



UNIVERSITY OF MINNESOTA



Pair-Instability Supernovae with CASTRO

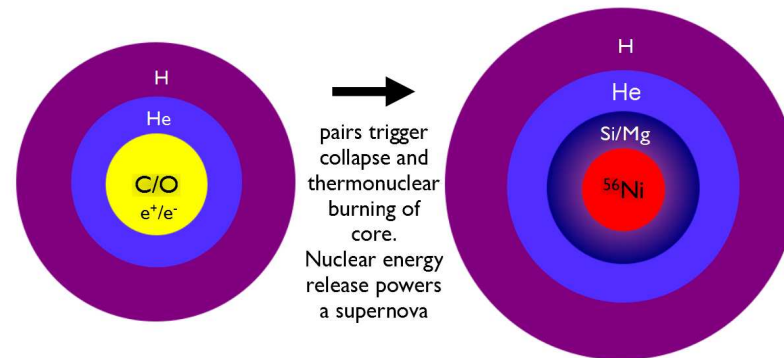
Ke-Jung (Ken) Chen

Alexander Heger

Ann Almgren

SciDAC Computational Astrophysics Consortium Meeting May 20, 2010

Pair-Instability Supernovae (PSN)



(Daniel Kasen)

- Initial mass at $140 < M < 260 M_{\odot}$
- The pair-production instability
- Explosive oxygen/silicon burning
- No remnant
- Lots of ^{56}Ni can be made up to $60 M_{\odot}$
- They are expected to be very luminous

Multi-D Simulations of PSN

- **1D models**

 - Heger, and Woosley (2002)

 - Heger, and Woosley (2008)

- **Explosion mechanism**

 - Explosive oxygen/silicon burning

 - Bakrat, Rakavy, and Sack (1967)

 - Bond, Arnett, and Carr (1984)

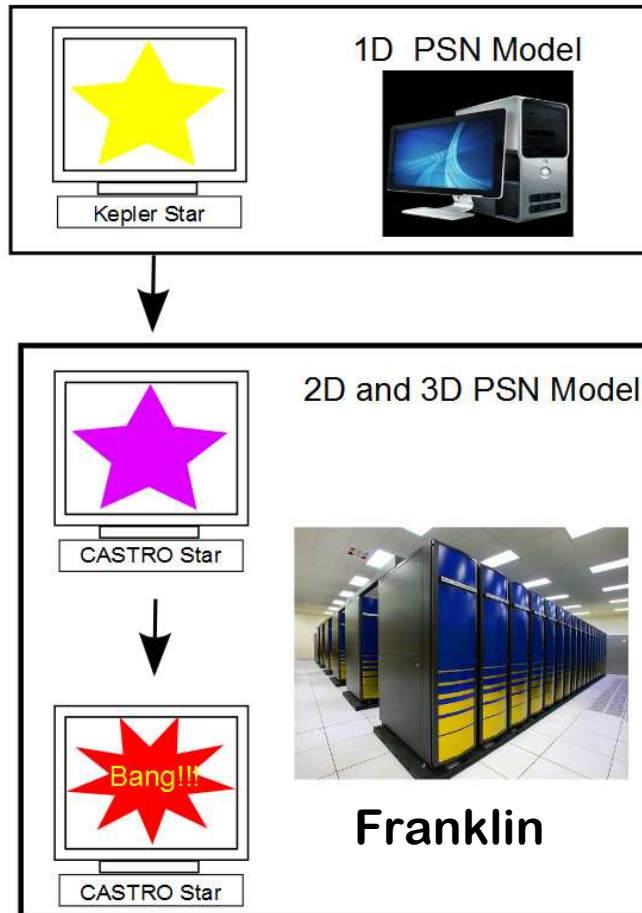
- **Fluid instability and Mixing**

- **Computing power and CASTRO**

Adding New Stuff for CASTRO

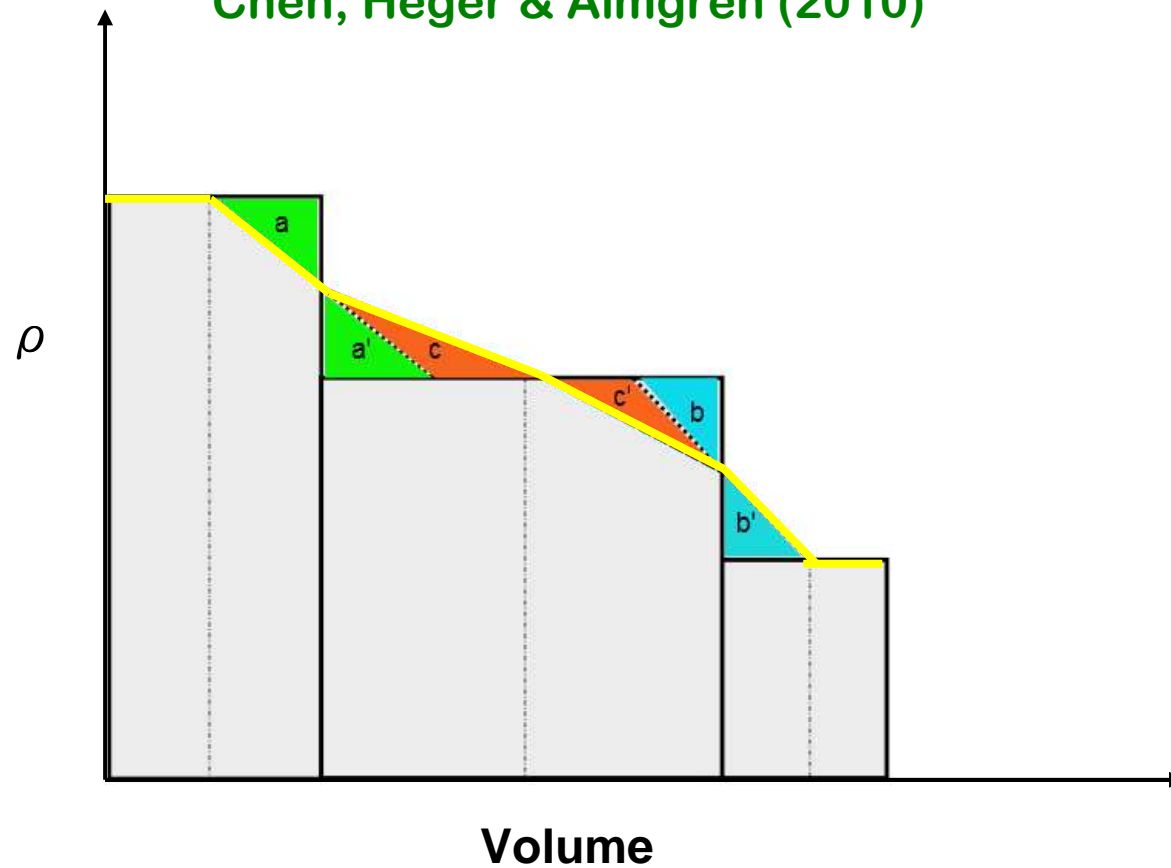
- **New mapping procedure**
Chen, Heger, & Almgren (2010)
- **Reaction networks for 7, 13, 19 isotopes**
Timmes (1999)
Weaver, Zimmerman, & Woosley (1978)
- **Rotation**
- **GR correction for super massive stars**
Kippenhahn, & Weigert (1994)

Numerical Setup



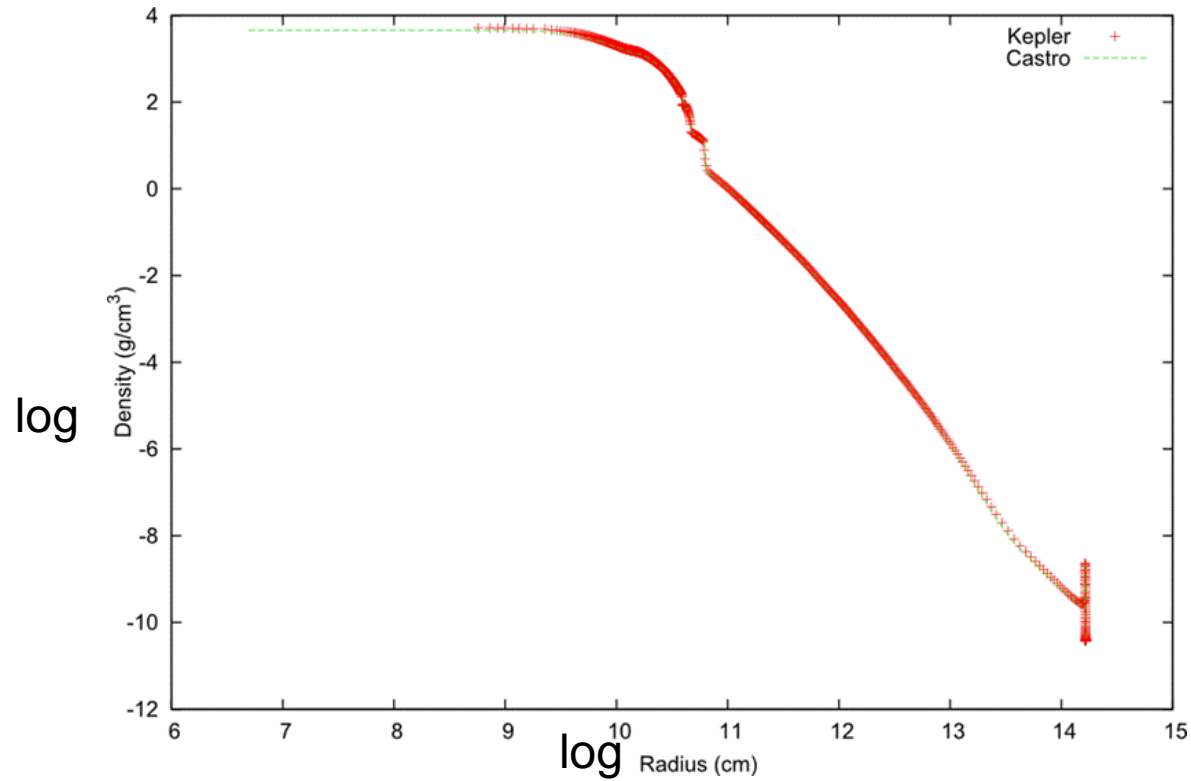
New Mapping Algorithm

Chen, Heger & Almgren (2010)



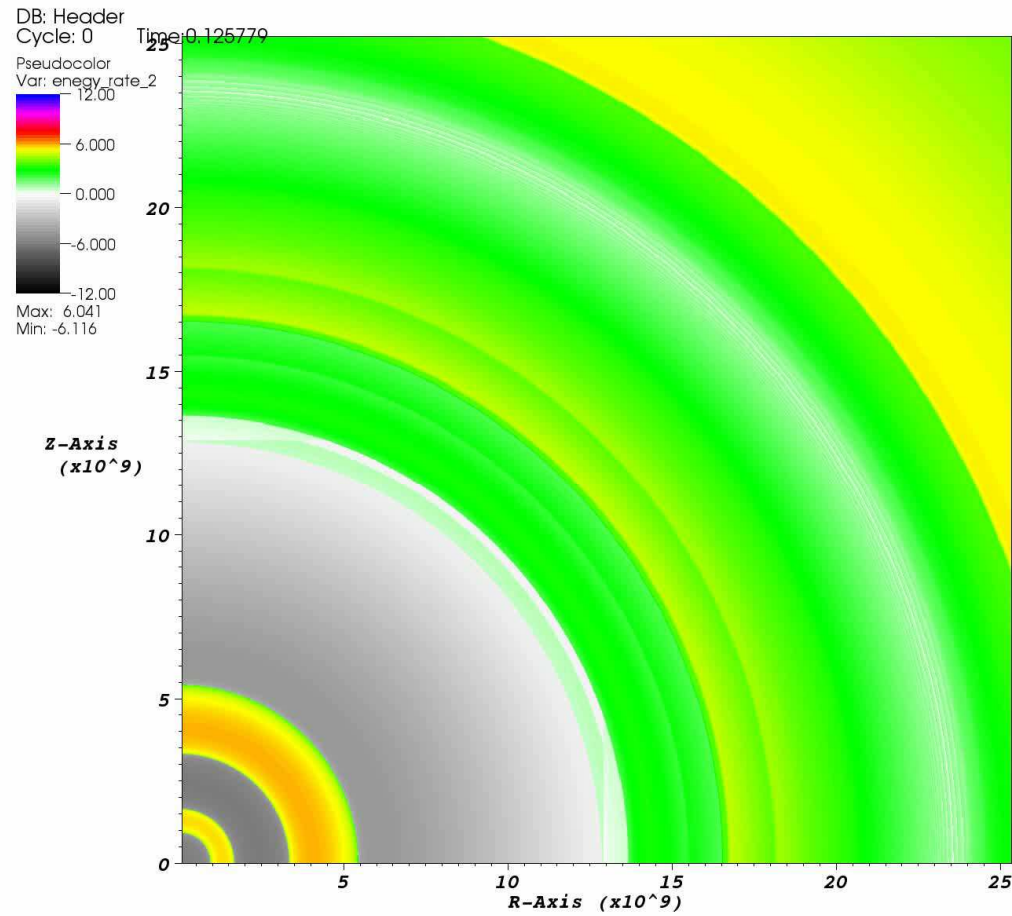
Accuracy of mapping is independent of resolution

19 Isotopes Reaction Network



< **1%** deviation in E_{tot} between results from KEPLER and CASTRO

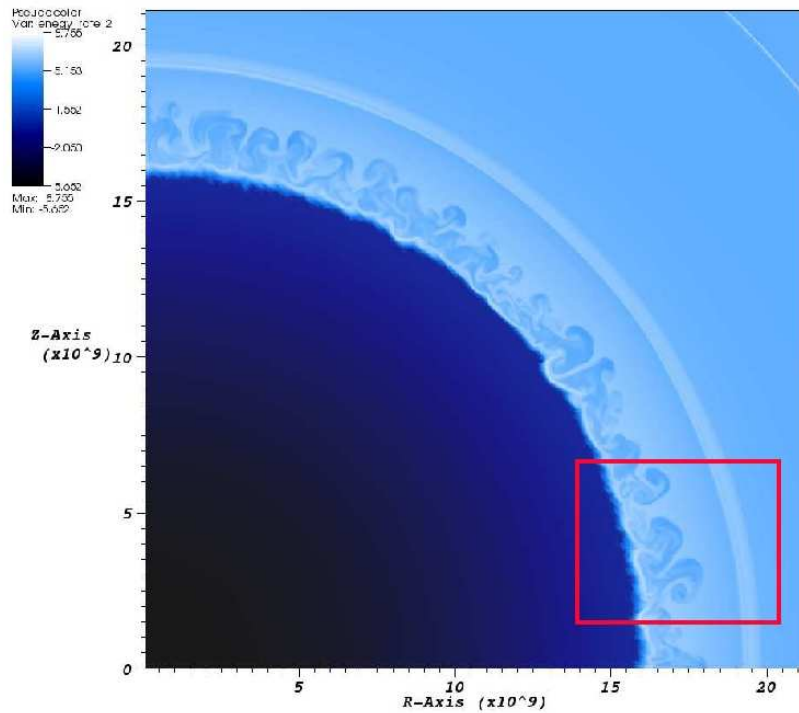
Energy Generation Evolution



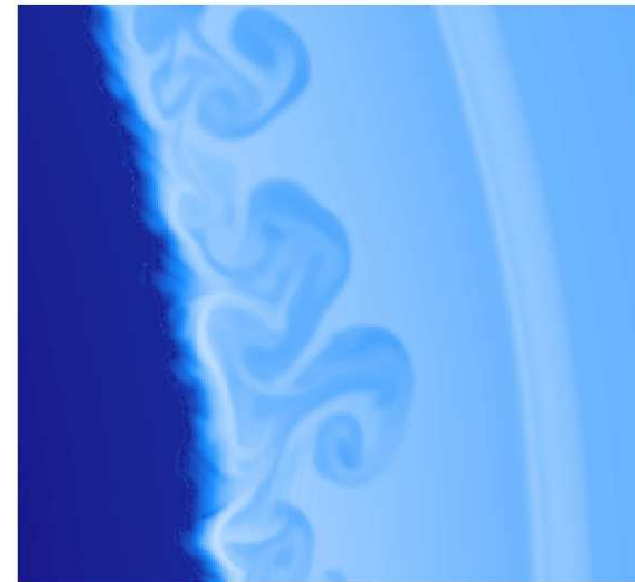
user: ken
Mon Nov 16 14:02:17 2009

150 M \odot PSN

Fluid Instability



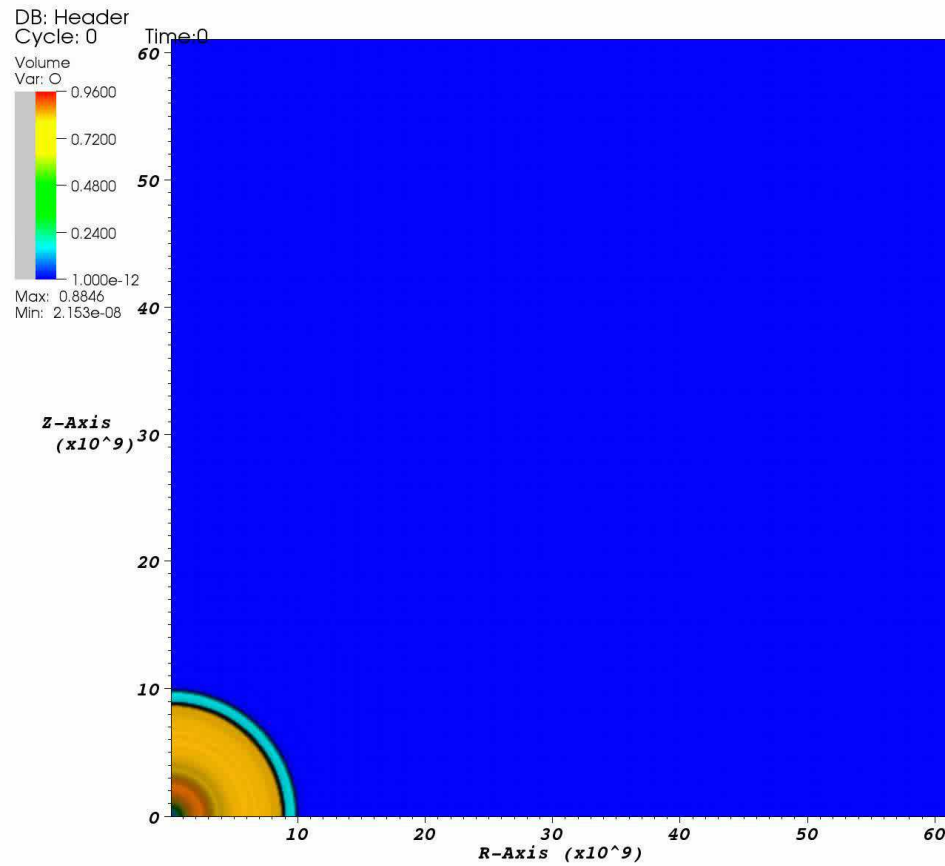
(a)



(b)

Rayleigh-Taylor instabilities

Rotation

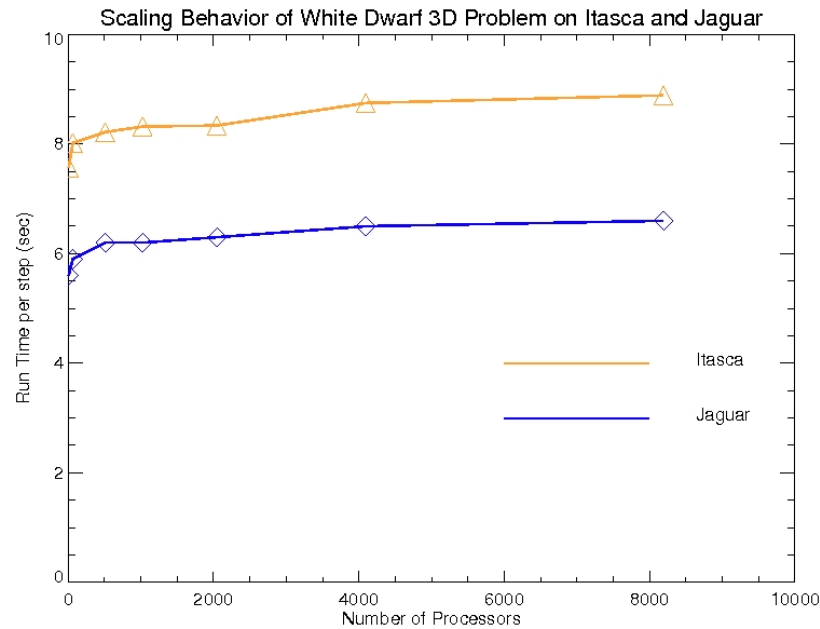


user: ken
Tue Dec 29 10:04:01 2009

150 M \odot PSN

CASTRO on Itasca@MSI

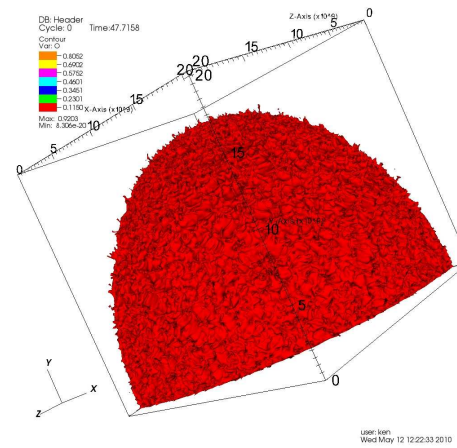
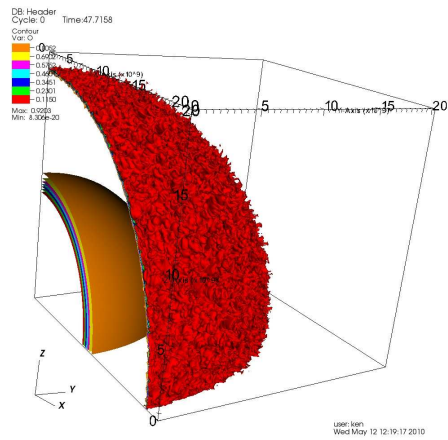
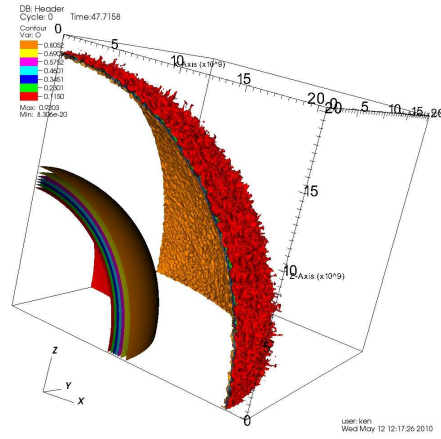
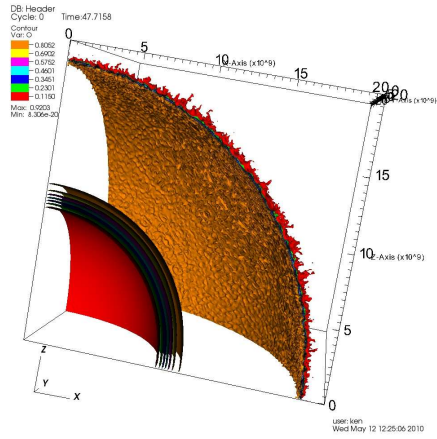
CASRTO is selected to test I/O, scaling, stability of Itasca



CASTRO on Itasca and Jaguar

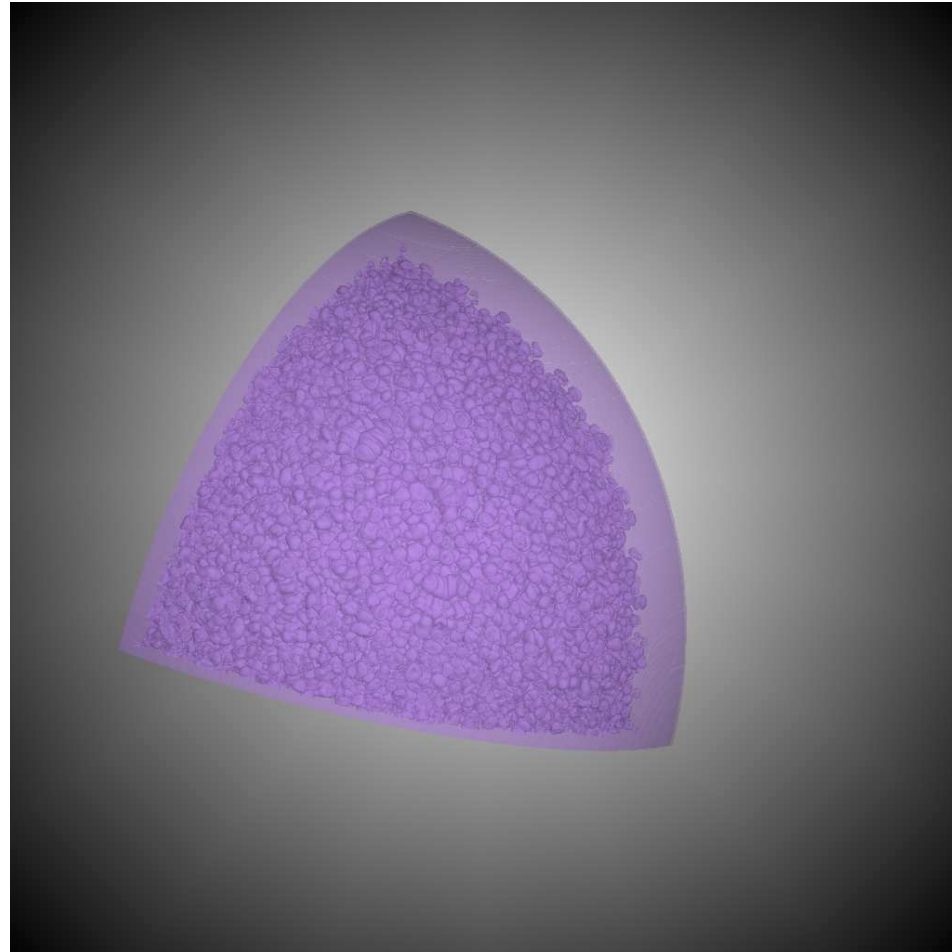
MSI Itasca(8848 cores,67th in TOP500)

3D 200 M_⊙ PSN



Oxygen mass fraction

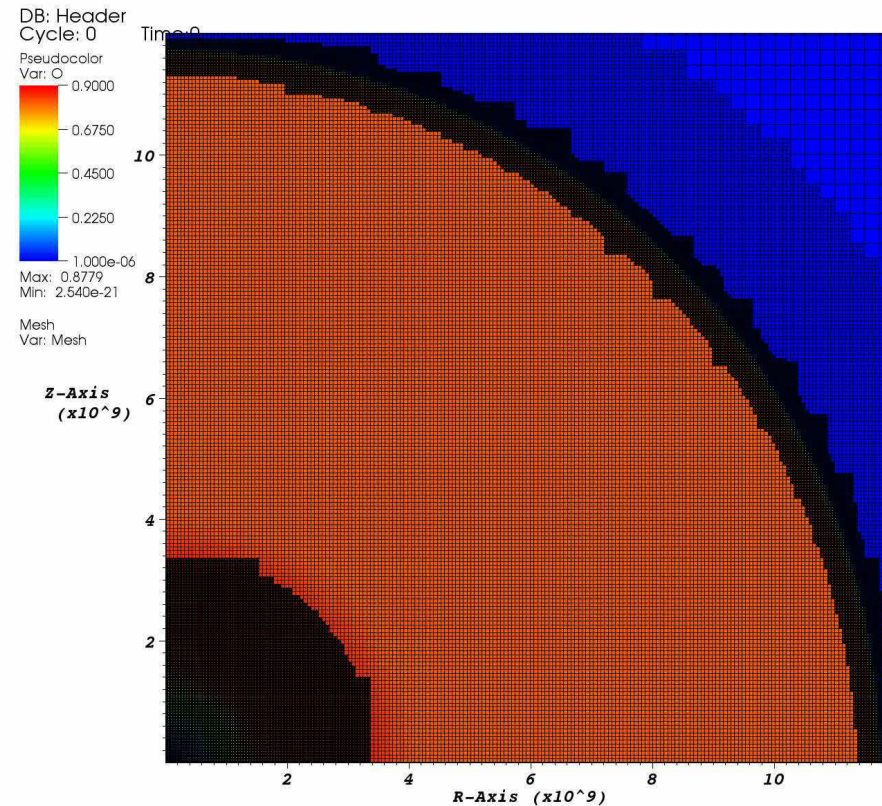
3D 200 M_{\odot} PSN



Helium mass fraction

Numerical Perturbation by Mesh Setup

Tracing O mass fraction gradient



user: ken
Mon May 17 11:29:31 2010

Mesh layout, AMR refinement criteria and ratio

Summary

- **Physics modules for studying PSN**
 - New mapping procedure
 - Reaction networks for 7, 13, 19 isotopes
 - Rotation
 - GR correction for super massive stars
- **Fluid instability from nuclear burning**
 - RT instability 2D and 3D
- **Numerical perturbation**
 - Be more careful when using AMR

Future Work

- Expanding simulations to full domain of PSN
- Rotational and 3D models
- Light curve and nucleosynthesis of PSN
Daniel Kasen
- Cosmic explosion of PSN

Thank YOU!

We appreciate the support from

