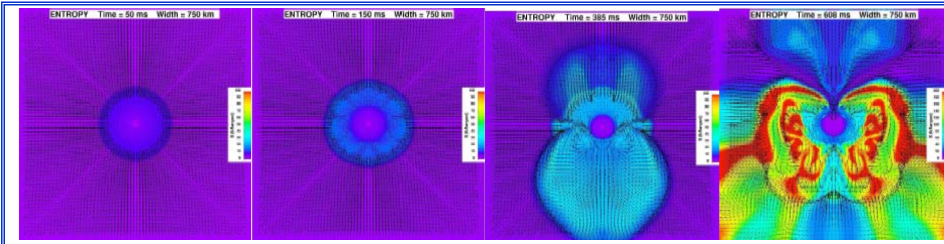
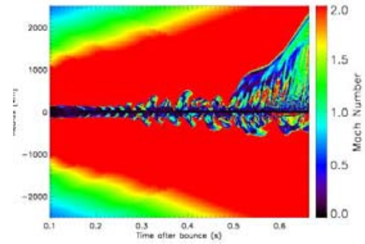
It's the BOOM, not the BANG: A New Mechanism for Core-Collapse Supernova Explosions



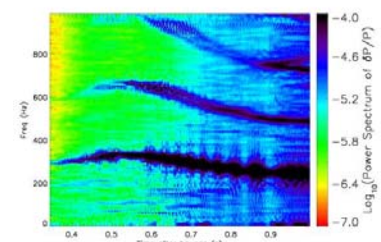
Understanding how supernovae explode are questions being addressed by leading edge research at the Joint Institute for Nuclear Astrophysics (JINA). What JINA researchers at the University of Arizona have recently suggested is that it is "boom" – the acoustic wave -- which drives supernovae explosions. This compliments and supports future research at JINA on the r-process in supernovae.

A new mechanism for core-collapse supernova explosions is suggested that relies upon acoustic power generated in the inner core as the driver. An advective-acoustic oscillation with a period of 25-30 milliseconds (ms) arises 200 ms after bounce and saturates in the generation of secondary shocks. However, this instability is not the primary agent of explosion. Rather, it is the acoustic power generated early on in the inner turbulent region stirred by the accretion plumes, and by the excitation and sonic damping of core oscillations. An oscillation with a period of 3 ms grows at late times to be prominent around 500 ms after bounce. The accreting protoneutron star is a self-excited oscillator! The associated acoustic power is sufficient to drive the explosion >600 milliseconds after bounce. The angular distribution of the emitted sound is fundamentally aspherical. The sound pulses radiated from the core, steepen into shock waves that merge as they propagate into the outer mantle and deposit their energy and momentum with high efficiency. The ultimate source of the acoustic power is the gravitational energy of infall and the core oscillation acts like a transducer to convert this accretion energy into sound. An advantage of the acoustic mechanism is that acoustic power does not abate until accretion subsides, so that it is available as long as it may be needed to explode the star. This suggests a natural means by which the supernova is self-regulating. First model calculations suggest that this scenario simultaneously and naturally provides the conditions required for the r-process.

This project was supported by the Joint Institute for Nuclear Astrophysics under NSF Grant PHY0216783.



By 500 ms after bounce, the acoustic power from the core is quite pronounced and is starting to power outflow and the beginnings of an explosion. The figure depicts the temporal evolution after 100 ms of the entropy profile along the poles. The position of the outer shock, the wobble due to the shock instability after 250 ms, the onset of explosion, and the high entropies which would provide excellent conditions for the r-process are all clearly seen.



This figure shows the time evolution of the spectrum of pressure fluctuations at a radius of 30 km. On this frequency-time plot one sees the emergence of the 3-ms core oscillation which dominates after 450 ms, as well as a number of other periodicities of lesser strength.

Researchers:

A. Burrows [1], J. Murphy [1], Eli Livne [2], Luc Dessart [1], Christian Ott [3]

[1] U. of Arizona
[2] Hebrew U., Israel
[3] MPI Potsdam, Germany