COMPARISON OF NEUTRINO-DRIVEN CONVECTION IN CORE COLLAPSE SUPERNOVAE IN TWO AND THREE DIMENSIONS

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Core collapse supernovae result from the collapse and rebound of unstable iron cores that develop late in the lives of stars more massive than ten times the mass of our Sun. The rebound generates a shock wave that is ultimately responsible for disrupting the star. Computer simulations of core collapse supernovae have illuminated the role played by neutrino transport in powering the supernova shock, and by convection in potentially aiding this process.[6,5,7,9] Consequently, supernova models will ultimately require multi-dimensional simulations coupling accurate multidimensional neutrino transport and multidimensional hydrodynamics. In particular, given that convection is a three-dimensional phenomenon, ultimately realistic supernova simulations will have to be carried out in three dimensions to accurately assess convection's potential role in generating explosions.

It is well known that energy cascades from long wavelengths to short wavelengths in three spatial dimensions, whereas in two spatial dimensions the energy flows in the opposite direction. In fact, in the earliest simulations of neutrino-driven convection, which were carried out in two dimensions, large-scale convection was seen, carrying high-entropy matter upward and lower entropy matter downward in well-separated flows that in turn gave rise to efficient heat engines and supernova explosions.[6] This large-scale character of the convective flow was confirmed in subsequent simulations, although the flows were generally more turbulent and the flow characteristics were time-dependent.[5,7,9] In light of this, we have undertaken a study of the development and evolution of neutrino-driven convection in two and three spatial dimensions. These are purely hydrodynamics simulations. We begin with realistic postbounce "slices" taken from detailed one-dimensional supernova models. These initial slices are seeded for convection, and the onset and development of convection is followed. In the absence of neutrino transport, the shock trajectories in this study cannot be expected to follow the trajectories in the more realistic case in which neutrino transport is included, and this certainly will have an impact on the precise character of the convective flow. However, this is a relative comparison, and we expect that the features uncovered in this study will carry over to the case in which two- and three-dimensional hydrodynamics and neutrino transport are coupled.

In Fig. 1 we show snapshots in both two and three dimensions of the convective flow.[8] These snapshots were taken at precisely the same postbounce time. It is evident that the convective flow in two dimensions is larger-scale, ultimately leading to a significant distortion of the supernova shock wave and, on average, to a larger shock radius. On the other hand, in three dimensions the flow is qualitatively more spherically symmetric and the shock radius does not differ much from the radius in our one-dimensional hydrodynamics model (indicated by the solid, spherical line). These results confirm our expectations: that three-dimensional supernova models will look qualitatively more like one-dimensional, spherically symmetric models, and that the potential for neutrino-driven convection to aid in shock revival and explosion will be reduced.

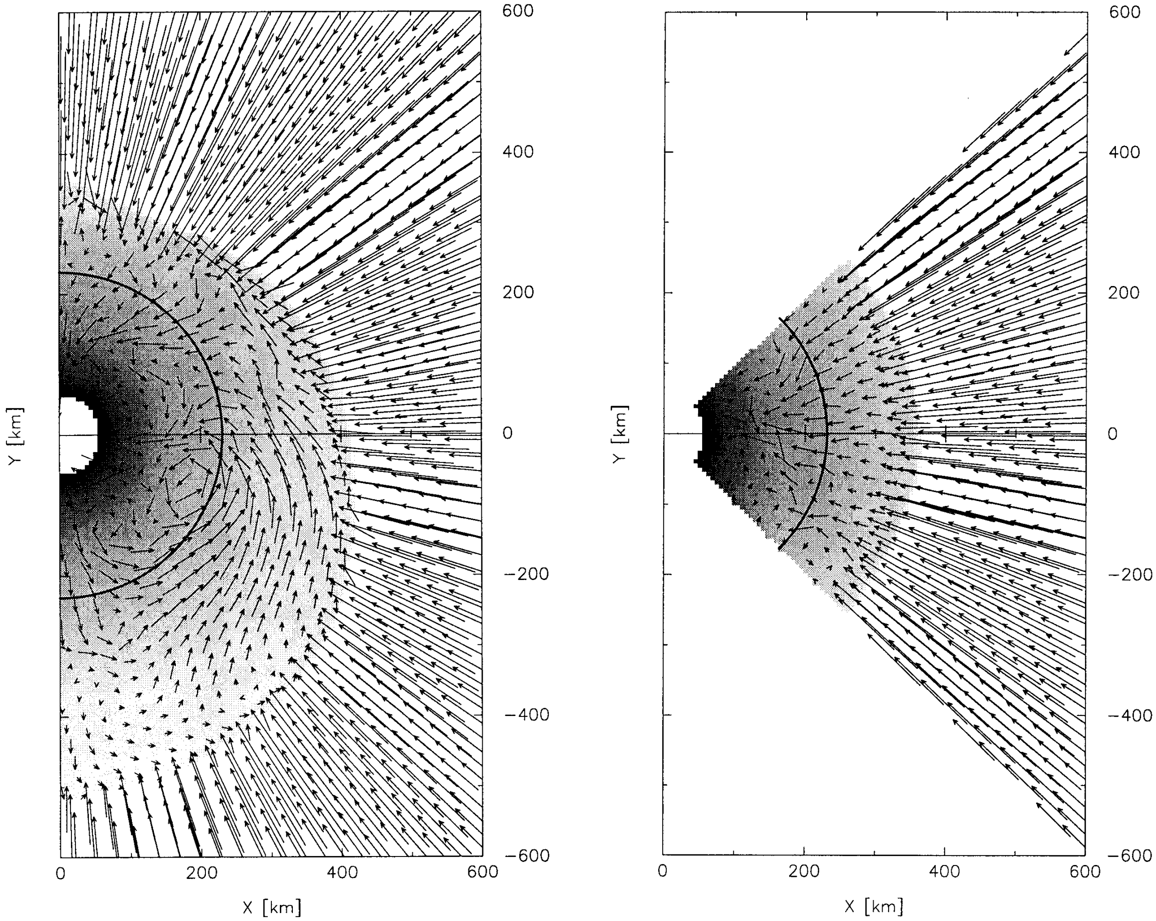

Figure 1: Left side: Log(ρ) – 128^2 grid; right side: Log(ρ) – k = 32 slice from $128 \times 64 \times 64$ grid.

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