The Terascale Supernova Initiative

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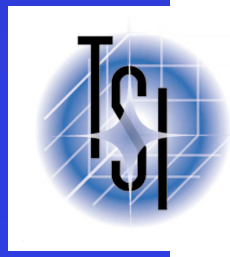
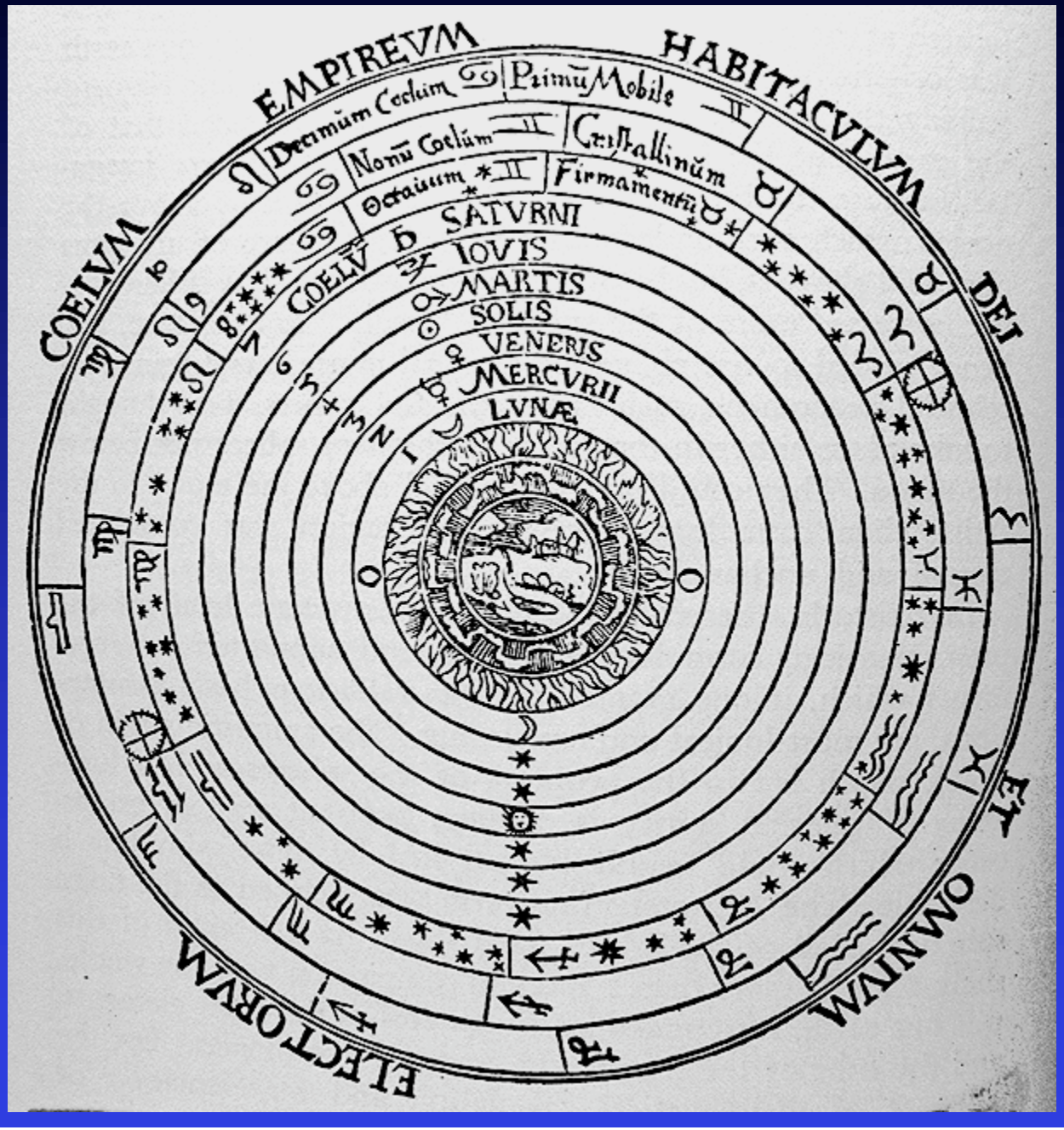
Terascale Supernova Initiative
http://www.phy.utk.edu/tsi



Introduction to supernovae



Peter Apian, *Cosmographia* (1524)

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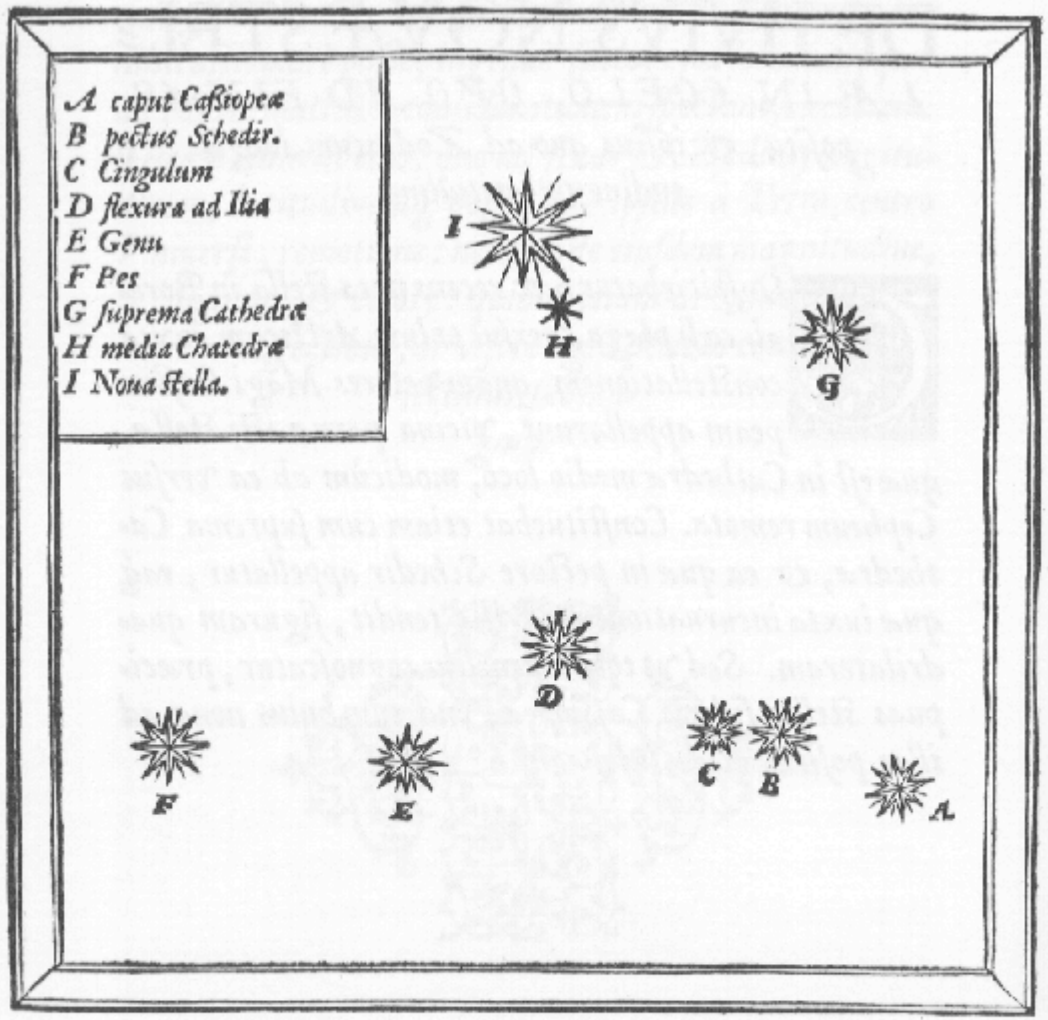
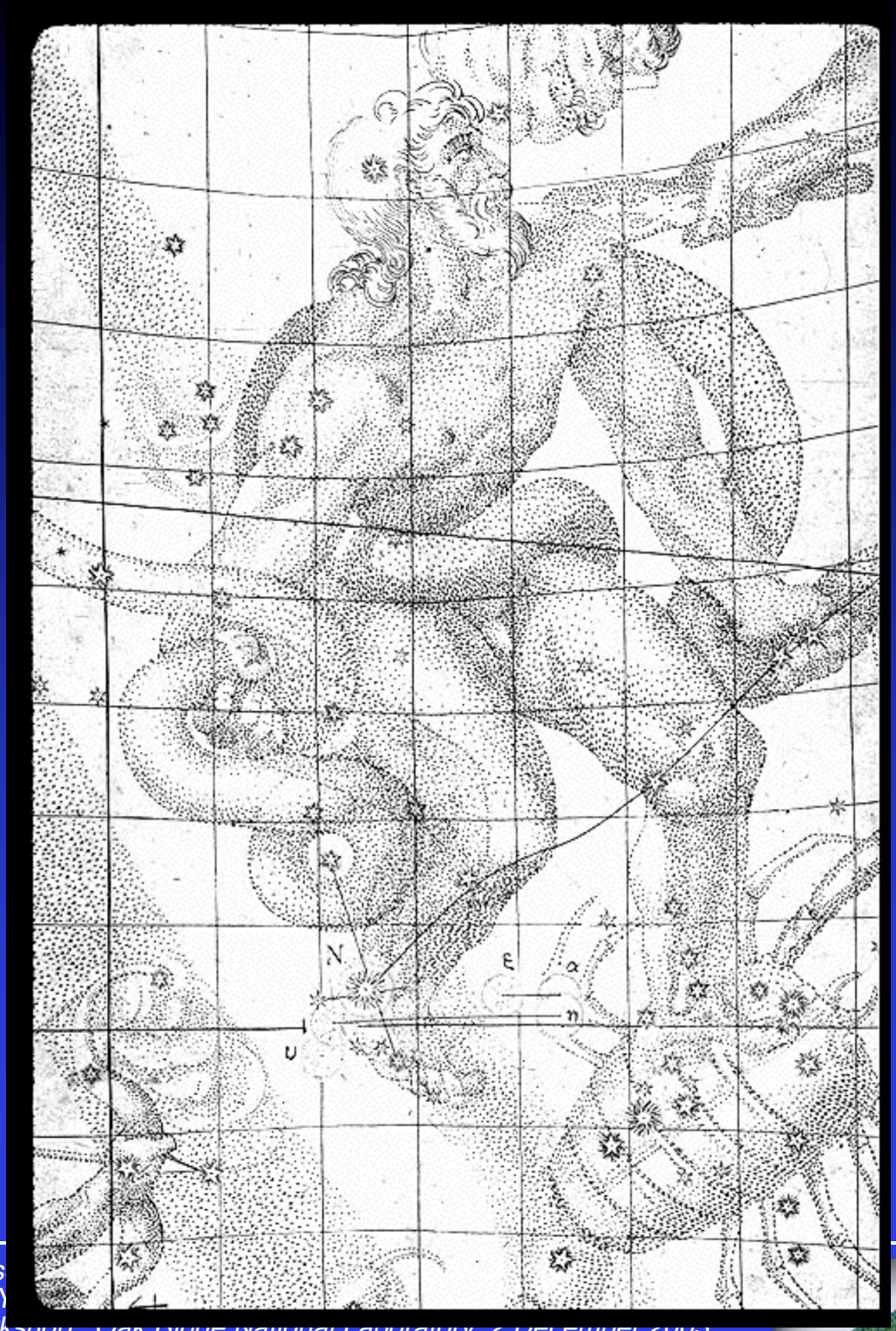
Tycho Brahe, *De Nova et Aevi Memoria Prius Visa Stella* (1573)



Diſtantiam verò huius ſtellæ à fixis aliquibus in hac Caßiopeiæ conſtellatione, exquiſito inſtrumento, & omnium minutorum capacj, aliquoties obſeruaui. Inueni autem eam diſtare ab ea, quæ eſt in pectore, Schedir appellata B, 7. partibus & 55. minutis: à ſuperiori

verò



Johannes Kepler, *De Stella Nova in Pede Serpentarii*, (1606)

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M31 (Andromeda Galaxy)

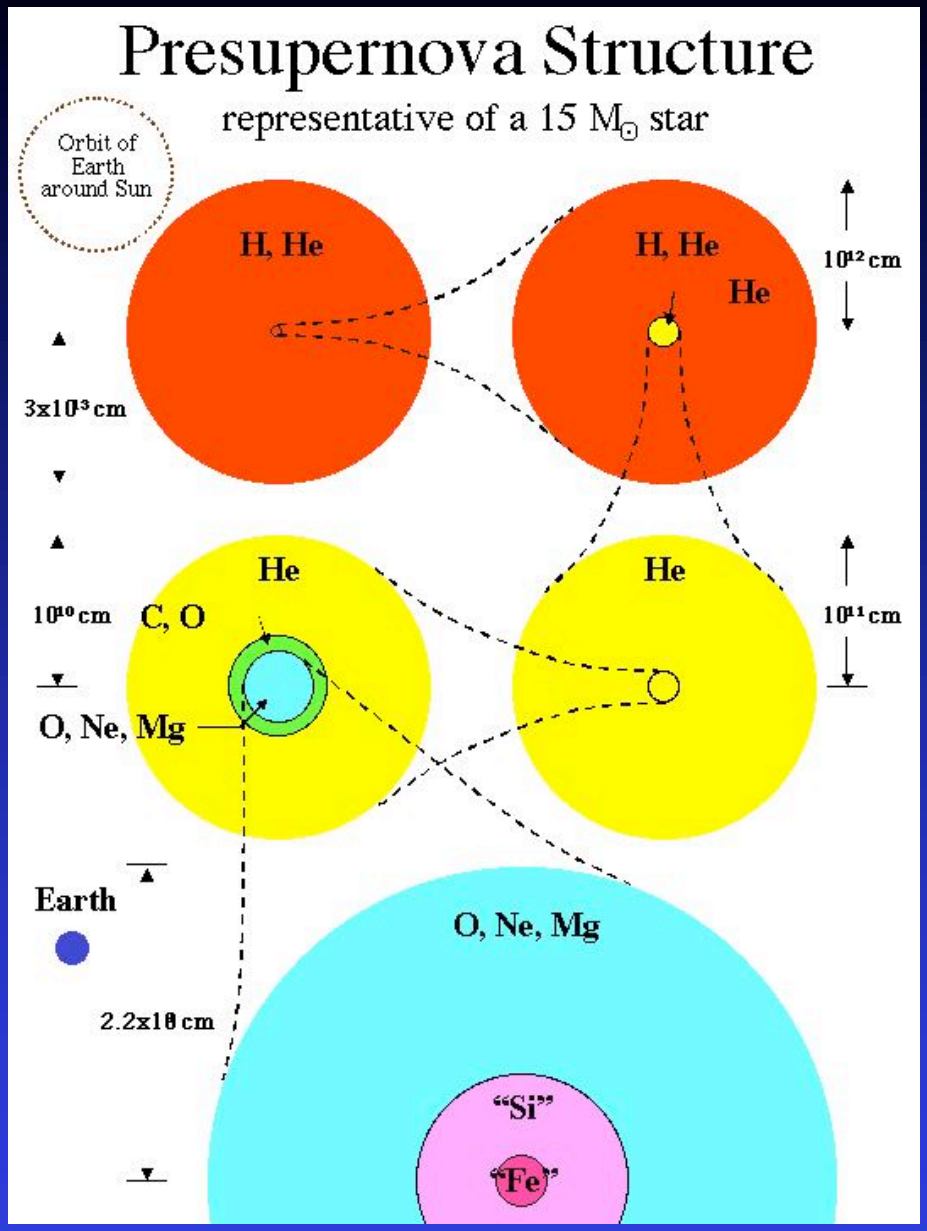
Tarantula
Nebula

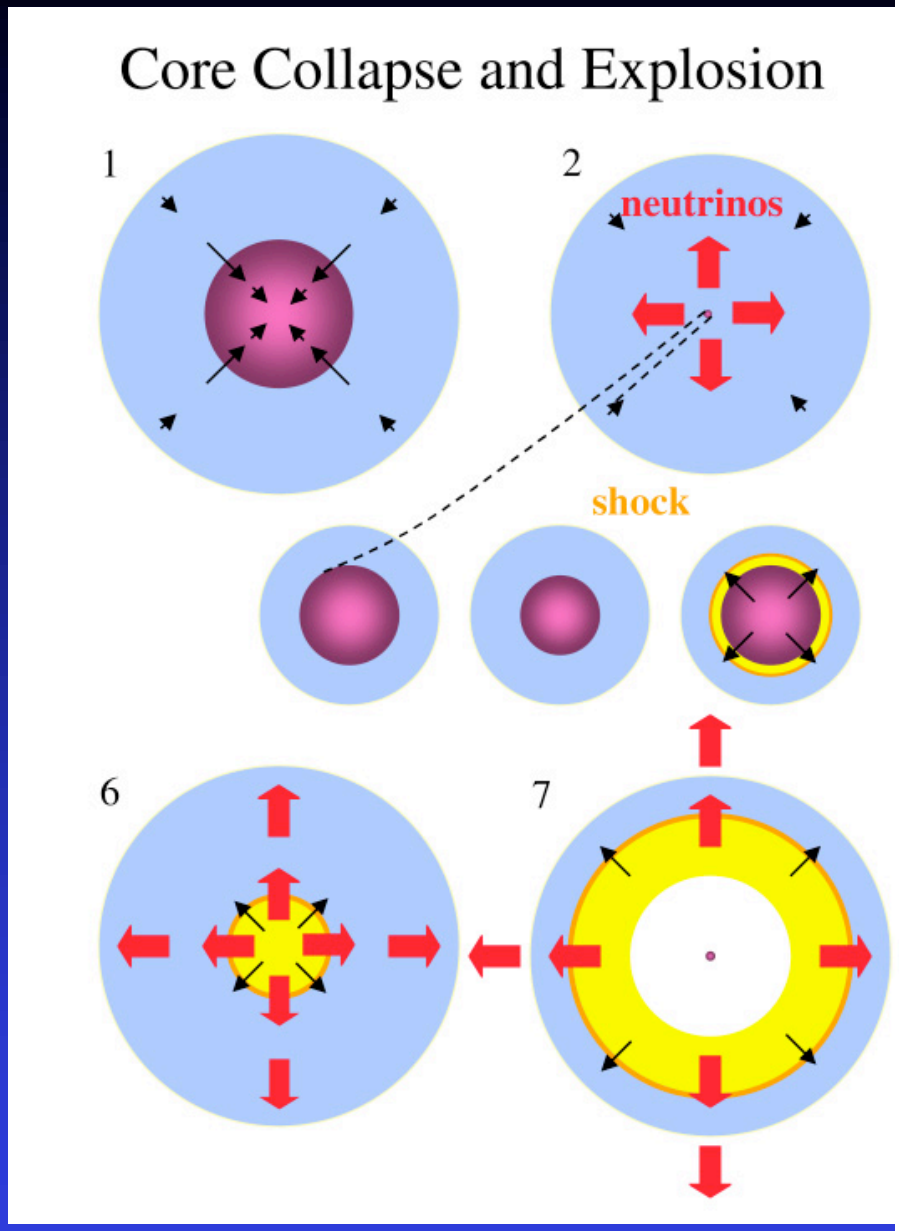
SN
1987A

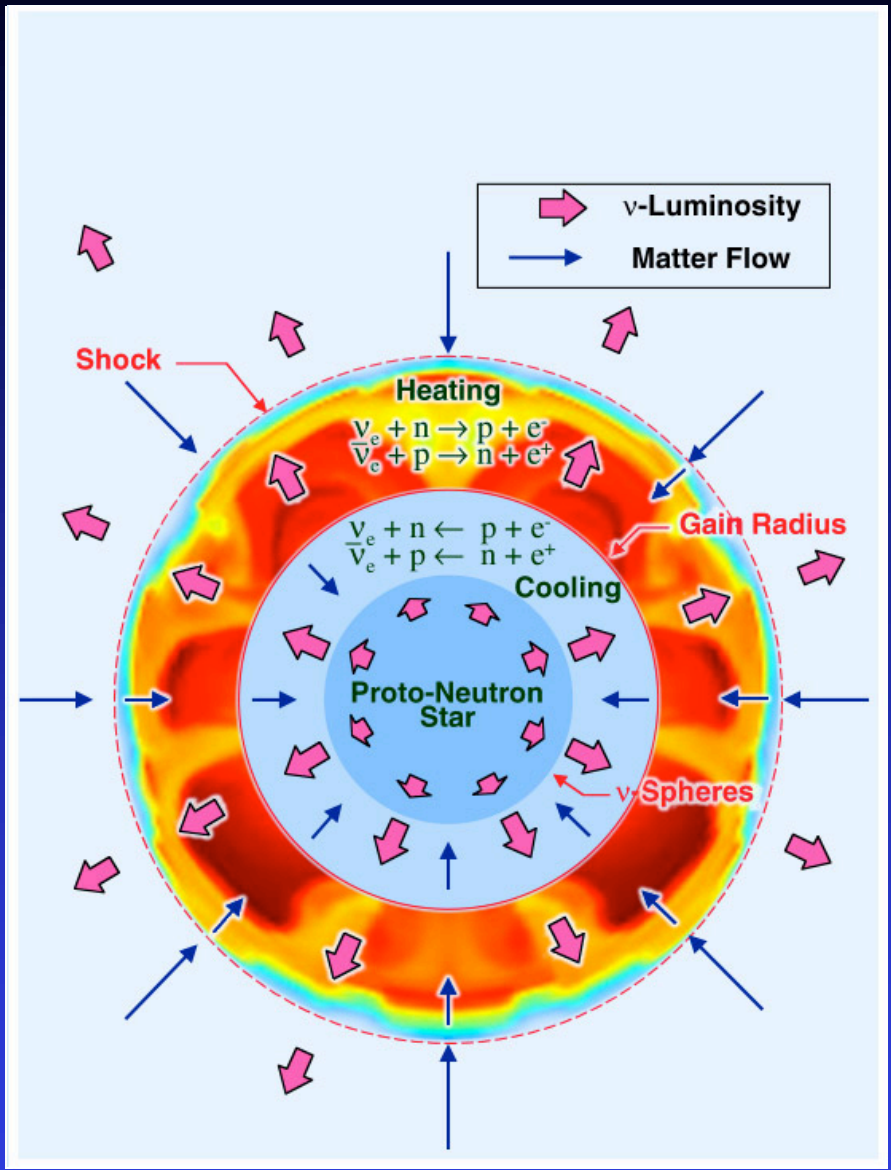
SN 1998aq
(in NGC 3982)

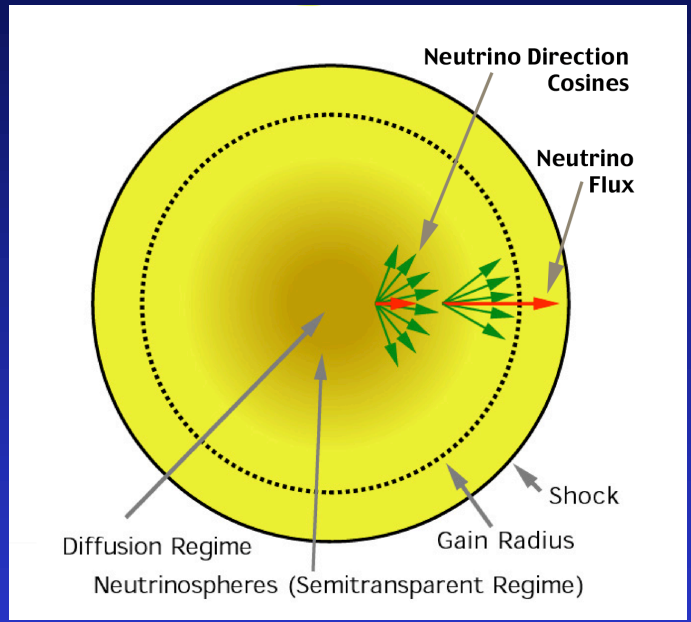
The name "supernova" dates from the 1930s.

- New stars or "novae" were well known.
- The debate about the nature of spiral nebulae led to the realization that there must be
  - "giant novae" (Lundmark 1920),
  - novae of "impossibly great absolute magnitudes" (Curtis 1921),
  - "exceptional novae" (Hubble 1929)
  - "Hauptnovae" (Baade 1929).


Presupernova Structure
representative of a 15 $M_\odot$ star
Orbit of Earth around Sun
H, He
H, He
He
10^{12} cm
$3x10^{13}$ cm
He
He
10^{10} cm
C, O
10^{11} cm
O, Ne, Mg
Earth
O, Ne, Mg
2.2x10 cm
"Si"
"Fe"


Core Collapse and Explosion
1
2
neutrinos
shock
6
7





$E_{explosion} \sim 10^{51}$ erg

$E_{neutrinos} \sim 10^{53}$ erg

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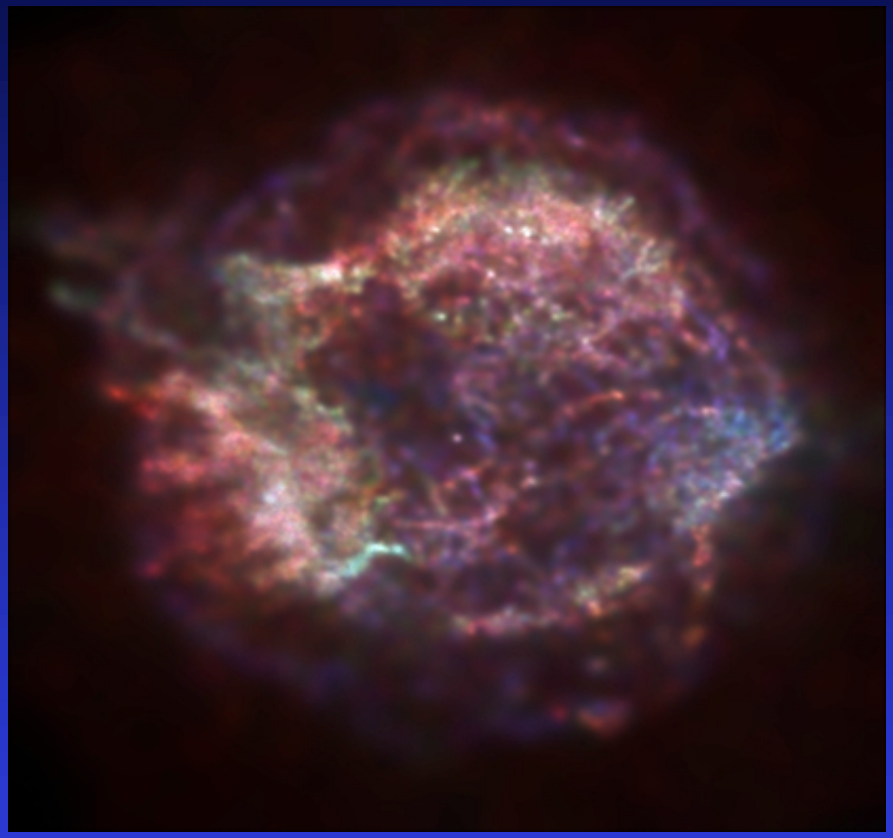
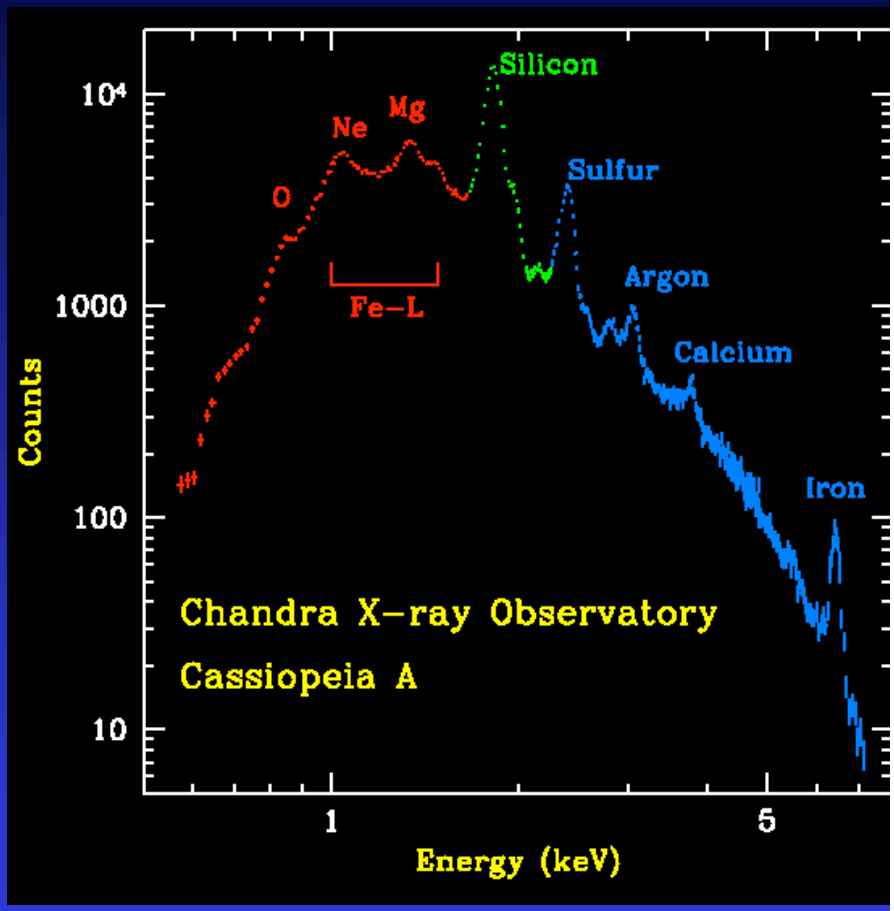
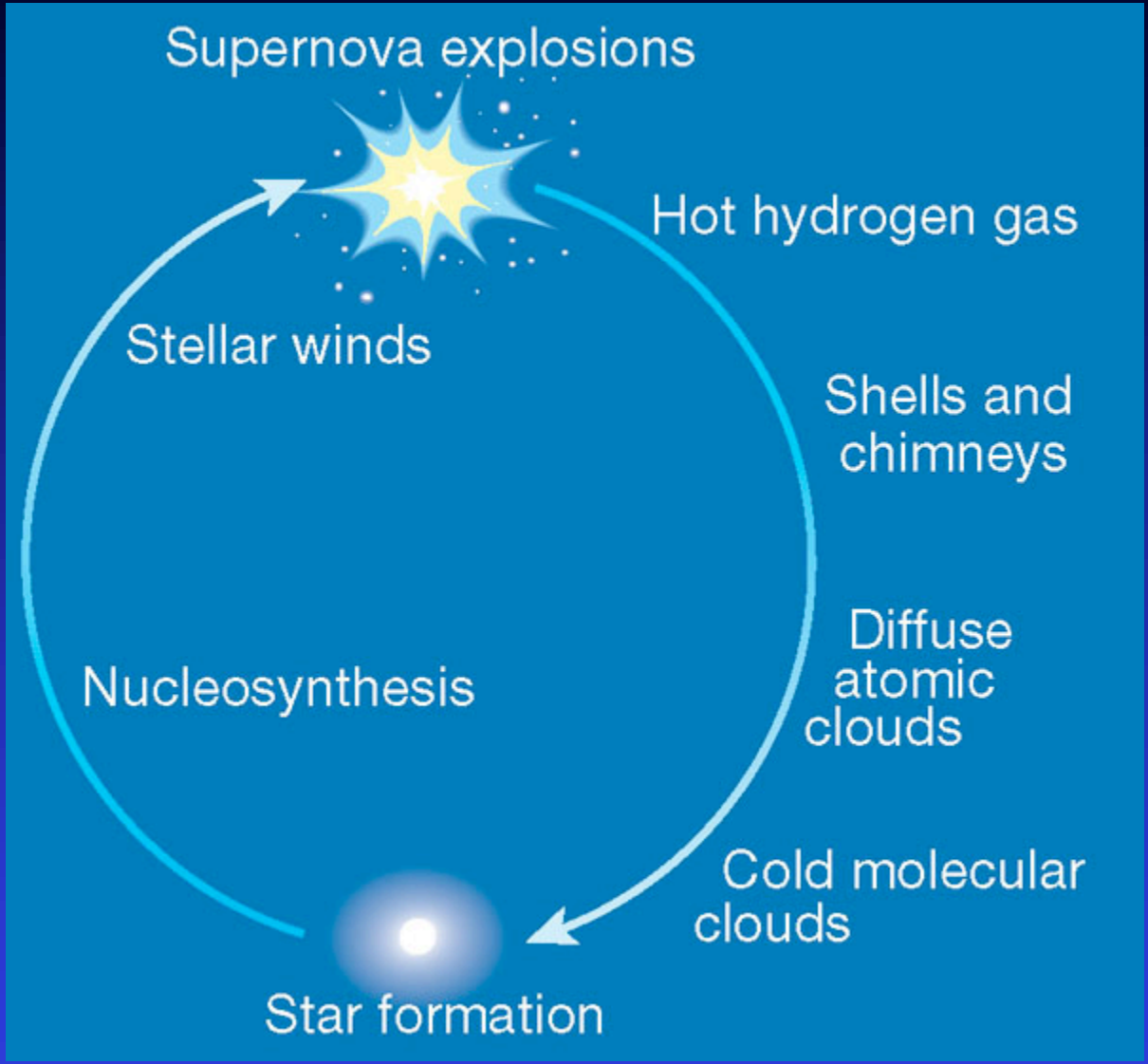


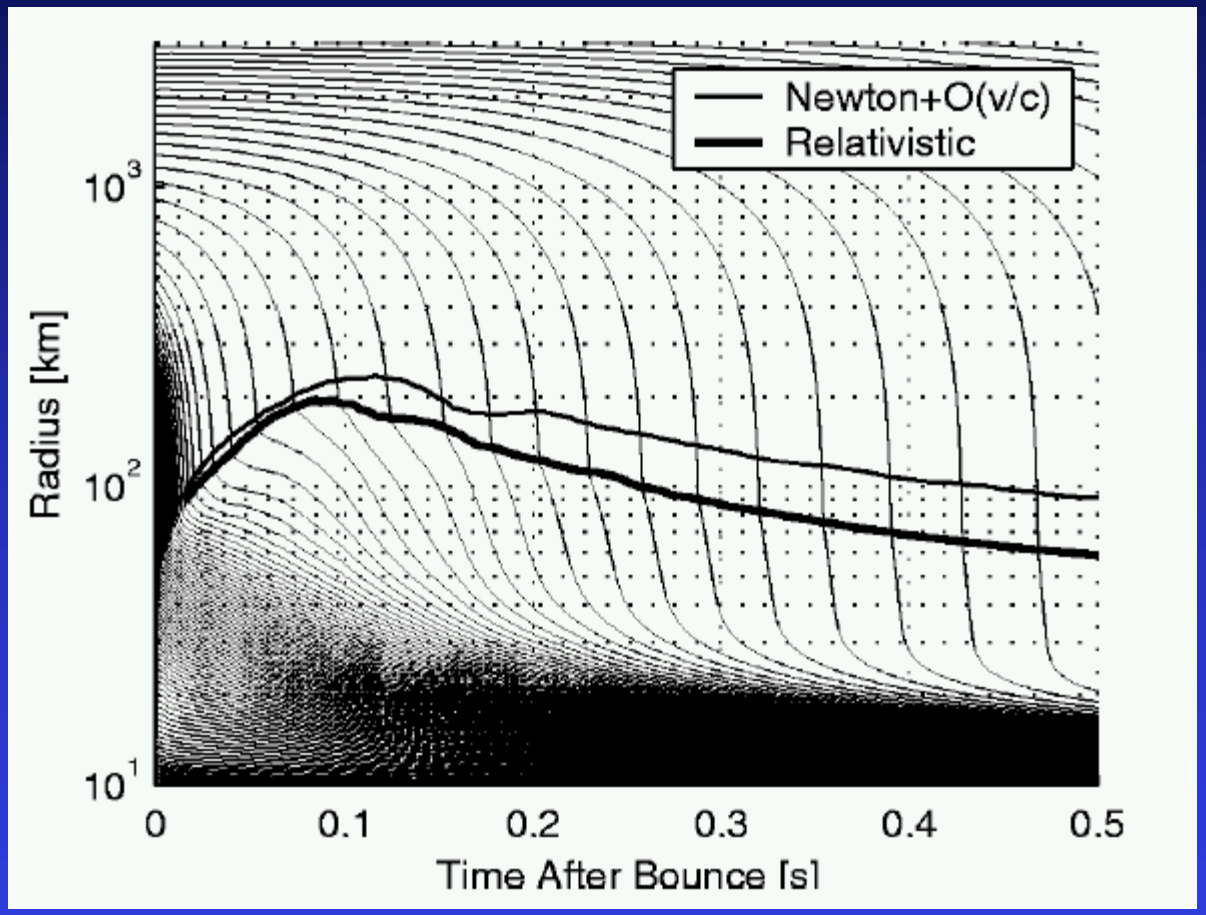

Silicon
Ne
Mg
O
Sulfur
Argon
Fe–L
Calcium
Iron
Counts
10^4
1000
100
10
1
5
Energy (keV)
Chandra X–ray Observatory
Cassiopeia A


Supernova explosions
Hot hydrogen gas
Shells and chimneys
Diffuse atomic clouds
Cold molecular clouds
Star formation
Nucleosynthesis
Stellar winds

Simulating supernovae

Simulations of collapse and explosion

Spherical symmetry, sophisticated neutrino transport



Liebendoerfer, Mezzacappa, Thielemann, Messer, Hix, & Bruenn (2001)

The Terascale Supernova Initiative: A diverse and experienced investigator team...

Oak Ridge National Laboratory	Anthony Mezzacappa David Dean Michael Strayer Ross Toedte
Clemson University	Brad Meyer
NC State University	John Blondin
Florida Atlantic University	Steve Bruenn
Stony Brook, State University of New York	James Lattimer Madappa Prakash Doug Swesty
UCSD	George Fuller John Hayes
NCSA	Pollly Baker Faisel Saied Paul Saylor
The University of Tennessee, Knoxville	Jack Dongarra Victor Eijkhout
University of Washington	Wick Haxton

...with expertise in all necessary areas...

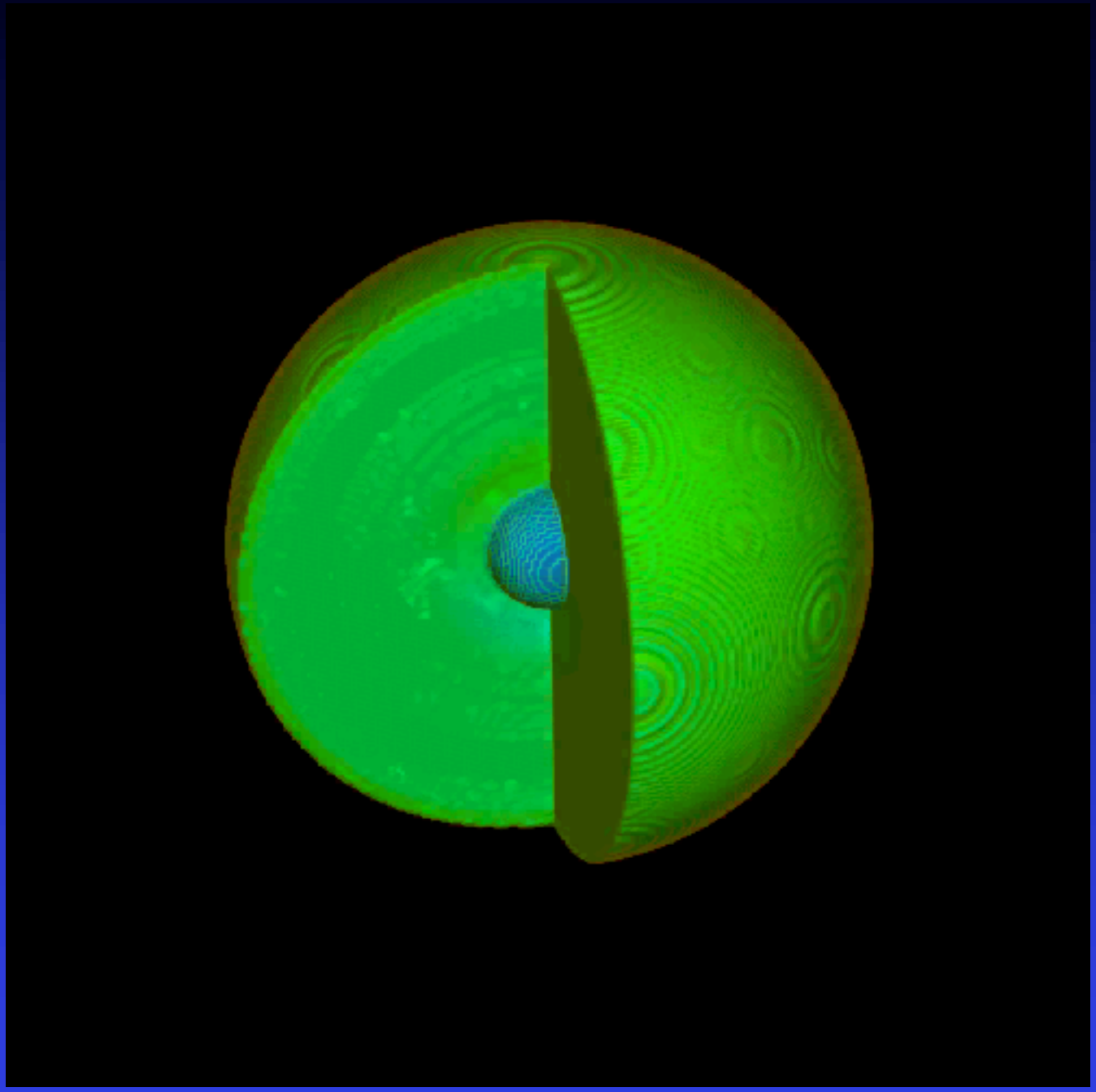
- Radiation transport,
- (Magneto-)hydrodynamics,
- Nuclear and weak interaction physics,
- Computer science,
  - Large sparse linear systems,
  - Data management and visualization;

...and support from the U.S. Department of Energy:

- Funding through the DOE Office of Sciences' SciDAC program,
- Access to DOE's terascale machines (several 10^{12} bytes of memory and flops),
- Access to the expertise of teams specializing in
  - Advanced solvers,
  - Advanced computational meshes,
  - Performance on parallel architectures,
  - Data management and visualization,
  - Software interoperability and reusability.

Mission- Explain supernova phenomena most closely associated with collapse:

- Successful launch of shock (explosion mechanism and energy);
- Neutrino signatures;
- Remnant mass, spin, kick velocity, and magnetic field;
- Gravitational waves;
- Heavy element (*r*-process) abundances.



Conclusion

Supernovae are important because...

...without them we wouldn't be here...

...they played a role in our intellectual history.

Supernovae are interesting because...

...they are spectacular astrophysical phenomena...

...they involve all four fundamental forces and many branches of physics.

Supernova are challenging because...

...their richness has prevented realistic simulations...

...but the Terascale Supernova Initiative will meet the challenge of elucidating the explosion mechanism.