Hertzsprung-Russell Diagram

- Hertzsprung and Russell found a correlation between luminosity and spectral type (temperature)

Luminosity (Solar units)

<table>
<thead>
<tr>
<th>Luminosity (Solar units)</th>
<th>O</th>
<th>B</th>
<th>A</th>
<th>F</th>
<th>G</th>
<th>K</th>
<th>M</th>
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<td>Hot, bright stars</td>
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<td>Cool, dim stars</td>
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Surface temperature (K)

- Rigel
- Sirius B
- Antares
- Betelgeuse
- Eta Aquarii
- Rigel
- Altair
- Vega
- Procyon B
- Sirius B
- Barnard's Star
- Procyon B
- Sirius B
- Procyon B

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Most stars (~90%) are on the main sequence
- The greater the temperature, the more luminous the star
- M type stars are the most common.
- O type stars are the least common.

Sizes of Stars

- Size of star is related to the temperature and the luminosity by:
  \[ L = \sigma T^4 \times 4\pi R^2 \]
  - If you know the position on HR diagram you know the size of the star.
• Supergiants -- cool, bright, red, large stars
• Giants -- cool, bright red, less large stars
• Main Sequence -- spans range from hot, bright stars to cool, dim stars.
• White dwarfs -- hot, small, dim stars.

• These classifications will give clues to stages in the evolution of stars.

Stars come in many sizes!

Sizes of Objects in our Universe

Images from webisto.com/space
Sizes of Objects in our Universe

Masses of Stars

- We cannot directly measure the mass of an isolated star.
- If something is orbiting the star, can use the general form of Kepler’s Third Law

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

- Luckily, 2/3 of all stars are binary stars, two stars that orbit one another

Mass-Luminosity Relation

- True ONLY for Main Sequence stars
- As the mass increases, the luminosity increases rapidly

\[\text{Luminosity } \propto \text{Mass}^3\]
HR Diagram:
Main sequence stars labeled by mass in units of solar masses.

Apparent Brightness

• The brightness an object appears to have.
• The further away the object, the dimmer it looks

\[
\text{Apparent Brightness} = \frac{\text{Luminosity}}{4\pi d^2} \quad d = \text{distance}
\]
Main-Sequence Fitting (see p. 411) 
(Spectroscopic Parallax)

• If luminosity and apparent brightness are known, distance can be determined.

\[ m - M = 5 \log d - 5 \]

• Difficult to accurately measure luminosity for one star
  – Use spectra to get spectral type and class
• Alternatively, we can use a cluster of stars
• Distance to the cluster can be determined by comparing the HR diagram of the cluster with a template HR diagram
The Distance Ladder

- See also Figure 16.17 on p. 416
- First rung: parallax
- Second rung: spectroscopic parallax, or "main-sequence fitting"
- Third rung: standard candles/inverse square law (Cepheids/supernovae)
- Fourth rung: Hubble’s Law

We will be discussing the longer distance “rungs” of the ladder in subsequent lectures.

Figure 26.12, Freedman and Kaufmann, 7th ed. University, © 2005 W. H. Freeman & Company