September 20, 2010

Reading, Sections 6.4, 6.5, 6.6. Chapter 7.

Sections 1.2, 2.1, 2.4, 2.5 for background.

Sections 3.3, 3.4, 3.5, 3.10 (binary stars), Sections 4.1, 4.2, 4.3, 4.4 accretion disks), Sections 5.2, 5.4 (cataclysmic variables) for background

Astronomy in the News?

Pic of the Day – Norway aurora

Goal

To understand how jets may trigger a core
–collapse supernova explosion

What jets do -

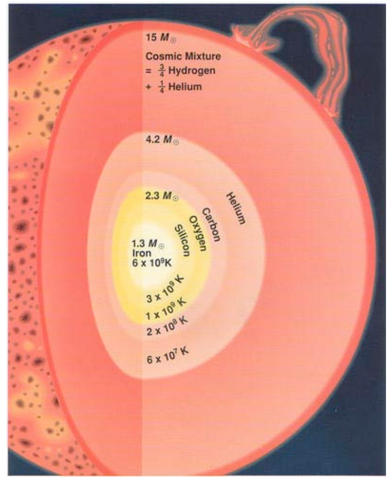
Bagel and breadstick, jet/torus shape "natural."

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

Account qualitatively for out-of-round shapes.

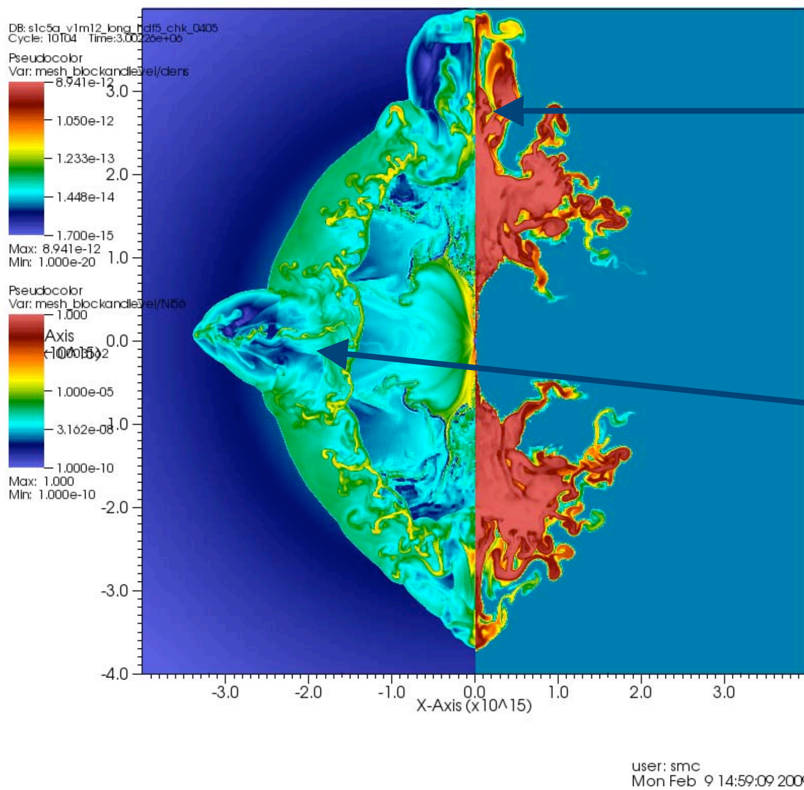
Test for shape (jet/torus), prediction of different elements exploded in different directions.

Initially
spherical
model,



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

Jet-induced
Explosion
axis/torus
structure



Jet
iron,
O
bread
stick

Torus
He
bagel

One Minute Exam

Why do astronomers think that jets may be involved in the core collapse explosion of massive stars?:

➡ Iron makes jets

⬅ Jets make iron and oxygen

⬆ Cassiopeia A has a collapsed object in the center of the explosion

⬇ All core collapse supernovae are out of round

Back to physics of Type Ia Supernovae - exploding white dwarfs

Chapter 6, Section 6 in Cosmic Catastrophes

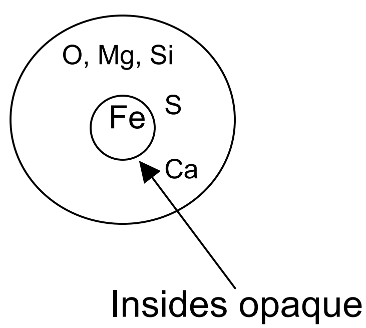
Background in Chapters 3, 4, 5.

Goal

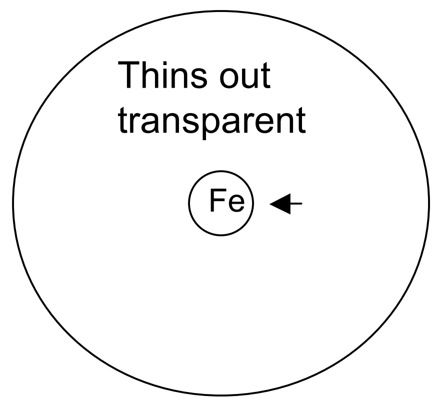
To understand the process of thermonuclear explosion in a white dwarf to make a Type Ia supernova.

Type II (Ib, Ic) energy from falling, gravity, Type Ia energy from thermonuclear explosion.

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



Near maximum light



Weeks after maximum

Discussion point:

What is the difference between a fire and a bomb?

Models based on Chandrasekhar-mass 1.4 solar 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

Deflagration versus Detonation

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

A supersonic detonation will propagate faster than pressure waves or exploding, expanding matter, catch up with and burn outer material.

Detonations do not give the star time to react.

⇒For ***detonation alone***, the white dwarf would burn at original high density and 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, so ***Wrong!***

⇒For deflagration followed by detonation, the detonation catches up with the expanding outer parts, burns everything, gives the right energy, predicts essentially no unburned carbon and oxygen. ***Matches wide variety of observations!***

Physics problem - why does the deflagration change to detonation?

Important unsolved problem of terrestrial physics as well as supernovae.

“Pinging” in car engines means the gas is detonating, not deflagrating, bad for engines

Pipeline, mine explosions – the recent disaster in San Bruno, California may have involved a detonation.

Very recent, highly detailed supercomputer simulations suggest that turbulence packs the subsonic flame until no matter which way it goes, it runs into another flame.

Rapid burning of large region triggers detonation.