Friday, March 6, 2015

Reading for Exam 3:

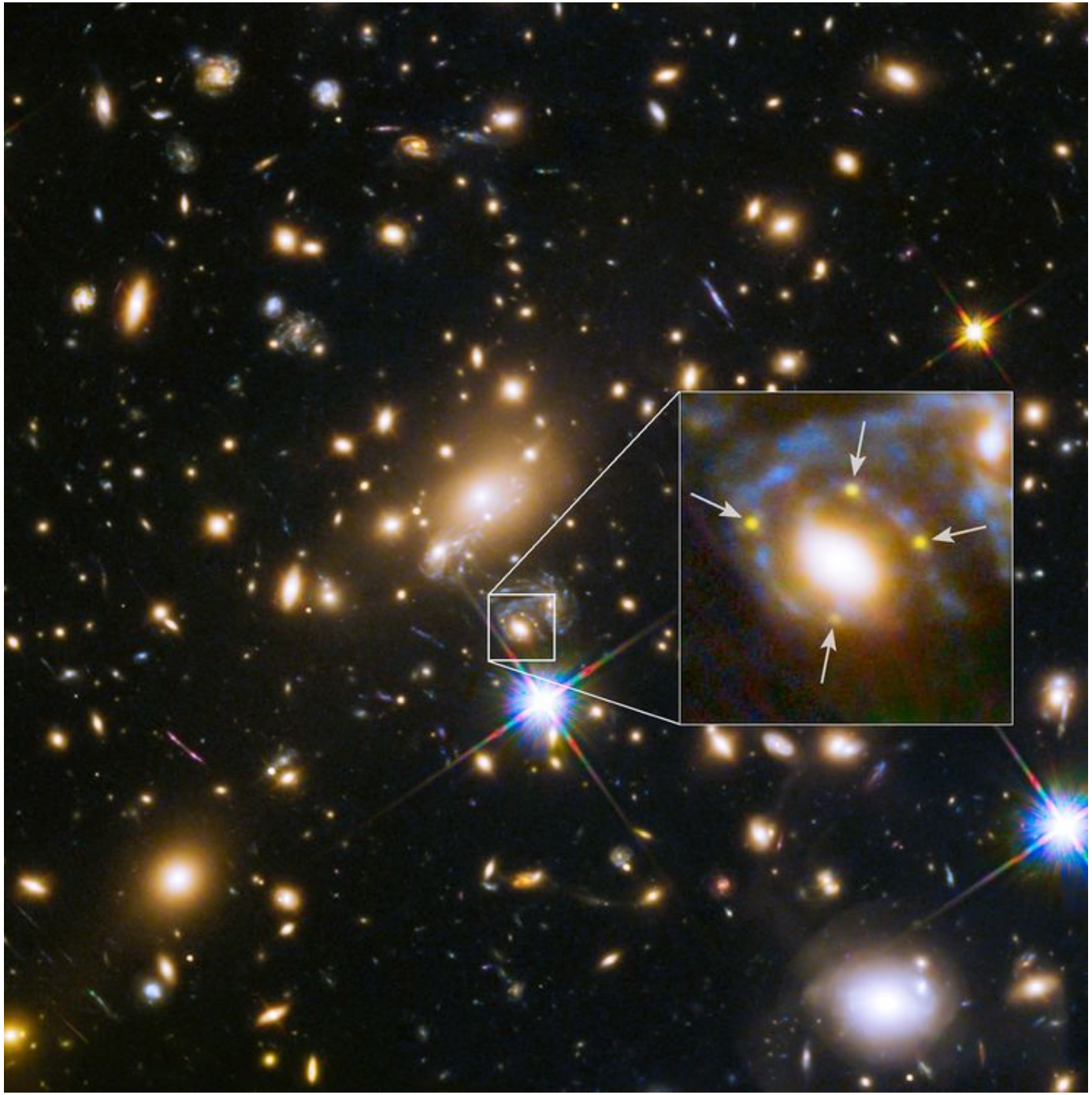
Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A)

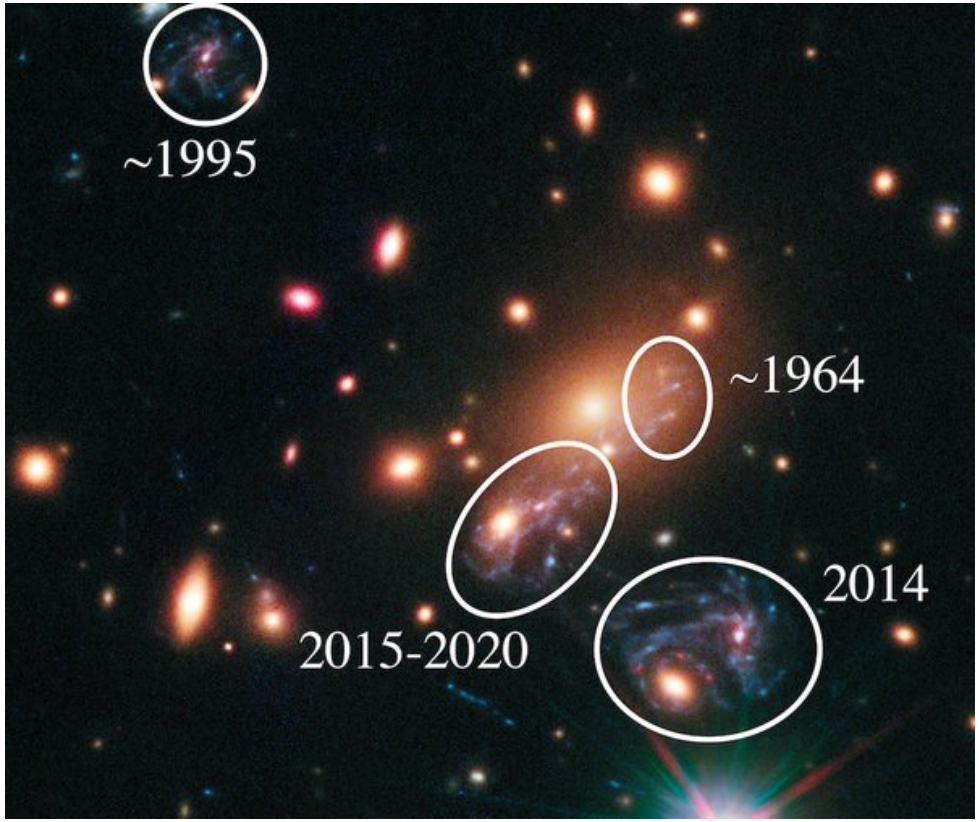
Background in Chapters 3, 4, 5.

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?

Distant Type Ia supernova “Refsdal” gravitationally lensed, appears multiple places and times.





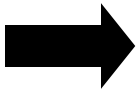
Supernova Refsdal discovered by Pat Kelly. JCW consulted on use of Hubble time. Supernova is 9 billion light years away, lensing galaxy is 5 billion light years away

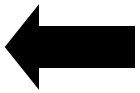
Goal

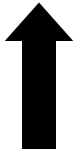
To understand how white dwarfs in binary star systems can, and cannot, grow to the Chandrasekar mass and explode.

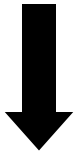
One Minute Exam:

In an accretion disk, friction causes moving matter to

 Slow down

 Speed up

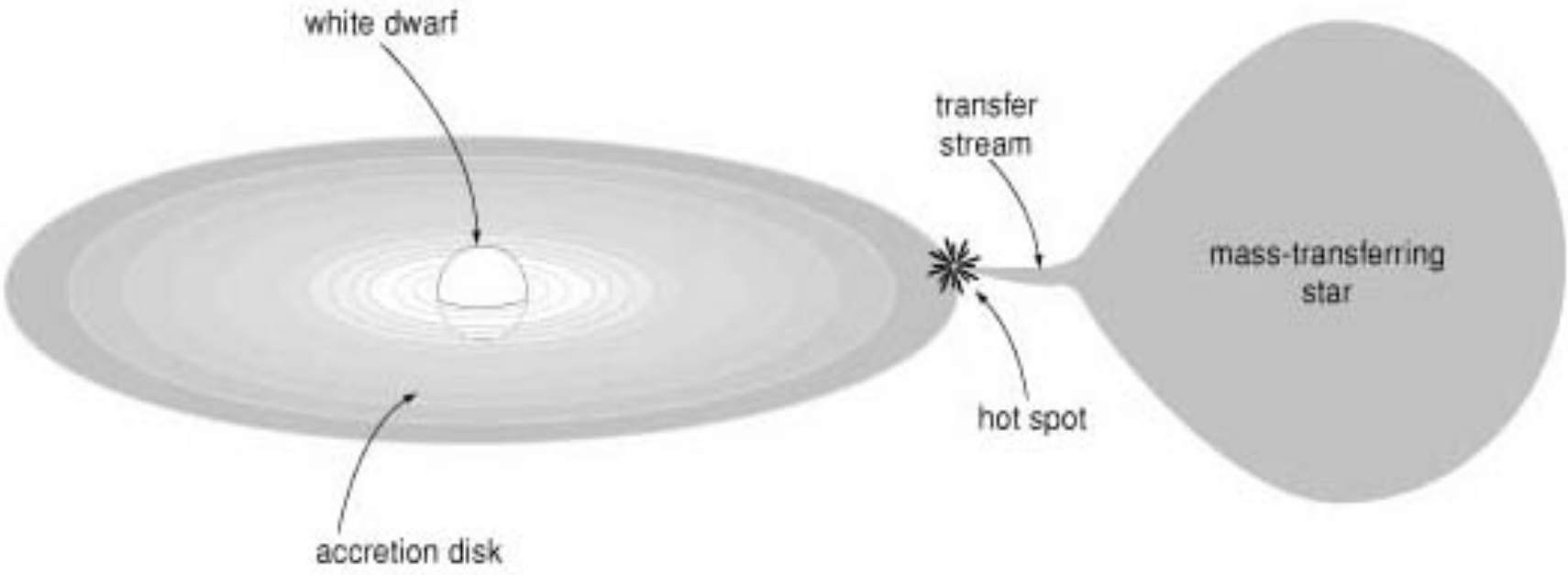
 Move outward

 Pass from one Roche lobe to another

Cataclysmic Variables

Second stage of mass transfer (Section 5.2)
General Category "Novae"
"New" stars flare up, see where none had been seen before.

All CVs share same general features: ***transferring star***, ***transfer stream***, ***hot spot***, ***accretion disk***, and ***white dwarf***.



§ 5.4 Final Evolution of Cataclysmic Variables

Some cataclysmic variables have managed to reach large white dwarf masses, $M_{wd} \sim M_{ch}$ Chandrasekhar mass, 1.4 solar masses, like U Sco, RS Oph

If get close enough to M_{ch}, attain high density and temperature (temperature does not contribute to pressure in a white dwarf, but does promote nuclear burning, helping to overcome charge repulsion)

$\Rightarrow$ ignite carbon in center

$\Rightarrow$ Quantum Deregulated $\rightarrow$ violent explosion
Type Ia Supernova?!

What cataclysmic variables have white dwarfs that reach M_{ch}?

Classical Novae:

Infrequent outbursts, powerful explosions on the surface of a white dwarf.

Not a supernova, the white dwarf survives.
Explosion of surface H shell also rips off a bit of the white dwarf mass - we see excess carbon & oxygen in ejected matter
white dwarf shrinks in mass rather than growing to the Chandrasekhar Limit.

Binary systems that have classical nova explosions seem unable to proceed to Type Ia supernova explosions.

Likely outcome in this case - 2nd star finally burns out H, tries to form red giant, mass transfer, mass loss from binary => ***Two WDs!***

If the first white dwarf formed does not explode, the other star will make a white dwarf, so will have two white dwarfs orbiting one another (details to follow).

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.

Recurrent Novae like U Sco, RS Oph:

More frequent outbursts, less disruptive explosions than classical novae on the surface of a white dwarf.

Recurrent nova systems do seem to have large mass white dwarfs that are gaining mass.

Encouraging, but maybe not enough of them to account for the rate of explosions of Type Ia supernovae.

Exactly what kind of binary system gives rise to Type Ia supernovae is not yet known.

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!

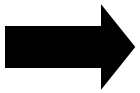
Might see Scorpius. Also has neutron stars and black holes.

T Pyx in constellation Pyxis.

RS Oph in Ophiuchus

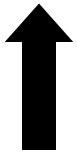
One Minute Exam

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

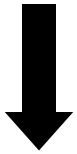


The first white dwarf loses mass and hence cannot grow and explode

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

Classical Novae:

Binary systems that have nova explosions seem unable to proceed to Type Ia supernova explosions.

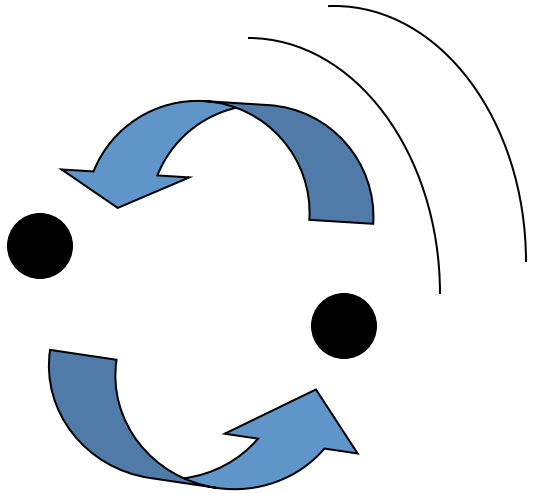
Eventually, the other star will make a white dwarf, so will have two white dwarfs orbiting one another.

We observe binary systems with two white dwarfs, so we know nature makes them somehow.

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 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?