ASTROPHYSICS

thornado-Hydro, xCFC: A Discontinuous Galerkin Hydrodynamics Solver for General Relativistic Core-Collapse Supernova Simulations

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Modeling core-collapse supernovae (CCSNe) has been an on-going effort since the 1960s. Despite advances in physics theory, physics experiments, and technology, consistent, multi-dimensional CCSN explosions are still difficult to achieve, and a consensus is yet to be reached regarding what physics is required. Here, we present the status of a novel simulation code, `thornado`, which aims to simulate the neutrino-radiation kinetics and the stellar hydrodynamics of CCSNe using high-order discontinuous Galerkin methods under the extended conformally flat condition (xCFC), an approximation to GR. Specifically, we show the progress in implementing a solver for the general relativistic (GR) hydrodynamics equations and we show results from several test problems designed to demonstrate the abilities and capabilities of the code. This includes evolving a Kelvin–Helmholtz instability problem, a multi-dimensional blast wave, and the adiabatic collapse, bounce, and post-bounce phases of a realistic progenitor. These simulations are performed in parallel with MPI and with adaptive mesh refinement via a coupling to AMReX, a software framework designed for exascale systems. This adiabatic collapse test also demonstrates the coupling of `thornado` to Poseidon, a hybrid spectral/finite-element xCFC metric solver that is also designed with an eye toward simulating CCSNe. We also analyze the performance of the solver with both strong- and weak-scaling tests. As a science application of our code, we show results from a study of the effects of GR on the standing accretion shock instability, a hydrodynamical instability that manifests in, among other scenarios, CCSNe.

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