October 4, 2010

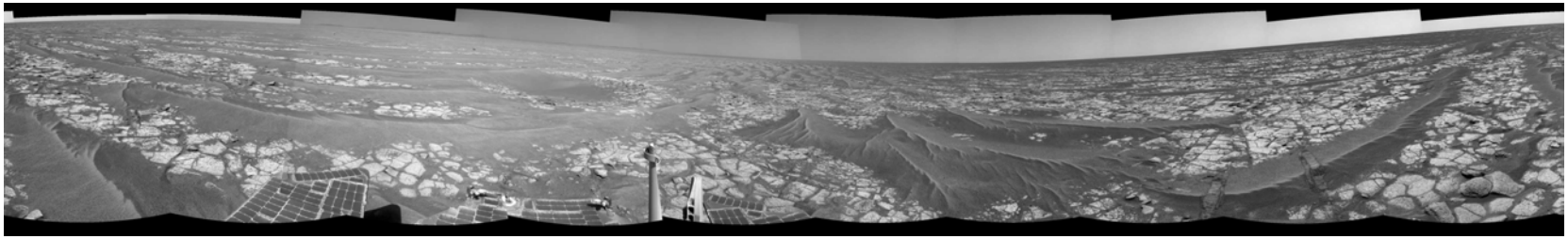
Exam 2 back Wednesday, Movie on Supernovae Friday

Reading Chapter 7

Astronomy in the News? Possible planet, Gleise581g, in the liquid water habitable zone of planet of 3-4 Earth masses. 20 Light years away toward Libra. Dim red host star. 37 day orbit, 4 million miles. One of 6 planets. Tidally locked. Dim stars good search targets first pointed out by John Scalo.

NASA funding passes Congress – kill Moon program, aim for an asteroid or Mars, less $ for new technology, need new heavy lift rocket.

Pic of the Day – Panorama of Mars



Goal – to understand the nature of a new class of super-luminous supernovae

A New Type of Supernova

By far the most dramatic discovery by Robert Quimby and the Texas Supernova Search was a whole new class of “super-luminous” supernovae, of order 10 to 100 times brighter than the classical types.

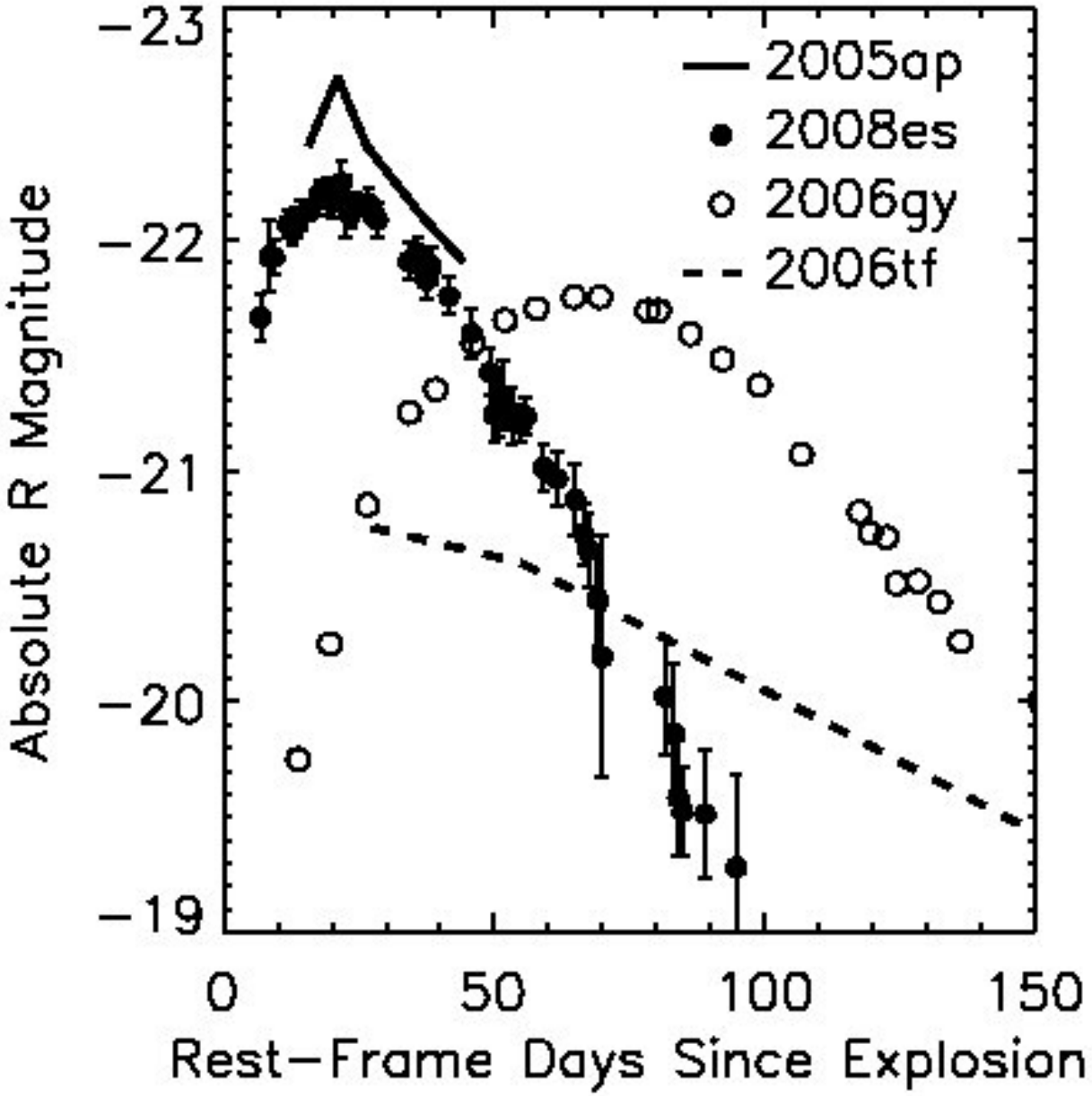
SN 2005ap

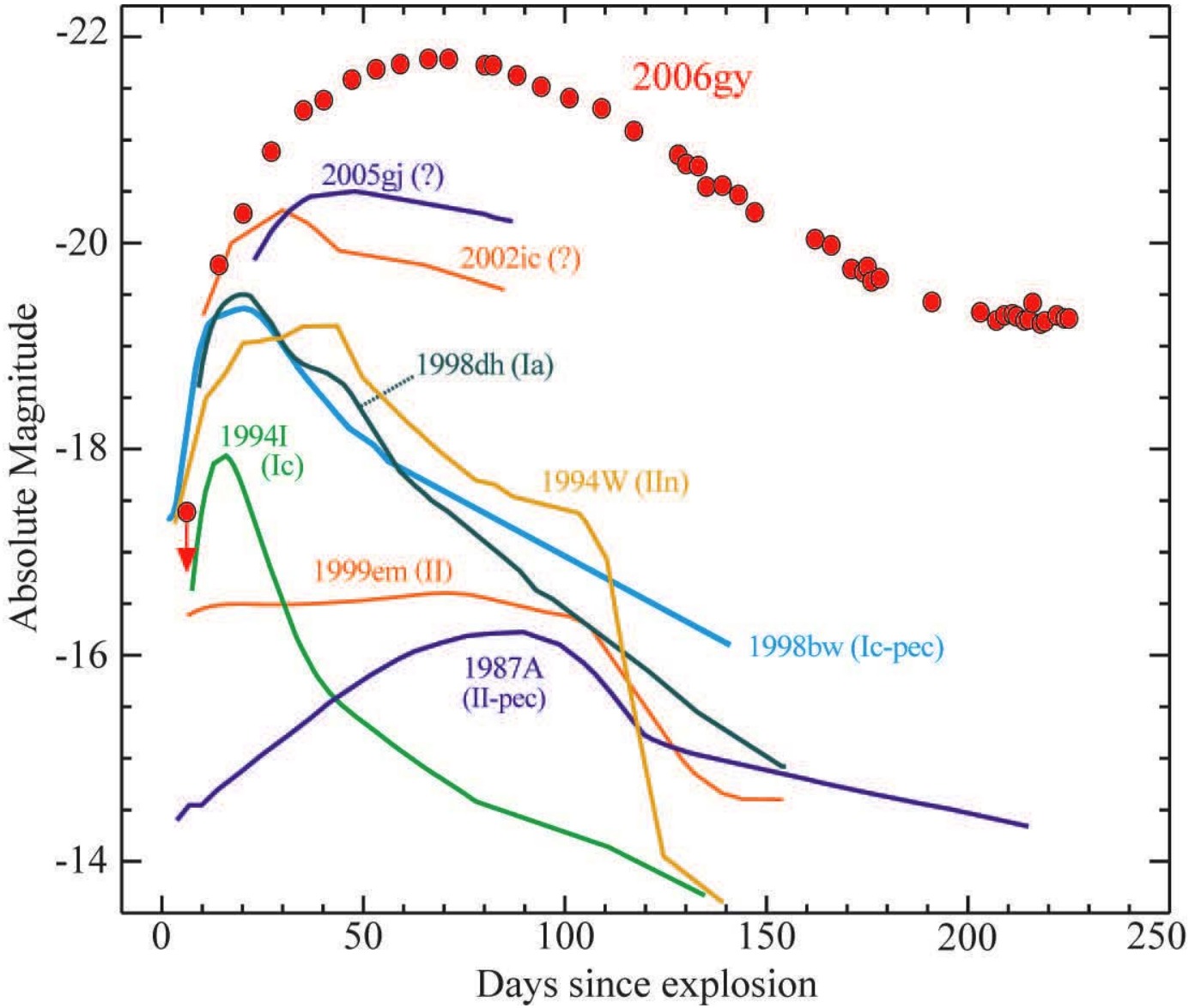
SN 2006gy

SN 2006tf

SN 2008es

SN 2008am (Manos working on this now)


−23
−22
−21
−20
−19
Absolute R Magnitude
0
50
100
150
Rest−Frame Days Since Explosion
2005ap
2008es
2006gy
2006tf


-22
-20
-18
-16
-14
Absolute Magnitude
0
50
100
150
200
250
Days since explosion
2006gy
2005gj (?)
2002ic (?)
1998dh (Ia)
1994I
(Ic)
1994W (IIn)
1999em (II)
1998bw (Ic-pec)
1987A
(II-pec)

SN 2006gy

The first to get major press was SN 2006gy

Rose to maximum in 70 days (1 to 2 weeks is typical) => large mass involved

~100 times brighter than normal

Slower decline

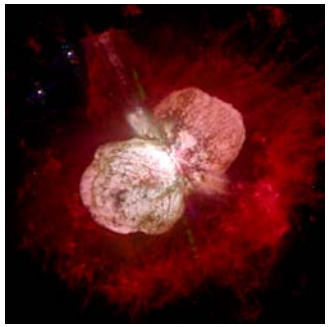
Rich spectrum, characterized by broad, intermediate, and narrow lines of Hydrogen, a Type II, but of a sort never seen before

Detailed analysis showed that SN 2006gy had to arise from a very massive star, ~100 solar masses

SN 2006gy

Explosion of a white dwarf quickly ruled out.

Role for massive star progenitors, perhaps luminous blue variables like Eta Carinae



JCW proposed that it was yet a different kind of explosion, proposed theoretically 40 years ago, more recently hypothesized to occur among the first stars ever formed in the Universe, but never seen.

A Pair-Formation Supernova (focus of Jacob's research)

The energy of high-energy photons can be converted to mass ($E = mc^2$) in the form of particles and their anti-particles, same mass, opposite electrical charge, matter and anti-matter. When matter and anti-matter combine they produce pure energy.

From Wikipedia: **Warp core** A primary component of the warp drive method of propulsion in the Star Trek universe is the "gravimetric field displacement manifold," more commonly referred to as a *warp core*. It is a fictional reactor which taps the energy released in a matter-antimatter annihilation to provide the energy necessary to power a starship's warp drive, allowing faster-than-light travel. In the *Star Trek* universe, fictional "dilithium crystals" are used to regulate this reaction. Usually, the reactants are deuterium, an isotope of hydrogen, and antideuterium (its antimatter counterpart).

Also Angels and Demons

Others?

A very massive star, > 100 solar masses, gets so hot in the post-helium burning, oxygen-core phase, that its radiation, gamma-rays, convert some energy to matter and anti-matter, pairs of ***electrons*** and ***positrons***.

According to theory, this process reduces the energy available to exert pressure, the oxygen core contracts, heats, undergoes a thermonuclear explosion, totally disrupting the star: a ***pair-formation supernova.***

Computer models of the explosion produce a large amount, 10's of solar masses, of radioactive ^{56}Ni, the decay of which to ^{56}Co and then to ^{56}Fe is predicted to produce a very bright, slow light curve.

SN 2006gy

NASA publicity machine engaged (Chandra X-ray observations)

#3 on Time Magazine's list of top 10 science discoveries of 2007

(after decoding of human genome and before 700 new species including carnivorous sponges and giant sea spiders; #1 was stem cells)

Robert Quimby won the 2010 Robert J. Trumpler Award of the Astronomical Society of the Pacific for Best PhD Dissertation in Astronomy

The Pair Formation Supernova Model was wrong for the first extremely luminous supernovae that defined the class.

SN 2005ap - very bright requiring a large amount of nickel, but rather narrow light curve, meaning the ejected mass was modest: would require more ^{56}Ni to power the peak light than the total mass constrained by the width of the light curve.

Same for 2008es

SN 2006gy is somewhat more subtle, but probably does not work there, either.

Need another mechanism for many of these very bright events.

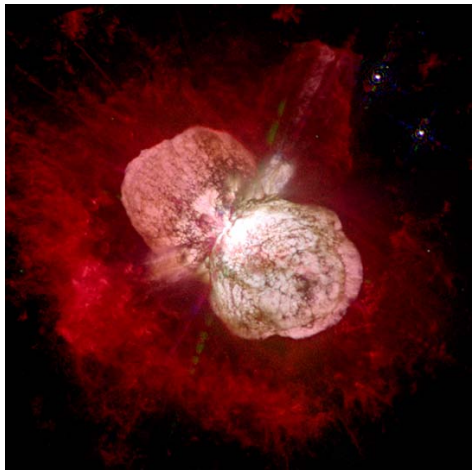
Shell Shock Model

Need a massive shell of circumstellar matter expelled by the progenitor star prior to its explosion.

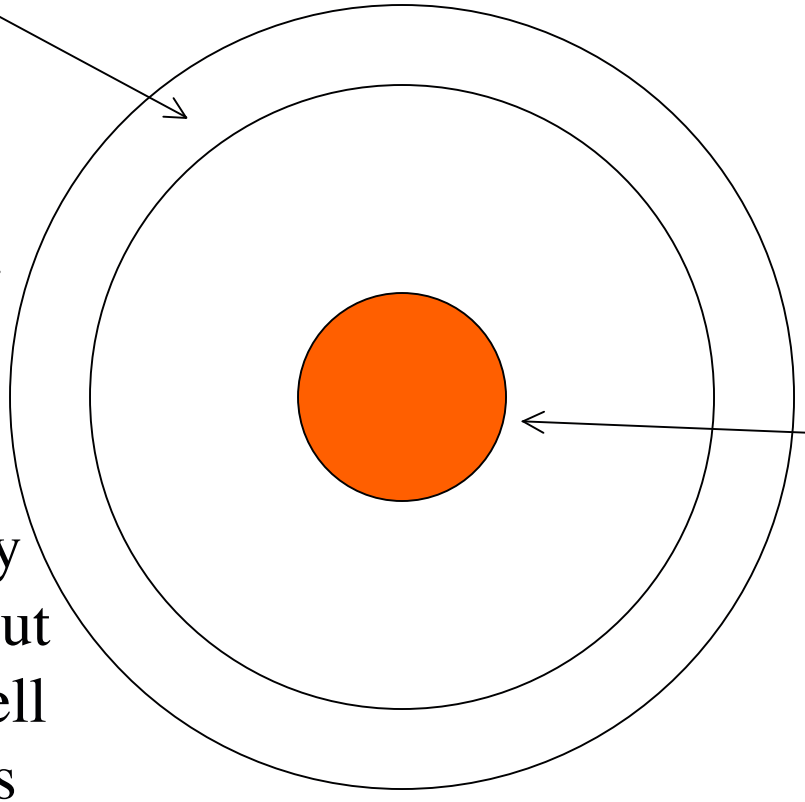
Shell sitting at a radius of about 100 times the size of the Earth's orbit does not have to expand at all to radiate.

Supernova then collides with that shell, efficiently radiates kinetic energy as radiant energy, no loss to expansion and cooling.

Candidate - Luminous Blue Variables, known to eject shells of matter in a burst, mechanism unknown



Shell of matter previously expelled by progenitor star with size about 100 times that of Earth's orbit



Supernova from massive star, but nature otherwise obscured by shell, unknown

The supernova may expand and cool, but when it hits the shell its kinetic energy is converted to heat that is radiated efficiently

What about pair formation?

An example?

SN 2007bi has no Hydrogen, no sign of circumstellar interaction, must be massive and is bright, radioactive decay is consistent, could be a pair-formation supernova.

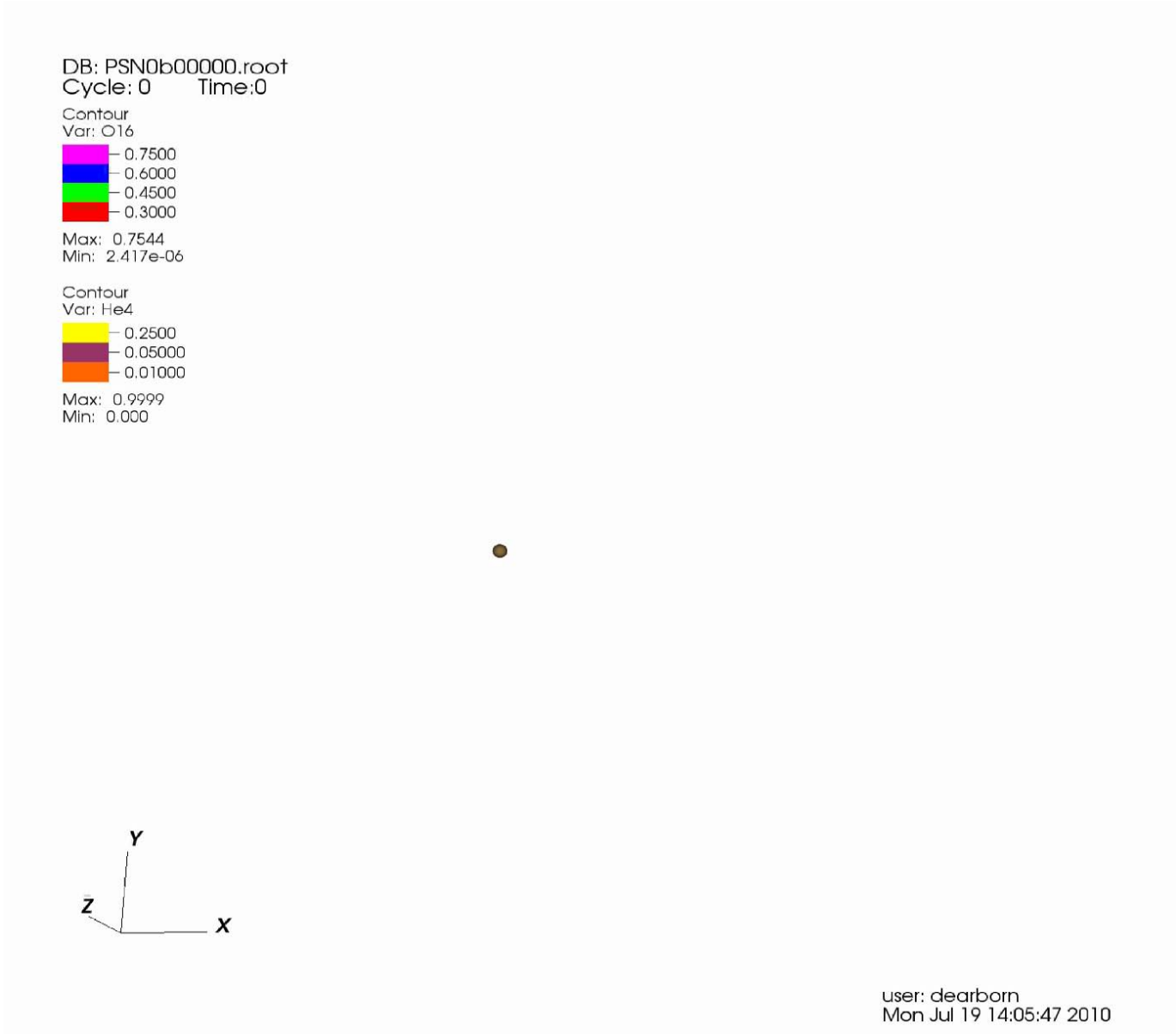
Models

All dynamical models to date have been spherically symmetric. When the Oxygen core contracts and burns violently, there is only one way for it to go, radially outward with great energy.

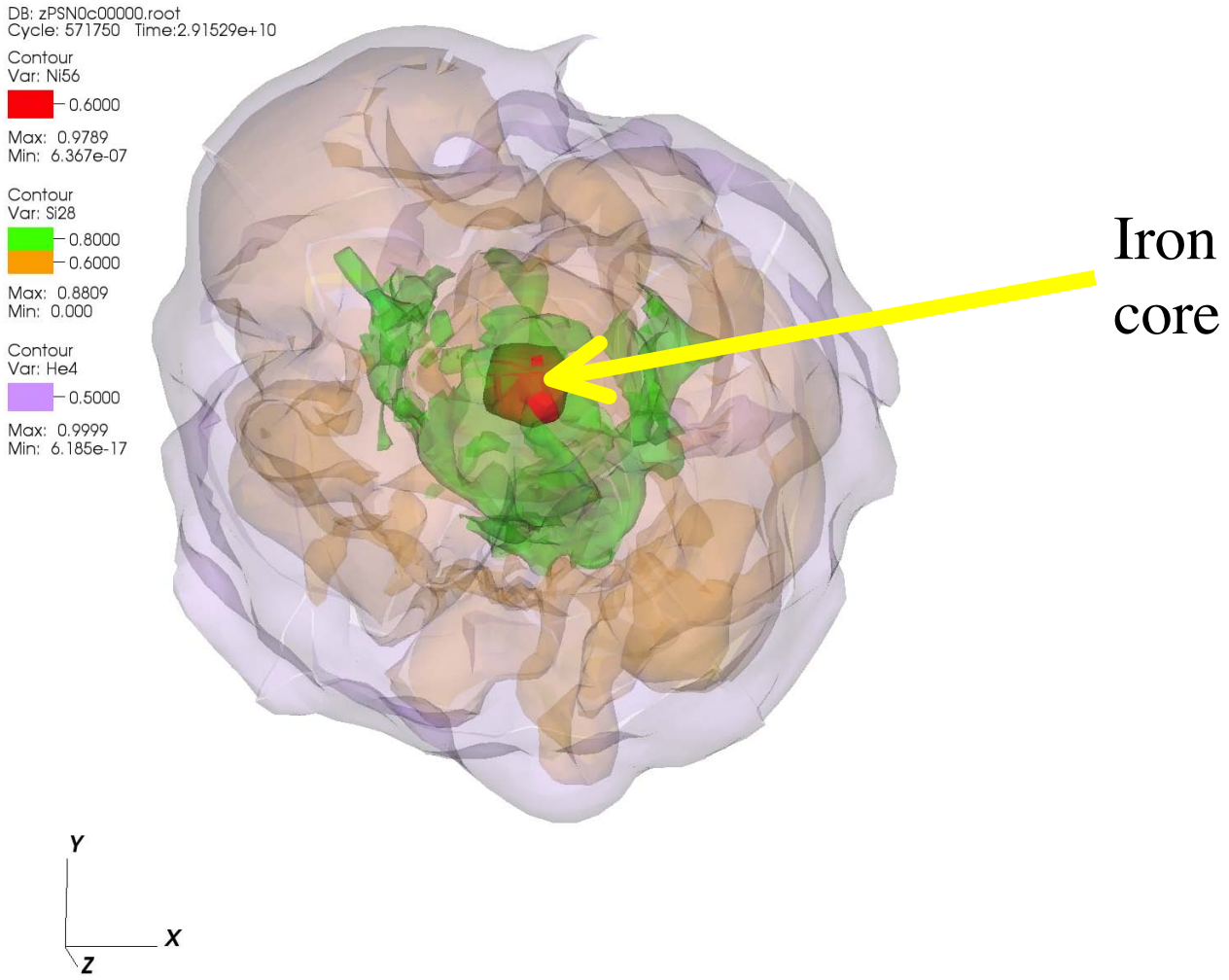
In 3D, there will be other modes of motion.

We (JCW, Manos, and a collaborator) are using a 3D code to investigate the pair-formation supernova process.

Preliminary results of 3D simulation of 50 solar mass Oxygen Core



Hot helium and oxygen burn to iron…
Collapse? Black Hole?



Preliminary result

Violent convection mixes Helium shell to center

Return to core helium burning, process never before seen in stellar evolution

Could still explode, or proceed to core collapse

Most recent result, hot helium/oxygen core burns to iron. Iron will collapse, maybe to black hole.

Possible paradigm shift…

Not a supernova, but the formation of a black hole.

Conclusions

Extremely luminous supernovae are a fascinating new category of stellar explosions

Challenge to classical models to understand shape and amplitude of light curves

Challenge to understand spectra, spectral evolution

Heterogeneous – need to characterize and understand diversity

Many are the result of collision of explosion with circumstellar shell, related to luminous blue variables; what is the underlying explosion?

Some may be related to pair formation, but pair-formation models need more exploration in full 3D

Great luminosity suggests new tool to study cosmology