Monday, March 9, 2015 (Class Friday)

Reading for Exam 3:

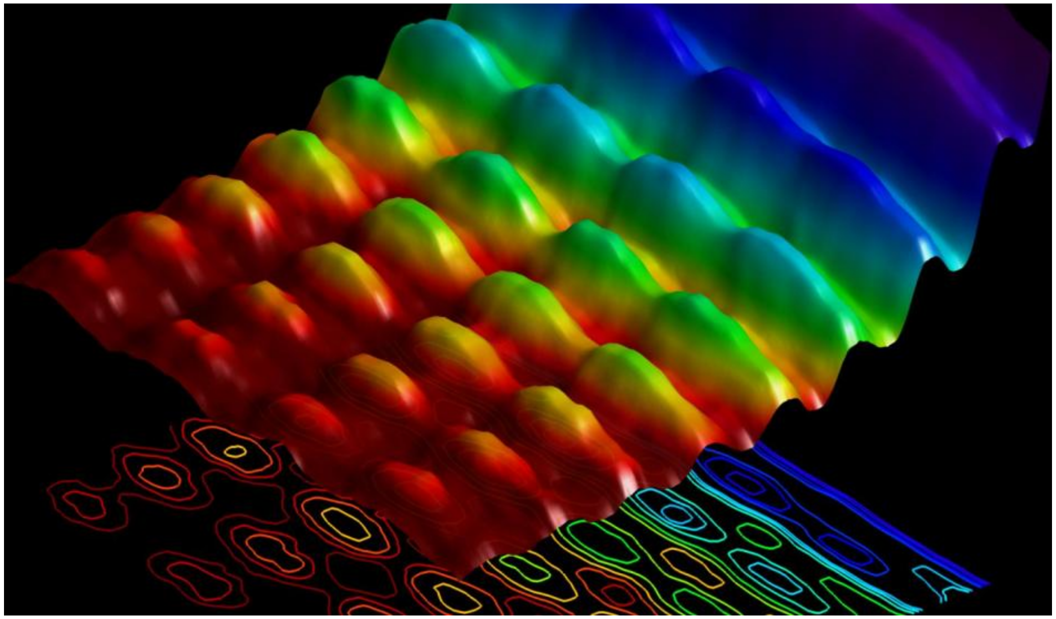
Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A)

Background in Chapters 3, 4, 5.

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?

Lab in Switzerland photographed electrons as both particles and waves.



Goal

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

Newly discovered nearby pair of orbiting white dwarfs

WD1242-105

130 light years away

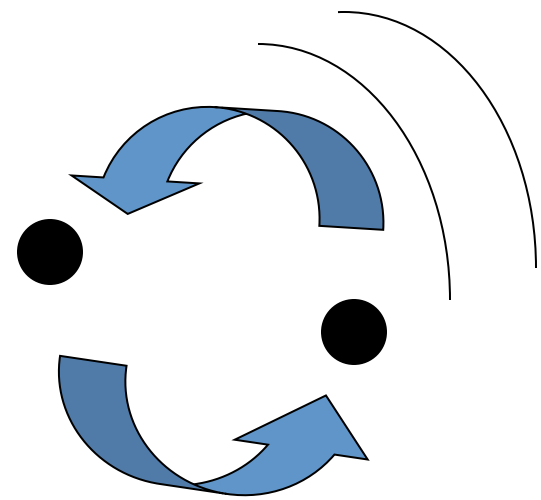
Just south of constellation Virgo, north of constellation Corvus.

Sky Watch target.

G*ravitational 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, it falls inward, speeds up, more gravitational radiation, more inspiral

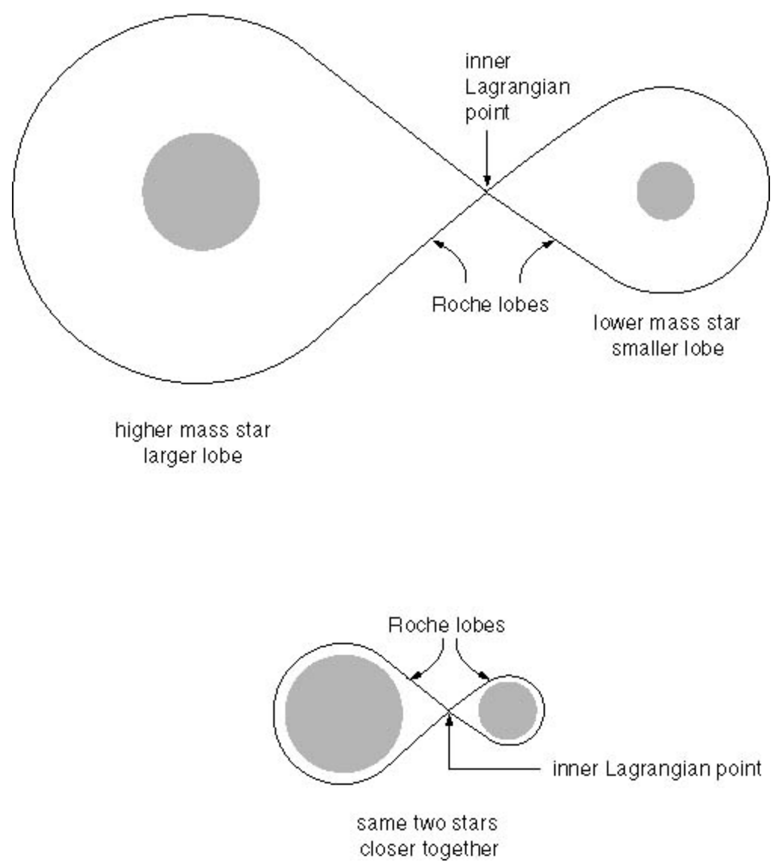
Given enough time (billions of years) 2 white dwarfs must spiral together!

Binary Stars - Chapter 3

Roche Lobes   Fig 3.1

Roche lobe is the gravitational domain of each star. Depends on size of orbit, but ***more massive star always has the largest Roche lobe.***

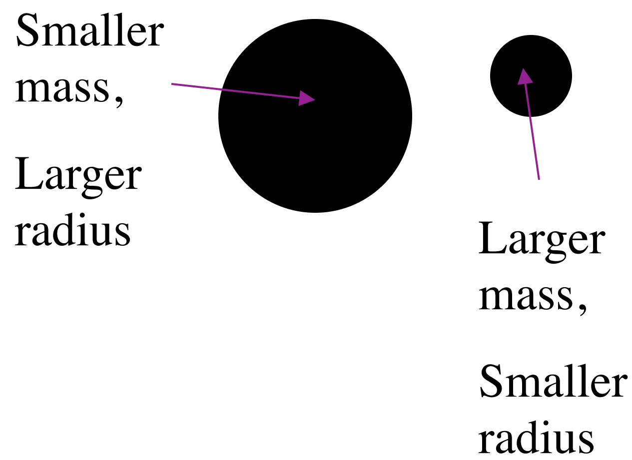
3.1



Caution: ***the most massive star may not have the largest radius!***

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?

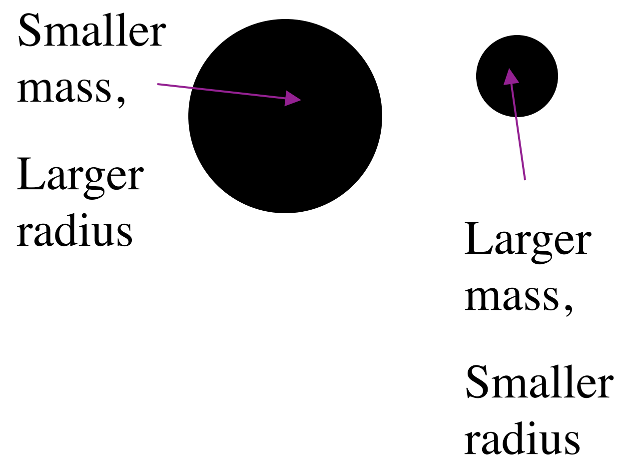
When that WD fills its Roche lobe, what happens to its radius?

When that 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 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

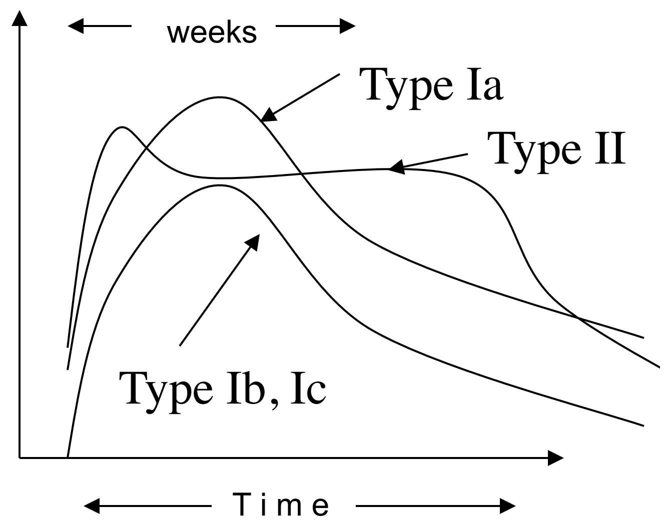
Newly discovered nearby pair of orbiting white dwarfs

WD1242-105

Will spiral together by gravitational radiation, but total mass of white dwarfs is less than the Chandrasekhar mass, so probably will make one larger white dwarf, not an explosion.

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

Light Curves



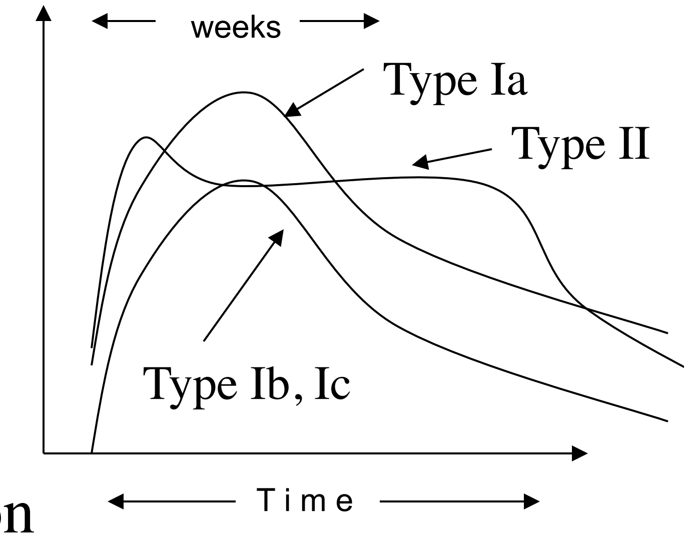
Why is the light curve different for Type II?

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!

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