Wednesday, February 15, 2012

Reading Chapter 6 (continued) Sections 6.4, 6.5, 6.6, 6.7
(background: Sections 1.2, 2.1, 2.4, 2.5, 3.3, 3.4, 3.5, 3.10, 4.1, 4.2, 4.3, 4.4, 5.2, 5.4)

Astronomy in the news?

News:

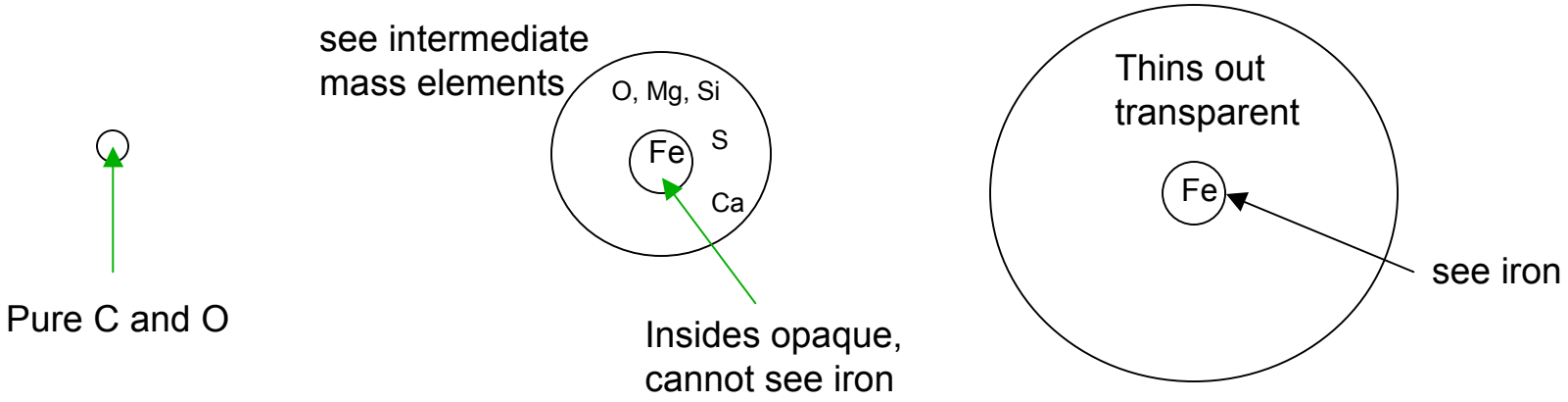
Goal

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.

For core collapse, iron is produce BEFORE the explosion in the progenitor star and triggers collapse, for thermonuclear explosion of carbon and oxygen, iron us produce DURING the explosion.

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



Initial White Dwarf 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 $\Rightarrow$ runaway $\Rightarrow$ 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 or a bomb

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

Deflagration versus Detonation

Important Principles

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 (a “flame”) cannot catch up with the pressure waves it creates, nor with the outer expanding matter.

A supersonic detonation (a “bomb”) will propagate faster than pressure waves or exploding, expanding matter, and thus can catch up with and burn outer material.

Thermonuclear burning of carbon and oxygen at high density characteristic of the white dwarf will producd iron.

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, but observe intermediate mass elements on the outside, so ***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.

Predict feeble explosion and careful observation shows little or no carbon, so ***Wrong!***

Deflagration followed by Detonation

The ***deflagration*** starts the explosion:

Produces iron on the inside

Shoves much of the unburned carbon and oxygen to lower densities.

The ***detonation*** catches up with the expanding outer parts

Burns carbon and oxygen to oxygen, magnesium, silicon, calcium

Deflagration followed by detonation:

Gives the right energy

Gives the right elements on the inside and outside

Predicts essentially no unburned carbon and oxygen.

Matches wide variety of observations!

Physics problem - why does the subsonic deflagration change to a supersonic 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 disasters in San Bruno, California, Upper Big Branch mine in West Virginia, may have involved a detonation, more violent, dangerous than “flame.”

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.

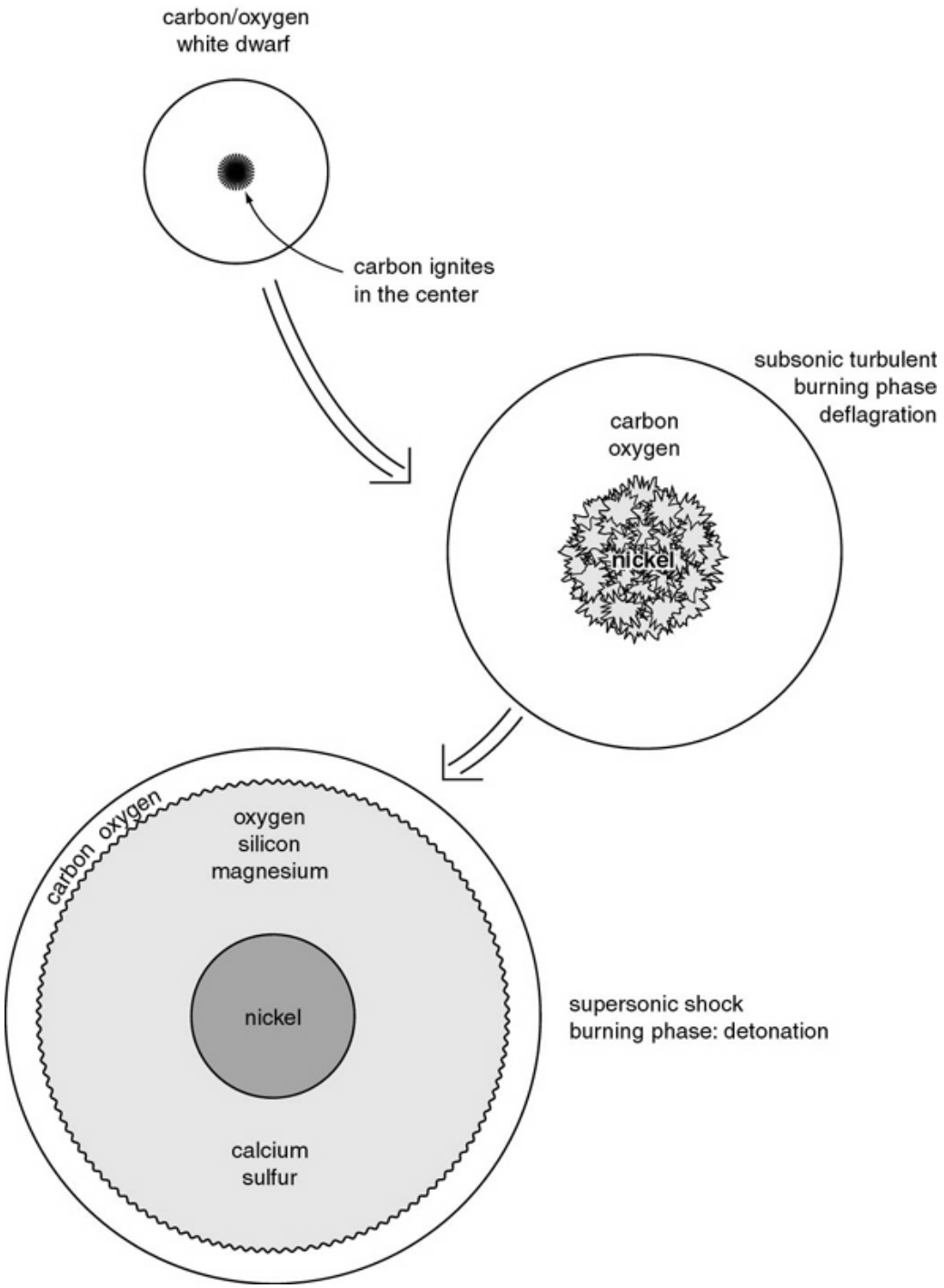


Figure 6.4

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

Goal

To understand how a white dwarf evolves in a binary star system to make a Type Ia supernova.

Algol, Beta Perseus, second brightest star in the constellation Perseus

Ancient Arabs called the star **Al-Ghul**, the Ghoul

The Hebrews knew Algol as **Rosh Ha'Satan**, Satan's Head, or perhaps **Rosh Ha'Shed**, head of the devil or of a genie.

The Chinese called it **Tseih She**, the Piled-up Corpses

In Greek mythology, Algol is the head of the Gorgon Medusa that Perseus carries under his left arm.

Algol

Algol is a binary system with a red giant eclipsed by an orbiting main sequence star, giving the impression of a "blinking" red demon.

Find Algol for your Sky Watch Project.

Sky Watch

Explosions on the surface of white dwarfs

Classical Novae:

CP Pup, toward constellation Puppis in 1942

Pup 91, another toward Puppis in 1991 (not same place in our Galaxy, just accidently off in the same approximate direction)

QU Vul, toward constellation Vulpecula, white dwarf composed of Oxygen, Neon, and Magnesium rather than Carbon and Oxygen.

GK Per toward constellation Perseus - has had both a classical nova eruption in 1901 and dwarf nova eruptions.

Sky Watch

Recurrent Novae:

U Sco in the constellation Scorpius is a Recurrent Nova,
It may be a candidate to explode as a supernova!

Might see Scorpius. Also has neutron stars and black holes.

T Pyx in constellation Pyxis.