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Funded by
Office of Science
U.S. Department of Energy

GWPAAW, Milwaukee   January 29, 2011
HOW IS THE SN SHOCK REVIVED?

Known, Potentially Important Ingredients

- Gravity
- Neutrino Heating
- Convection
- Shock Instability
- Nuclear Burning
- Rotation
- Magnetic Fields

Need 3D models with all of the above, treated with sufficient realism.
“RbR-Plus” MGFLD Neutrino Transport
- \( O(v/c) \), GR time dilation and redshift, GR aberration (in flux limiter)

2D PPM Hydrodynamics
- adaptive radial grid

Lattimer-Swesty EOS
- Cooperstein et al. for low densities

Nuclear (Alpha) Network
- 14 alpha nuclei between helium and zinc

2D Effective Gravitational Potential
- GR time dilation, effective gravitational potential,
15 M\textsubscript{☉} PROGENITOR COLLAPSE IN 2D
\[
h_+ D = \frac{1}{8} \sqrt{\frac{15}{\pi}} (\sin^2 \theta) A_{20}
\]

CHIMERA simulation for 15 $M_\odot$ progenitor

GWPAW, Milwaukee January 29, 2011
Murphy, Ott, and Burrows (2009)

\[ f_p \propto \left( \frac{GM r}{r^3} \right)^{1/2} \]
\[ h_+ \propto \frac{4\pi G}{Dc^4} \rho f_p \nu_p r^3 \Delta r \Delta \mu \]

Newtonian potential & Shen EoS

Effective GR potential & LS EoS
Marek and Janka (2009)
Neutrinos

Epstein-Müller approximation

\[ h_{ij}^{TT} = \frac{4G}{c^2 R} \int_{-\infty}^{t-R/c} dt' \int_{4\pi} d\Omega' \frac{(n_i n_j)^{TT}}{1 - \cos \theta} \frac{dL_\nu(\Omega', t')}{d\Omega'} \]

- \( R \) - distance from the source to the observer
- \( \theta, \varphi \) - direction angles of neutrino emission in observer’s frame
- \( dL_\nu/d\Omega \) - direction dependent neutrino luminosity
Post-bounce time = 0 ms

Post-bounce time = 5 ms

Post-bounce time = 157 ms

Heger 15 model: 5000 particles = 40 per row x 125 rows
Low frequency component of early signal ($t_b<100$ ms) produced by deflection of infalling matter through the shock.
DETECTABILITY BY ADV. LIGO

CHIMERA simulation for 15 $M_{\odot}$ progenitor
2D simulations of core-collapse SN show sustained explosions for a range of non-rotating progenitors

There is qualitative agreement between several groups on the main characteristics of the GW signals from 2D Core Collapse Supernovae simulations

Galactic event detection by AdvLIGO will provide unique insights of the collapse dynamics and proto-neutron star structure

3D simulations are necessary for the complete realistic GW waveforms