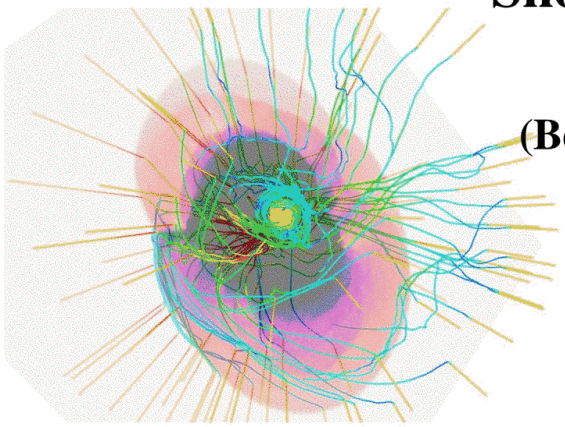
Terascale Supernova Initiative

NC STATE ASTROPHYSICS

SASI: The Spherical Accretion Shock Instability



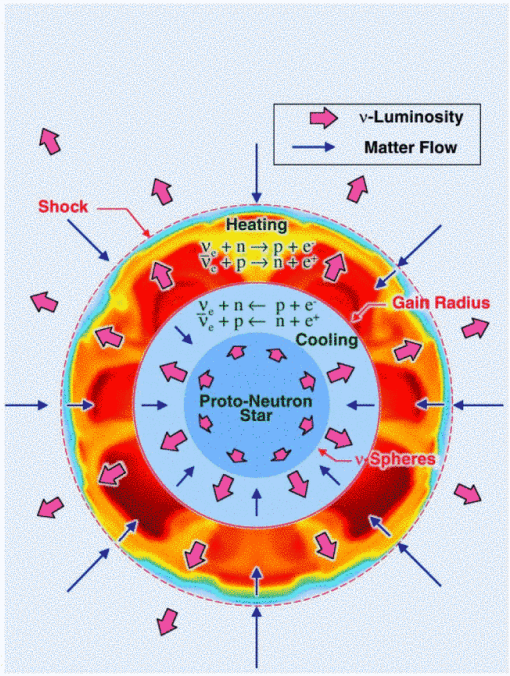
(Beware of Multi-D)

John M. Blondin
NC State University

Outline…

- Define shock models in context of supernova theory
- Quantifying the SASI with 2D models
- What is the SASI
- What happens in 3D
- After the supernova

Anatomy of a Core-Collapse Supernova

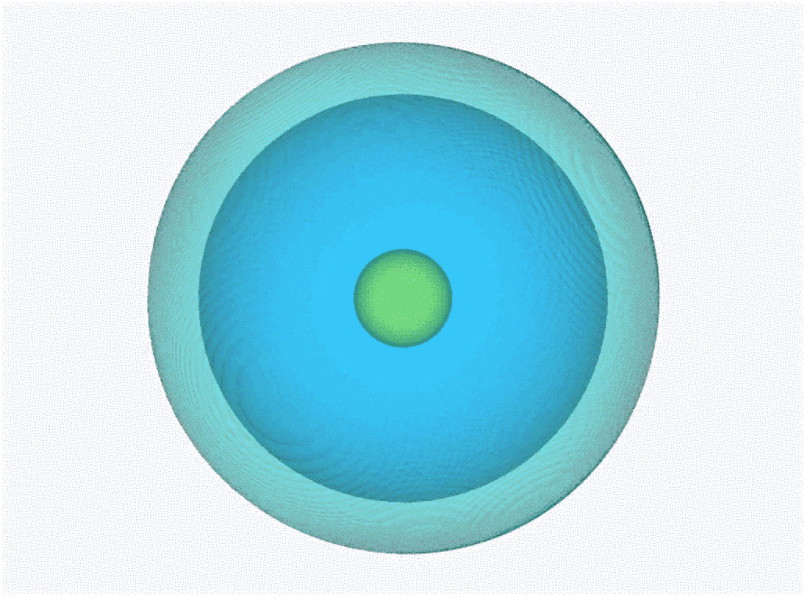


The last decade has seen a great deal of interest in multidimensional effects:

- Convection with the proto-neutron star
- Neutrino-driven convection below the stalled shock
- Instability of the stalled shock

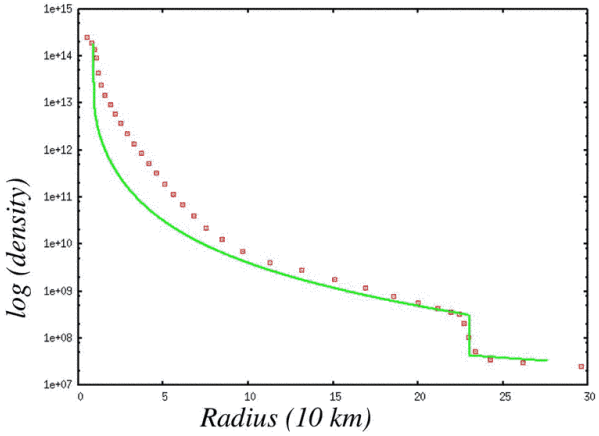
All of these may operate together!

Modeling post-bounce shock

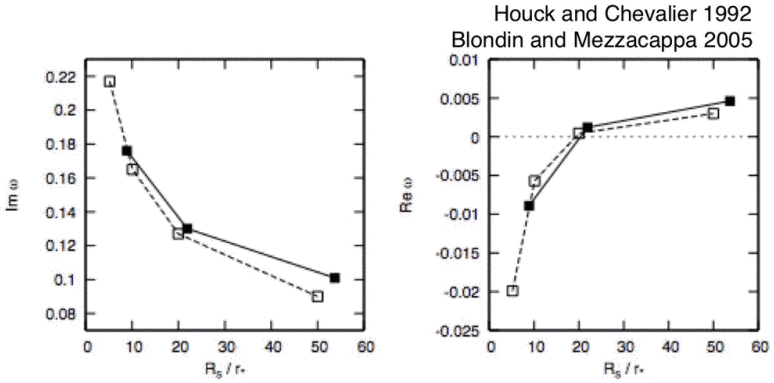


An analytic solution is provided by Houck & Chevalier (1992).

- Reflecting inner boundary
- Adiabatic gas with $\gamma = 4/3$
- Cooling proportional to T^{10}
- Convectively stable

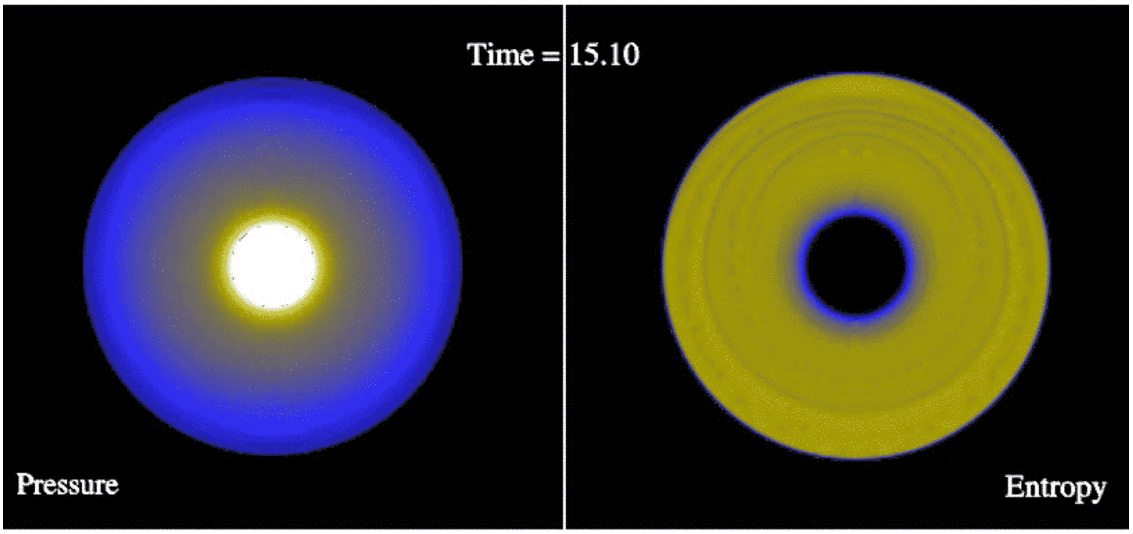


SN Code Verification

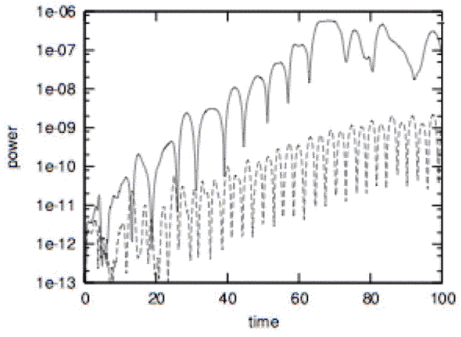


This post-bounce model provides an opportunity to verify supernova codes against the results of a linear perturbation analysis.

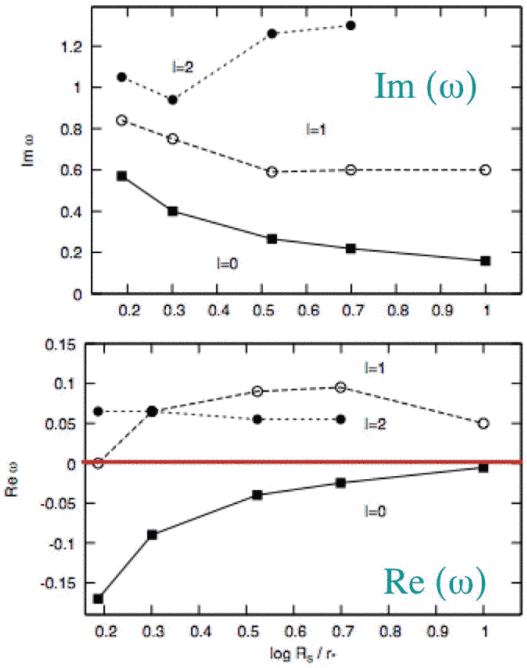
Spherical Accretion Shock Instability



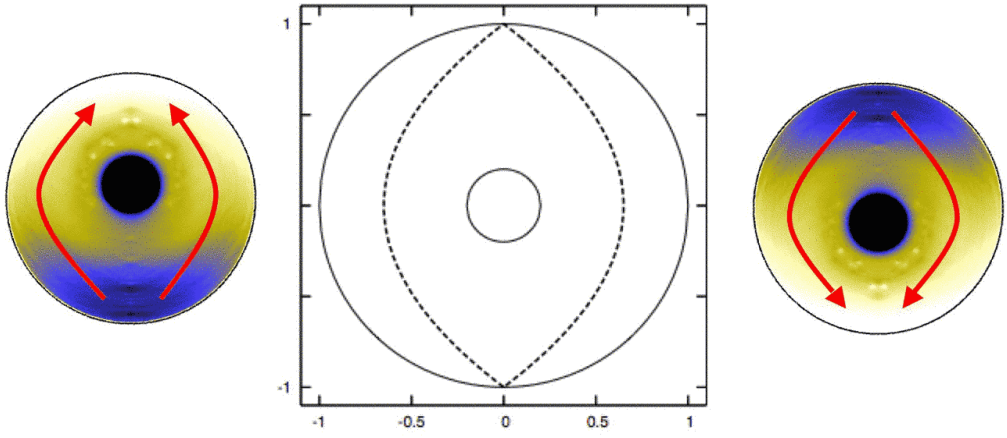
Track the growth of global modes and fit with $e^{\omega t}$.



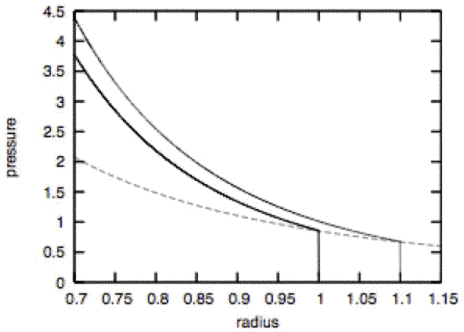
VH-1, ZeusMP, V2D

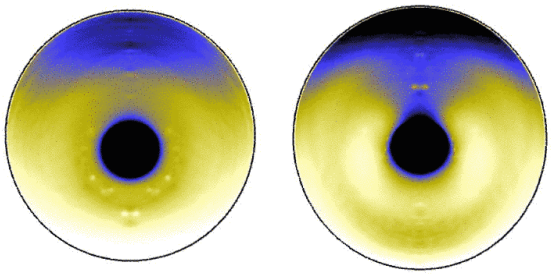


The SASI is a goblal acoustic mode.

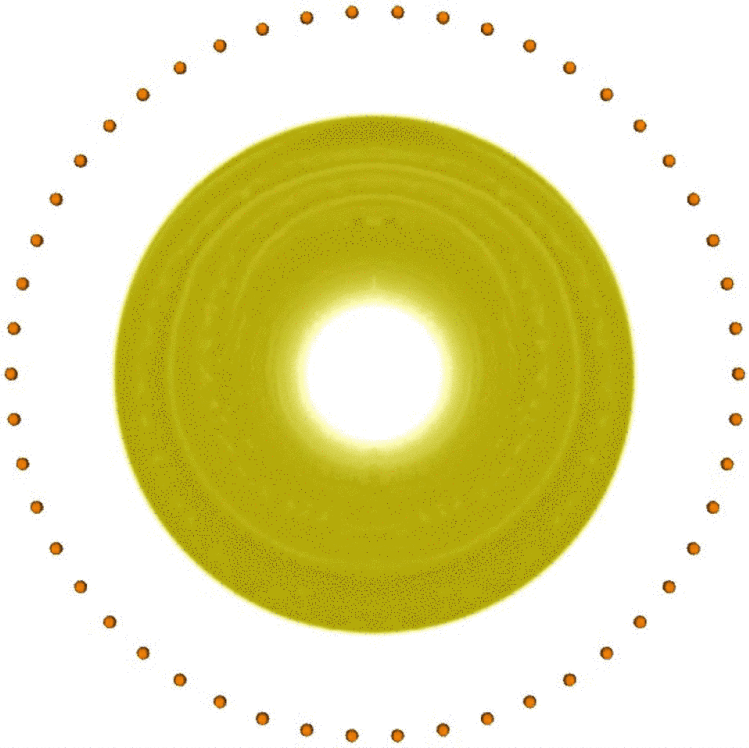


SASI is driven by dynamic response of the shock.

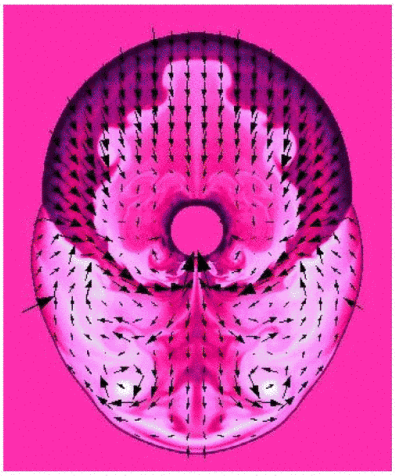




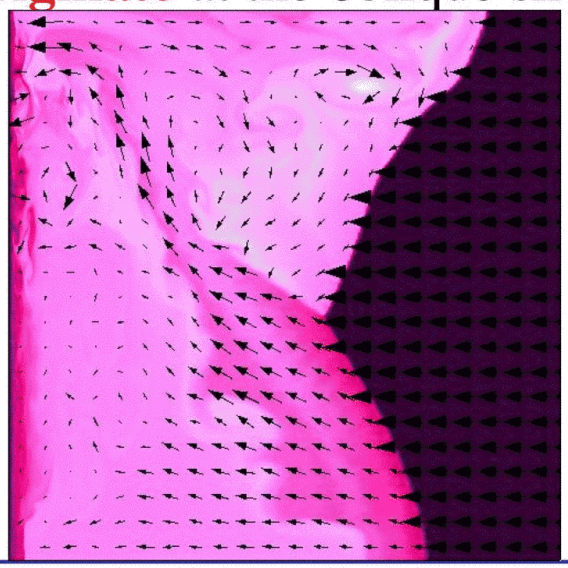
- Pressure pushes shock out
- Lower ram pressure at shock
- HIGHER pressure at fixed radius

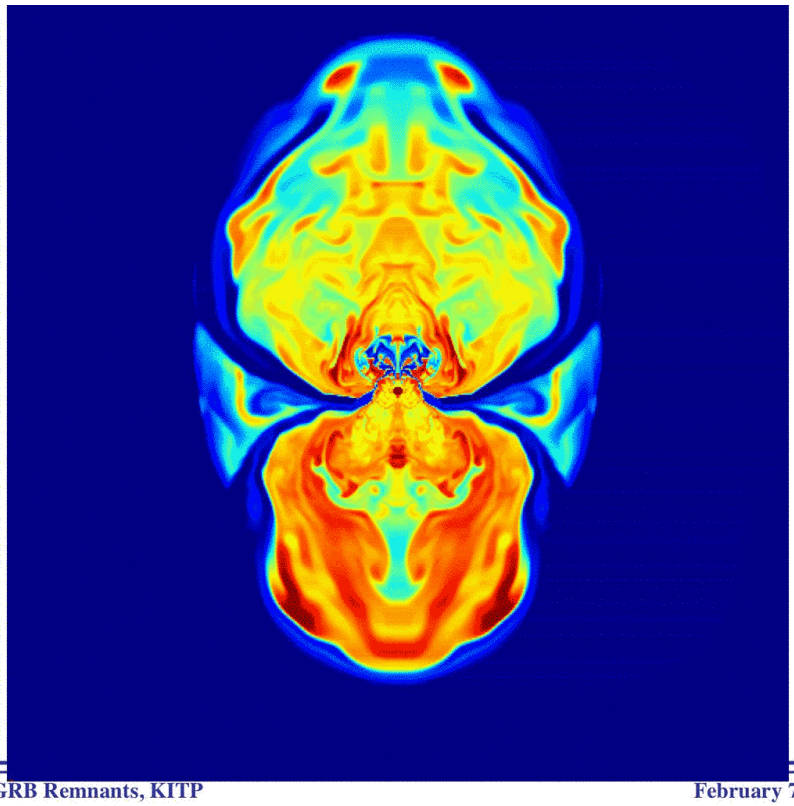


Bulk flow and entropy variations **originate** at the oblique shock.



Bulk flow and entropy variations **originate** at the oblique shock.

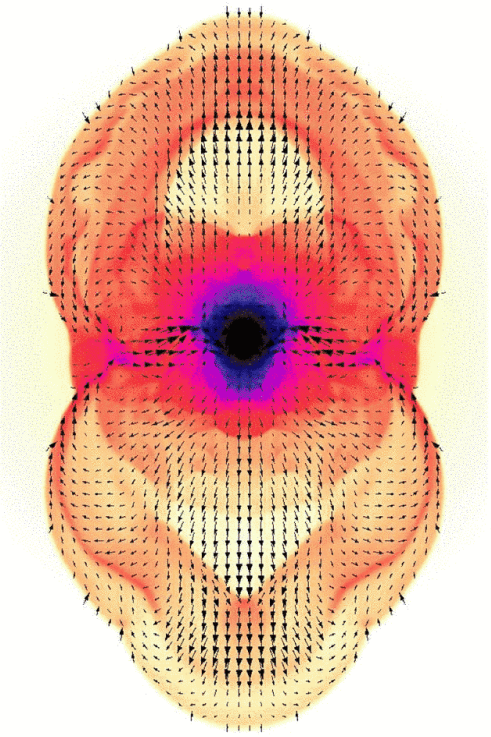




Must move to 3D!

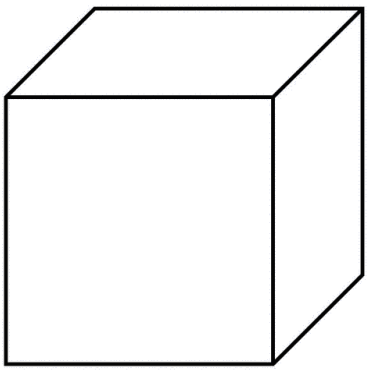
This initial SASI discovery with axisymmetric 2D simulations pointed to the obvious need for models in full 3D.

To better understand the challenges of 3D, let us first look at the process of discovery for the initial 2D models.



Is this all an artifact of the imposed symmetry?

- 3D models in a cartesian box
- Inner boundary conditions replaced by an absorbing sphere

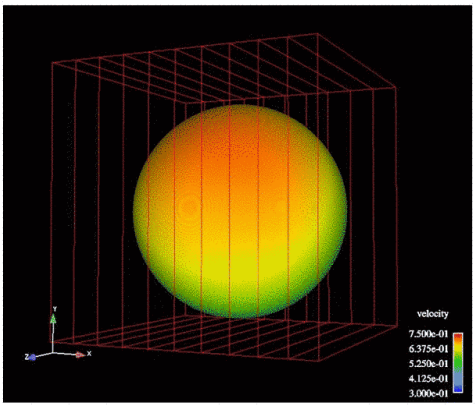


Visualization of TB Datasets is non-trivial

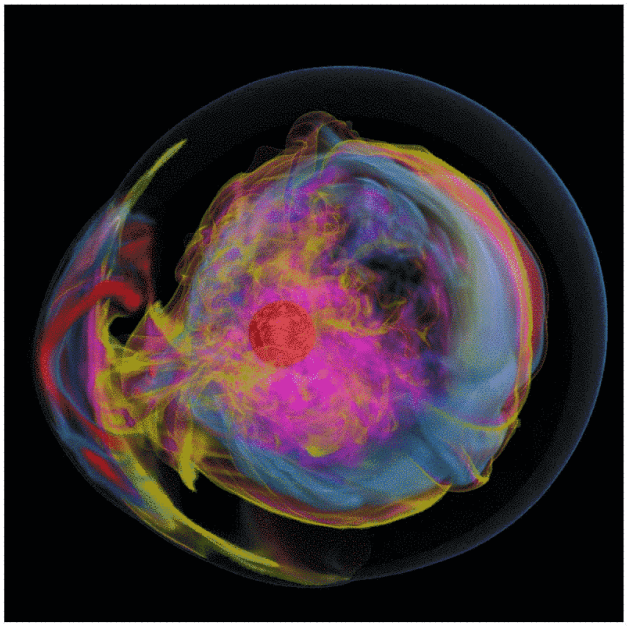
Stepping up the simulations to 3D was simple, dealing with the increased volume of data was not.

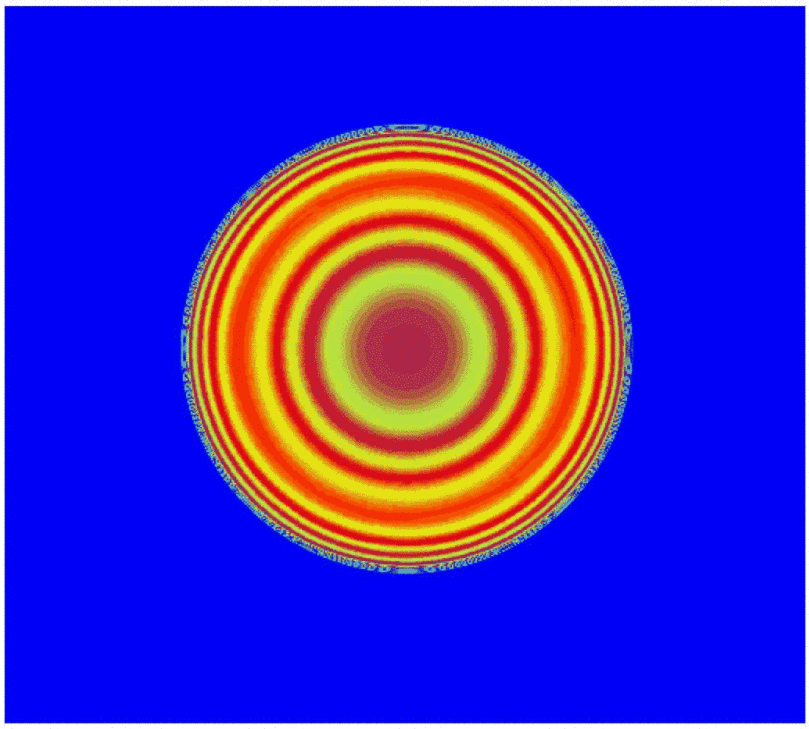
Data is sliced into slabs and stored on local disks on the cluster nodes.

EnSight Gold provides an easy visualization solution, including remote client-server operation and collaboration.

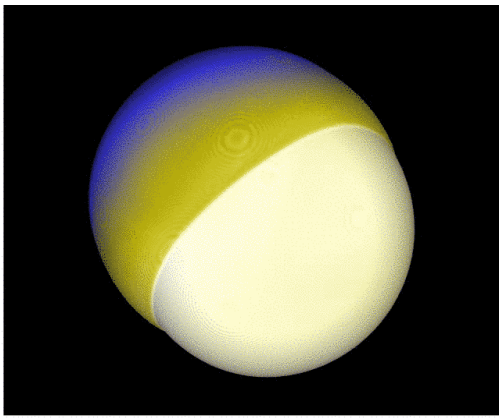


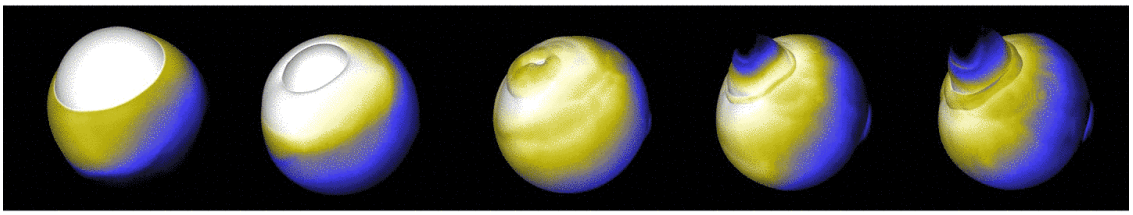
The *l=1* SASI mode grows up out of random acoustic noise. If the random seed is changed, the same axisymmetric mode develops, but oriented along a different random axis.

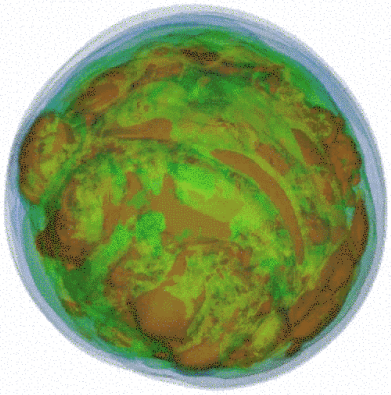


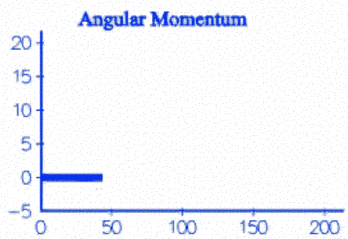


Once the SASI becomes nonlinear, axisymmetry is broken within a few oscillations.

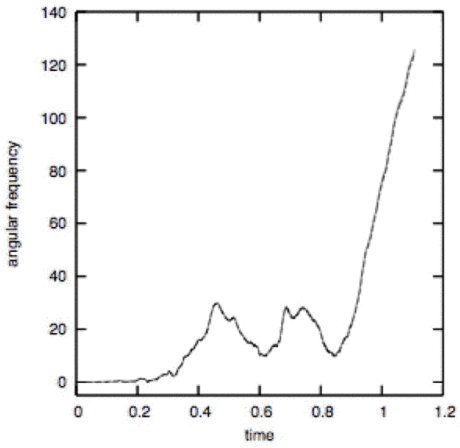


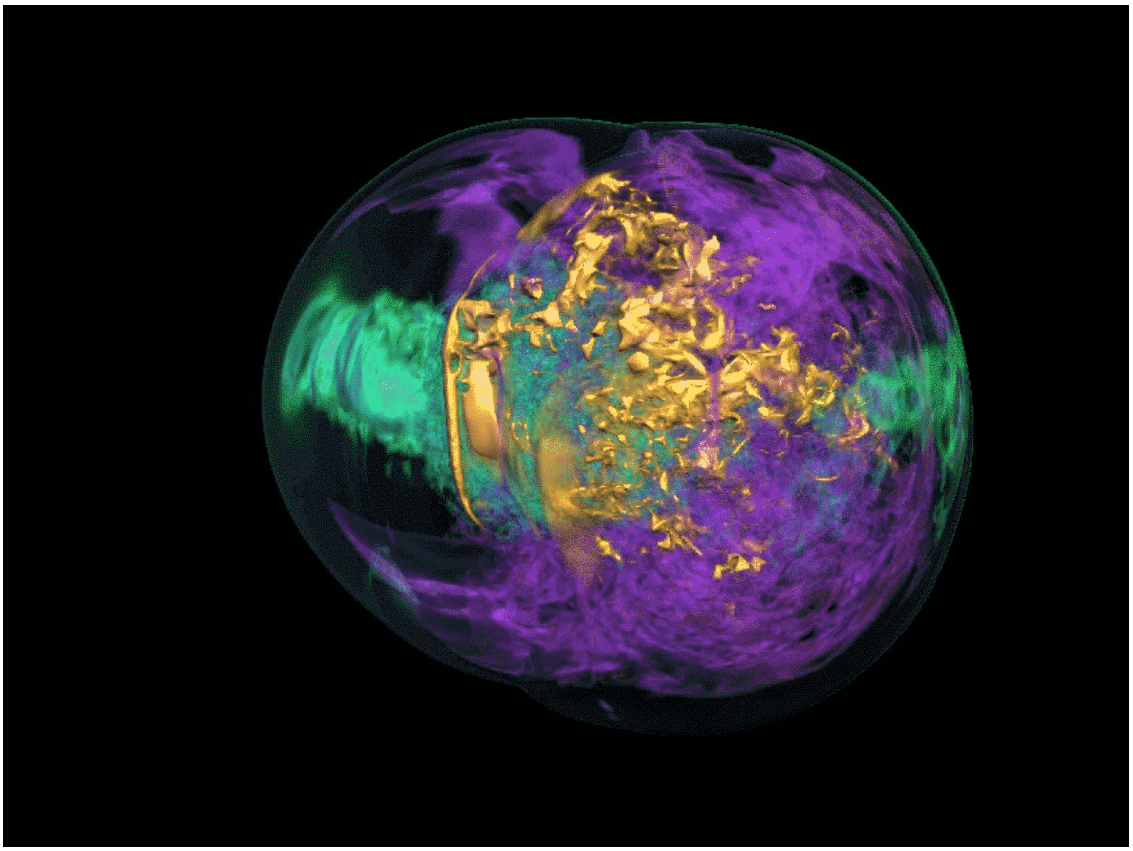


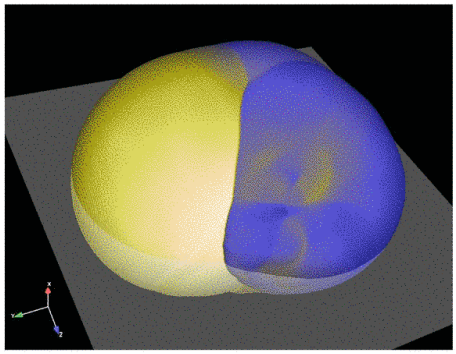


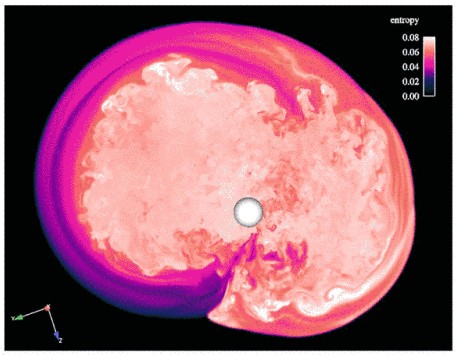


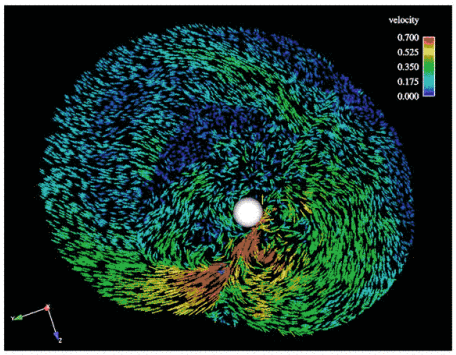
The total angular momentum remains zero, but the angular momentum accretion rate onto the central star can be significant.

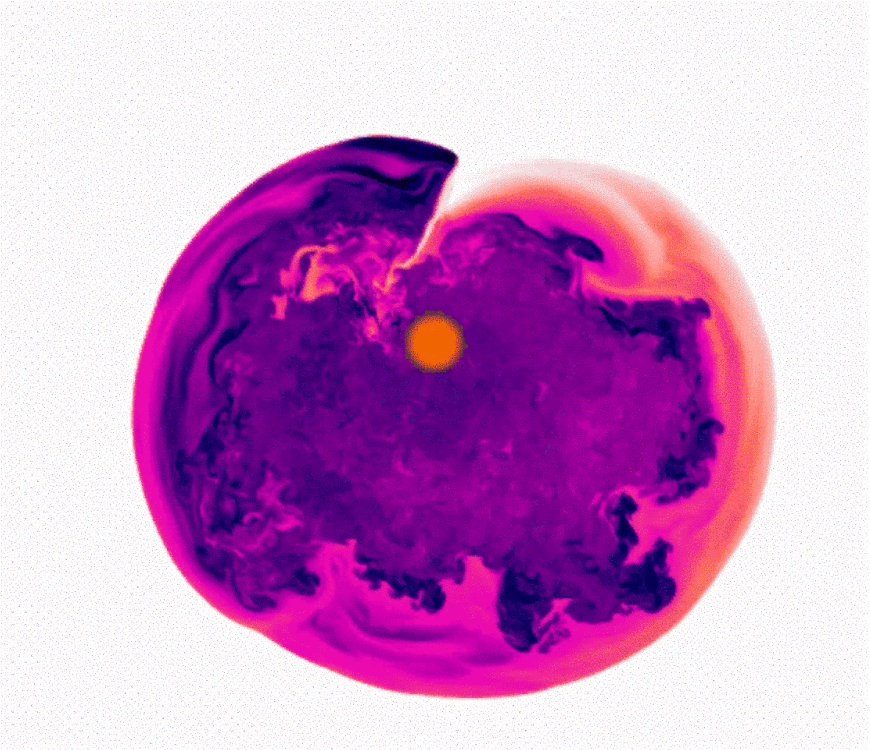




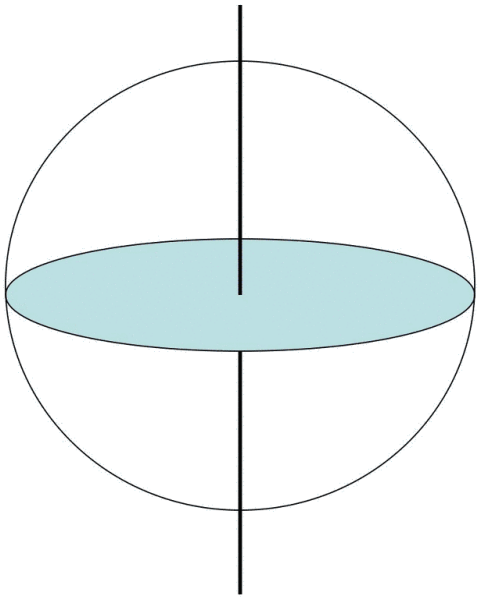


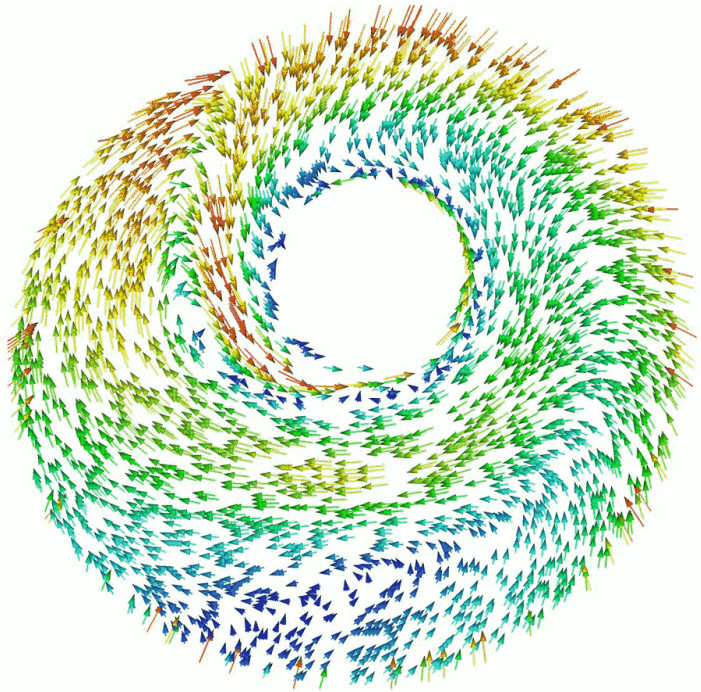

entropy
0.08
0.06
0.04
0.02
0.00


velocity
0.700
0.525
0.350
0.175
0.000



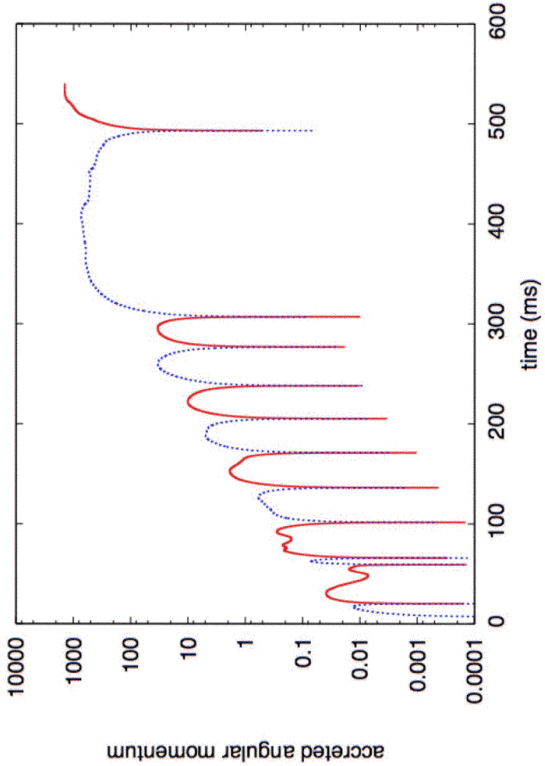
We (Samantha Shaw), are using 2D simulations of flow in the equatorial plane to capture the non-axisymmetric modes of the SASI.





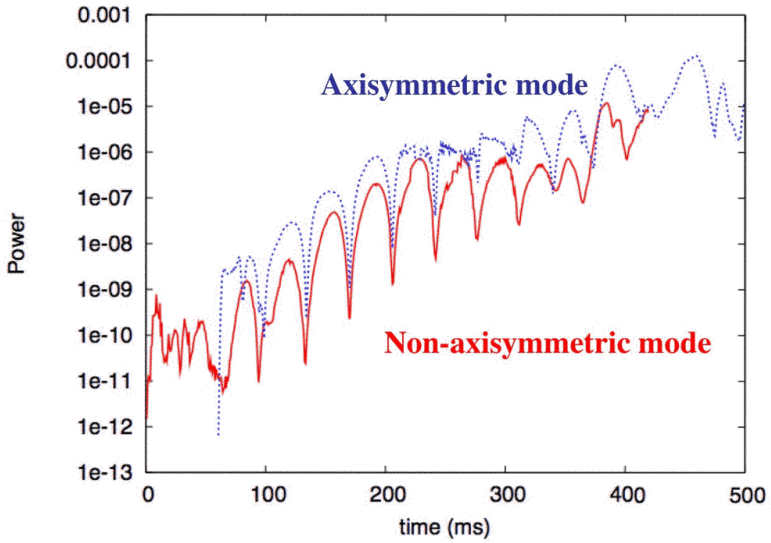
SN & GRB Remnants, KITP

February 7, 2006

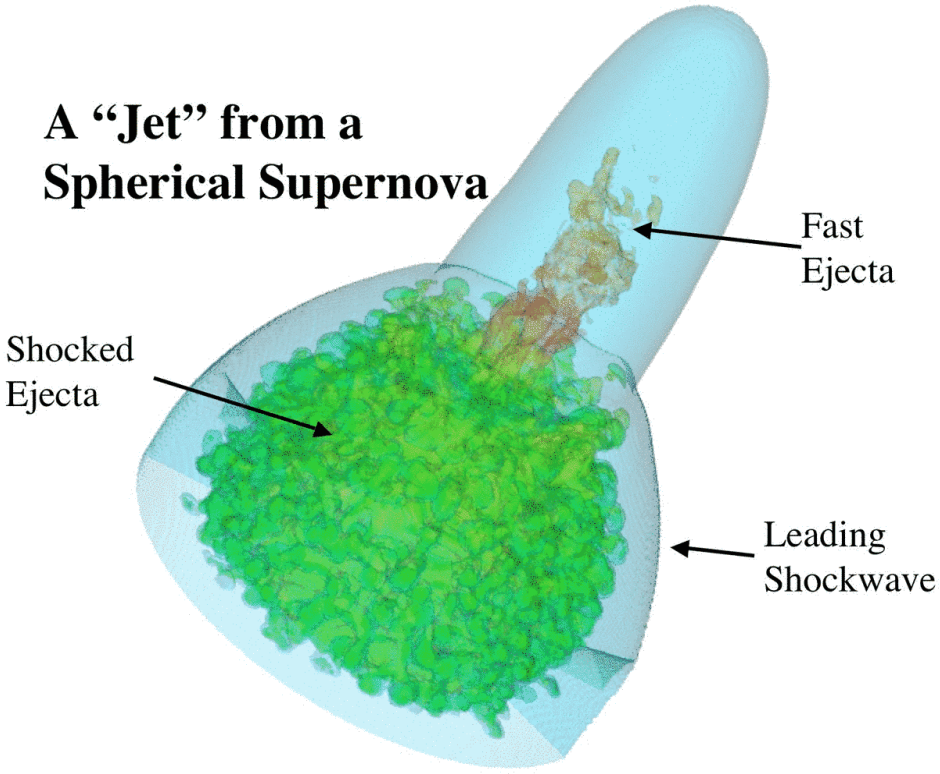


SN & GRB Remnants, KITP

February 7, 2006



A "Jet" from a Spherical Supernova



Spherically symmetric SN ejecta evolving into an axisymmetric circumstellar medium.