February 17, 2010

Second exam, Friday, February 26.

Reading, Sections 6.4, 6.5. Sections 1.2, 2.1, 2.4, 2.5 for background., Section 6.6, 6.77. Chapter 3, Sections 3.3, 3.4, 3.5, Chapter 4, Sections 4.1, 4.2, 4.3, 4.4 for background

Astronomy in the News?

Pic of the Day - Calypso, moon of Saturn

Back to physics of Type Ia Supernovae - exploding white dwarfs

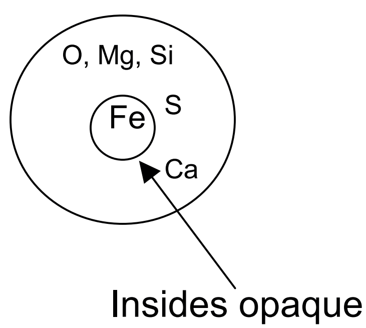
Chapter 6, Section 6 in Cosmic Catastrophes

Background in Chapters 3, 4.

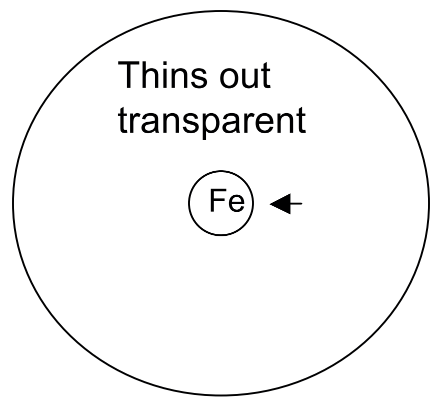
Type II (Ib, Ic) energy from falling, gravity, Type Ia energy from thermonuclear explosion. About the same energy, that required to explode a core with the mass of the Sun, radius of the Earth.

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 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.

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.

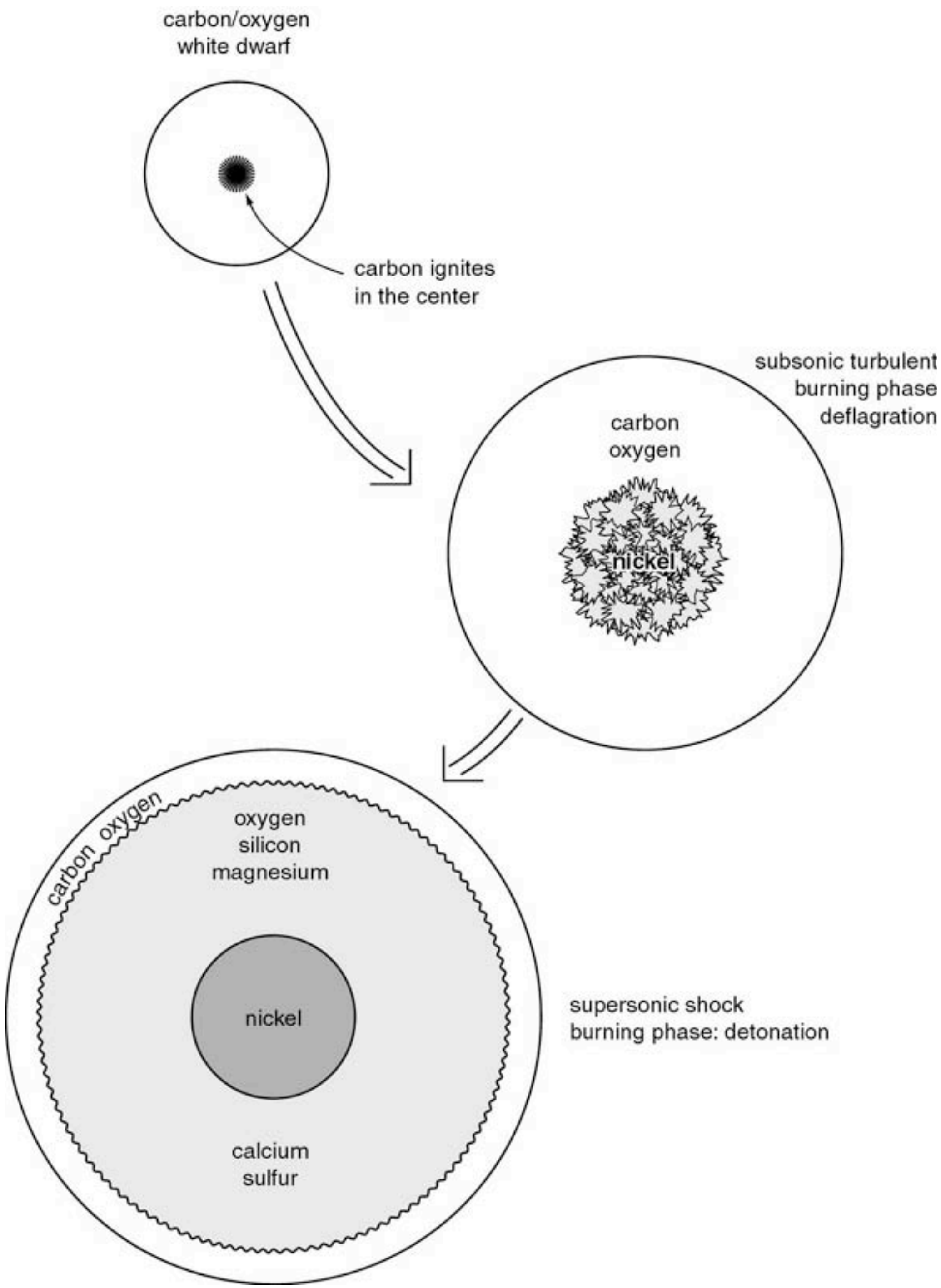
⇒For ***deflagration alone***, the outer parts are never burned, explosion would be relatively weak, substantial unburned carbon and oxygen must be expelled.

Careful observation in the ***infrared*** show no carbon, 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?

Figure 6.4


carbon/oxygen
white dwarf
carbon ignites
in the center
subsonic turbulent
burning phase
deflagration
carbon
oxygen
nickel
carbon oxygen
oxygen
silicon
magnesium
nickel
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:

- ➡ The exploded material is made of equal parts silicon and iron
- ⬅ The white dwarf that exploded could not be made of carbon and oxygen
- ⬆ The iron is in the inner portions of the ejected matter, the silicon in the outer portions
- ⬇ The supernovae was powered by the collapse of an iron core

One Minute Exam

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

➡ All the ejected matter would be iron.

⬅ A neutron star would be left behind.

⬆ The ejected matter would contain lots of carbon

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

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

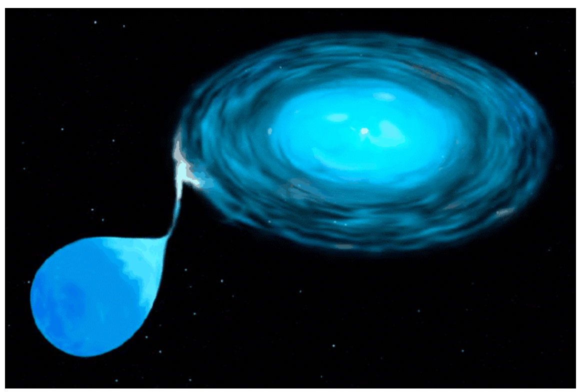
How does nature grow a white dwarf to 1.4 $M_\odot$?

Probably a binary star system, everyone assumes so.

No direct evidence, some recent indirect hints.

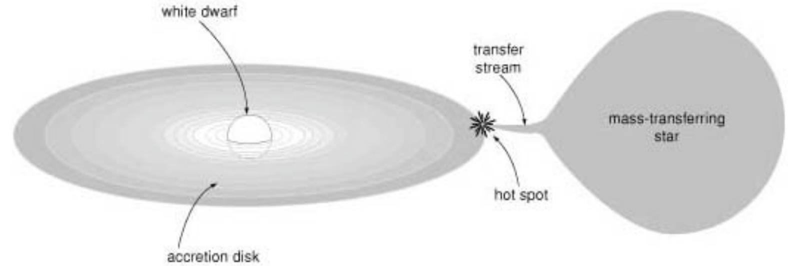
Hint from polarization - not quite round -- *why?*

The progenitors of Type Ia supernovae may look like this:



What's going on?

White dwarfs in Binary Systems



Binary Evolution: **Chapter 3**

Kepler's 3rd Law $P^{2\text{(squared)}}$ proportional to $a^{3\text{ (cubed)}}$

Period
Time to orbit

size of orbit

Newton: P^2 proportional to $\dfrac{a^3}{M_1 + M_2}$

total mass of 2 stars: method to "weigh" the system, get total, subtract "normal" star, get weight of WD, NS, BH