Reminders/Announcements

• Exams handed back at end of class tomorrow.
• Homework due Tuesday @ 5 pm.
• Extra Credit Opportunities:
  – Midterm corrections = Turn in a short explanation (typed or neatly hand written) of WHY the correct answer should have been chosen. Each explanation is worth 0.5 points.
  – Attend the Curiosity Mars Rover Landing Live Viewing at 6:00 pm, August 5th, in IFA Auditorium.

Lecture 16

The Nature of Stars

Luminosity

• Luminosity = Total Energy emitted per second
Luminosity, Temperature and Size

We can detect the same luminosity (energy per second) from:

1. a small, hot star
2. a medium size, warm star
3. a large, cool star

It’s not easy to measure luminosity!

How bright something appears to be ≠ How much light something emits

Apparent brightness depends on...

- Luminosity
- Distance

A star or galaxy will appear bright if it’s intrinsically brighter or if it’s closer.
Stars A and B could have the same apparent brightness but star A could be intrinsically fainter, but closer than star than B.

Apparent brightness:

Energy in photons received per second, in the area of your detector

Also called “flux”

Apparent brightness...

...increases when more photons are emitted per second.
Apparent brightness:

More photons intercepted here...

...than here.

Apparent Brightness = # of photons arriving / Area
~ # photons / d²

Class Action!

If two stars appear to be the same brightness in the night sky, the star closer to Earth will generally have:

A) A higher flux
B) A hotter temperature
C) A lower luminosity
D) Identical Physical Properties
Class Action!

If two intrinsically identical stars are at different distances from the Earth, the more distant star will have:

A) Bluer color  
B) Higher luminosity  
C) Lower luminosity  
D) Lower apparent flux

Spectral Lines

• Stars aren’t perfect blackbodies, they have spectral lines!  
• We know that the different spectral lines are due to different chemicals.

Spectral Classifications

• Annie Jump Cannon  
• Antonia Maury  
• Meghnad Saha  
• Cecilia Payne-Gaposchkin
A Revolution

- Most astronomers believed that the differences in spectral lines were due to subtle differences in chemical abundance.
  - But, Annie Jump Cannon proposed a scheme that instead depended on surface temperature.
- Indian physicist Meghnad Saha offered another explanation, which was confirmed at Harvard by Cannon and Maury’s work.

Temperature and Particle Speed

- Higher temperature => faster particles

Together Saha and Payne-Gaposchkin

- Gave theoretical explanation for Cannon’s classification scheme.
- Showed that the differences in spectra (absorption lines) are due to temperature and thermal ionization of atoms not abundance of elements
- Provided a convincing argument that stars are mostly made of hydrogen.
Stars are classified by their spectra as O, B, A, F, G, K, and M spectral types.

What does this give us?

- a new way to classify stars:
  - Color
  - Peak wavelength of the black body curve
  - Spectral class
- All of these are indicators of a star’s temperature

Summary of Spectral Classes

<table>
<thead>
<tr>
<th>Spectral Class</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>hotter than 25,000 K</td>
</tr>
<tr>
<td>B</td>
<td>11,000 - 25,000 K</td>
</tr>
<tr>
<td>A</td>
<td>7500 - 11,000 K</td>
</tr>
<tr>
<td>F</td>
<td>6000 - 7500 K</td>
</tr>
<tr>
<td>G</td>
<td>5000 - 6000 K</td>
</tr>
<tr>
<td>K</td>
<td>3500 - 5000 K</td>
</tr>
<tr>
<td>M</td>
<td>cooler than 3500 K</td>
</tr>
</tbody>
</table>
Stars are classified by their spectra as O, B, A, F, G, K, and M spectral types
• O B A F G K M
• hottest to coolest
• bluish to reddish
• An important sequence to remember:
  – Oh Be a Fine Guy (or Girl), Kiss Me
  – Overseas Broadcast - A Flash: Godzilla Kills Mothra
  – Over-Budget Adult Films Give Knights Merriment
  – One Boring Afternoon, Frank Grew Killer Marijuana

For thousands of nearby stars we can find:
• the total luminosity
• the temperature (color or spectral type)
• the size (radius)
• the distance

CAN WE FIND ANY RHYME, REASON, OR RELATIONSHIPS?

Looking for correlations:
  Height vs. IQ ?
  Height vs. Weight ?
Questions:

• Are more luminous stars always larger?
• What combinations of temperature and luminosity are possible?

The H-R Diagram

• Done independently by Enjar Hertzsprung and Henry Norris Russell

• Graph of luminosity (or absolute magnitude) versus temperature (or spectral class)

The Hertzsprung-Russell (H-R) diagram identifies a definite relationship between temperature and absolute magnitude.

**HR DIAGRAM**

absolute magnitude vs temperature  

or  
luminosity vs spectral type
The Hertzsprung-Russell (H-R) diagram identifies a definite relationship between temperature and absolute magnitude.

**HR DIAGRAM**

- Absolute magnitude vs temperature
- Or
- Luminosity vs spectral type

**MAIN SEQUENCE**

- Goes from top left (hot and bright) to bottom right (cool and dim).
- 90% of the stars are in the Main Sequence stage of their lives.
- Includes our Sun.

- Main Sequence stars are found in a band from the upper left to the lower right.
Lecture Tutorial

• Break up into groups of 2-3
  – NO MORE THAN 3
• In your group, work through the following:
  – Luminosity, Temperature, and Size (pages 53-56)
  – Discuss the answers – don’t be silent!
• I will be roaming around if you need help…
• If your group finishes, check your answers with another group

What about the Masses of Stars on the H-R Diagram?

• **Main Sequence stars** range from $0.1M_\odot$ to $\sim100M_\odot$
• The masses of **Main Sequence stars** increase with increasing luminosity, size and temperature
• **Main Sequence stars** increase in mass from the lower right to the upper left of the H-R Diagram

There is a relationship between mass and luminosity for **Main Sequence stars**

Bigger (more massive) is brighter and hotter!
There is a relationship between mass and luminosity for Main Sequence stars.

Bigger (more massive) is brighter and hotter!