Friday, March 3, 2017

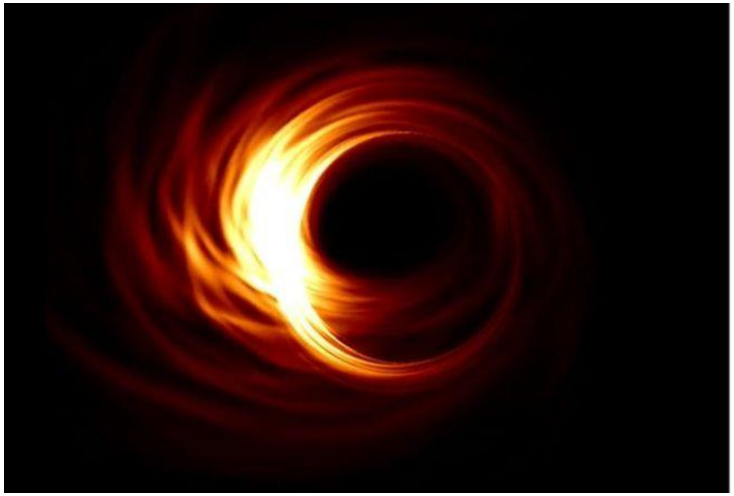
Exam 2, Skywatch 2, returned.

Reading for Exam 3:

Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A), Background: Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.8, 3.10, 4.1, 4.2, 4.3, 4.4, 5.2, 5.4 (binary stars and accretion disks).

Astronomy in the news?

The Event Horizon Telescope, a linkage of many radio telescopes spanning the Earth, will try to make out the actual size of the event horizon of the 4 million solar mass black hole in the center of the Milky Way (Sagittarius), April 5 to 14.

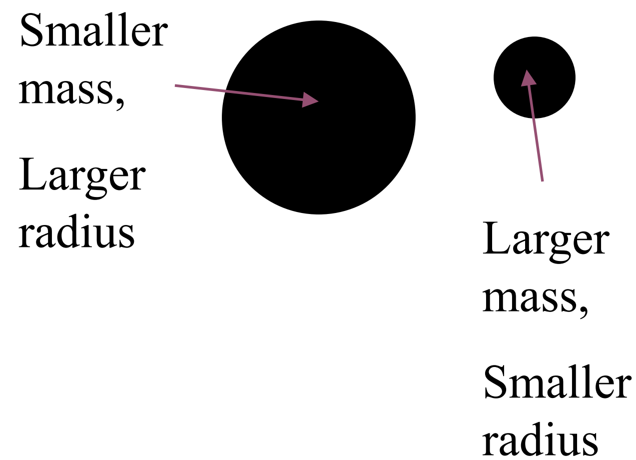


Goal

To understand how stars, and Type Ia supernovae, evolve in binary systems.

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 size of the Roche lobes as the WDs spiral closer by gravitational radiation?

Which fills its Roche Lobe first?

When that WD fills its Roche lobe and transfers mass, what happens to its radius?

When that WD fills its Roche lobe and transfers mass, what happens to its Roche lobe?

What happens to the white dwarf?

What happens when two white dwarfs spiral together?

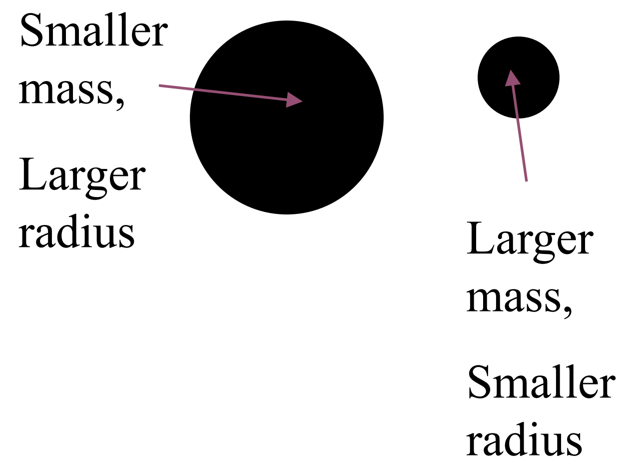
Which WD has the smaller Roche lobe?

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 by 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. Models give good spectra, but no companion yet seen before or after the explosion.

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. Expect not to see a companion, but I am pessimistic that these models predict the right spectra.

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

One Minute Exam

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

➡ It has the larger Roche lobe

⬅ As it loses mass, more mass loss is induced

⬆ Gravitational radiation pulls it apart

⬇ Carbon ignites it its center

Goal - to understand what makes supernovae shine (Section 6.7).

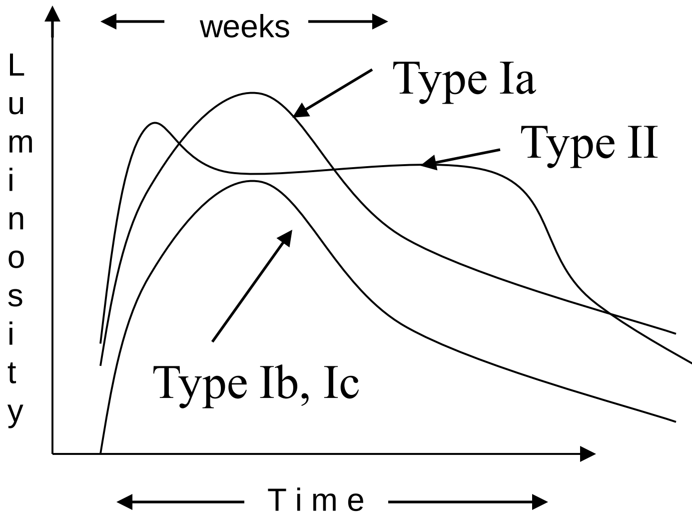
Light Curves

What makes supernovae bright?

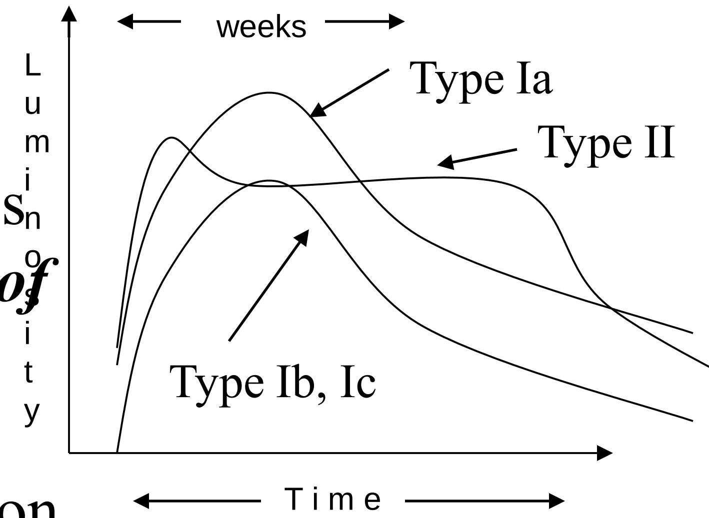
Why is the light curve different for Type II?

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 × radius of 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 by a 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 number of protons and neutrons.***

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 that surrounds the iron core. Silicon has #p = #n, burns too quickly for weak nuclear force to convert p to n.

Fast explosion of C/O in Type Ia and 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.**

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"
Radioactive decay caused by (slow) weak force, converting 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