More on The Nature of the Stars

Chapter 19
Couple of notes:

• Final is on May 16 1:30-4:15pm!

• I will start posting lists of concepts that you must know and a week before a sample of the exam

• 1st exam is on February 23. There will be a review session on the 21 (Physics secretary will e-mail when/where)
Review on measuring stars (parallax)

Measuring Distances

* How would you measure the distance across a large river?

Triangulation

\[ \tan A = \frac{\text{DAR}}{\text{KD}} \]
\[ \text{DAR} = \text{KD} \times \tan A \]

* By using trigonometry or similar triangles, you can calculate the distance across the river

Large Baselines: Earth’s Orbit

* A very large baseline is needed to measure the parallax of stars
Parallax

\[
\text{Distance (in parsecs)} = \frac{1}{\text{parallax (in arcseconds)}}
\]

- the formula
Parallax Example

Distance = \frac{1}{\text{Parallax}}

Distance = \frac{1}{0.2} = 5 \text{ pc}

• What is the distance of a star with a parallax of 0.2 Arcseconds?
Inverse Square Law:

• Light is “diluted” over the surface of a sphere

• The more distant a source, the more “diluted” the light is:

Flux $\propto 1/\text{distance}^2$
Thus:

\[ \text{Flux } \propto \frac{\text{LUMINOSITY}}{\text{DISTANCE}^2} \]

Example: The same star at twice the distance is \(2^2 = 4\) times dimmer; at three times the distance is \(3^2 = 9\) times dimmer; etc
Astronomers often use the magnitude scale to denote brightness

**Apparent magnitude:** how bright an object *appears* from Earth.

- The greater the apparent magnitude, the dimmer the star.

- The **absolute magnitude** of a star is the apparent magnitude it would have if viewed from a distance of 10 parsecs.
Apparent magnitudes of stars in the Pleiades
(Look at box 19-3: Relationship between *Absolute magnitude* and *Apparent Magnitude*)

each step in magnitude corresponds to a factor of 2.512 in brightness
Example:

\[
\begin{array}{ccc}
m_2 - m_1 & b_1/b_2 \\
1 & 2.512 \\
2 & (2.512)^2 \\
\end{array}
\]

\[
m_2 - m_1 = 2.5 \log(b_1/b_2)
\]

\[
m - M = 5 \log d - 5
\]
A star’s color depends on its surface temperature

Red stars are relatively cold, with low temperatures; blue stars are relatively hot, with high surface temperatures
Photometry and Color Ratios

- Photometry measures the apparent brightness of a star $b_u, b_b, b_V$.
- The color ratios of a star are the ratios of brightness values obtained through different standard filters, such as the U, B, and V filters.
- These ratios are a measure of the star's surface temperature.
### Colors of Selected Stars

<table>
<thead>
<tr>
<th>Star</th>
<th>Surface temperature (K)</th>
<th>$b_V/b_B$</th>
<th>$b_B/b_U$</th>
<th>Apparent color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellatrix ($\gamma$ Orionis)</td>
<td>21,500</td>
<td>0.81</td>
<td>0.45</td>
<td>Blue</td>
</tr>
<tr>
<td>Regulus ($\alpha$ Leonis)</td>
<td>12,000</td>
<td>0.90</td>
<td>0.72</td>
<td>Blue-white</td>
</tr>
<tr>
<td>Sirius ($\alpha$ Canis Majoris)</td>
<td>9400</td>
<td>1.00</td>
<td>0.96</td>
<td>Blue-white</td>
</tr>
<tr>
<td>Megrez ($\delta$ Ursae Majoris)</td>
<td>8630</td>
<td>1.07</td>
<td>1.07</td>
<td>White</td>
</tr>
<tr>
<td>Altair ($\alpha$ Aquilae)</td>
<td>7800</td>
<td>1.23</td>
<td>1.08</td>
<td>Yellow-white</td>
</tr>
<tr>
<td>Sun</td>
<td>5800</td>
<td>1.87</td>
<td>1.17</td>
<td>Yellow-white</td>
</tr>
<tr>
<td>Aldebaran ($\alpha$ Tauri)</td>
<td>4000</td>
<td>4.12</td>
<td>5.76</td>
<td>Orange</td>
</tr>
<tr>
<td>Betelgeuse ($\alpha$ Orionis)</td>
<td>3500</td>
<td>5.55</td>
<td>6.66</td>
<td>Red</td>
</tr>
</tbody>
</table>

*Source: J.-C. Mermilliod, B. Hauck, and M. Mermilliod, University of Lausanne.*

Blue is ….Hot
Red is…Cold
Questions

1. How far away are the stars?
2. What evidence do astronomers have that the Sun is a typical star?
3. What is meant by a “first-magnitude” or “second magnitude” star?
4. Why are some stars red and others blue?
The spectra of stars reveal their chemical compositions as well as surface temperatures.

- Stars are classified into spectral types (subdivisions of the spectral classes O, B, A, F, G, K, and M), based on the major patterns of spectral lines in their spectra ("Oh Be A Fine Girl/Guy Kiss Me")
The Sun whose spectrum is dominated by calcium and iron is a G2 star.
Line Intensity

Temp = 3000 K

Temp = 10,000 K

- temperature determines line intensity
The spectral class and type of a star is directly related to its surface temperature: O stars are the hottest and M stars are the coolest.
Most brown dwarfs are in even cooler spectral classes called L and T.

Unlike true stars, brown dwarfs are too small to sustain thermonuclear fusion.
Relationship between a star’s luminosity, radius, and surface temperature

\[ L = 4\pi R^2 \sigma T^4 \]

- \( L \) = star’s luminosity, in watts
- \( R \) = star’s radius, in meters
- \( \sigma \) = Stefan-Boltzmann constant = \( 5.67 \times 10^{-8} \) W m\(^{-2}\) K\(^{-4}\)
- \( T \) = star’s surface temperature, in kelvins

Stars come in a wide variety of sizes
Finding Key Properties of Nearby Stars

Parallax ($p$)

Distance ($d$)

$d = \frac{1}{p}$

Luminosity ($L$)

$L = 4\pi d^2 b$

Spectrum

Spectral type

Surface temperature ($T$)

$L = 4\pi R^2 \sigma T^4$

Radius ($R$)

Chemical composition
Hertzsprung-Russell (H-R) diagrams reveal the different kinds of stars

- The H-R diagram is a graph plotting the absolute magnitudes of stars against their spectral types—or, equivalently, their luminosities against surface temperatures.
- The positions on the H-R diagram of most stars are along the **main sequence**, a band that extends from high luminosity and high surface temperature to low luminosity and low surface temperature.
On the H-R diagram, giant and supergiant stars lie above the main sequence, while white dwarfs are below the main sequence.
By carefully examining a star’s spectral lines, astronomers can determine whether that star is a main-sequence star, giant, supergiant, or white dwarf.
Using the H-R diagram and the inverse square law, the star’s luminosity and distance can be found without measuring its stellar parallax.