Two-Dimensional Simulations of Core Collapse Supernovae

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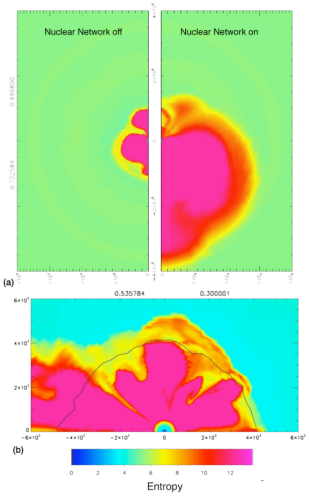
Core collapse supernovae are stellar explosions, the death throes of massive stars with mass greater than ten times the mass of the Sun. They result from the collapse of their iron cores. This collapse produces a shock wave that moves through the star to produce the spectacular explosion that obliterates the star almost entirely. On the Leadership Computing Facility at the Oak Ridge National Laboratory a set of two-dimensional core collapse supernova simulations is underway. These simulations will advance current two-dimensional supernova models in a significant way through their inclusion of new physics and will pave the way for near-term three-dimensional models in preparation. In two-dimensional models, certain assumptions are made. We are looking at one slice through the center of the supernova (much like one slice through the center of a watermelon) and assuming that all such slices are the same. In reality, a supernova is three-dimensional and no two slices are alike. Nonetheless, looking at one slice tells us much about the entire supernova. In ongoing work to be completed this year, the ORNL-centered supernova effort, with close collaborators Stephen Bruenn (Florida Atlantic University) and John Blondin (NCSU), has included three key ingredients in the simulations: (1) Sophisticated models of the production, transport, and interaction of nearly-massless particles known as neutrinos. These particles behave like radiation in the supernova environment and are central to generating the supernova explosion. (2) Nuclear fusion reactions that occur in the star as the supernova shock wave responsible for the explosion moves out through the star and heats it. (3) The simulation of the supernova shock wave's movement through the star for a much longer period of time relative to past models. Given these three critical ingredients, exciting new results and conclusions are emerging from the ORNL-FAU-NCSU models. [Early results from these studies have been published in Bruenn et al., *Journ. Phys. Conf. Ser.* **46**, 393 (2006).]



An explosion is obtained in this two-dimensional model of a core collapse supernova, evidenced by the expanding shock wave in the bottom panel. The shock wave is distorted, and the explosion takes on a cigar shape. Below the shock wave we see the turbulent dynamics of the stellar core during the explosion, with rising plumes (red) pushing on the shock and flows moving toward the center (yellow).