# AST 301 Introduction to Astronomy John Lacy RLM 16.332 471-1469 Iacy@astro.as.utexas.edu

Myoungwon Jeon RLM 16.216 471-0445 myjeon@astro.as.utexas.edu Bohua Li RLM 16.212 471-8443 bohuali@astro.as.utexas.edu

web site: <u>www.as.utexas.edu</u> Go to Department of Astronomy courses, AST 301 (Lacy), course website

# Topics for this week

- How do we use the Hertzsprung-Russell diagram to make sense of the temperatures and luminosities of stars? Describe the life stages of a low-mass star, like the Sun. Use the HR diagram to show the evolution of a low-mass star graphically. How long can a star remain a main-sequence star? What happens inside of a star that makes it change from a main-sequence star into a red giant, then a planetary nebula and a white dwarf? How do the life stages of a high-mass star differ, and why?
- Describe the two types of supernovae.

# Becoming a Red Giant

- (The complete explanation for how a main-sequence star becomes a red giant is complicated, and I'm not really giving you the whole story. But the conclusion is right. Don't worry if you don't follow all of the explanation.)
- When all of the hydrogen in the core of a main-sequence star is all turned into helium, fusion will stop in the core (the central part of the star), and the core will contract and heat up.
- Fusion will continue in a shell around the helium core, and will generate more energy than fusion in the core did.
- The extra energy going out from the core+shell will make the envelope (the outer part of the star) expand and cool off.

# **Red Giants**

When the Sun becomes a red giant, its radius will increase to about ½ AU, and it will become more than 1000 times more luminous than it is now.

Life will not be pleasant on Earth.

The core of the Sun will be mostly helium, and will continue to contract and heat up.

When the temperature in the core reaches about 10<sup>8</sup> K (about 1 billion years after the Sun leaves the main sequence), helium will begin to fuse to make carbon.

## A Red Giant with helium fusion

- When helium fusion starts generating energy in the core of a red giant, the core expands and hydrogen fusion in the shell around the core slows down.
- As a result, less total energy is being generated, and the envelope contracts and warms up some.
- Meanwhile, the envelope contracts and heats up.
- After about 100 million years, all of the helium in the core is converted into carbon and fusion stops again in the core.
- Then the core again contracts, surrounded by two shells, one with He  $\rightarrow$  C fusion, and one with H  $\rightarrow$  He fusion. The envelope again expands and cools off.

This may be easier to keep track of with a drawing.

# Display stellar evolution with the HR diagram (pictures on right show only the inner parts of the star)



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Addison-Wesley.

How long can I drive?

My car uses about 2 gallons/hour driving at 70 mph. It has a 12 gallon gas tank. How long can I drive before I run out of gas?

My brother's SUV uses about 4 gallons/hour driving at 70 mph.He has a 16 gallon gas tank.

How long can he drive?

Does the vehicle with the bigger tank drive for a longer or a shorter time?

# How long will the Sun shine?

- The Sun is fusing hydrogen to make helium at about 0.01 M<sub>sun</sub> / Gyr.
- It will fuse about 0.1  $M_{sun}$  of its hydrogen into helium while on the main sequence.
- How long can it stay on the main sequence?

Spica has a luminosity 10,000 times that of the Sun. How does the amount of hydrogen it fuses in a year compare to the amount the Sun fuses?

Spica has a mass of 14 M<sub>sun</sub>, and like the Sun it can fuse 1/10 of its hydrogen while on the main sequence. How does its main sequence lifetime compare to the Sun's? Is stellar evolution just a theory? Or is it even a (scientific) theory?

- For a hypothesis to be a scientific theory it must be testable.
- Almost all of stellar evolution occurs so slowly that we cannot watch it happen.

Our tests of stellar evolution must be indirect.

- The primary test involves observing stars in a star cluster, which we have reason to believe all formed at the same time, so have the same age.
- Stellar evolution theory predicts the pattern they should form on an H-R diagram.

## Globular Cluster NGC 6093





#### What the theory predicts for a very young star cluster



Low mass stars are still contracting, some high mass stars have died, becoming supergiants.



#### Stars with M > 8 $M_{Sun}$ have died. Stars dying now become red giants.



#### Stars with M = $3 M_{Sun}$ are becoming red giants. More massive stars have died.



#### 1 M<sub>Sun</sub> stars are now becoming red giants.









## Have we proved the theory right?

- The theory of stellar evolution provides a very good explanation for the H-R diagrams of star clusters.
- We have tested the theory and it passed the test.
- But for a hypothesis to be a scientific theory it must be testable, and a test only makes sense if it is conceivable that the theory will fail.
- In that sense, we can never prove a scientific theory right.
- If a hypothesis can be proved right, it may be a valid mathematical or logical theorem, but it's not a scientific theory.
- We are confident that the theory of stellar evolution is essentially correct, but we will keep testing and refining it.

## **Becoming a Planetary Nebula**

- When the red giant has a contracting carbon core and two fusion shells, it is generating so much energy that radiation pressure from the high energy light trying to get out of the star pushes away the envelope, exposing the very hot core.
- The ultraviolet radiation from the core ionizes and heats the expelled envelope, causing it to glow like our gas lamps.
- The glowing envelope is called a planetary nebula, because it looks somewhat like a planet through a small telescope. It actually has nothing to do with planets.





