Friday, February 19, 2016

Reading for Exam 2: Sections 6.1, 6.4, 6.5, 6.6, Betelgeuse interlude.

Background: Sections 1.2.1, 2.1, 2.2, 2.4, 2.5

Exam 2, Sky Watch 2, Friday, February 26. *A week from today!*

Astronomy in the news?

The Hubble Space Telescope detects biggest black hole ever observed: 21 billion times the mass of the Sun

Back to physics of Type Ia Supernovae - exploding white dwarfs

Chapter 6, Section 6 in Cosmic Catastrophes

Sky Watch

Explosions on the surface of white dwarfs, related to Type Ia, but not full-fledged supernovae

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

More explosions on the surface of white dwarfs

Recurrent Novae:

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

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

T Pyx in constellation Pyxis.

RS Oph in Ophiuchus

Goal

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

What do we know about white dwarfs?

Mass ~ Sun
Most are single, 0.6 $M_\odot$ (solar masses)
Some in binary systems have higher mass

Size ~ Earth ~1% radius of Sun

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \rightarrow \frac{10^6 \text{ grams}}{\text{c. c.}} \sim \frac{\text{tons}}{\text{cubic centimeter}}$$

OR MORE!

HUGE GRAVITY!

QUANTUM PRESSURE!

A normal star supported by thermal pressure regulates its temperature. If excess energy is lost, the star contracts and heats. If excess energy is gained, the star expands and cools. Feedback loop, akin to the furnace, thermostat in your house.

A white dwarf, supported by the quantum pressure, cannot regulate its temperature. If excess energy is lost (the case for the vast majority of white dwarfs), they just get cooler. If Excess energy is gained, they heat up and can explode.

Behavior of white dwarf, Quantum Pressure, worked out by S. Chandrasekhar in the 1930's

Limit to mass that the Quantum Pressure of electrons can support

Chandrasekhar mass limit ~ 1.4 $M_{\odot}$

density ~ billion grams/cc ~ 1000 tons/cubic centimeter

Maximum mass of white dwarf.

If more mass is added, the white dwarf must collapse or explode!

One Minute Exam

If excess nuclear reactions start burning in an ordinary star like the Sun, what happens to the temperature?

➡ The temperature goes up

⬅ The temperature remains constant

⬆ The temperature goes down

⬇ Insufficient information to answer the question

One Minute Exam

If excess nuclear reactions start burning in a white dwarf, what happens to the temperature?

➡ The temperature goes up

⬅ The temperature remains constant

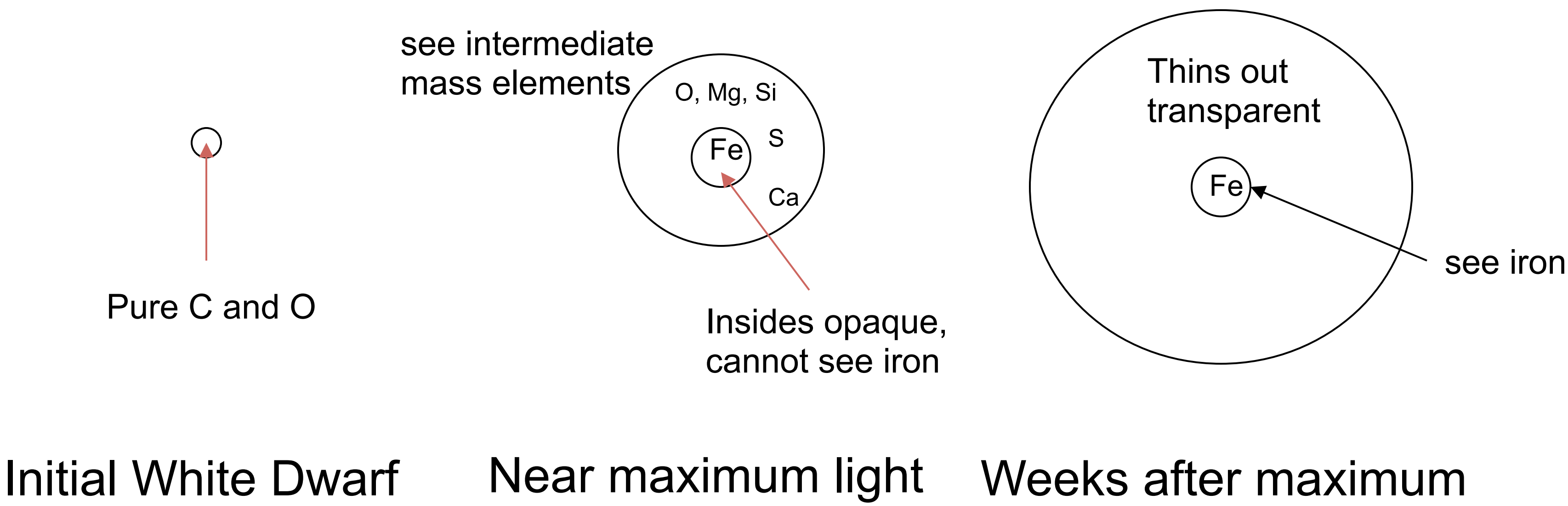
⬆ The temperature goes down

⬇ Insufficient information to answer the question

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

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

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



Models based on Chandrasekhar-mass 1.4 solar mass C/O white dwarfs give observed composition structure!

Higher temperature in a white dwarf helps to overcome charge repulsion (but does NOT contribute to the pressure).

Large quantum pressure deep inside the white dwarf -- high density and temperature overcome charge repulsion, start burning - **very unregulated.**

Ignite Carbon, temperature goes up, easier to overcome charge repulsion, more burning, higher temperature

$\Rightarrow$ 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.

Discussion point:

What is the difference between a fire and a bomb?

Burning and an explosion?

Two stages to explosion:

Deflagration - slower than speed of sound, like a flame

Detonation – involves a supersonic shockwave, faster than the speed of sound. Shock wave ignites the fuel, burning drives the shock. A detonation is self-propagating. Result is like a stick of dynamite or a bomb

Force, acceleration are related to the change in pressure.

A shock wave involves a sharp, steep growth in pressure from in front to behind the shock front. Severe force and acceleration.

A detonation is faster and more violent than a deflagration since it involves a shock wave.

http://abcnews.go.com/GMA/video/baltimore-train-derailment-explosion-video-sudden-blast-strikes-19277884

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.