

Reading: Chapters 1 - 5 pdf files on web site

Who does not have a book?

2 -hour reserve copies at PMA library RLM.

Lectures posted (pdf files) on the web site

Anyone try to find Sirius? Betelgeuse? What direction?

Astronomy in the news?

Large Magellanic Cloud

Nearby Galaxy



Quantum Pressure -- just depends on squeezing particles,  
electrons for white dwarf, to very high density  
-- depends on density only  
-- *does not* depend on temperature

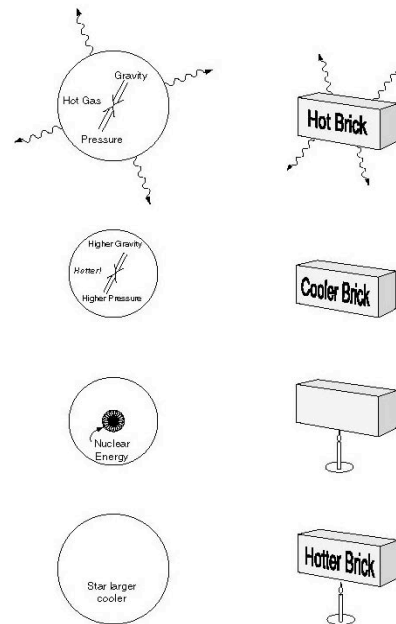
### Important Implication:

Normal ☆ Radiate energy, pressure tries to drop, star gets **hotter** (and higher pressure)

White Dwarf Radiate energy, *temperature does not matter*,  
pressure remains constant, star gets **cooler**

<i>Opposite behavior</i>	Normal Star - <i>Regulated</i>	put in energy, star expands, cools
	White Dwarf - <i>Unregulated</i>	put in energy, hotter, more nuclear burning -- explosion!

Figure 1.3



Behavior of white dwarf, Quantum Pressure, worked out by  
S. Chandrasekhar in the 1930's

Limit to mass the Quantum Pressure of electrons can support

**Chandrasekhar limit**  $\sim 1.4 M_{\odot}$

density  $\sim$  billion grams/cc  $\sim$  1000 tons/cubic centimeter

**Maximum mass of white dwarf.**

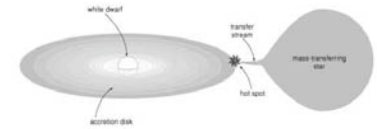
## One Minute Quiz

If nuclear reactions start burning in a white dwarf, what happens to the temperature?

- A the temperature goes up
- B the temperature remains constant
- C the temperature goes down

## White dwarfs in Binary Systems

### Binary Evolution: Chapter 3

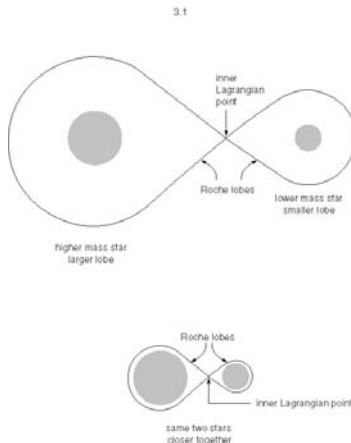


Kepler's 3rd Law  $P^2$  (squared) proportional to  $a^3$  (cubed)  
 Period  
 Time to orbit size of orbit

Newton:  $P^2$  proportional to  $\frac{a^3}{M_1 + M_2}$   
 total mass of 2 stars: method to "weigh" the system, get total, subtract "normal" star weight WD, NS, BH

## 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.



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

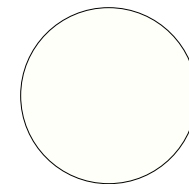
## Fundamental property of stellar evolution:

A more massive star has more fuel, but is also brighter, burns that fuel faster.

=> *stars with higher mass on the main sequence evolve more quickly than stars with lower mass.*

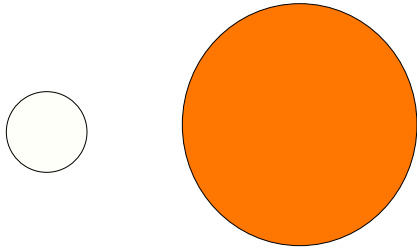


small mass, long life



high mass, short life

*Algol paradox:* Algol is a binary star system with a Red Giant orbiting a blue-white Main Sequence companion.



Which is most massive?

Use Kepler's law to measure total mass, then other astronomy (luminosity of main sequence star tells the mass) to determine the individual masses.

Answer: the unevolved main sequence star!

Red Giant  $\sim 0.5 M_{\odot}$  - but more evolved

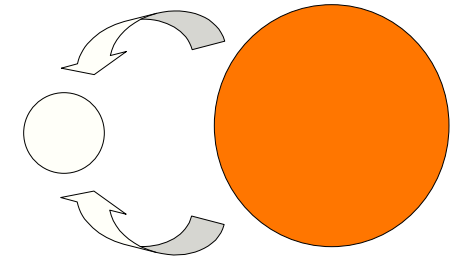
Blue-white Main Sequence star  $\sim 2-3 M_{\odot}$  - but less evolved

## Solution

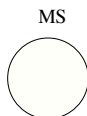
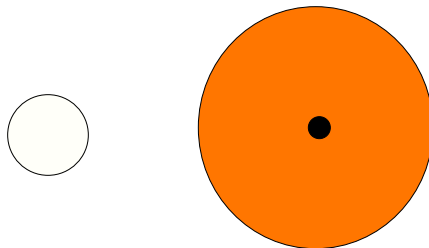
### *Mass Transfer*

The red giant swells up, fills then overfills its Roche lobe and transfers mass to the companion.

The star that will become the red giant starts as the more massive star, but ends up the less massive.



In common circumstances, all the hydrogen envelope is transferred to the companion (or ejected into space), leaving the core of the red giant as a white dwarf orbiting the remaining main sequence star



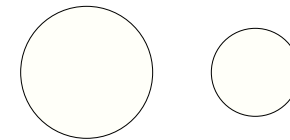
MS

WD



## One Minute Quiz

Two stars orbit one another in a binary system



Which star has the largest Roche lobe?

A the one on the left

B the one on the right

C insufficient information to answer the question

Then the main sequence star evolves, the second star that was *originally* the less massive.

Mass flows onto the white dwarf.

The white dwarf is a moving target, the transfer stream collides with itself, forms a ring, settles inward to make a flat disk.

Matter gradually spirals inward, a process called *accretion*.

⇒ forms an *Accretion Disk* (Chapter 4).

