Celestial Census

Distances

\[ d = \frac{1}{p''} \text{ (pc)} \]

\[ d = \frac{206,265}{p''} \text{ (AU)} \]

1 pc = 3.26 LY
Radial Velocity

\[ \frac{\Delta \lambda}{\lambda} = \frac{v}{c} = \frac{(\lambda_{\text{obs}} - \lambda)}{\lambda} \]

\[ \Delta v = c \frac{\Delta \lambda}{\lambda} \]

Proper Motion & Tangential Velocity

\[ T = 4.74 \mu d = 4.74 \frac{\mu}{p''} \text{ (km/s)} \]

where \( \mu \) is in arcsec/year, \( d \) is in parsecs, and \( p'' \) is in arcsec.
Space Velocity

The total space velocity is

\[ V^2 = V_R^2 + V_T^2 \]

Apparent Magnitudes

\[ \frac{F_2}{F_1} = 100^{(m_1 - m_2)/5} \]

\[ \log (x^n) = n \log (x) \]

\[ \log \left( \frac{F_2}{F_1} \right) = \frac{(m_1 - m_2)}{5} \log (100) = 2 \frac{(m_1 - m_2)}{5} \]

\[ m_1 - m_2 = 2.5 \log \left( \frac{F_2}{F_1} \right) \]
Absolute Magnitudes

\[ m_1 - m_2 = 2.5 \log \left( \frac{F_2}{F_1} \right) \]

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

\[ \frac{F(10)}{F(d)} = (\frac{d}{10})^2 \]

\[ m - M = 5 \log \left( \frac{d}{10} \right) \]
Ionization via Temperature

\[ L \propto R^2 T^4 \]

Diameters of Stars

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

\[ L \propto R^2 T^4 \]
Masses of Stars

Kepler's 3rd Law

\[(M_1 + M_2) P^2 = a^3\]

- \(M\) is in solar masses
- \(P\) is in years, and
- \(a\) is in Astronomical Units

(1 AU = mean Earth-Sun distance)

Spectroscopic Binaries

Conservation of Angular Momentum

\[\frac{M_1}{M_2} = \frac{v_2}{v_1}\]

\[\frac{v_2}{v_1} = \frac{r_1}{r_2}\]

Doppler Shift

\[\frac{\Delta \lambda}{\lambda} = \frac{v}{c}\]
Mass-Luminosity Relationship

\[ L \propto M^{4.0} \]

0.08 solar < \( M \) < 50 solar

How Can We Visualize It All?

E. Hertzsprung (1911) and Norris Russell (1913) independently produced plots to investigate stellar properties.

Today, those graphs are called **H-R Diagrams**.
Fig. 1.—Russell’s diagram. The original data can reproduce well, but this is a
faithful reproduction showing the data points and style used.

Hertzsprung-Russell Diagram
Hertzsprung-Russell Diagram

The most significant feature of the HR diagram is that the stars are not distributed over it at random. Rather they cluster into certain parts of the diagram.

- **Main Sequence**
- **Red Giants**
- **Supergiants**
- **White Dwarfs**

\[ L \propto R^2 T^4 \]

The Brightest Stars

Of the 20 brightest stars, only 6 are within 10 pc of the Sun.

The vast majority of nearby stars, those less luminous than the Sun, do not send enough light across interstellar distances to be seen without optical aid.
The Nearest Stars

Only 3 of the 44 nearest stars are among the 20 brightest stars: Sirius, Alpha Centauri, and Procyon.

The nearby stars also tend to have large proper motions. Interestingly, 13 of the 44 stars are really binary- or multiple-star systems. Total of 59 stars are within 5 pc.
The Nearest Stars

The most important datum is that **most nearby stars are intrinsically faint**.

Only 10 of the 50 nearest stars are visible to the unaided eye.

Only 3 are as intrinsically luminous as the Sun.

43 have luminosities less than 0.01 solar.

If the stars in our immediate stellar neighborhood are representative of the stellar population in general, we must conclude that the most numerous stars are those of low luminosity. In this sample, only about 1 star in 20 is as luminous as the Sun. (90% are main sequence; 10% are white dwarfs)
Main Sequence Masses

Luminosity, Temp, Radius, & Mass
Main Sequence Extremes

<table>
<thead>
<tr>
<th>Most Luminous</th>
<th>Least Luminous</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L = 50,000$ solar</td>
<td>$L = 0.005$ solar</td>
</tr>
<tr>
<td>$M = 60$ solar</td>
<td>$M = 0.08$ solar</td>
</tr>
<tr>
<td>$R = 40$ solar</td>
<td>$R = 0.1$ solar</td>
</tr>
<tr>
<td>$T = 45,000$ K</td>
<td>$T = 3000$ K</td>
</tr>
<tr>
<td>O5</td>
<td>M5</td>
</tr>
</tbody>
</table>

Further Distances

1. Take the Spectrum of the star.
2. Classify the Spectrum.
3. Use the HR Diagram to assign an Absolute Magnitude ($M$).
4. Measure the Apparent Magnitude ($m$).

$$m - M = 5 \log \left( \frac{d}{10} \right)$$

**Spectroscopic Parallax**