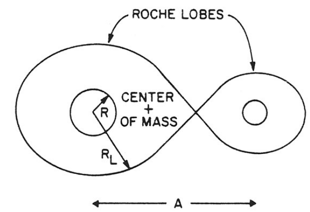
# Agenda for Ast 309N, Nov. 20

- Announcements: HW 3 (due Nov. 27), Quiz 8 (Nov. 29), survey retake (Dec. 4), Exam 3 (Dec. 6)
- Exam 2.5 feedback
- Recap: WD's in interacting binaries, going "bang"
- Neutron stars in mass-transfer binaries
- Introducing black holes
- Card question
- Reading for after Thanksgiving:

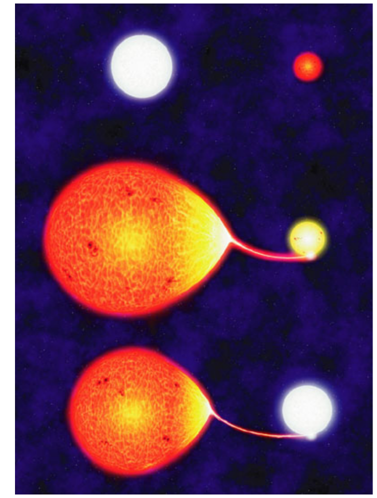
  Wheeler, chs. 9, 10, & 11



# Mass Transfer in Interacting Binaries

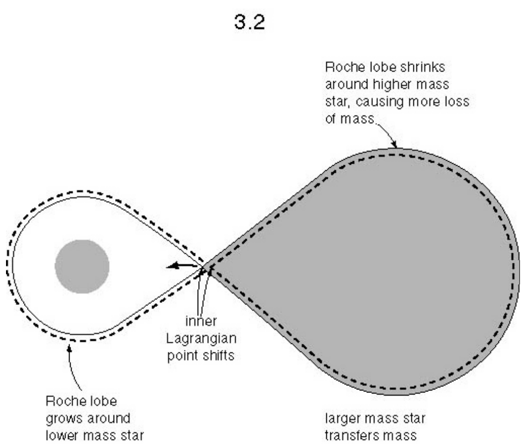



When a star evolves into a red giant, its surface enlarges and it can fill its Roche lobe. As it keeps trying to expand, mass is "pushed through" the mid-point between the lobes, and transferred to the gravity domain of the other star.



# Consequences of Mass Transfer

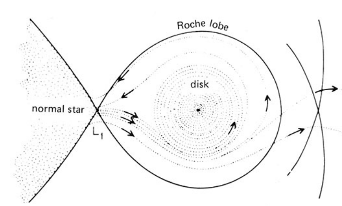
As the higher-mass star loses mass to its companion, its Roche lobe shrinks; but the star is moving up the red giant branch, so it swells up even more. The process can get out of hand and undergo a runaway!

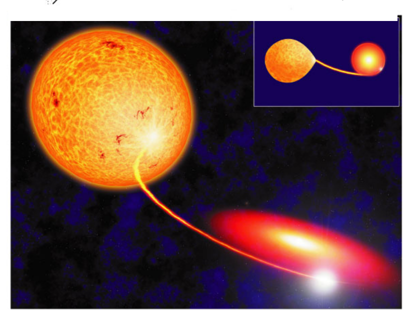





# Accretion Disks in Interacting Binaries

(View from above)

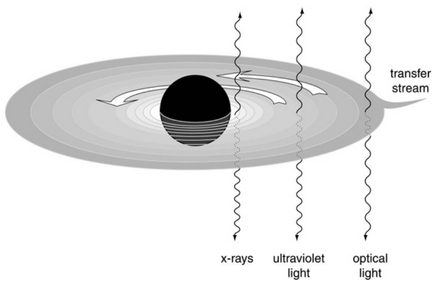


Mass being transferred from one star to the other in a binary system retains *orbital angular momentum*. This gives it sideways motion.

The matter therefore goes into a spinning accretion disk around the other star. If the latter is a white dwarf instead of a Main Sequence star, there's a lot more room for the accretion disk!

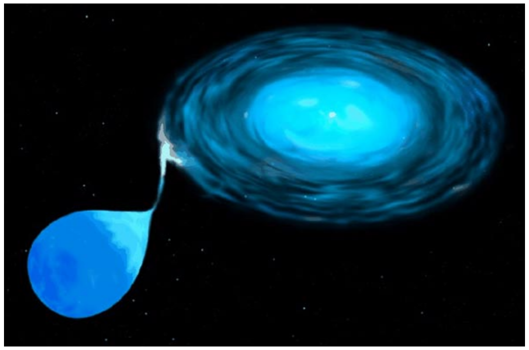
## Anatomy of an Accretion Disk




The inner part of the accretion disk is hotter than the outer part, so the inner disk emits radiation of shorter wavelength and higher frequency, e. g. UV light near a white dwarf, up to X-rays around a neutron star.

Wheeler, Fig. 4.2.

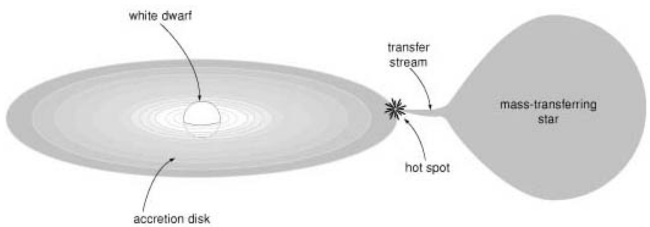
## Accretion Disk & “Hot Spot”



Artist’s conception of an accretion disk, showing the “hot spot” where the matter stream hits the disk. Notice also the distorted shape of mass-donating companion star.

http://antwrp.gsfc.nasa.gov/apod/binary_systems.html

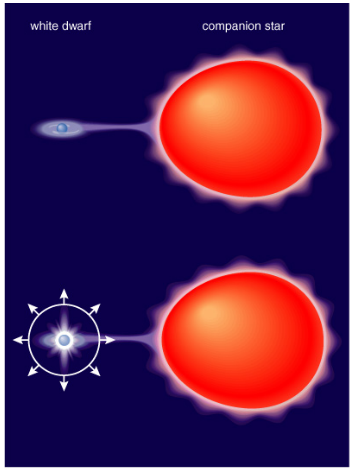
## ”Cataclysmic Variable” Stars



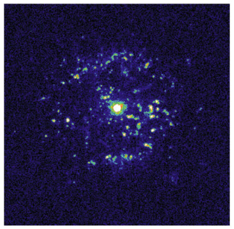

Mass is not always delivered steadily and slowly onto the white dwarf. The accretion disk can become unstable, and dump a large amount of mass all at once, causing a severe flare-up in brightness.

These are the dwarf novae, recurrent novae, and other CVs.

## Classical Novae




- Mass accumulates on the surface of the white dwarf until it gets hot enough for H fusion to begin.
- The nova star system appears much brighter, ***temporarily***.
- The explosion drives the accreted matter out into space



# What Happens in a Classical Nova

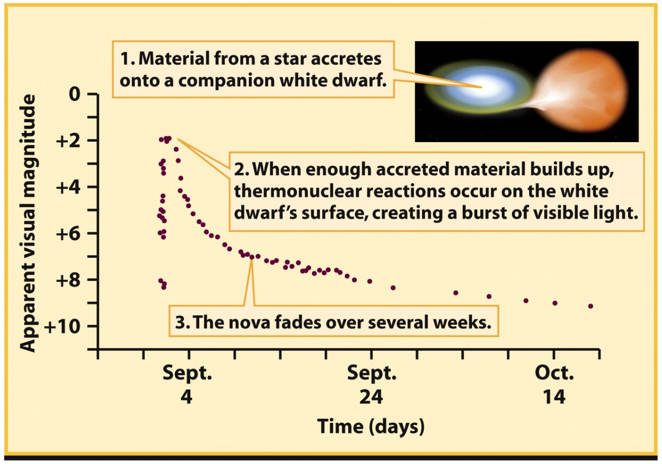



Figure 21-15
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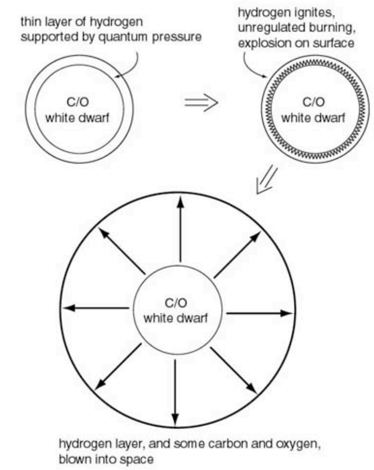
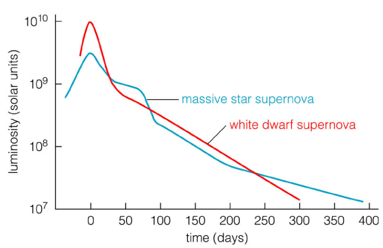
# Classical Novae

- The classical novae reach much brighter flare-ups than the dwarf and recurrent novae.
- They can run nuclear fusion reactions up to the light even-numbered elements like Ne and Mg; they may also actually blast off some of the outer layers of the white dwarf.
- But they do not destroy the white dwarf, so after the system settles down, mass transfer can resume, and eventually another nova explosion can occur.




# What Happens in a Type Ia Supernova

If enough mass accumulates on the white dwarf, it can be heated to the point that its interior "goes up in flames" and explosive nuclear fusion blows the white dwarf apart. This takes place at nearly the white dwarf mass limit of 1.4 $M_\odot$ . This is a "Type Ia" supernova, also called a "white dwarf" or "thermonuclear" supernova. (These are key to the discovery of the acceleration of the expansion of the universe.)




# Recap: Kinds of Stellar Explosions

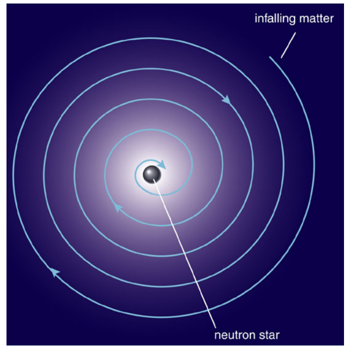
***Nova:*** A modest amount of mass is transferred slowly onto a white dwarf from a binary companion. The surface heats up until it ignites in runaway H fusion reactions. The ensuing explosion blows the surface layers off the WD but does not destroy it.

***White dwarf or "thermonuclear" supernova:*** A larger amount of mass is transferred onto a white dwarf so that its mass exceeds the WD limit of 1.4 $M_\odot$. The entire WD "goes up in flames," and is incinerated into heavier elements, including a good deal of Fe and Ni. This is a "Type Ia" supernova.

***Massive-star or "core collapse" supernova:*** A high-mass star reaches the end of its life and forms an iron core. This core collapses, the layers above it "bounce off" and explode into a supernova remnant. This is a Type II supernova.

## Neutron Star in an Interacting Binary

Matter falling toward a neutron star forms an accretion disk, just as in a white-dwarf binary




Accreting matter adds angular momentum to a neutron star, increasing its spin rate. Remember, this is how we think "millisecond" pulsars are made.

## X-Ray Binary Containing a Neutron Star

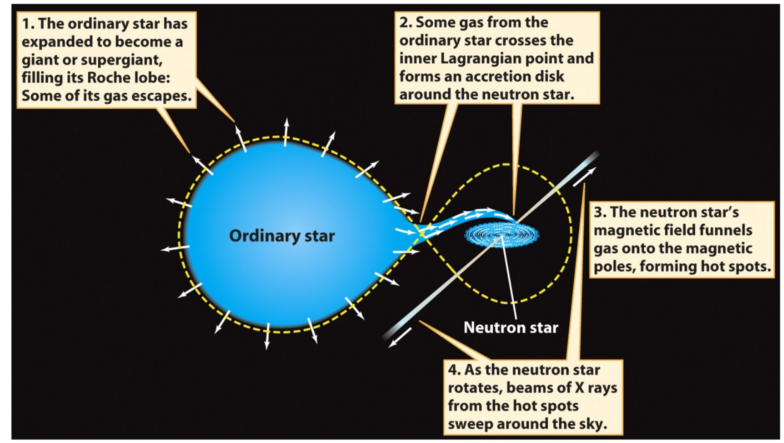



Figure 21-13
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## The Neutron Star Mass Limit

- Analogous to electron degeneracy pressure (which holds up white dwarfs), except for neutrons; occurs at much higher densities (factor of $10^{6-8}$ times higher).
- Neutron degeneracy pressure cannot support a neutron star against gravity if its mass exceeds about 2 - 3 $M_{sun}$ (this is akin to the Chandrasekhar limit for white dwarfs)
- Some massive star supernovae can make black holes, if enough mass falls onto core; astronomers now think that a certain sub-class of gamma-ray bursts are events that form black holes ("collapsar" model).

## Types of "Compact Objects"