Previously on Astro-1

• The Sun
  – Internal structure
  – Energy source
  – Neutrinos and the solar neutrino problem
  – Sunspots and the sun cycle
Today on Astro-1

- Introduction to stars
- Measuring Distances
- Inverse square law: luminosity vs brightness
- Colors and spectral types
- Masses of stars
The closest stars to the sun.

But how do we know the distance to them?
When you are at position B, the tree appears to be in front of this mountain.

When you are at position A, the tree appears to be in front of this mountain.
Parallax measuring the distance to a star
\[ d = \frac{1}{p} \]
\( p = \) parallax in arcsec
\( d = \) distance in parsecs
\[ 1 \text{ pc} = 3.26 \text{ ly} \]
Parallax measuring the distance to a star
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\[ p = \text{parallax in arcsec} \]
\[ d = \text{distance in parsecs} \]
\[ 1 \text{ pc} = 3.26 \text{ ly} \]

Remember 1pc is the distance at which 1AU subtends 1 arcsec
Example
A star has a parallax of 0.1". What is its distance?
\[ d = \frac{1}{p} \]
\[ p = \text{parallax in arcsec} \]
\[ d = \text{distance in parsecs} \]

\[ d = \frac{1}{0.1} = 10 \text{ pc} \]
In January, the nearby star appears to be here.

In July, the nearby star appears to be here.

The closer the star, the more its apparent position shifts as seen from Earth.

Parallax of a nearby star

Parallax of an even closer star
Consider two stars, star 1 and star 2. Star 1 has a parallax of 0.05 arcsec. Star 2 has a parallax of 0.40 arcsec. How far away are the two stars?

A) Star 1: 5 pc, Star 2: 40 pc
B) Star 1: 1/5 pc, Star 2: 1/40 pc
C) Star 1: 10 pc, Star 2: 25 pc
D) Star 1: 20 pc, Star 2: 2.5 pc
To put in perspective:
If 1pc = distance from SB to NYC, distance from Sun to Earth ~ 10m!
Less than this room!
Inverse square law

determining the luminosity of a star

\[ b = \frac{L}{4\pi d^2} \]

- \( b \) = brightness of star as we see it
- \( L \) = luminosity of star (wattage)
- \( d \) = distance to star
The Inverse-Square Law

Radiation from a light source illuminates an area that increases as the square of the distance from the source. The apparent brightness decreases as the square of the distance. The brightness at $d = 2$ is $1/(2^2) = 1/4$ of the brightness at $d = 1$, and the brightness at $d = 3$ is $1/(3^2) = 1/9$ of that at $d = 1$. 

With greater distance from the star, its light is spread over a larger area and its apparent brightness is less.
Question 20.2 (iclickers!)

At the distance of the Earth from the Sun (1 AU) the intensity of sunlight is 1370 watts/m². What is the intensity at the distance of Saturn from the Sun (10 AU)?

A. 13,700 watts/m²  
B. 1370 watts/m²  
C. 137 watts/m²  
D. 13.7 watts/m²
Stars like the Sun (luminosity $1 \, L_\odot$) are relatively common.

Curve is high: Low-luminosity stars are common.

Curve is low: Very luminous stars are quite rare.
(a) A cool star with surface temperature 3000 K emits much more red light than blue light, and so appears red.

(b) A warmer star with surface temperature 5800 K (like the Sun) emits roughly equal amounts of all visible wavelengths, and so appears yellow-white.

(c) A hot star with surface temperature 10,000 K emits much more blue light than red light, and so appears blue.
Figure 17-9
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<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
The Stars

distances – from parallax
luminosites – from \( b = \frac{L}{4\pi d^2} \)
temperatures — from color and spectrum

Hot  
O  B  A  F  G  K  M  L  T  

Cold

Diagram showing the classification of stars based on their types and colors.
Spectra of stars with different surface temps
Hydrogen absorption line: electron jumps from $n = 2$ to $n = 4$ orbit
If surface temperature is low, few hydrogen atoms have their electron in the \( n = 2 \) orbit: hence no absorption.
If surface temperature is high, most hydrogen atoms have lost their electron completely: hence no absorption.
If surface temperature is not too hot and not too cold, many hydrogen atoms have their electron in the $n = 2$ orbit: hence strong absorption.
Question 20.3 (iclickers!)

• A star has a radius half of that of the Sun and a luminosity equal to 60% of that of the Sun. What’s the star’s surface temperature? The surface temperature of the Sun is 5800K.

A. 7220 K  
B. 6650 K  
C. 4660 K  
D. 3610 K
A Hertzsprung-Russell (H-R) diagram

Surface temperature (K)
25,000 10,000 8000 6000 5000 4000 3000

$10^6$ $10^4$ $10^2$ 1 $10^{-2}$ $10^{-4}$

Luminosity ($L_\odot$)

Absolute magnitude

Spectral type
O5 B0 A0 F0 G0 K0 M0 M8

The red curve is the main sequence.
(a) A Hertzsprung-Russell (H-R) diagram

(b) The sizes of stars on an H-R diagram

Figure 17-15

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The mass of stars
To determine stellar masses we rely on binary star systems. As seen from Earth, the two stars that make up this binary system are separated by less than 1/3 arcsecond. For simplicity, the diagram shows one star as remaining stationary; in reality, both stars move around their common center of mass.
The center of mass of the system of two children is nearer to the more massive child.

A “binary system” of two children
The center of mass of the binary star system is nearer to the more massive star.

A binary star system

Figure 17-20b
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H-R diagram with masses

The main sequence is a mass sequence!
Summary

• Parallax is a tool to measure distances
• The Inverse-Square Law relates luminosity and brightness
• Low luminosity stars are more common than more luminous ones
• Colors and spectral types measure a star’s temperature
• The Hertzsprung-Russell (H-R) diagram is a graph plotting luminosity vs temperature
• Most stars belong to the main sequence. Other important classes are giants, supergiants and white dwarfs.
• Spectral typing can be used to determine distances
• Masses can be determined for binaries. The main sequence is a mass sequence!!
The End

See you on Monday!