation of neutrino heating rates in optically thin conditions. The scheme has been calibrated and tested against Boltzmann transport in the context of Newtonian spherically symmetric models of CCSNe. ASL shows a very good qualitative and a partial quantitative agreement for key quantities from collapse to a few hundreds of milliseconds after core bounce. We have proved the adaptability and flexibility of our ASL scheme, coupling it to an axisymmetric Eulerian and to a three-dimensional smoothed particle hydrodynamics code to simulate core collapse. Therefore, the neutrino treatment presented here is ideal for large parameter-space explorations, parametric studies, high-resolution tests, code developments, and long-term modeling of asymmetric configurations, where more detailed neutrino treatments are not available or are currently computationally too expensive.
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