More on The Nature of the Stars

Chapter 19
• The iClickers are in the bookstore...please get them if you want extra credit. We will start using them next week!

• You will need to register them on the web: http://www.iclicker.com/registration/index.html
Questions from last class (iClicker format))

1. If the Hipparcos satellite measures the parallax motion of a star against the background stars and concludes that the star has a parallax of 0.004 arcseconds, how far is that star from Earth?
   - A. 250 pc or 800 ly
   - B. 0.004 pc or 0.013 ly
   - C. 25 pc or 81 ly
   - D. 400 pc or 1300 ly
Questions from last class (iClicker format))

• 2. Coronal mass ejections are
  – A. large bits of the sun that blow out into interplanetary space
  – B. charged particles from the sun accelerated/guided by magnetic field lines
  – C. richer in heavier elements than other mass ejections
  – D. nothing to be feared by spacecraft and humans in space
  – E. never going to achieve escape velocity
• 3. What is the Sun’s photosphere?
  – A. the middle layer of the Sun’s atmosphere
  – B. the lowest layer of the Sun’s atmosphere
  – C. the envelope of convective mass motion in the outer interior of the Sun
  – D. the upper layer of the Sun’s atmosphere
• 4. What does apparent magnitude tells us about a star?
  – A. its size compared to the Sun
  – B. the intrinsic brightness of a star (the total light actually emitted by the star)
  – C. the brightness of a star as it appears in our sky
  – D. the brightness the star would appear to have if it were exactly 10pc from the Earth
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 apparent magnitude scale is an alternative way to measure a star’s apparent brightness.
- The absolute magnitude of a star is the apparent magnitude it would have if viewed from a distance of 10 parsecs.
Inverse Square Law:

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

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

\[ \text{Flux} \propto \frac{1}{\text{distance}^2} \]
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.
Apparent magnitudes of stars in the Pleiades
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 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.
<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 (γ Orionis)</td>
<td>21,500</td>
<td>0.81</td>
<td>0.45</td>
<td>Blue</td>
</tr>
<tr>
<td>Regulus (α Leonis)</td>
<td>12,000</td>
<td>0.90</td>
<td>0.72</td>
<td>Blue-white</td>
</tr>
<tr>
<td>Sirius (α Canis Majoris)</td>
<td>9400</td>
<td>1.00</td>
<td>0.96</td>
<td>Blue-white</td>
</tr>
<tr>
<td>Megrez (δ Ursae Majoris)</td>
<td>8630</td>
<td>1.07</td>
<td>1.07</td>
<td>White</td>
</tr>
<tr>
<td>Altair (α 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 (α Tauri)</td>
<td>4000</td>
<td>4.12</td>
<td>5.76</td>
<td>Orange</td>
</tr>
<tr>
<td>Betelgeuse (α 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.*
Guiding 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
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
Questions

• 5. Spectral classification determines a nearby star’s surface temperature by examining
  – A. the peak wavelength of the star spectrum
  – B. the relative intensities of light measured through different wavelength band filters
  – C. the pattern of spectral “absorption” lines from various atoms
  – D. the overall shape of the star’s spectrum compared to a black body
Finding Key Properties of Nearby Stars

- Parallax ($p$)
  \[ d = \frac{1}{p} \]
- Apparent brightness ($b$)
- Spectrum
  - Spectral type
  - Chemical composition
- Distance ($d$)
- Luminosity ($L$)
  \[ L = 4\pi d^2 b \]
- Surface temperature ($T$)
  \[ L = 4\pi R^2 \sigma T^4 \]
- Radius ($R$)
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.
Questions

• 6. Two objects have the same size and different temperatures. The hotter object is
  – A. bluer and brighter than the cooler object
  – B. bluer and fainter than the cooler object
  – C. redder and brighter than the cooler object
  – D. redder and fainter than the cooler object
  – E. None of the above can be true.
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.