APR14-2013-000102

Abstract for an Invited Paper
for the APR14 Meeting of
the American Physical Society

Petascale Simulations of Core-Collapse Supernovae[1]

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Core-collapse supernovae from massive stars are among the most energetic events in the universe. They liberate a mass-energy equivalent of $\sim$15% of a solar mass in the collapse of their progenitor star's core. The majority ($\sim$99%) of this energy is carried away by neutrinos, while $\sim$1% is transferred to the kinetic energy of the explosive outflow. A smaller, yet still tremendous amount of energy is emitted in electromagnetic and gravitational waves. Core collapse and the subsequent supernova evolution towards explosion involve a broad range of physics: Boltzmann transport of neutrinos, weak interactions, nuclear reactions, the nuclear equation of state, magnetohydrodynamics, and gravity. The problem is also multi-scale and for modeling the supernova engine, one must generally resolve physical scales from $\sim$10000 km down to below $\sim$100 m. Due to its multi-physics multi-scale nature, the core-collapse supernova problem poses a formidable computational challenge that requires petascale resources of the caliber of the NSF BlueWaters system. I review the computational approaches employed by the core-collapse supernova modeling community and present an overview of recent results from the first set of full 3D simulations.

[1]Supported by NSF under grant nos. PHY-1151197, AST-1212170, and OCI-0905046