TWO-DIMENSIONAL STUDIES OF CORE COLLAPSE SUPERNOVAE

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Core collapse supernovae result when a shock wave forms after the initial collapse and rebound of a massive star's iron core. Because of dissociation and neutrino losses, the shock stagnates. This sets the stage for a shock reheating mechanism whereby neutrino energy deposition via electron neutrino and antineutrino absorption on nucleons behind the shock reenergizes it. This shock revival mechanism is thought to be aided by convection below the neutrinospheres, which is thought to boost the neutrino luminosities, and/or by neutrino-driven convection behind the shock, which is thought to boost the neutrino heating efficiency or to move the shock outward in radius, facilitating revival.[6,5,7,8,10,9]

The ORNL supernova group has coupled state-of-the-art (PPM) two-dimensional hydrodynamics to realistic one-dimensional (multigroup flux-limited diffusion) neutrino transport to investigate convection in core collapse supernovae and its impact on the explosion mechanism. This was the first implementation of multigroup transport in multidimensional supernova modeling, and the first implementation of a transport scheme that is able to transit seamlessly between neutrino-thick (diffusive) and neutrino-thin (free-streaming) regimes. We have seen large-scale convection develop behind the shock, characterized by high-entropy, mushroom-like, expanding upflows and dense, infalling, low-entropy, finger-like downflows. However, despite the appearance of violent convection, the shock eventually recedes and no evidence of an explosion or of a developing explosion is present.[9] We have also seen that, in regions near and below the neutrinospheres where neutrinos are more strongly coupled to the matter, neutrino transport may equilibrate a convecting element with its surroundings in entropy and leptons before the element has a chance to convect; i.e., neutrino transport may severely damp proto-neutron star convection.[10] This is in contrast to the results obtained by another group,[8] and this difference needs to be investigated and understood.

Although coupling one-dimensional multigroup flux-limited diffusion neutrino transport to two-dimensional hydrodynamics marked a major step toward realistic multidimensional supernova models, ultimately self-consistent fully two-dimensional simulations coupling two-dimensional multigroup neutrino transport and two-dimensional hydrodynamics must be carried out. To accomplish this goal, we are currently developing a new neutrino transport/neutrino radiation hydrodynamics code for two-dimensional supernova modeling which will implement a two-dimensional multigroup variable Eddington factor scheme/closure for the neutrino transport. Once this code is developed, we will be able to consider (1) the development of proto-neutron star convection below the neutrinospheres, (2) the development of neutrino-driven convection behind the shock, (3) the combined effects of both modes of convection, (4) the effects of rotation, and (5) the combined effects of convection and rotation on the explosion mechanism.

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