SPASH ASTRONOMY
CHAPTER 17: BEHAVIOR OF NEARBY STARS: THE H-R DIAGRAM
OVERHEAD LECTURE NOTES

1. List at least two interesting discoveries about properties of stars:
1). Stars come in a wide variety of forms: massive or not, bright or not, large or not, different colors, different distances, with partner stars or not, with planets or not, etc.
2). All stars pass through a variety of evolutionary stages, thus stars are born, have their toddler years, teenage years, mid-life years, retirement years, and finally die.
3). Stars of different initial mass evolve at different rates and into different final forms.

2. How do astronomers arrange and study stars in a sensible way?
They use the Hertzsprung-Russell (H-R) diagram which is made by plotting the spectral class of stars (the temperature) versus their luminosity (actual brightness) because among most stars there is a smooth relation between spectral class and luminosity. Using this method places all stars in just one of four groups at any one time of their life.

3. Who introduced the H_R diagram and around what time frame was it introduced?
This method was introduced around 1905 to 1915 by Danish astronomer Ejnar Hertzsprung and American astronomer Henry Norris Russell.

4. What is the spectral class of a star mean?
The stars TEMPERATURE.

5. Name the seven spectral classes of stars from hottest to coldest:
O, B, A, F, G, K, M
Most famous way to remember them is:
Oh Be A Fine Girl/Guy Kiss Me

6. Study the H-R diagram for awhile.
Where are the redder, cooler stars? The right side.
Where are the bluer, hotter stars? The left side.
Where is our sun? A little lower than the middle of the main sequence.
Where are the bigger stars? Upper right side.
Where is the old-folks home? Lower left side.

7. Name the four main regions of the H-R diagram:
Main-sequence (O thru M)(stable), red-giants (G, K & M) (large and cold), super-giants(G, K & M)(larger and cold), and white dwarfs (O, B & A)(small and hot).

8. If one placed the nearest 100 stars to our Sun on the H-R diagram what would be the result?
93% of these 100 stars would fall on the main sequence of which only six of them would be larger than our sun.

9. What is one other interesting fact about nearby stars?
Most of them are inhabitants of systems in which two or three stars orbit around one another. Stars without stellar companions, such as the Sun, are in the minority. Maybe Jupiter was supposed to be our Suns companion originally.

10. What is the closest star system to the Sun?
The closest star system to us is a triple star system of Alpha Centauri, which is the brightest star in the southern constellation of Centaurus and is only 1.33 pc away.

11. What is a pc?
A pc is a parsec, which is a distance of 206,265 AU or 3.26 ly, or 3.09 X 10^{16} km; defined as the distance corresponding to a parallax of 1 second of arc.

12. What problem do we run into as we place more distant stars we see on the H-R diagram?
The only distant stars we can see have to be unusually bright ones or we wouldn't be able to see them. In fact, the prominent stars in our night sky are mostly distant, unusually luminous stars. Thus the statistics of prominent stars are biased toward the "whales" or giants and super-giants.

13. What is the bolometric luminosity of a star?
An equivalent measure of the total energy of a star taking in account the entire electromagnetic spectrum and not just the visible sliver of it.

14. Name two causes for the four distinctive types of stars found on the H-R diagram:
1). Stars start out with different masses depending on how much nebula shrinks to make it. High-mass main-sequence stars are hotter, brighter, and bigger than low-mass main-sequence stars. Thus stars start their life on the main-sequence at different spots.
2). Stars evolve off the main sequence to the upper right of the H-R diagram and then possibly to the lower left white-dwarf region. Since we see stars with different ages, we see stars with different forms on or off the stable main-sequence.

15. What is a stars evolutionary track?
Because a star's temperature and luminosity, as well as other properties, can be calculated for each state of its evolution, the stages of that evolution can be plotted on an H-R diagram. The sequence of such points is called an evolutionary track – the set of "footprints" a star leaves on an H-R diagram as it evolves.

16. How can we determine the ages of stars?
-- Certain indicators, such as the amount of "unburned" light elements (lithium, for example) in a star's atmosphere, can be used to estimate a star's age.
-- Considering a group of stars that formed at the same time is easier because the older the cluster, the more of the main-sequence stars will be gone.

17. How long does the fusion of each of the elements lasts for lets say a star that has 20 times the mass of our Sun?

Fusion Times

Fusion Time in a 20 M_{sun} Star

Fuel	Time (years)
H	7,000,000 years
He	500,000 years
C	600 years
O	0.5 years
Si	1 day

Note that the reaction times get much faster as we go to heavier elements. This is basically a runaway effect.

18. What three ways can stars explode and what are the results?

Stars Explode!

- Mild Explosion => Planetary Nebula
  - Ejection of the outer layers of the red giant
- Strong Explosion => Nova
  - Eruptions in a binary star system
- Catastrophic Explosion => Supernova
  - Blasting away the outer parts of a star

Explosion Results

- Explosions put the processed stellar material back into the interstellar medium for the next generation of stars to use!
- In a <u>*supernova*</u>, neutrons bombard nuclei and *build up <u>very heavy elements</u>*, e.g. Gold, Uranium, etc.

Stellar End-Products

- White dwarfs
  - Light up planetary nebulae for a while
  - Eventually cool and fade away. It becomes to faint to see.
- Pulsars => cold neutron stars
  - A big nucleus in the sky
- Black Holes => ???

19. What is the importance of the initial mass of a star?

Importance of Mass

- The fate of a star is linked to its mass when it nears the end of it's life.
- And depends upon
  - Its initial mass
  - How much mass it loses along the way.

White Dwarfs

- For $M_{core} < 1.4\ M_{sun}$, the core is stable.
- A *white dwarf* forms
  - Size of the earth but mass of the sun!
- As the star cools we might expect it to get smaller and smaller.
- ... It doesn't!

What Stops Core Collapse?

- *The Pauli Exclusion Principle*:
  - No two electrons can be at the same place at the same time with the same energy.
- Electrons cannot move closer together because they have nowhere to go.
- The strong repulsion caused by the Exclusion Principle is called
  - *Electron Degeneracy Pressure*

The Winner is?!

- Electron degeneracy pressure can balance gravity when $M_{core} < 1.4\ M_{sun}$.
- When $M_{core} > 1.4\ M_{sun}$, collapse continues as the electron get "assimilated" into the nuclei to create a *Neutron Star*.
- When $M_{core} > \sim 4\ M_{sun}$, even nuclear "pressure" can not halt the collapse. Gravity creates a *Black Hole*.

The Death of Stars

Stellar Mass	Nature of collapse	Size of Radius (km)	Density (g/cm^3)	End Product
$M_{star} < 1M_{sun}$	Slow gravitational contraction	---	---	White Dwarf
$1\ M_{sun}$ to $\sim 5\ M_{sun}$	Mild core collapse	7000	10^7	White Dwarf
$\sim 5\ M_{sun}$ to $15\ M_{sun}$	Fast core collapse	20	3×10^{14}	Neutron Star
$M_{star} > 15\ M_{sun}$	Very fast core collapse	4	10^{16}	Black Hole

WOW!