

Monday, October 3, 2011

Exam 2 back Wednesday.

Reading: Section 6.7, Chapter 7

Astronomy in the news? China has put the Tiangong-1 (Palace of Heaven) in orbit, the first module for a space station. Unmanned Shenzou-8 capsule in early November to test remote-controlled docking.

Cover story this month's Sky and Telescope, "Supercharged Supernovae" with radio interview with ex-Texan, Robert Quimby

Nobel prize season – watch for Nobel Prize in physics.

Pic of the day: dark matter <http://apod.nasa.gov/apod/astropix.html>

Goal – to understand what happens to two white dwarfs in a binary system.

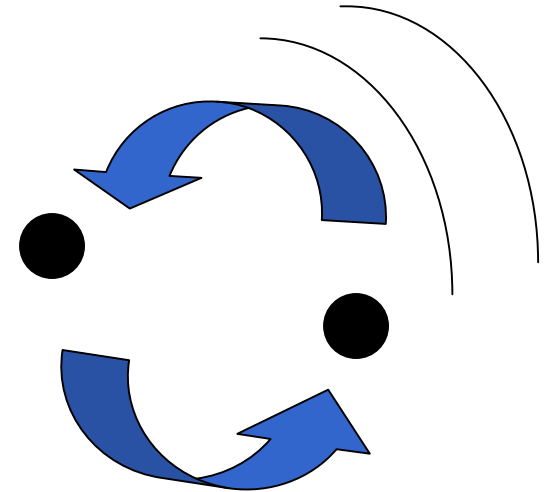
We do observe 2 white dwarfs in orbit in some cases - is that the end?

No: *gravitational radiation* (§ 3.10)

ripples in curved space-time

like paddle on surface of pond

remove energy from orbit - acts as drag



If you try to slow down an orbiting object what happens?

Falls inward, speeds up,

Get more gravitational radiation, more inspiral

Given enough time (billions of years) 2 white dwarfs must spiral together!

What happens when two white dwarfs spiral together?

New physical fact:

Larger mass WD has smaller radius

Which WD has the smaller Roche lobe?

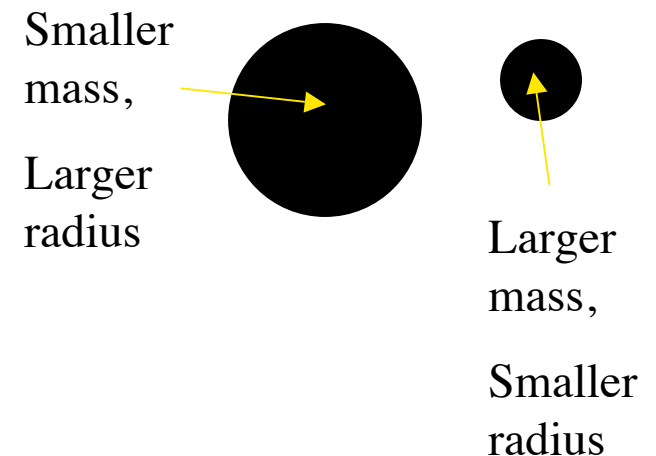
What happens to the Roche lobes as the WDs spiral closer by gravitational radiation?

Which fills its Roche Lobe first?

When the first WD fills its Roche lobe, what happens to its radius?

When the first WD fills its Roche lobe, what happens to its Roche lobe?

What happens to the white dwarf?



What happens when two white dwarfs spiral together?

Which WD has the smaller Roche lobe?

The smaller mass

What happens to the Roche lobes as the WDs spiral closer by gravitational radiation?

They both get smaller

Which fills its Roche Lobe first?

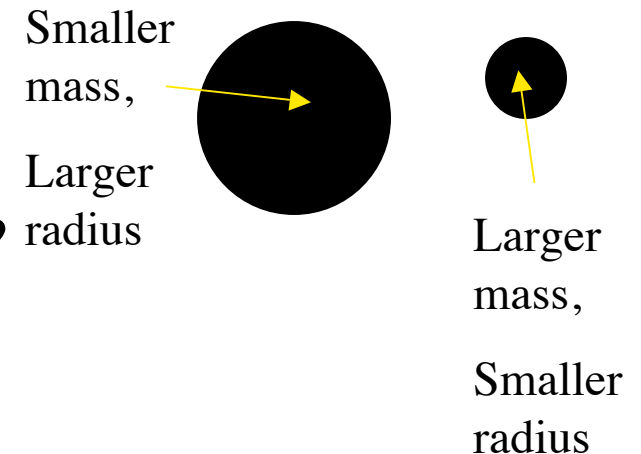
Must be the smaller mass

As small mass WD loses mass, its *radius gets larger*, but its *Roche Lobe gets smaller!* Runaway mass transfer.

Small mass WD transfers essentially all its mass to larger mass WD

Could end up with one larger mass WD

If larger mass hits M_{ch} \rightarrow could get explosion \Rightarrow Supernova



Bottom line:

There are two plausible ways in which a binary star system can lead to a Type Ia supernova:

1) The first white dwarf to form, from the originally most massive star, grows to very near the Chandrasekhar mass, ignites carbon and explodes while the other star is still transferring mass. My preferred explanation, but not firmly proven.

2) Two white dwarfs form, spiral together, the least massive one is torn apart when it fills its Roche lobe and the most massive one grows to near the Chandrasekhar mass, ignites carbon and explodes.

Astronomers are trying to determine which (if either) works.

One Minute Exam

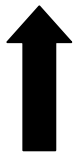
In a binary white dwarf system, the smaller mass white dwarf is destroyed because:



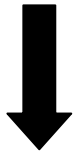
It has the larger Roche lobe



Gravitational radiation pulls it apart



As it loses mass, more mass loss is induced



Carbon ignites at its center

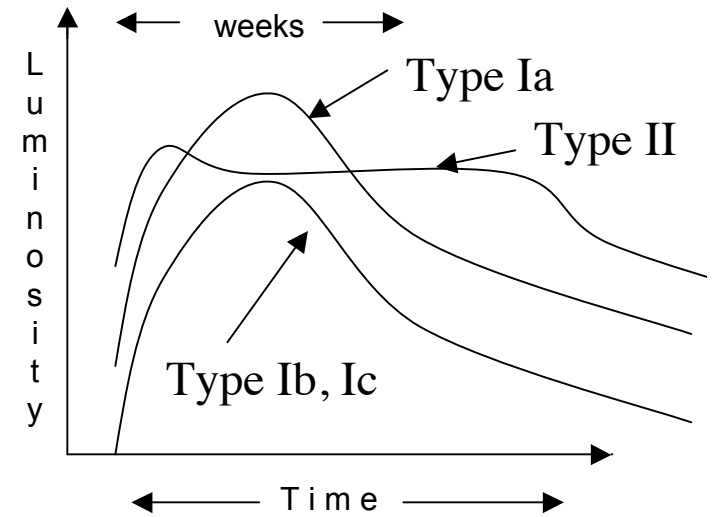
Goal - to understand what makes supernovae shine.

Light Curves

Why is the light curve different for Type II?

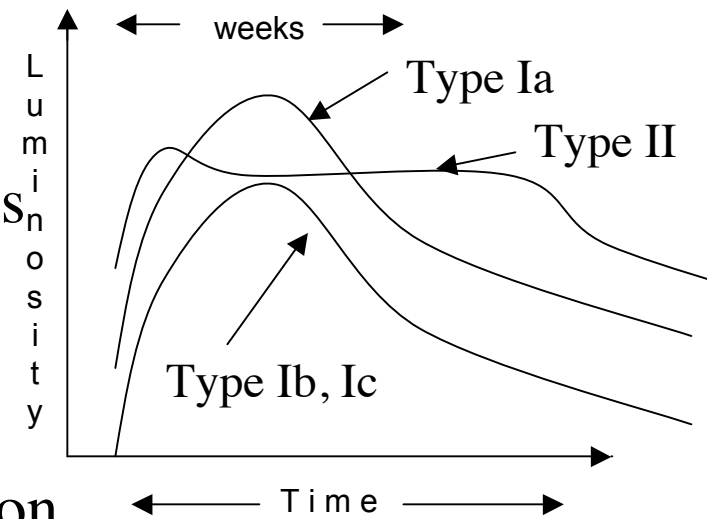
Why is the light curve similar for Type Ia, Ib, Ic?

Why are Type Ia brighter than Type Ib, Ic?



Light Curves

Ejected matter must expand and dilute before photons can stream out and supernova becomes bright: *must expand to radius $\sim 100 \times \text{Earth orbit}$*



Maximum light output ~ 2 weeks after explosion

Type II in red giants have head start, radius already about the size of Earth's orbit; light on plateau comes from *heat of original explosion*

Ejected matter cools as it expands: for white dwarf (Type Ia) or bare core (Type Ib, Ic) tiny radius about the size of Earth, must expand huge factor $> 1,000,000$ before sufficiently transparent to radiate.

All heat of explosion is dissipated in the expansion

By time they are transparent enough to radiate, there is no original heat left to radiate

Need another source of energy for Type I a, b, c to shine at all!

Goal - to understand what makes Type Ia,b,c supernovae shine.

Type Ia start with C, O: number of protons equal to number of neutrons (built from helium building blocks)

Iron has 26p 30n *not equal*

C, O burn too fast (~ 1 sec) for weak nuclear force to convert p to n (§1.2.1)

Similar argument for Type Ib, Ic, core collapse. Shock wave hits silicon layer with $\#p = \#n$, burns too quickly for weak nuclear force to convert p to n.

Fast explosion of C/O in Type Ia, shock hitting layer of Si in Type Ib, Ic make element closest to iron (with same total $p + n$), but with $\#p = \#n$

Nickel-56: 28p 28n total 56 -- Iron-56: 26p 30n total 56

Ni-56 is unstable to radioactive decay

Nature wants to produce iron at bottom of nuclear “valley”
decay caused by (slow) weak force $p \rightarrow n$

| | | | | |
|------------|------------------------|-----------|------------------------|---------|
| Nickel -56 | γ -rays heat | Cobalt-56 | γ -rays heat | Iron-56 |
| 28p | → “half-life” | 27p | → “half-life” | 26p |
| 28n | 6.1 days | 29n | 77 d | 30n |

Secondary heat from radioactive decay γ -rays makes Type I a, b, c shine

Type Ia are brighter than Type Ib and Ic because they produce more nickel-56 in the original explosion.

The thermonuclear burning of C and O in a white dwarf makes about 0.5 - 0.7 solar masses of nickel-56.

A core collapse explosion that blasts the silicon layer makes about 0.1 solar masses of nickel-56.

Type II also produce about 0.1 solar mass of nickel-56, but the explosion energy radiated from the red giant envelope in the plateau tends to be brighter. After the envelope has expanded and dissipated, the remaining radioactive decay of Cobalt-56 is seen.

