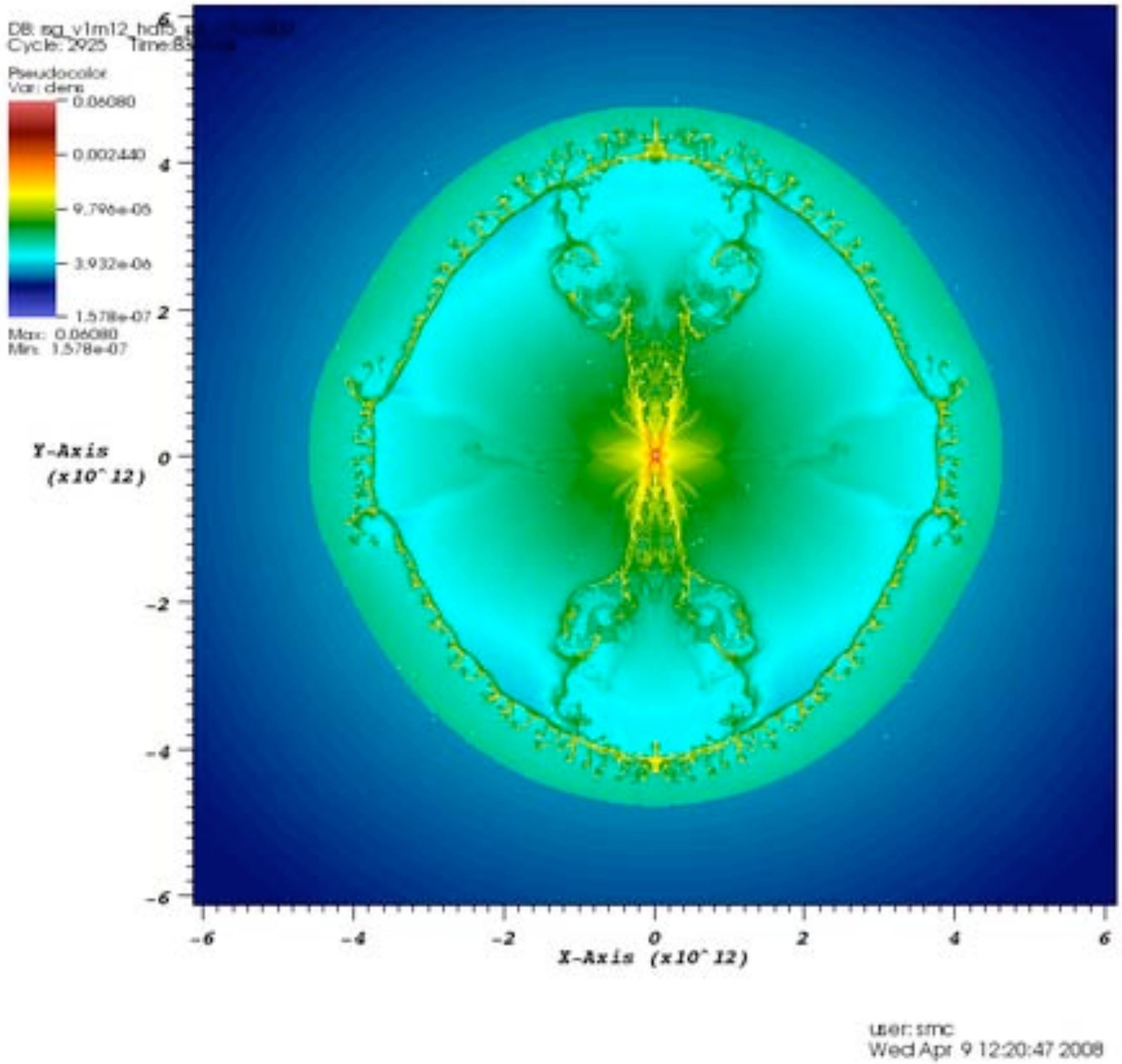
Tuesday, March 3, 2009

Reading Chapter 6 (omit Section 6.7)

Background, Chapter 2, Sections 1, 4, 5

Astronomy in the News? An asteroid that may be as big as a ten-storey building, known as 2009 DD45, thought to be 68-152ft across, raced by our planet on Monday. The gap was just 44,750 miles; a fifth of the distance between our planet and the Moon. It is in the same size range as a rock which exploded over Siberia in 1908 with the force of 1,000 atomic bombs.

Pic of the Day - Helix nebula, beautiful planetary nebular and central white dwarf



Explosion of two identical jets in a red giant star like Betelgeuse

Couch et al. 2009

What jets do -

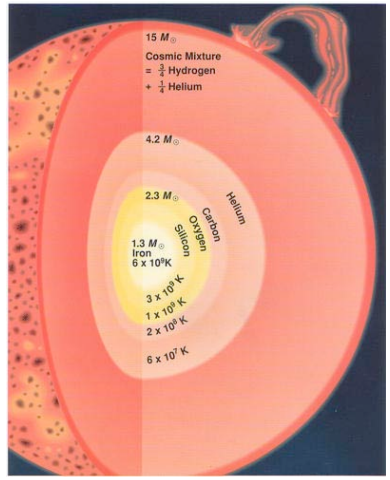
Bagel and breadstick, jet/torus shape "natural."

Strong enough jet can explode the star, but neutrinos also play a role - complicated problem!

Account qualitatively for out-of-round polarization.

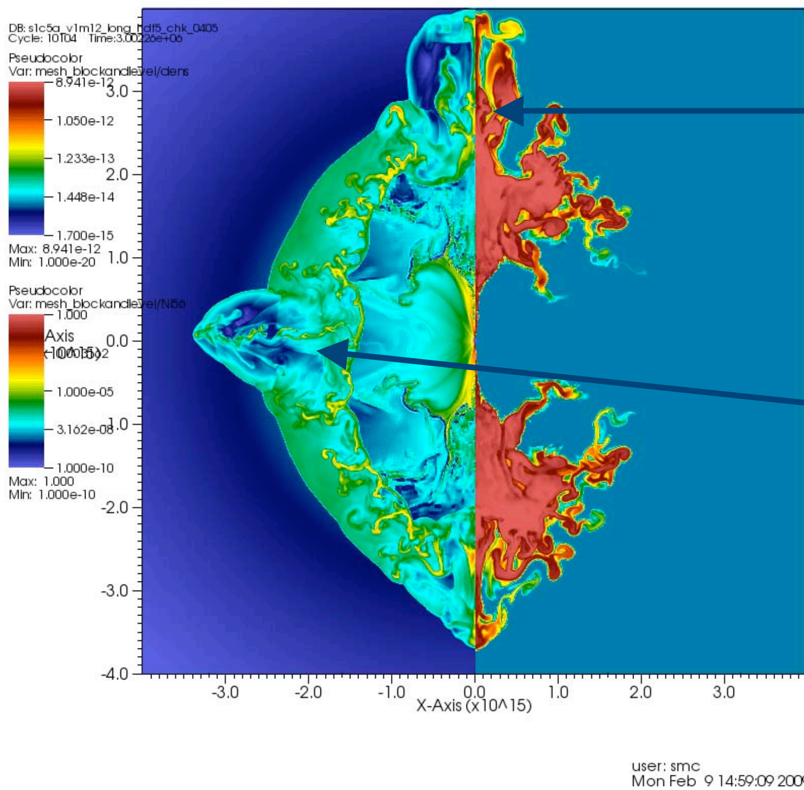
Test for shape (jet/torus), prediction of different elements exploded in different directions.

Initially spherical model,



Spherical Explosion oxygen, silicon, calcium, and iron would be exploded in all directions

Jet-induced Explosion axis/torus structure



jet "iron" bread stick

torus, O, Ca, bagel

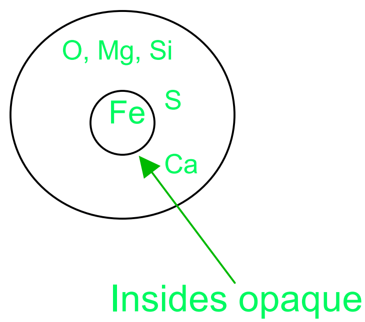
Back to physics of Type Ia Supernovae - exploding white dwarfs

Chapter 6, Section 6 in Cosmic Catastrophes

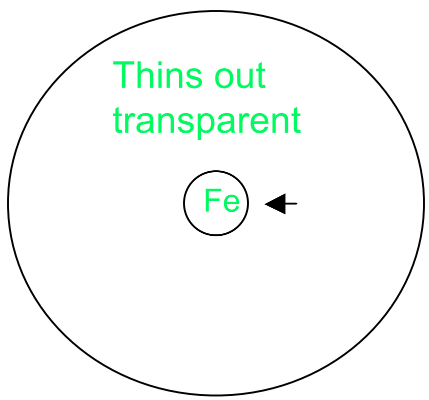
Type II (Ib, Ic) energy from falling, gravity, Type Ia energy from thermonuclear explosion. About the same energy, that required to explode a core with the mass of the Sun, radius of the Earth.

Type Ia - many, if not all, are old ⇒ only credible idea is to grow a white dwarf by mass transfer in a binary system.

Type Ia - see O, Mg, Si, S, Ca early on, iron later => iron inside



Near maximum light



Weeks after maximum

Models based on Chandrasekhar-mass C/O white dwarfs give observed composition structure!

Large quantum pressure deep inside the white dwarf -- high density and temperature overcome charge repulsion - very unregulated - ignite Carbon ⇒ runaway ⇒total explosion, no neutron star or black hole.

Models give thorough burning to iron on inside, only partial burning of C and O leaving O, Mg, Si, S, Ca in outer layers.

Two stages to explosion:

Deflagration - slower than speed of sound, like a flame

Detonation - supersonic shockwave, faster than the speed of sound - like a stick of dynamite

All data, UV, optical, IR, X-ray are consistent with this picture

Pressure waves that cause a star to expand and explode travel at about the speed of sound.

An exploding star expands at about the speed of sound in the ejected matter.

A deflagration cannot catch up with the pressure waves it creates, nor with the outer expanding matter.

A detonation will propagate faster than pressure waves or exploding, expanding matter.

Detonations do not give the star time to react.

⇒For ***detonation alone***, the white dwarf would be turned essentially entirely to iron, *Wrong!*

Deflagrations give the outer parts of the white dwarf time to expand, quench burning.

⇒For ***deflagration alone***, the outer parts are never burned, explosion would be relatively weak, substantial unburned carbon and oxygen must be expelled.

Careful observation in the ***infrared*** show no carbon survives the explosion, so ***Wrong!***

⇒For deflagration followed by detonation:

The detonation catches up with the expanding outer parts

Burns everything to intermediate mass elements, Mg, Si, S, Ca, but not to iron

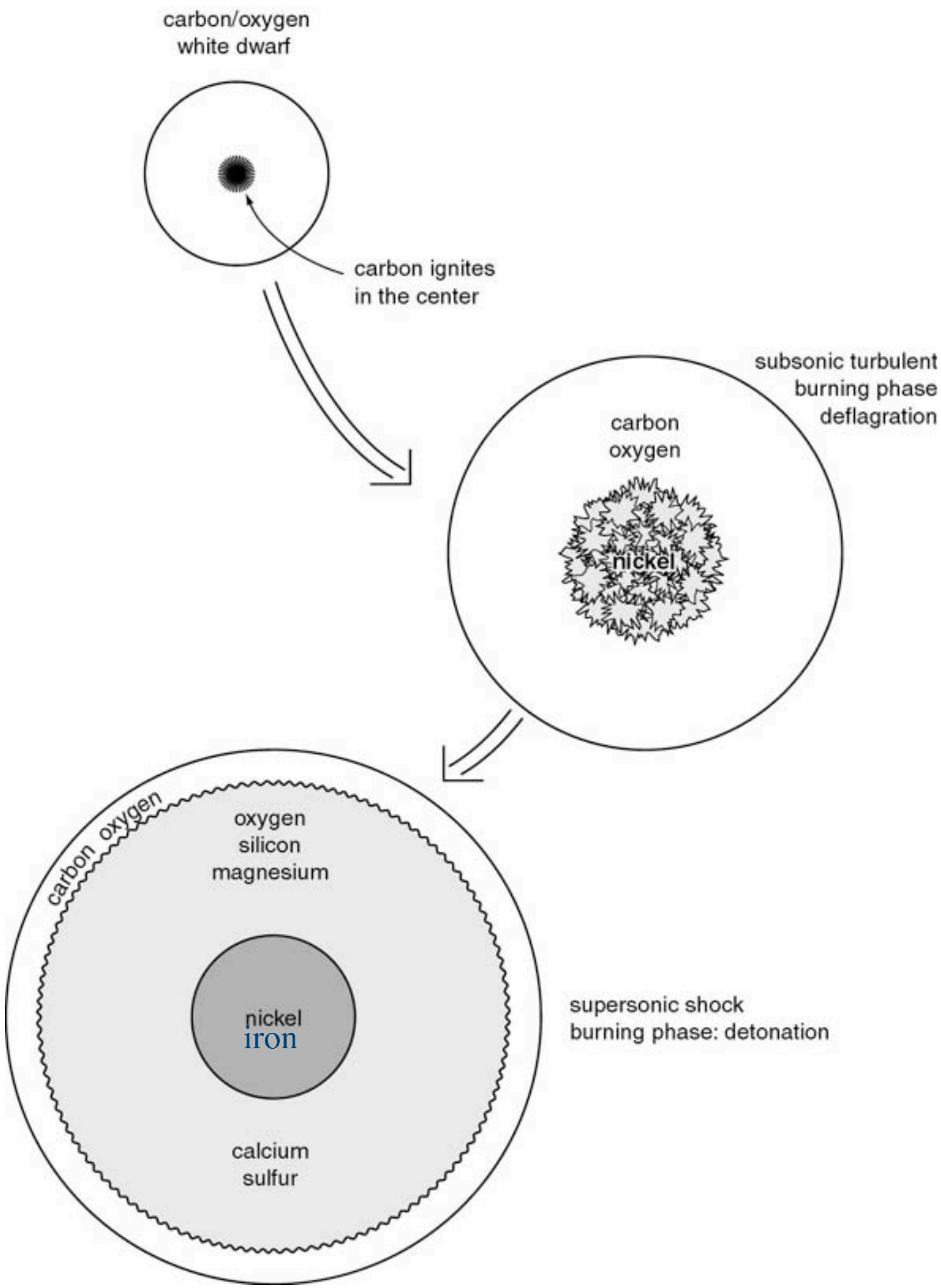
Gives the right energy

Pedicts essentially no unburned carbon and oxygen.

Matches wide variety of observations!

Physics problem - why does the deflagration change to detonation?

Figure 6.6


carbon/oxygen
white dwarf
carbon ignites
in the center
subsonic turbulent
burning phase
deflagration
carbon
oxygen
nickel
carbon oxygen
oxygen
silicon
magnesium
nickel
iron
calcium
sulfur
supersonic shock
burning phase: detonation

One Minute Exam

Astronomers detect Silicon when a Type Ia supernova is brightest and iron after it has faded. This means:

A) The exploded material is made of equal parts silicon and iron

B) The white dwarf that exploded could not be made of carbon and oxygen

C) The iron is in the inner portions of the ejected matter, the silicon in the outer portions

D) The supernovae was powered by the collapse of an iron core

Type Ia ***are*** Chandrasekhar mass carbon/oxygen white dwarfs

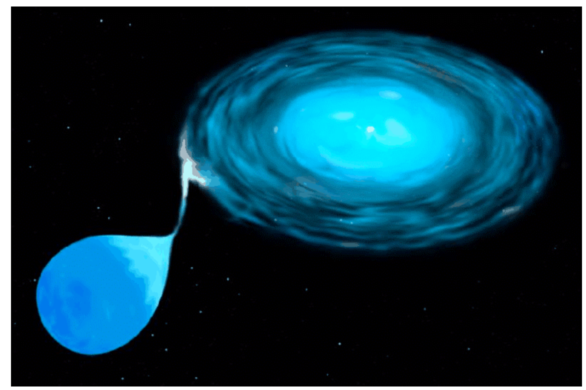
How does nature grow a white dwarf to 1.4 $M_\odot$?

Classical Novae: Problem with losing mass from white dwarf

Recurrent Novae: do seem to have large mass white dwarfs, encouraging.

Probably a binary, everyone assumes so.

No direct evidence, some recent indirect hints.



One Minute Exam

Why does a subsonic deflagration “flame” alone fail to account for the observations of a Type Ia supernova?

A) All the ejected matter would be iron.

B) A neutron star would be left behind.

C) The ejected matter would contain lots of carbon

D) The ejected matter would have silicon on the outside and iron on the inside

Sky Watch

Can only count each object once for credit, but can do any objects missed earlier in later reports.

Add relevant objects that I don't specifically mention in class, other examples of planetary nebulae, main sequence stars, red giants, binary stars, supernovae….

Don't wait until the last minute. It might be cloudy.

The Earth orbits around the Sun, some objects that were visible at night become in the direction of the Sun, "up" in daylight, impossible to see, other objects that were inaccessible become visible at night. Check it out.

Sky Watch Objects mentioned so far

Lyra - Ring Nebula, planetary nebula in Lyra

Cat's Eye Nebula, planetary nebula in constellation Draco

Sirius - massive blue main sequence star with white dwarf companion

Algol - binary system in Perseus

Vega - massive blue main sequence star in Lyra

Antares - red giant in Scorpius

Betelgeuse - Orion, Red Supergiant due to explode "soon" 15 solar masses

Rigel - Orion, Blue Supergiant due to explode later, 17 solar masses

Aldebaran - Bright Red Supergiant in Taurus, 2.5 solar masses (WD not SN)

Castor, Rigel - massive blue main sequence stars

Capella, Procyon - on their way to becoming red giants

SS Cygni - brightest dwarf novae in the sky, Cygnus,

U Geminorum - dwarf nova in Gemini

CP Pup, classical nova toward constellation Puppis in 1942

Pup 91, classical nova toward Puppis in 1991

QU Vul, classical nova toward constellation Vulpecula,

GK Per -Perseus, both a classical nova eruption and dwarf nova.

U Sco - Scorpius, recurrent nova

SN 1006 - Lupus/Centaurus (difficult this time of year)

SN 1054 Crab Nebula - Taurus

SN 1572 Tycho - Cassiopeia

SN 1604 Kepler - Ophiuchus

Cassiopeia A - Cassiopeia

Vela supernova - Vela (not this time of year)