February 21, 2011

Reading: Sections 6.6, 6.7, Betelgeuse, Sections 3.1 – 3.5, 3.10, 4.1 – 4.5.

Astronomy in the news? Space Shuttle Discovery due to launch to International Space Station on Thursday.

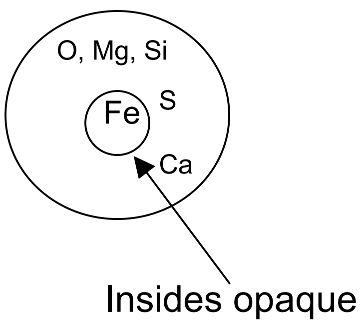
Look on the cover of your book. Some astronomers have just claimed that the blue arc in the lower left corner of Tycho's remnant might be the matter stripped from a binary companion star.

Pic of the day: Milky Way over Switzerland.

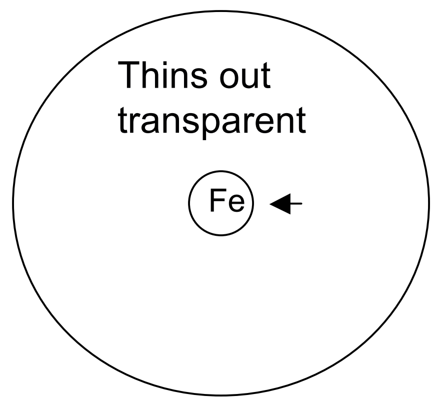
Goal

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

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 (important detail later), 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 would 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.

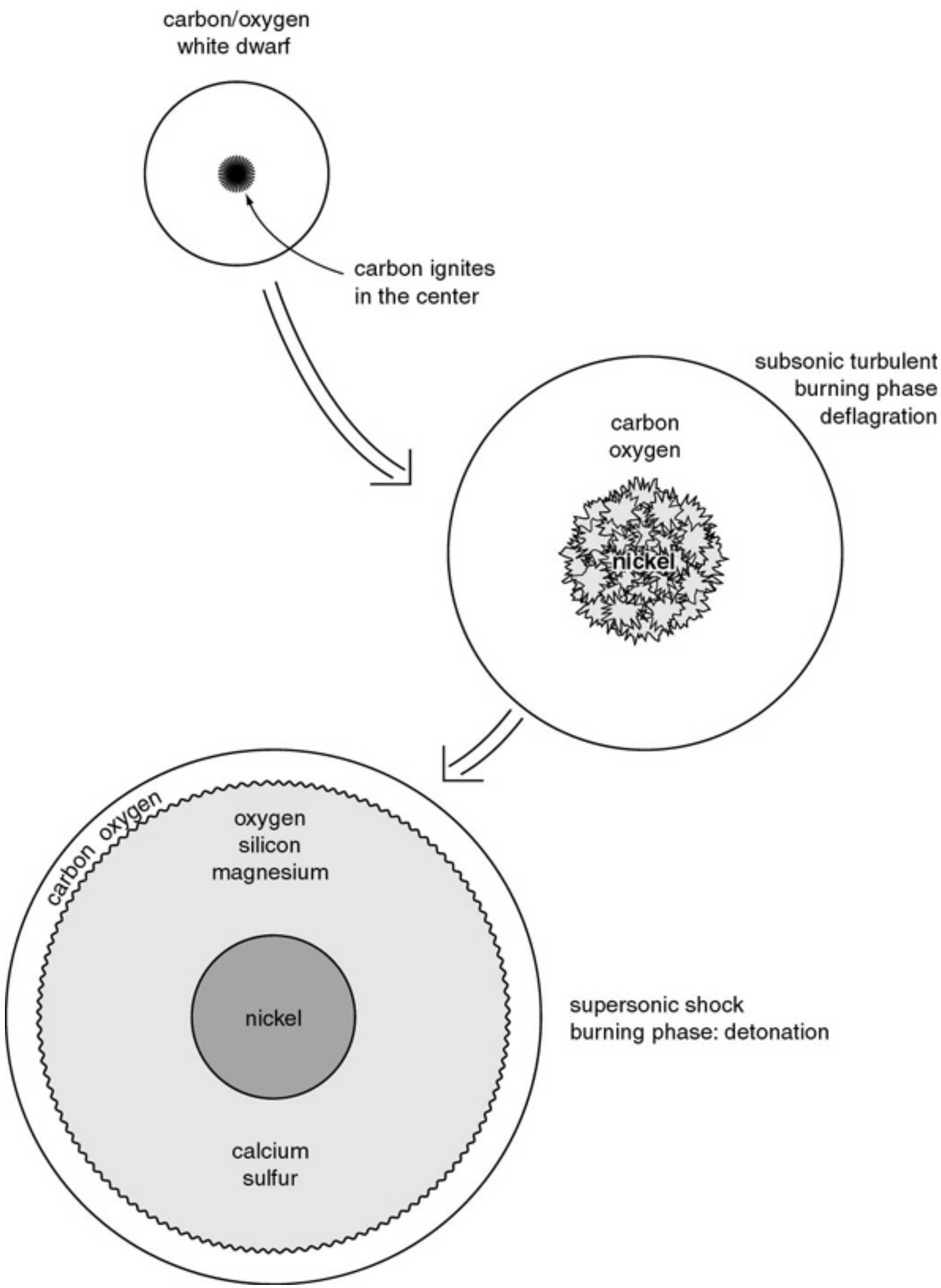


Figure 6.4

Presence of nickel, conversion of nickel to iron explained later

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

Normal Type Ia ***are*** Chandrasekhar mass, 1.4 $M_\odot$, carbon/oxygen white dwarfs; many, if not all, are old.

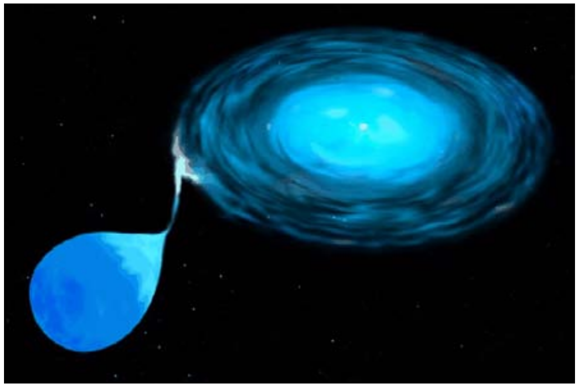
Only credible idea is to grow a white dwarf by mass transfer in a binary system.

No direct evidence for binary systems, some recent indirect hints.

Hint from polarized light - not quite round – *why?*

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

The progenitors of Type Ia supernovae may look like this:



What's going on?