Lecture 10: The Hertzsprung-Russell Diagram
Reading: Sections 19.7-19.8

Key Ideas
The Hertzsprung-Russell (H-R) Diagram
  Plot of Luminosity vs. Temperature for stars
Features:
  Main Sequence
  Giant & Supergiant Branches
  White Dwarfs
Luminosity classes

Review of what we know about Stellar Properties
Large range of Stellar Luminosities
  10^{-4} to 10^{6} L_{sun}
Large range of Stellar Radii
  10^{-2} to 10^{3} R_{sun}
Modest range of Stellar Temperature
  3000 to > 50,000 K
Moderate range of Stellar Masses
  0.1 to 50 M_{sun}

Reminder: Luminosity-Radius-Temperature Relation
Box 19-4 in the book.

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

In words: if two stars have the same temperature, the larger one will be more luminous.

Hertzsprung-Russell Diagram

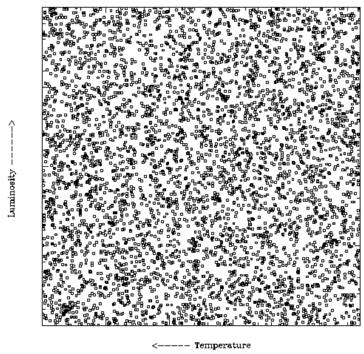
Plot of <u>Luminosity</u> versus <u>Temperature</u>
  Temperature (T) from spectral type
  Luminosity (L) from apparent brightness and distance

Diagram was drawn independently in 1912 by:

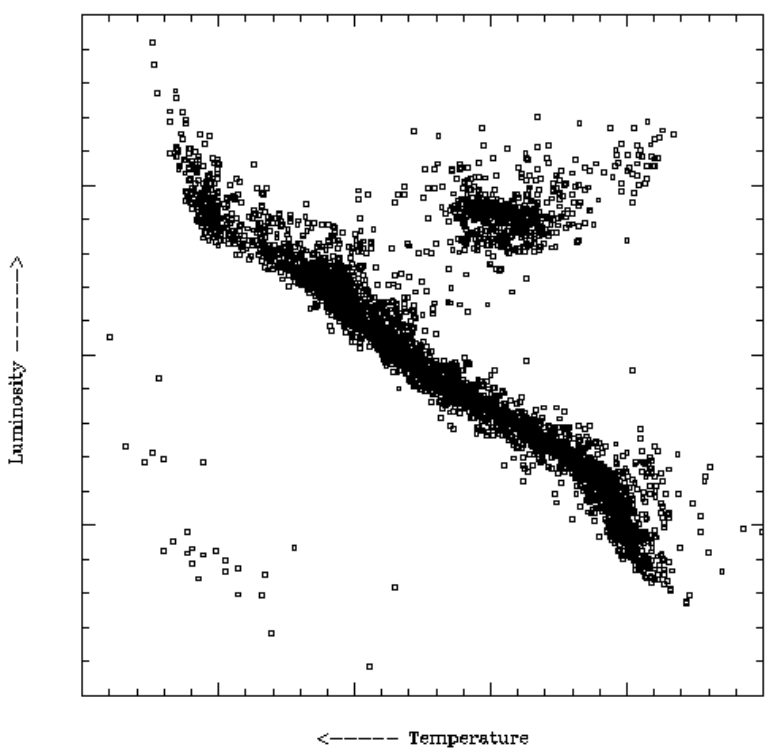
Eijnar Hertzsprung for star clusters (all stars at same distance)

Henry Norris Russell for nearby stars (stars close enough to have good parallax measurements)

It could have turned out that stars could have had any combination of luminosity and temperature. Then if we plotted them up, they'd look something like this.



However, when we actually make the plot, we find that stars fall only in certain areas of the temperature-luminosity plot. See Figure 19-14 as well.



The Major Regions of the Hertzsprung-Russell Diagram

Main Sequence

Most nearby stars (85%) lie along a diagonal band called the Main Sequence.
Range of properties

- $L=10^{-2}$ to 10^{6} L_{sun}
- $T=3000$ to $> 50{,}000$ K
- $R=0.1$ to 10 R_{sun}

The Sun is a Main Sequence Star.

Giants & Supergiants

Stars brighter than Main Sequence stars of the same Temperature.

- Means they must be larger in radius

Giants:

- $R=10\text{-}100$ R_{sun}
- $L=10^{3}\text{-}10^{5}$ L_{sun}

Supergiants

- $R>10^{3}$ R_{sun}
- $L=10^{5}\text{-}10^{6}$ L_{sun}

White Dwarfs

Stars on the lower left of the H-R Diagram fainter than Main Sequence stars of the same Temperature

- Means they must be smaller in radius
- L-R-T relation predicts $R\sim0.01$ R_{sun} = about the size of Earth
- These are very unusual objects

Luminosity Classes

Absorption lines are Pressure-sensitive

- Lines broader as the pressure increases
- Larger stars puffier, hence lower pressure

Implications

- Larger Stars have Narrower Lines
- Larger Stars are brighter for the same Temperature

Way to assign a luminosity to stars based on their spectra.

Consistency Check→ both the L-T-R relation and the spectral classes say that giant and supergiant stars are big. Whew! See Figure 19-16.

Spectral Classes from some well-known stars
Sun G2V
Betelgeuse M2Ib
Rigel B8Ia
Sirius A1V
Aldebaran K5III

H-R Diagram for the Brightest Stars

Shows that these stars tend to be intrinsically luminous

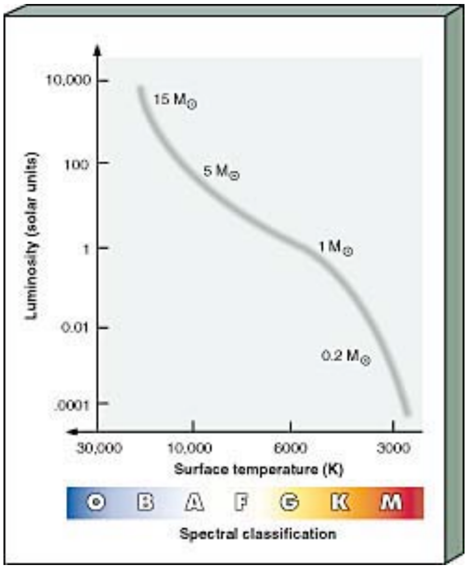
H-R Diagram for the Nearest Stars

Shows that these stars tend to be intrinsically un-luminous. Lots of G, K and M dwarfs.

Note: if we relied on the brightest stars to tell us about the Universe, we would underestimate the number of low-luminosity dwarfs (both white and red) by a lot!

Mass and the Main Sequence

We know the masses for a few of the stars on the H-R diagram. When we plot the masses of the stars, we see that the main sequence is actually a mass sequence. More massive stars on the main sequence are hotter, low mass stars are cooler. Why? This is one of the things our model of how stars work need to explain.



See also Figure 19-21 in your book

There is a mass-luminosity relation on the main sequence. We can use that + a sample of stars where we get all the stars within a certain distance of the Sun to figure out how many stars of what masses are out there.

Answer: Lots of low-mass stars! Very few high-mass stars. This is something our theory of star formation will need to explain.

Questions:

1. Why don't stars have just any luminosity and temperature?

2. Why is there a distinct Main Sequence?

3. What makes on main-sequence star different from another?

4. Are giants, supergiants, and white dwarfs born that way, or is something else going on?

Patterns on the H-R Diagram are telling us about the internal physics of stars.