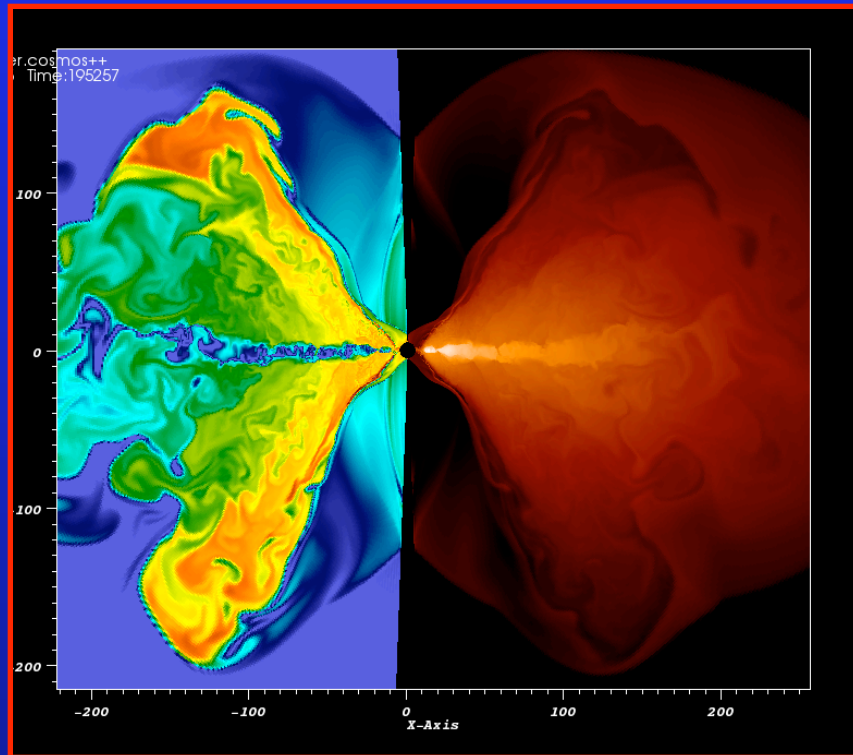


The
COSMOS ++
Code

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The COSMOS++ Code



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Overview of COSMOS++

- Massively parallel
 - Good scaling up to 2048 processors
- Unstructured mesh
 - 1, 2, or 3D cartesian, curvilinear, or arbitrary coordinates
 - Eulerian or Lagrangian mesh motion
- Adaptive Mesh Refinement
- Multi-physics



Physics in COSMOS++

- Newtonian & General Relativistic Hydrodynamics and MHD
- Numerous EOS': Opal, fully relativistic (Mignone 2005, Helmholtz, **modern nuclear EOS (C. Ott)**)
- Chemistry (27 reactions), 9 & 19 element nuclear reaction nets
- Radiative cooling, **deleptonization** (Neutrinos)
- Newtonian external & self-gravity
- Arbitrary spacetime curvature through fixed background metric and **Einstein solver**
- Radiation transport: **Multi-group flux-limited diffusion & Monte Carlo**
- **Boxed-sphere mesh**

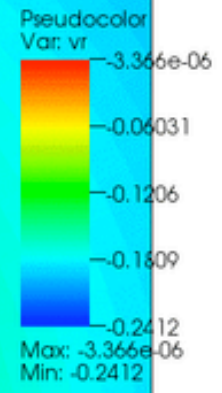
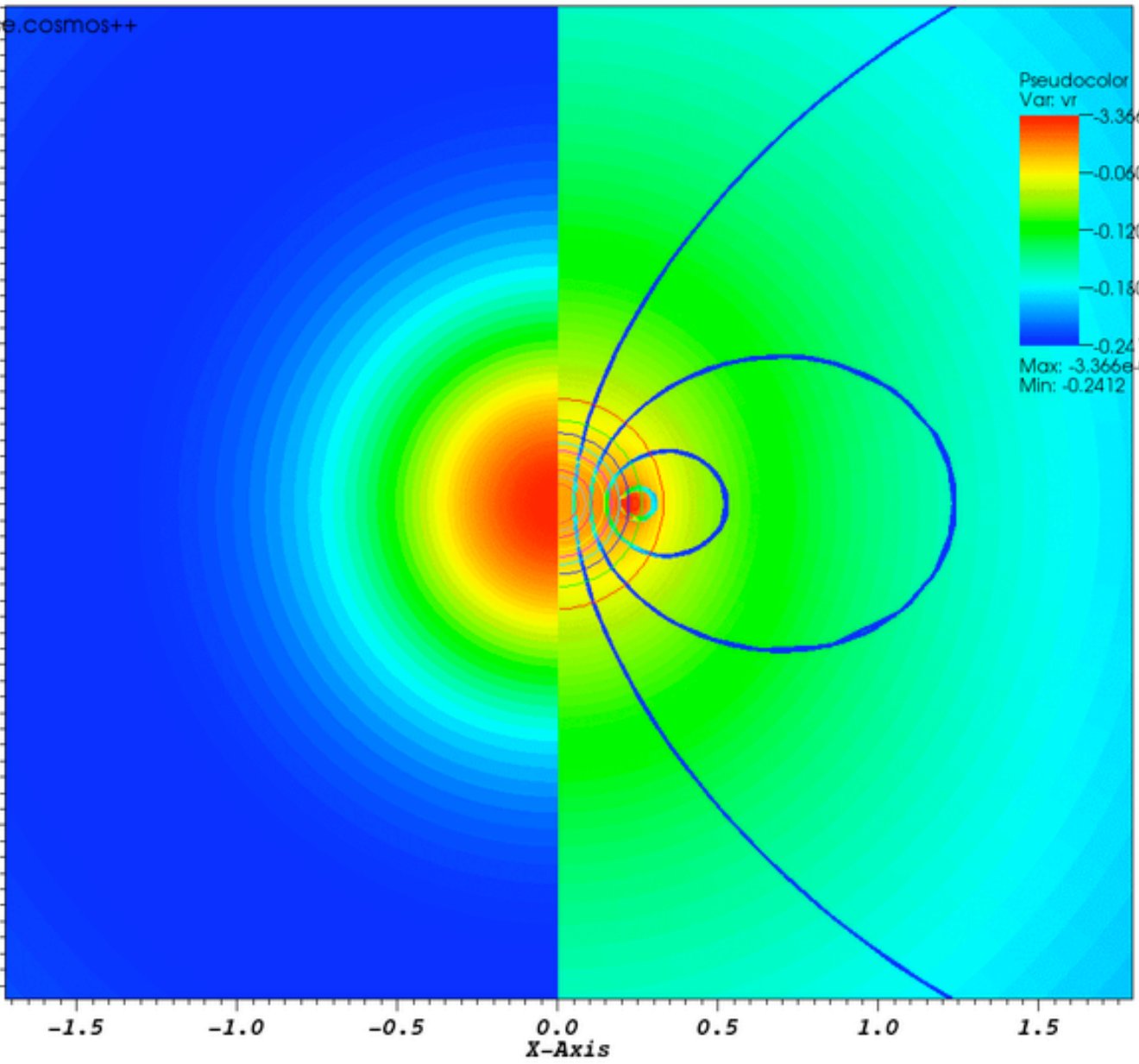
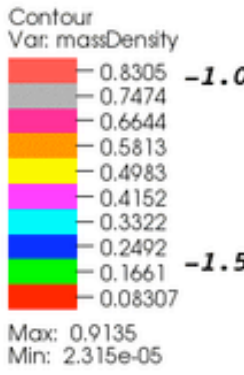
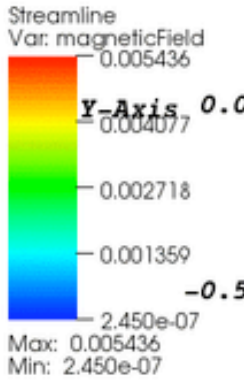
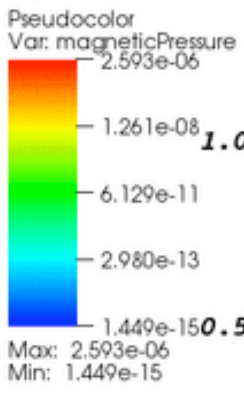


Modeling Magnetic Core Collapse

- Newtonian MHD code: COSMOS++
 - Modern nuclear EOS (C. Ott)
 - Realistic 15 solar mass stellar progenitor model s15s7b2 (Woosley)
 - Deleptonization model (Liebendorfer et al. 2005)
- Remap and zoom into interesting areas in 2D or 3D

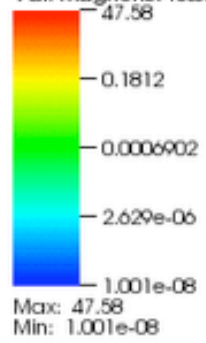


DB: out-core-cal...
Cycle: 0 Time: 0.0



DB: out-core-collapse-remap3.cosmos++
Cycle: 0 Time: 3.50665

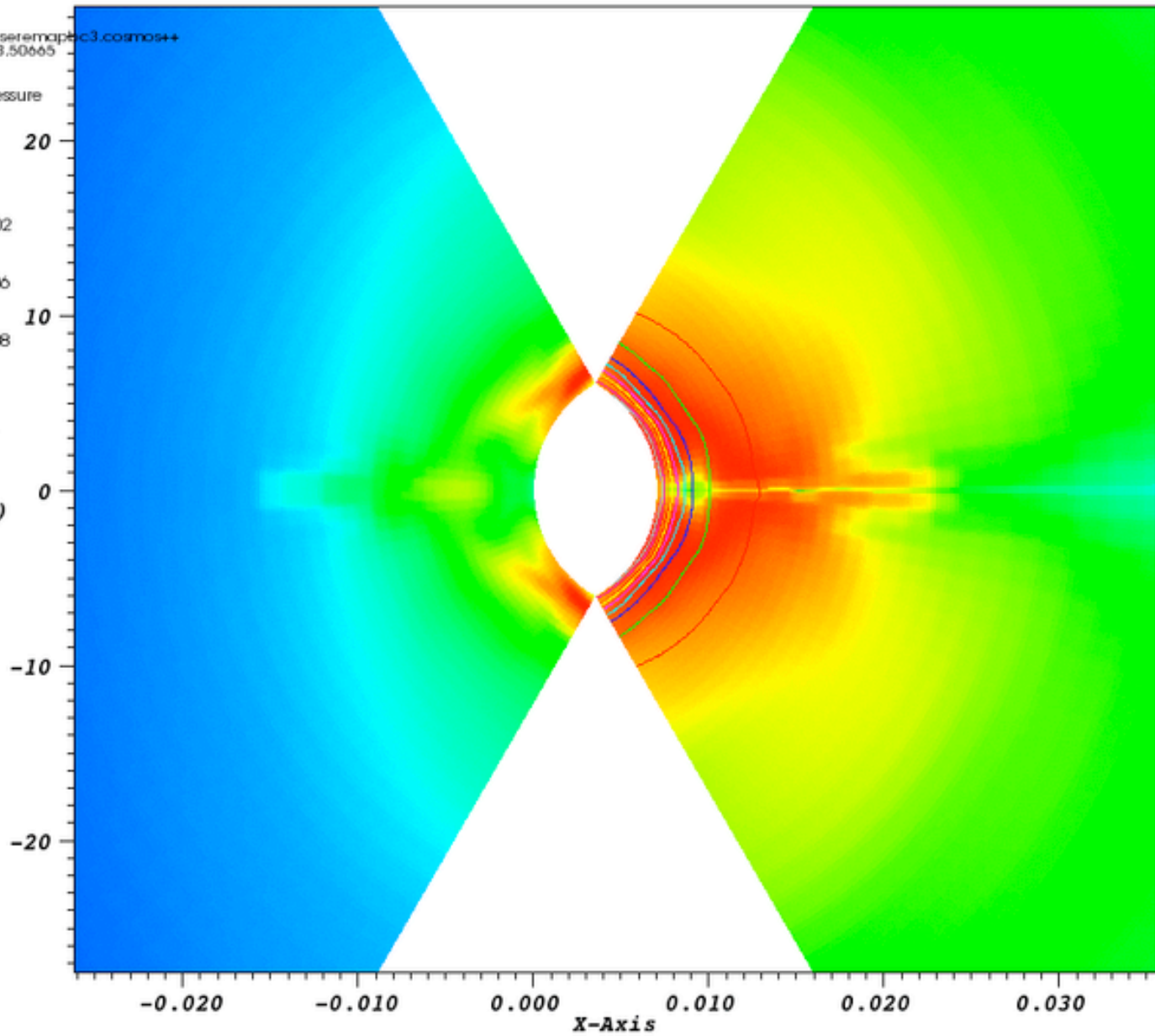
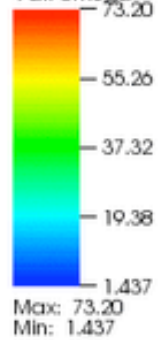
Pseudocolor
Var: magneticPressure



Contour
Var: massDensity

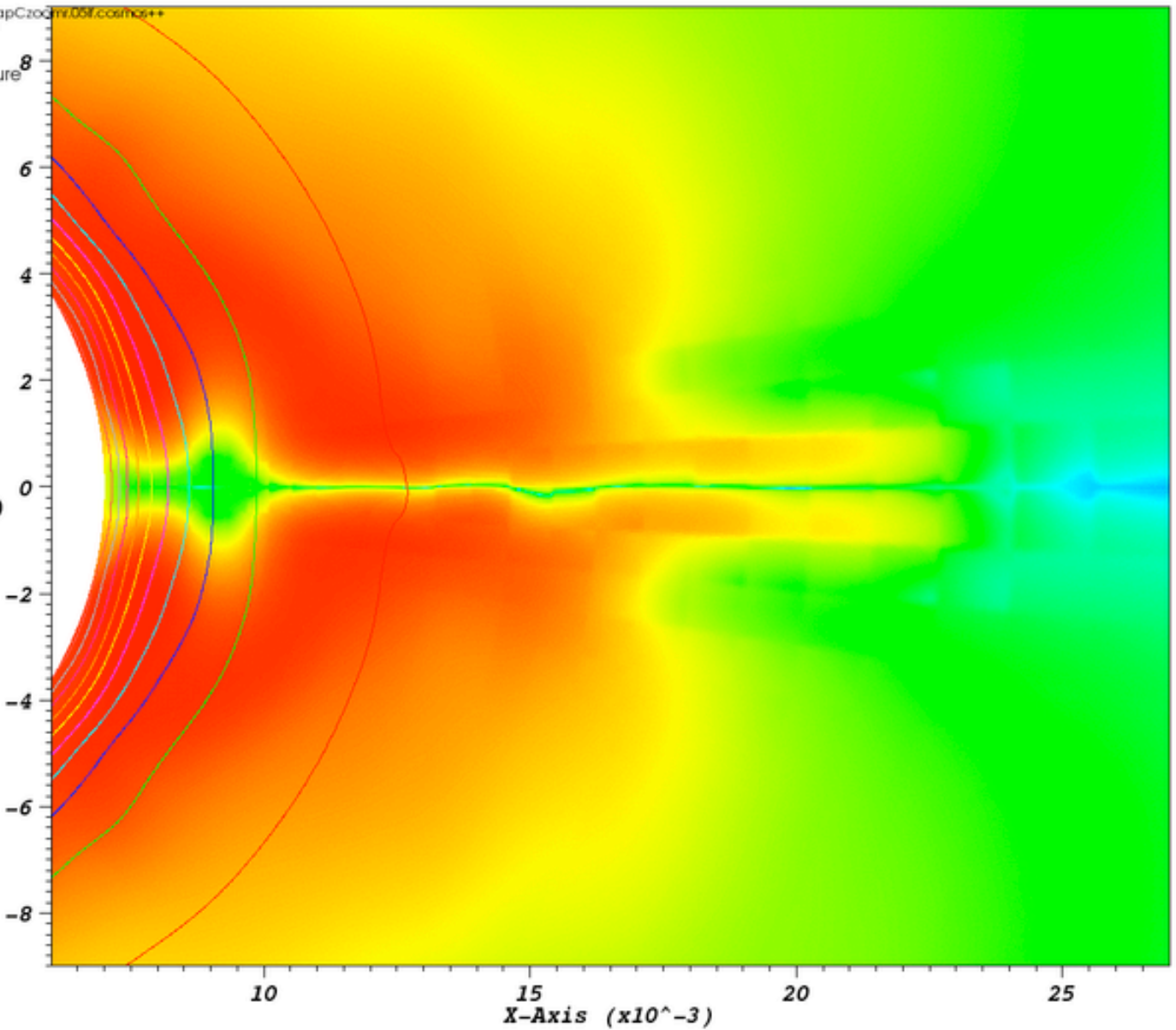
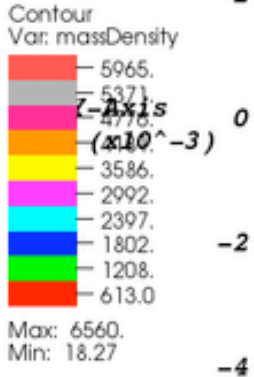
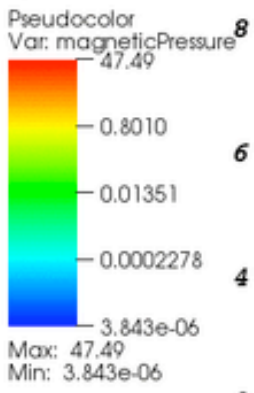


Pseudocolor
Var: omega



user: jay
Thu Apr 22 15:29:24 2010

DB: out-core-collapse-mapCzodrr.05f.cosmas++
Cycle: 0 Time: 3.50665

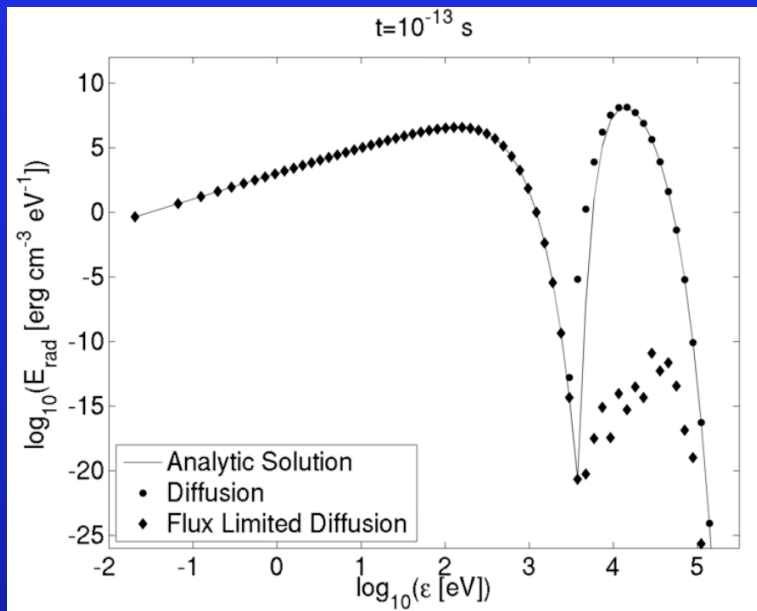


Magnetic core collapse

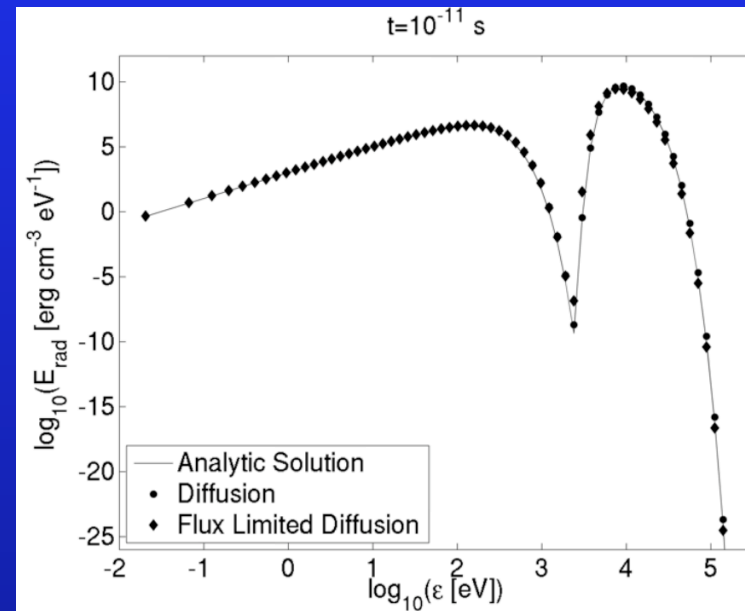
- What is the roll of magnetic fields in core collapse?
 - Does MRI grow the field to dynamically significant values (currently $1/\beta \approx 0.15$)?
 - Do magnetic fields aid in
 - Powering the shock?
 - Transporting neutron star angular momentum?
 - Coupling neutrinos to stellar mantle?
- Neutrino Transport



Flux Limited Multi-group Diffusion



Early time



Later time

Weis
et al.

**Flux limiting delays emission from hot sphere
embedded in cooler absorbing medium**



The Difference Formulation of Radiation Transport

$$\left[\left(\frac{1}{c} \frac{\partial}{\partial t} + \Omega \cdot \nabla \right) + \sigma_{av} \right] I_v = \sigma_{av} B_v$$

$$\rho \frac{\partial \varepsilon}{\partial t} = c \int \sigma_{av} (I_v - B_v) dv$$

Brooks &
Szoke

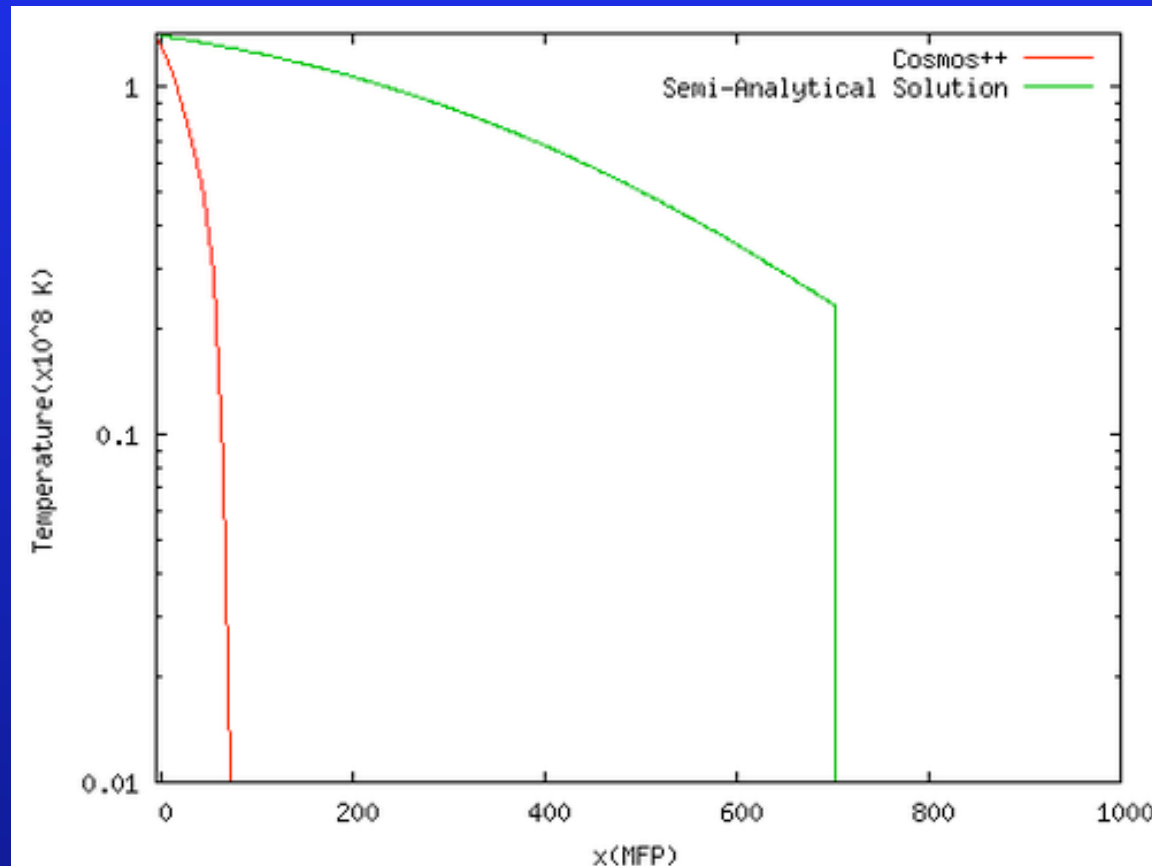
$$D = I - B$$

$$\frac{1}{c} \frac{\partial D}{\partial t} + \Omega \cdot \nabla D = -\sigma_a D - \frac{1}{c} \frac{\partial B}{\partial t} - \Omega \cdot \nabla B$$

$$\frac{\partial}{\partial t} E_{mat} = \int dv \int d\Omega \sigma_a D$$



1D Marshak wave



Robinson
et al.

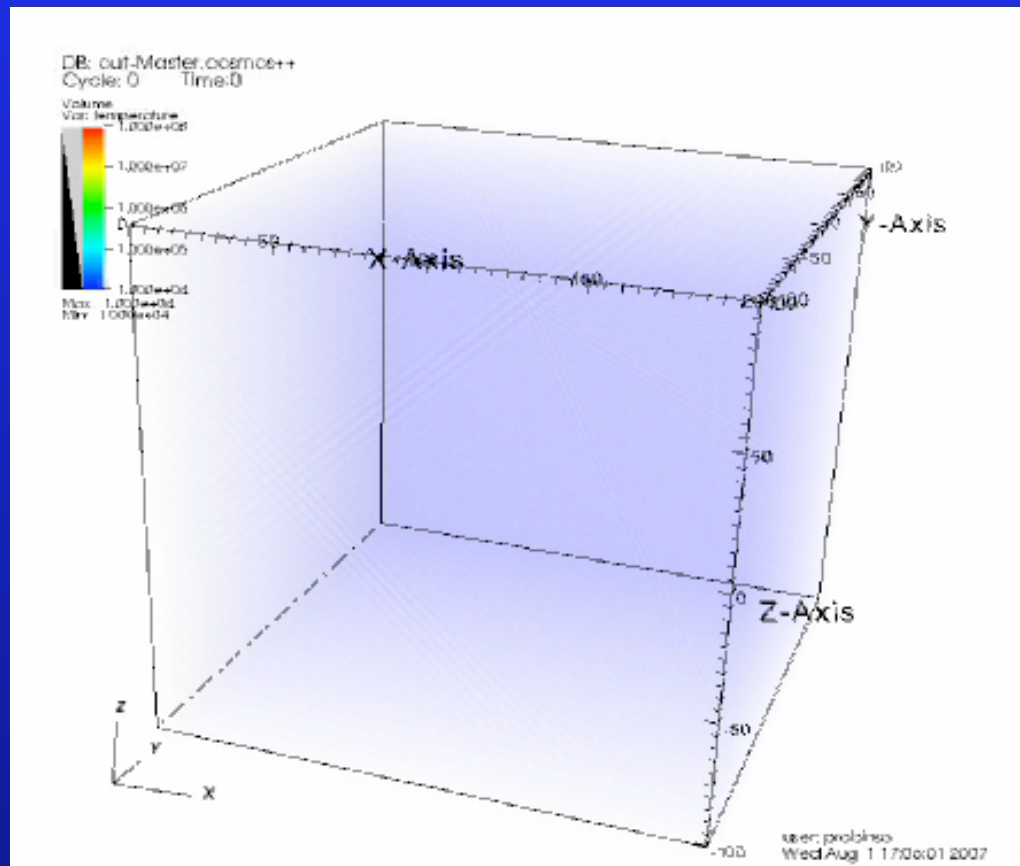


10 mean free paths per zone

5/19/10 SciDAC CAC 2010

LLNL-PRES-403872

3D Marshak wave



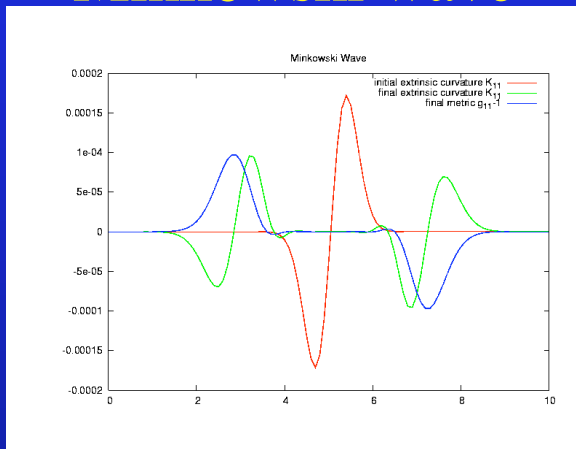
Robinson
et al.



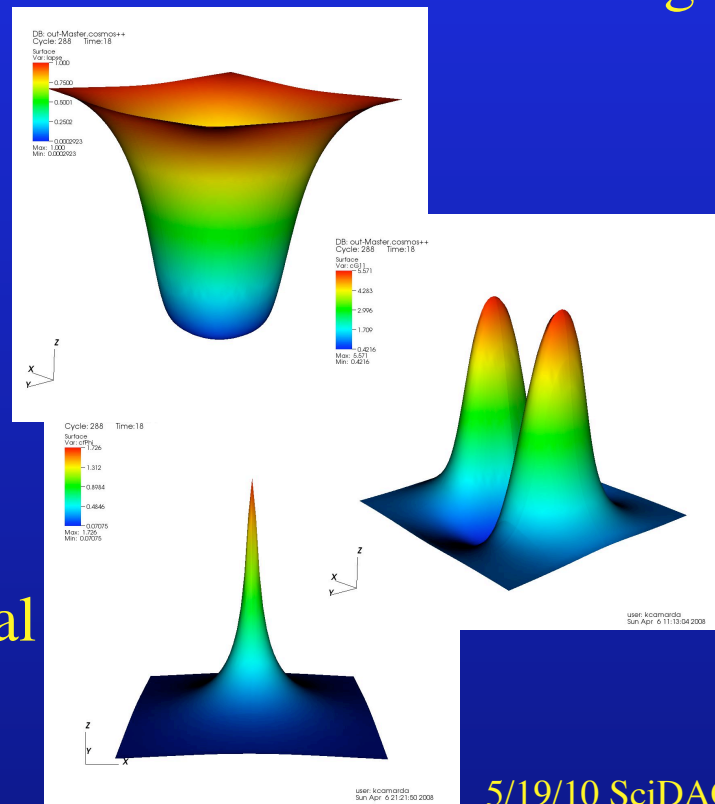
The Einstein Solver

3D Schwarzschild black hole evolved with Maximal Slicing

Minkowski wave



Lapse



g_{xx}

Conformal factor

Camarda



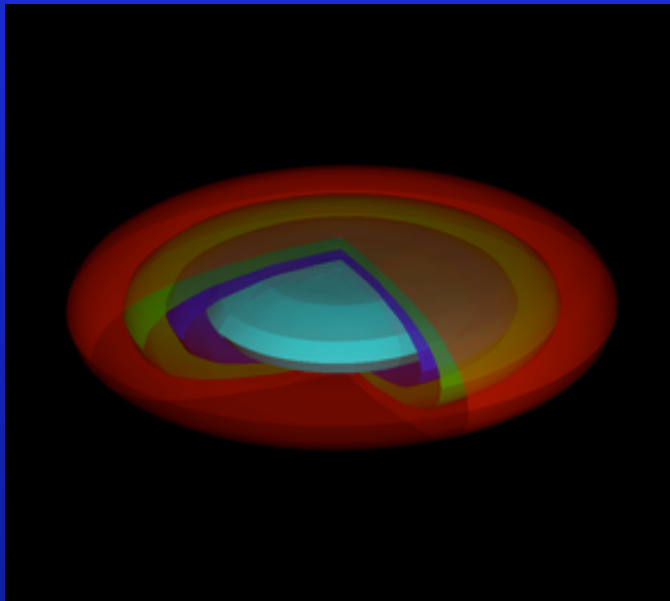
Dynamical bar-mode instability in differentially rotating magnetized neutron stars

Camarda,
Anninos,
Fragile
& Font
2010

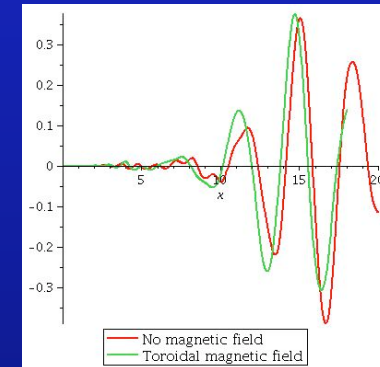
$$I_{ij}^{tt} = \int \rho (x_i x_j - \frac{1}{3} \delta_{ij} r^2) d^3 r$$

$$h_+ = \frac{G}{c^4} \frac{1}{r} (\ddot{I}_{xx}^{tt} - \ddot{I}_{yy}^{tt})$$

$$h_{\times} = \frac{G}{c^4} \frac{2}{r} \ddot{I}_{xy}^{tt}$$



h_+



Summary

- Magnetic core collapse (Akiyama)
 - Realistic EOS, progenitor, deleptonization
- Flux Limited Multi-group Diffusion
 - Neutrino Transport (Weis)
- Radiation Transport advanced concept
 - Monte Carlo Difference Formulation (Robinson)
- Einstein solver
 - Maximally sliced Schwarzschild BH
- Rotationally unstable magnetic neutron stars
 - Gravity wave extraction

