September 27, 2010

Exam 2 This Friday. Review sheet posted. Review Thursday 5 PM room TBD

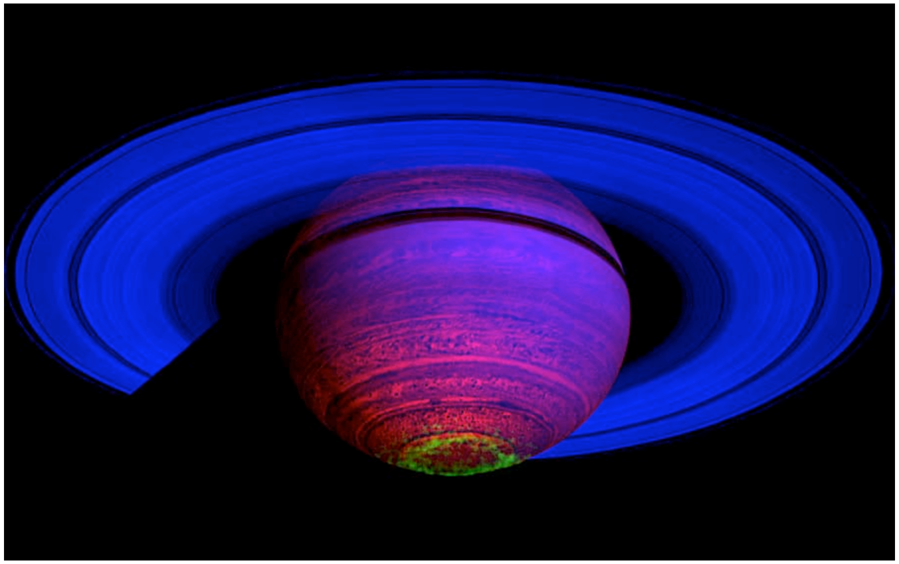
Reading, Sections 6.4, 6.5, 6.6.

Sections 1.2, 2.1, 2.4, 2.5, 3.3, 3.4, 3.5, 3.10 (binary stars), 4.1, 4.2, 4.3, 4.4 (accretion disks), 5.2, 5.4 (cataclysmic variables) for background

Chapter 7 will be on 3rd exam.

Astronomy in the News?

Pic of the Day – false color image of Saturn from Cassini spacecraft



Goal – to understand how white dwarfs in binary star systems can, and cannot grow to the Chandrasekar mass and explode.

One Minute Exam

We expect classical nova systems to end up making two white dwarfs orbiting one another because:

➡ The first white dwarf loses mass and hence cannot grow and explode

⬅ The first white dwarf will accrete mass until it reaches the Chandrasekhar limit

⬆ The main sequence star transferring mass must eventually make a white dwarf

⬇ The second white dwarf has the Chandrasekhar mass

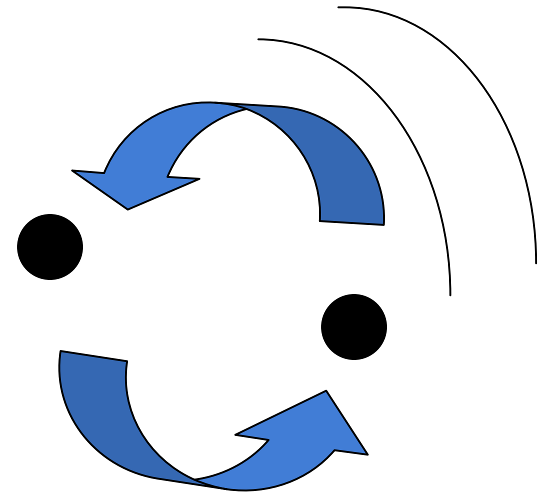
Goal – to understand what happens to two white dwarfs in a binary system.

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



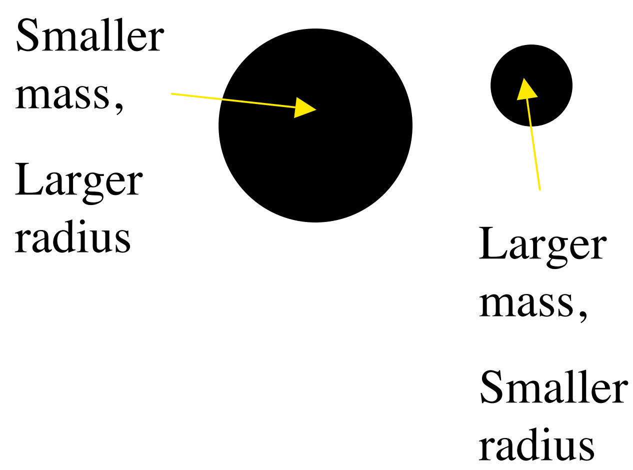
remove energy from orbit - acts as drag

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?

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

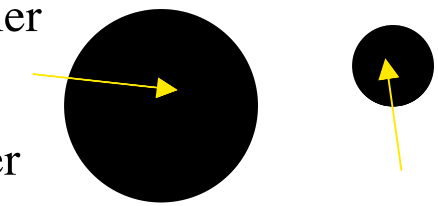
What happens to the Roche lobes as the WDs spiral closer by gravitational radiation?

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 => 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 it 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.

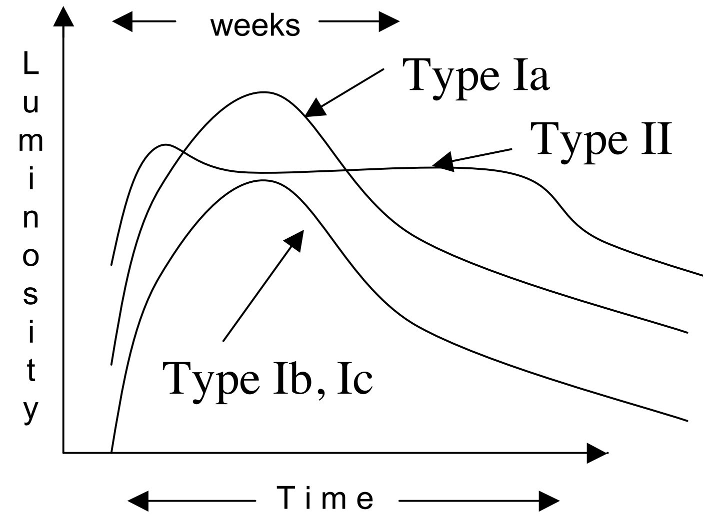
Goal - to understand what makes supernovae shine.

Light Curves

Why is the light curve different for Type II?

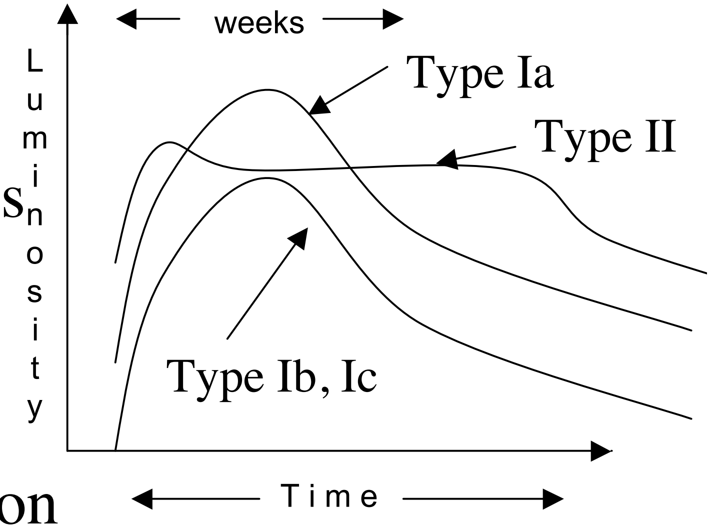
Why is the light curve similar for Type Ia, Ib. Ic?

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 ~ 100 × 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!

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 (same total p + n) with #p = #n

Nickel-56: 28p 28n <u>total 56</u> -- Iron-56: 26p 30n <u>total 56</u>

Ni-56 is unstable to radioactive decay

Nature wants to produce iron at bottom of nuclear "valley"
decay caused by (slow) weak force p → 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 γ-rays makes Type I a, b, c shine