NEW PRECOLLAPSE MODELS FOR CORE COLLAPSE SUPERNOVAE

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Core collapse supernovae result when the iron core of a massive star becomes unstable through a combination of electron capture and iron dissociation. At this point in the evolution, the core collapses gravitationally to supernuclear matter densities. The core pressure is dominated by electron degeneracy pressure during most of the collapse, but as nuclear matter densities are exceeded, the core undergoes a transition to bulk nuclear matter and becomes incompressible owing to Fermi effects and the presence of a hard core in the nuclear interaction potential at very small distances. At this point the core rebounds and a shock wave forms near the sonic point in the stellar core, which separates a subsonically infalling inner iron core from a supersonically infalling outer iron core. Ultimately this supernova shock wave must propagate out of the iron core and through the star's outer layers to disrupt the star in a core collapse supernova explosion.

Unfortunately, because of dissociation losses suffered by the shock as it compresses the core nuclei that infall through it, and because of electron neutrino losses incurred as the shock propagates out beyond the electron "neutrinosphere," above which the electron neutrinos produced by electron capture on the newly dissociation-liberated protons escape, the shock stalls to form an accretion shock, to be revived later by a "delayed shock mechanism" first discovered by Wilson[6] and fully developed by Bethe and Wilson.[4] In this mechanism, the stalled shock is revived by neutrino heating, i.e., by the absorption of electron neutrinos and antineutrinos by protons and neutrons behind it.

The location of shock formation and the initial shock strength provide the key initial conditions that dictate the subsequent shock stall radius. All other things being equal, for a shock that initially forms farther out and/or is initially stronger, its stall radius will be farther out, which in turn would facilitate shock revival. Moreover, for an iron core mass that is smaller, the shock would have to traverse and consequently dissociate less iron and, therefore, would suffer less dissociation loss. Thus, the size of the iron core, among other characteristics of the precollapse star, is an important quantitative input to supernova models that in part dictates the initial conditions for the entire post-core-bounce evolution.

In light of this, we have recently begun a collaboration with a new stellar modeling group. Most notable among the differences between their models and those produced by Weaver and Woosley[7] is the trend in iron core mass. Whereas the Weaver–Woosley models show a sharp rise in iron core mass — from 1.3–1.4 solar masses to 1.7–1.8 solar masses — as the main sequence mass becomes greater than $\approx$17 solar masses, the Chieffi et al.[5] models have an iron core mass that is rather insensitive to the main sequence mass, with an iron core mass between 1.4–1.6 solar masses throughout. This would make it less difficult to explode very massive stars, but more difficult to explode stars in the mass range 10–15 solar masses. Nonetheless, the differences are important and must be considered in detailed numerical simulations. We will carry out Newtonian and fully general relativistic simulations using multigroup flux-limited diffusion neutrino

transport that begin with the Chieffi et al. precollapse models. Moreover, we will consider precollapse models with both zero and solar metallicity, i.e., with precollapse stars that would have formed early and late in the evolution of the Universe, respectively.

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