BLUE WATERS
SUSTAINED PETASCALE COMPUTING

Allocation: Illinois/1000 Knh

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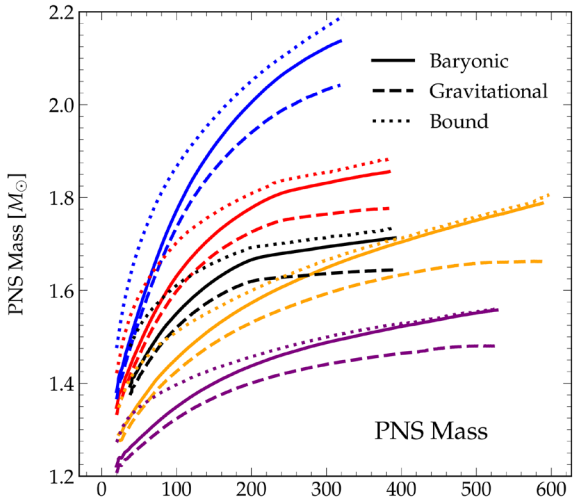
Space Science

CORE-COLLAPSE SUPERNOVA SIMULATIONS: SIMULATING THE BRIGHTEST OBJECTS IN THE SKY AND THE SOURCE OF LIFE'S BUILDING BLOCKS

Research Challenge

To understand how differing stellar properties, just prior to core collapse, affect the behavior of supernovae events and to characterize the radiation that will be generated from the next supernova to occur in our galaxy.



The mass of the neutron star forming at the center of the supernova for the different progenitor stars simulated by the team The highest mass simulation (in blue) is still accreting at 0.45 solar masses per second and will likely collapse to a black hole.

Methods & Codes

These simulations use the Zelmani Core Collapse Simulation Package and leverages the Cactus Framework. Zelmani provides OpenMP+MPI parallelized adaptive mesh refinement, high-order shock capturing finite volume methods for the fluid and finite difference methods for the metric evolution equations, and handles neutrino radiation using an approximate M1 scheme. All simulation output uses HDF5 for data and metadata storage.

Results & Impact

The team has published a first set of results in [1] where they present a study of the progenitor dependence of a three-dimensional neutrino mechanism of core-collapse supernovae. The results suggest a complex, nonmonotonic dependence on progenitor parameters, hinting at a complex interplay between multiple proposed explosion mechanisms, necessitating more detailed numerical studies to fully understand the effects.

Ott, C.D., et al., The Progenitor Dependence of Core-collapse Supernovae from Three-dimensional Simulations with Progenitor Models of 12–40 M⊙. Astrophys.J.,855 (2018). DOI: 10.3847/2041-8213/aaa967

Why Blue Waters

Fully three-dimensional, general-relativistic, radiation-magnetohydrodynamic simulations are simply too demanding of computational resources for any but a leadership-class facility to support them. The project's simulations required the use of hundreds of compute nodes to provide sufficient memory for the simulation's state vector. The exceptional speed of Blue Waters' network provided the capability to scale to the number of nodes required to complete these simulations.