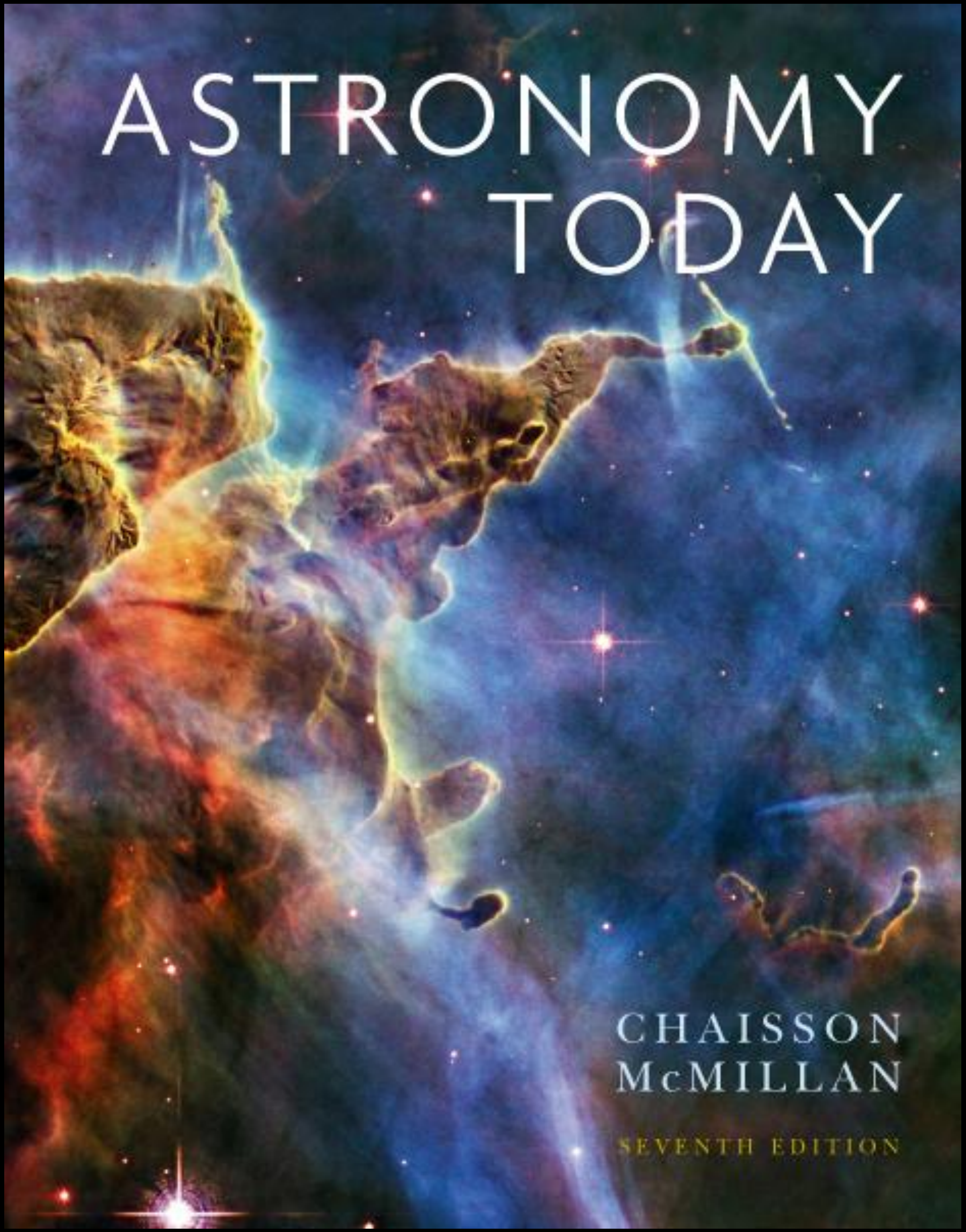



Lecture Outlines

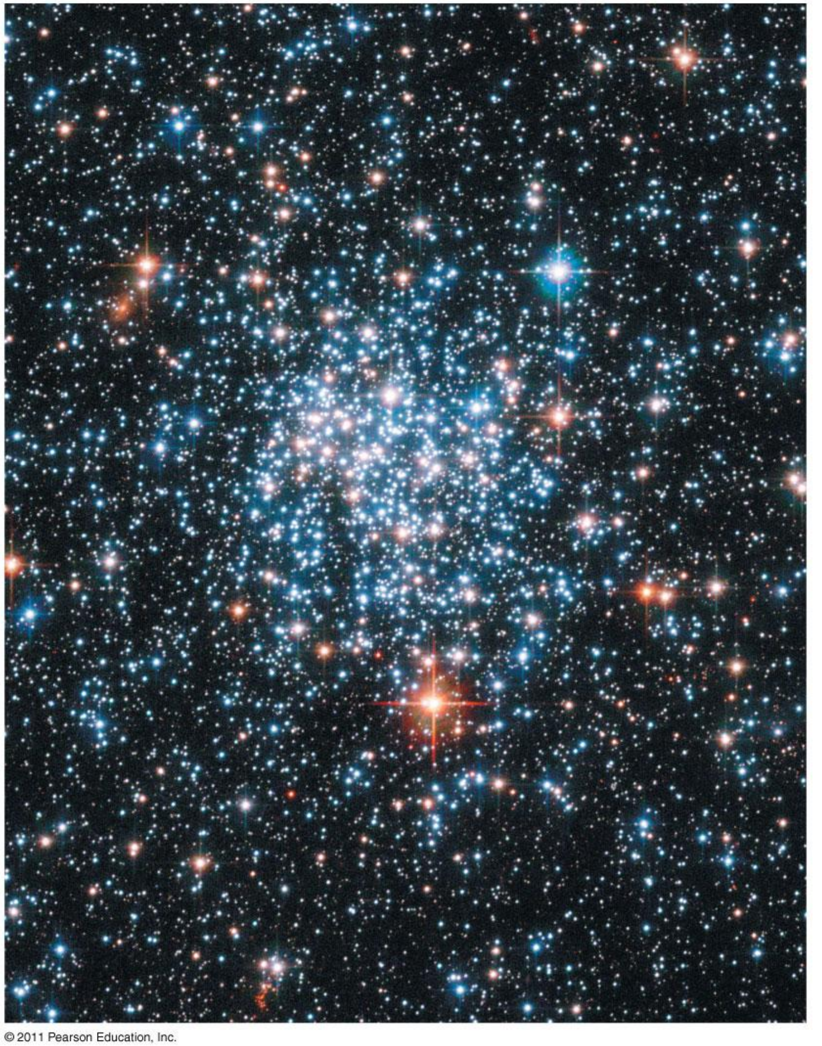
# Chapter 17

***Astronomy Today***

***7th Edition***

Chaisson/McMillan

# Chapter 17
# Measuring the Stars

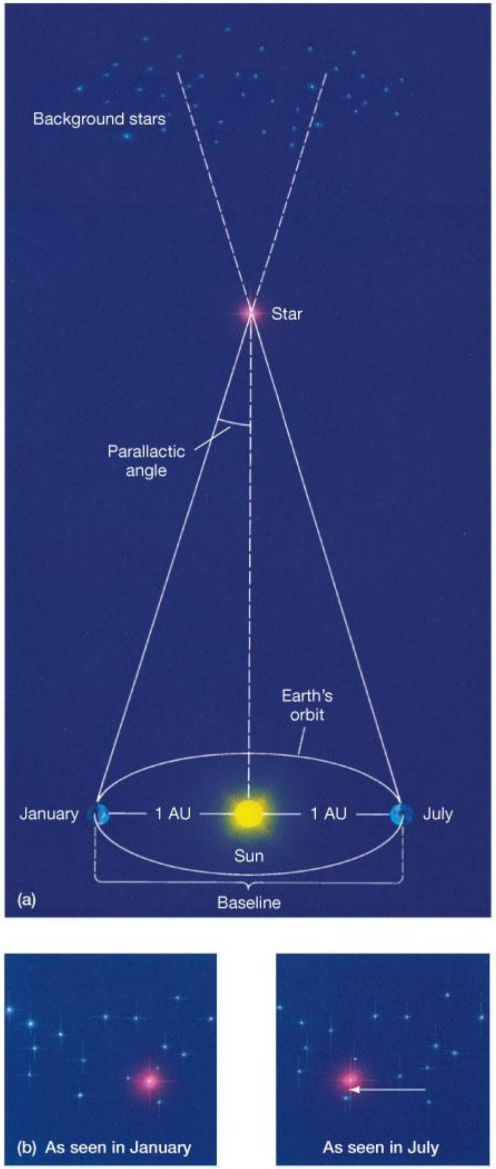


# Units of Chapter 17

# Units of Chapter 17 (cont.)

# 17.1 The Solar Neighborhood

Remember that stellar distances can be measured using parallax



# 17.1 The Solar Neighborhood

Nearest star to the Sun: Proxima Centauri, which is a member of the three-star system Alpha Centauri complex

Model of distances:

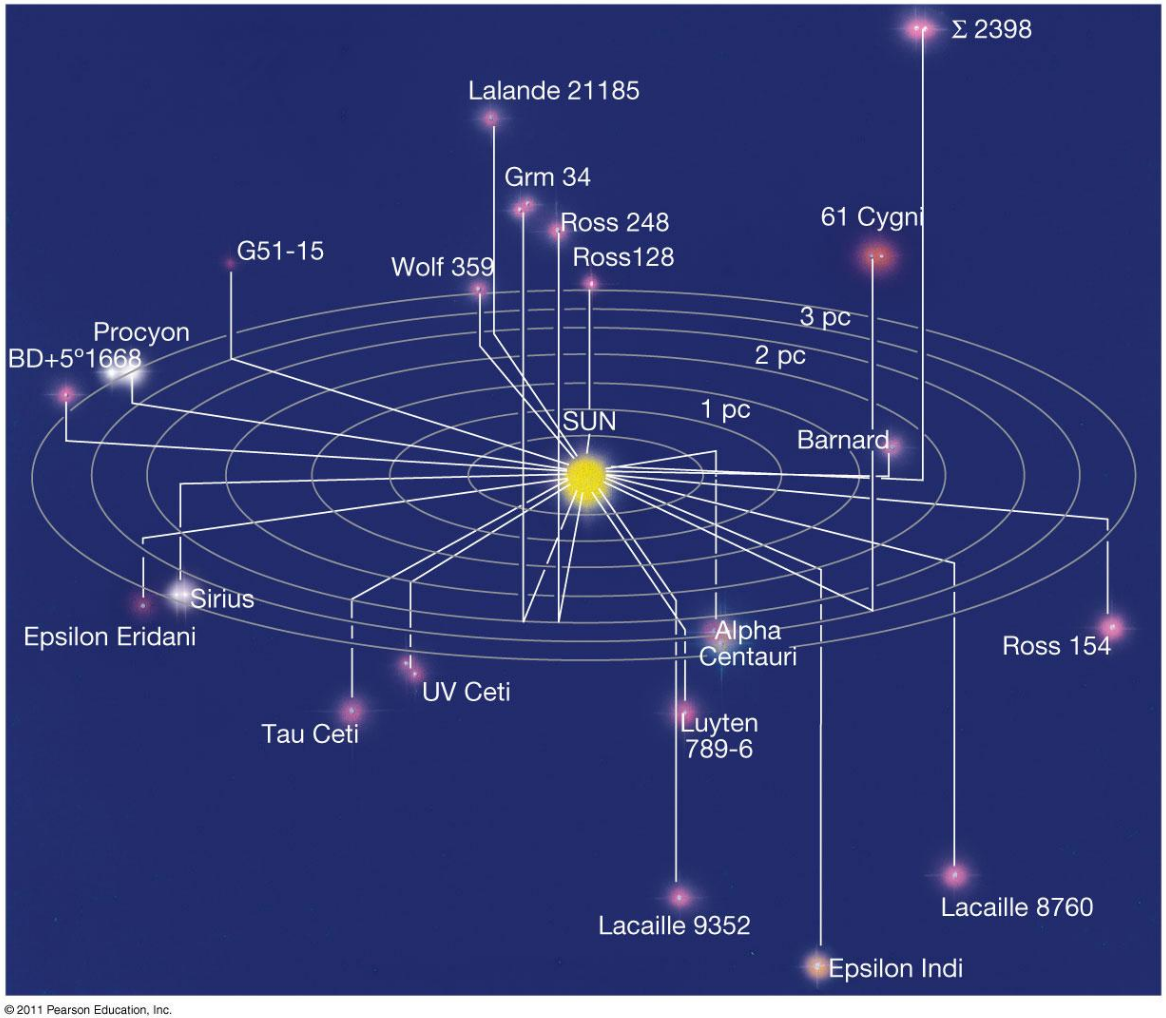
Sun is a marble, Earth is a grain of sand orbiting 1 m away

Nearest star is another marble 270 km away

Solar system extends about 50 m from Sun; rest of distance to nearest star is basically empty

# 17.1 The Solar Neighborhood

The 30 closest stars to the Sun

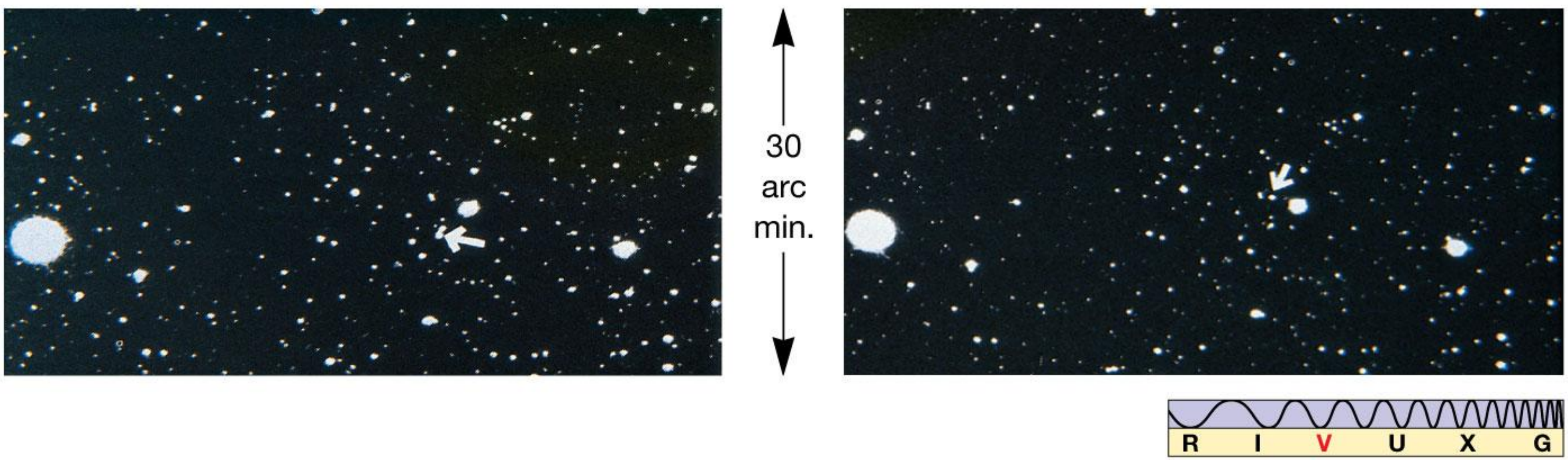


# 17.1 The Solar Neighborhood

Next nearest neighbor: Barnard's star

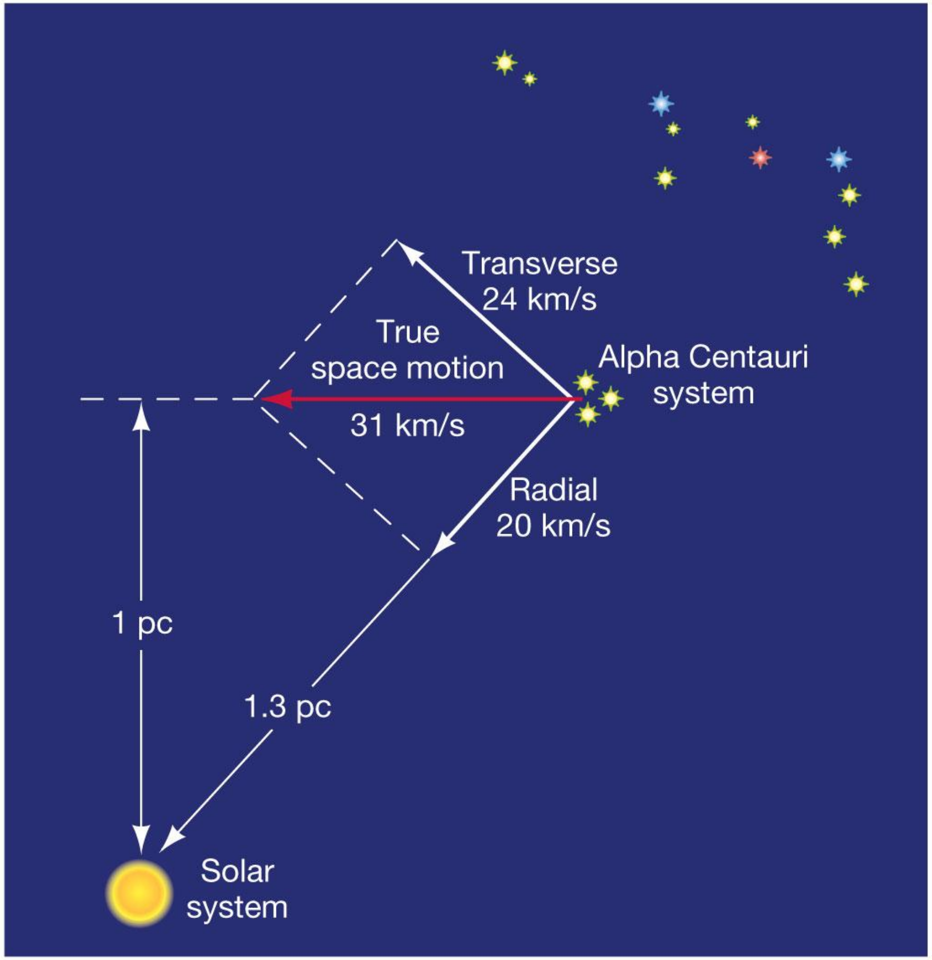
Barnard's star has the largest proper motion of any star—proper motion is the actual shift of the star in the sky, after correcting for parallax

These pictures were taken 22 years apart



# 17.1 The Solar Neighborhood

Actual motion of the Alpha Centauri complex



# 17.2 Luminosity and Apparent Brightness

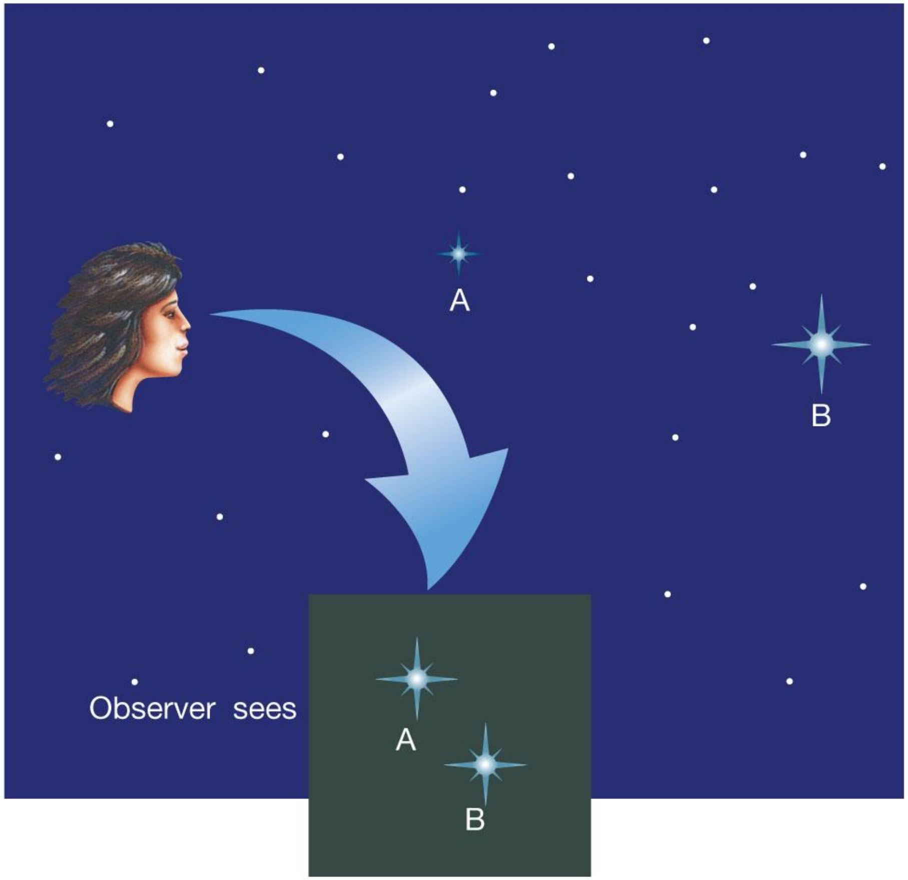
Luminosity, or absolute brightness, is a measure of the total power radiated by a star.

Apparent brightness is how bright a star appears when viewed from Earth; it depends on the absolute brightness but also on the distance of the star.

$$\text{apparent brightness (energy flux)} \propto \frac{\text{luminosity}}{\text{distance}^2}.$$

# 17.2 Luminosity and Apparent Brightness

Therefore, two stars that appear equally bright might be a closer, dimmer star and a farther, brighter one

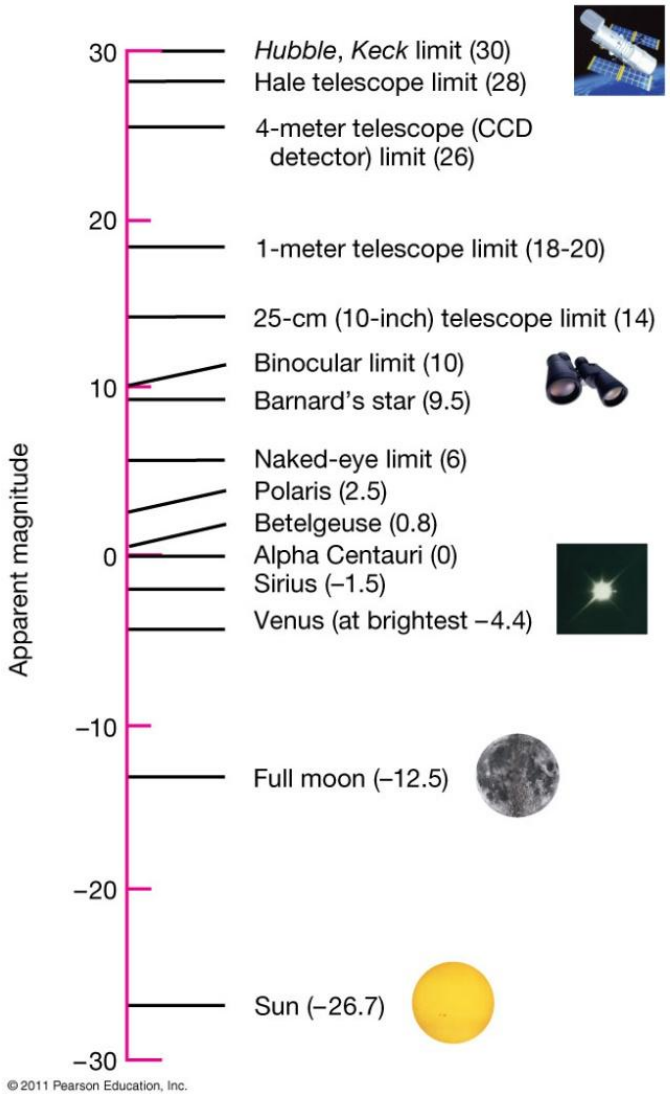


# 17.2 Luminosity and Apparent Brightness

Apparent luminosity is measured using a magnitude scale, which is related to our perception.

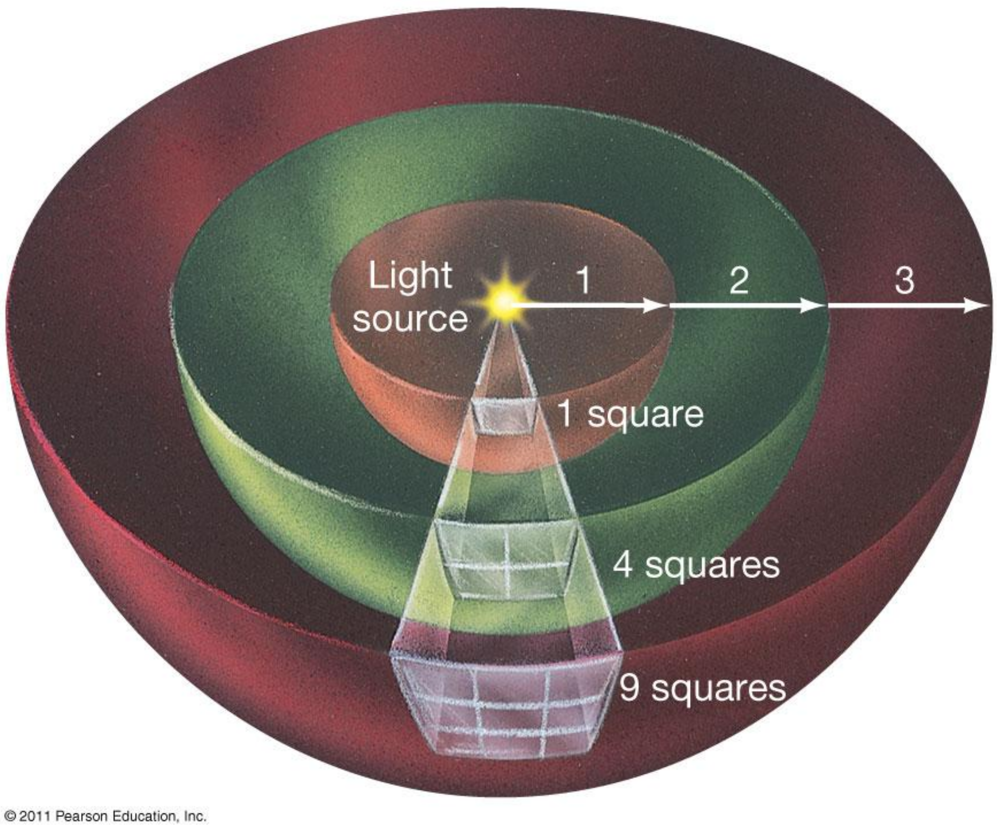
It is a logarithmic scale; a change of 5 in magnitude corresponds to a change of a factor of 100 in apparent brightness.

It is also inverted—larger magnitudes are dimmer.



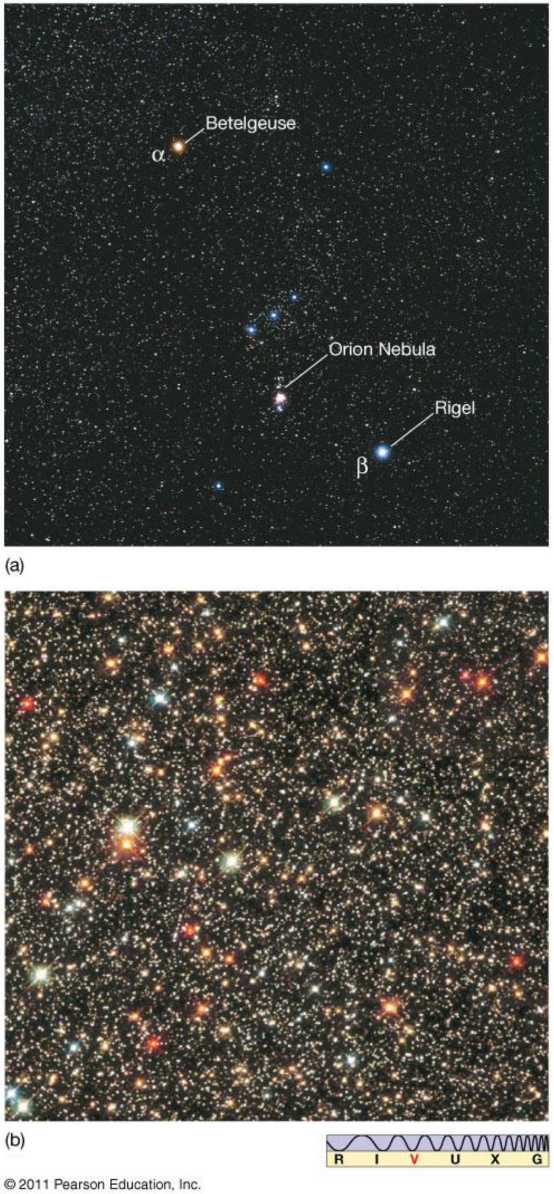
# 17.2 Luminosity and Apparent Brightness

If we know a star's apparent magnitude and its distance from us, we can calculate its absolute luminosity.



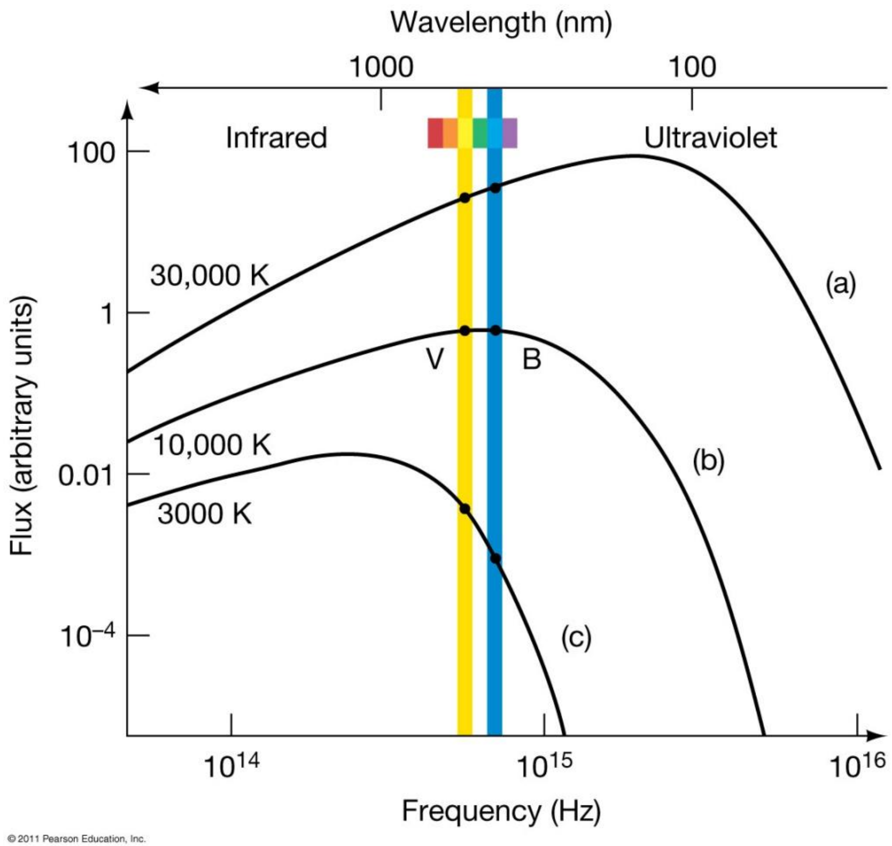
# 17.3 Stellar Temperatures

The color of a star is indicative of its temperature. Red stars are relatively cool, whereas blue ones are hotter.



# 17.3 Stellar Temperatures

The radiation from stars is blackbody radiation; as the blackbody curve is not symmetric, observations at two wavelengths are enough to define the temperature.



# 17.3 Stellar Temperatures

Stellar spectra are much more informative than the blackbody curves.

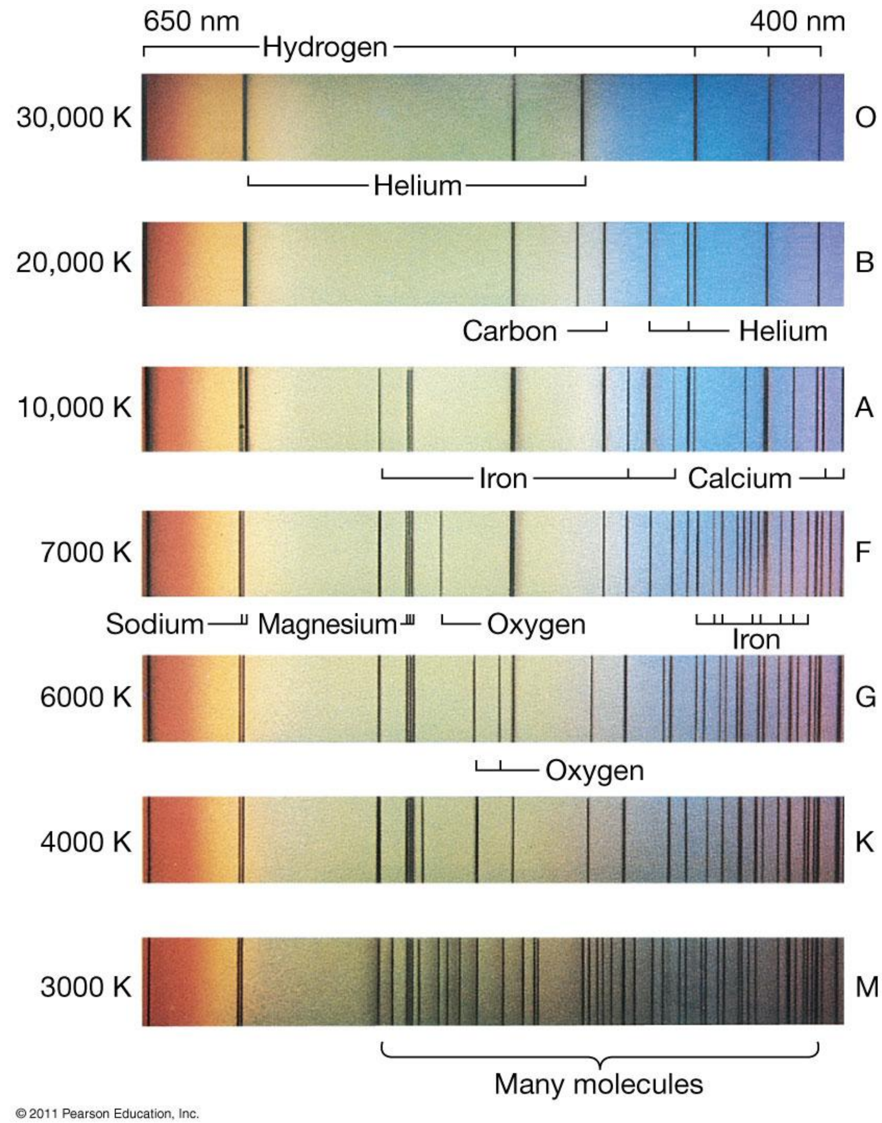
There are seven general categories of stellar spectra, corresponding to different temperatures.

From highest to lowest, those categories are

O B A F G K M

# 17.3 Stellar Temperatures

Here are their spectra



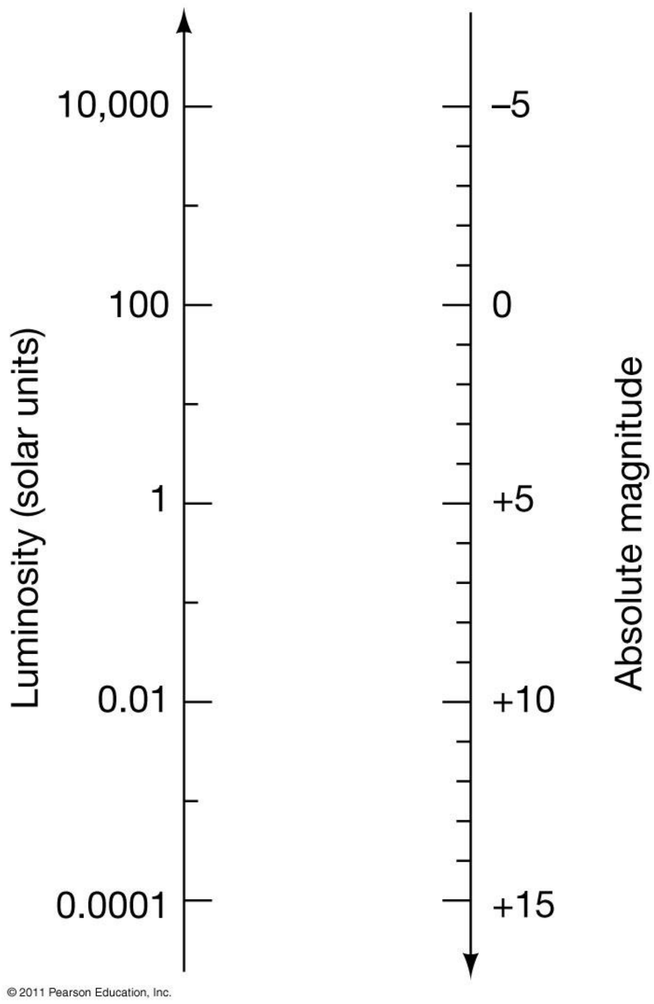
# 17.3 Stellar Temperatures

Characteristics of the spectral classifications

**TABLE 17.2 Stellar Spectral Classes**

| Spectral Class | Approximate Surface Temperature (K) | Noteworthy Absorption Lines | Familiar Examples |
|---|---|---|---|
| O | 30,000 | Ionized helium strong; multiply ionized heavy elements; hydrogen faint | Mintaka (O9) |
| B | 20,000 | Neutral helium moderate; singly ionized heavy elements; hydrogen moderate | Rigel (B8) |
| A | 10,000 | Neutral helium very faint; singly ionized heavy elements; hydrogen strong | Vega (A0), Sirius (A1) |
| F | 7000 | Singly ionized heavy elements; neutral metals; hydrogen moderate | Canopus (F0) |
| G | 6000 | Singly ionized heavy elements; neutral metals; hydrogen relatively faint | Sun (G2), Alpha Centauri (G2) |
| K | 4000 | Singly ionized heavy elements; neutral metals strong; hydrogen faint | Arcturus (K2), Aldebaran (K5) |
| M | 3000 | Neutral atoms strong; molecules moderate; hydrogen very faint | Betelgeuse (M2), Barnard's star (M5) |

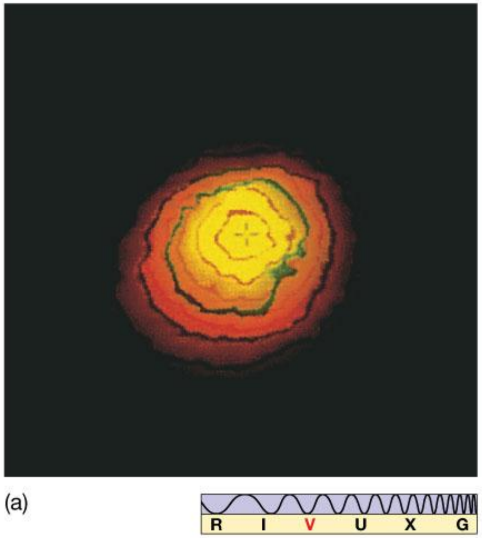
# More Precisely 17-1: More on the Magnitude Scale



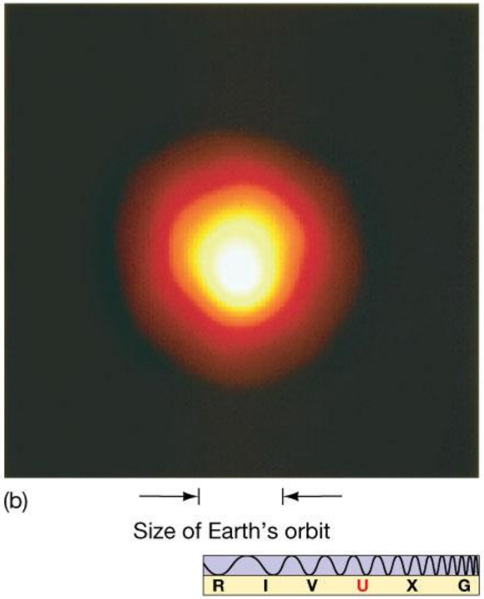

Converting from magnitude to luminosity in solar units: This graph allows us to perform this conversion simply by reading horizontally. A reduction of 5 in magnitude corresponds to an increase in a factor of 100 in luminosity, as it should.

# 17.4 Stellar Sizes

A few very large, very close stars can be imaged directly using speckle interferometry. This is Betelgeuse.



(a)



(b)

# 17.4 Stellar Sizes

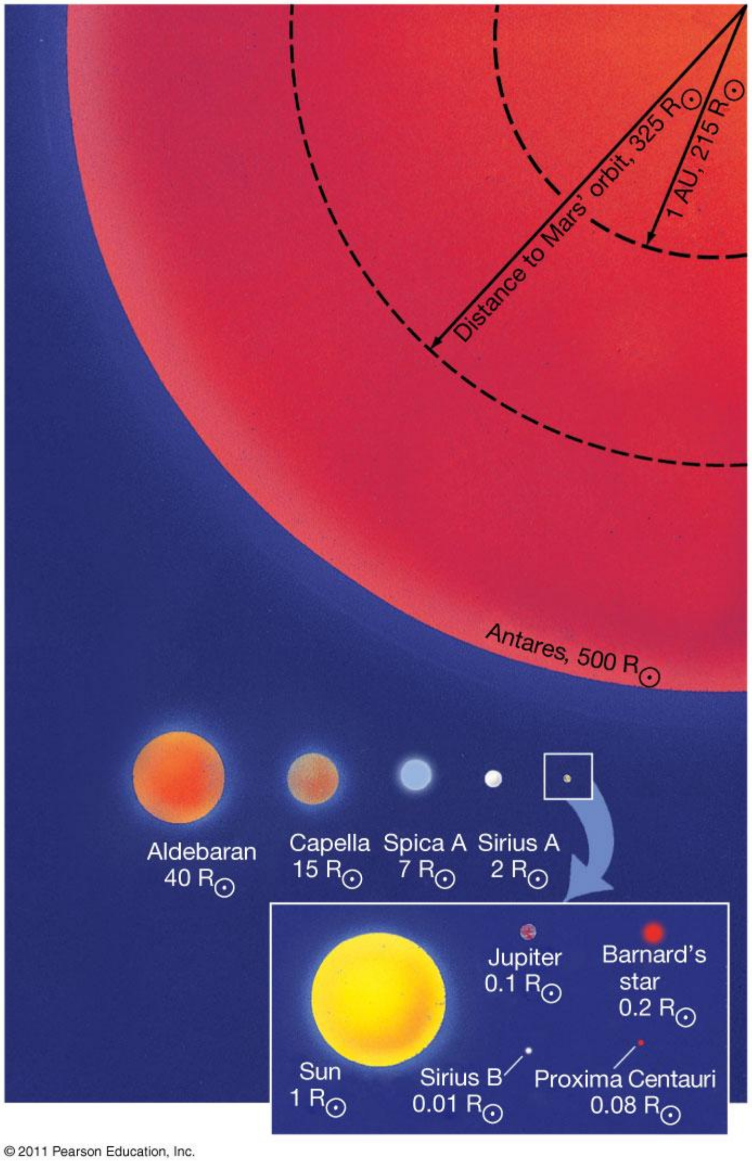
For the vast majority of stars that cannot be imaged directly, size must be calculated knowing the luminosity and temperature

$$\text{luminosity} \propto \text{radius}^2 \times \text{temperature}^4.$$

- Giant stars have radii between 10 and 100 times the Sun's
- Dwarf stars have radii equal to, or less than, the Sun's
- Supergiant stars have radii more than 100 times the Sun's

# 17.4 Stellar Sizes

Stellar radii vary widely



# More Precisely 17-2: Estimating Stellar Radii

Combining the Stefan-Boltzman law for the power per unit area emitted by a blackbody as a function of temperature with the formula for the area of a sphere gives the total luminosity

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

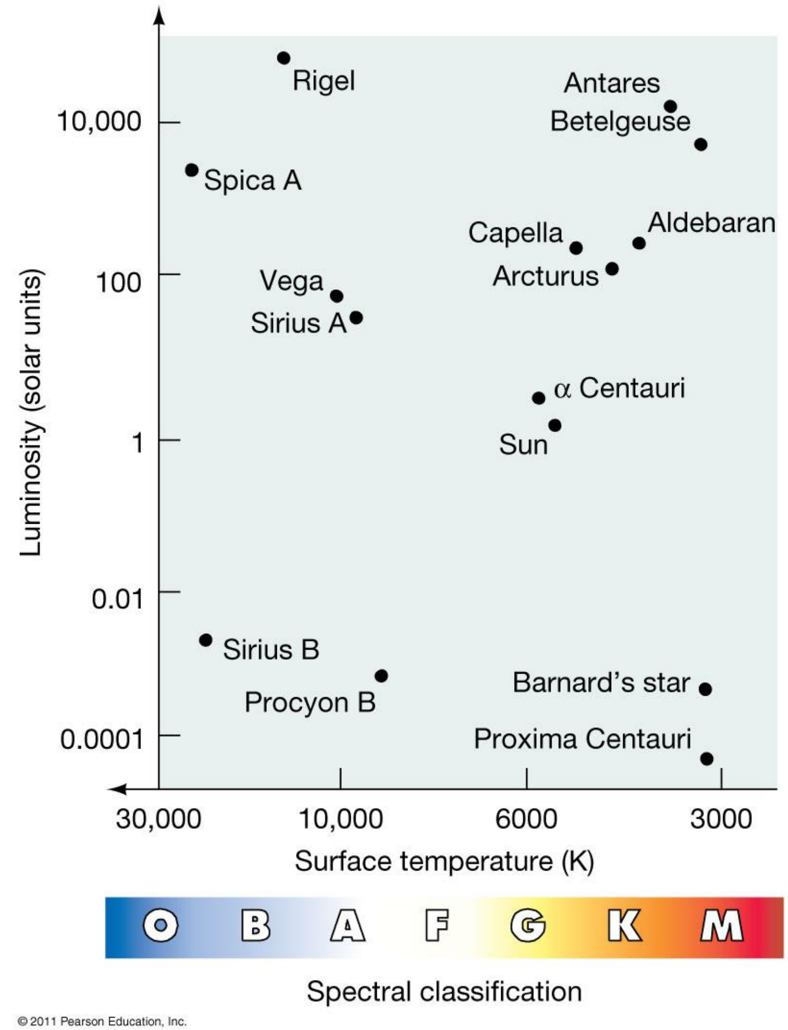
If we measure luminosity, radius, and temperature in solar units, we can write

$$L = R^2 T^4$$

# 17.5 The Hertzsprung–Russell Diagram

The H–R diagram plots stellar luminosity against surface temperature.

This is an H–R diagram of a few prominent stars.



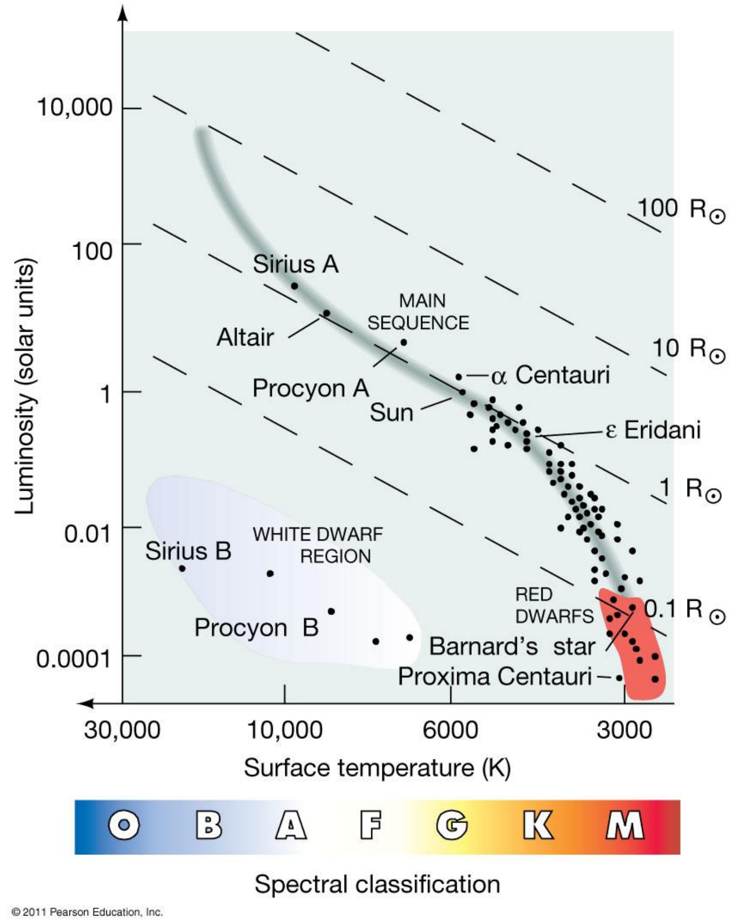
# 17.5 The Hertzsprung–Russell Diagram

Once many stars are plotted on an H–R diagram, a pattern begins to form.

These are the 80 closest stars to us; note the dashed lines of constant radius.

The darkened curve is called the main sequence, as this is where most stars are.

Also indicated is the white dwarf region; these stars are hot but not very luminous, as they are quite small.

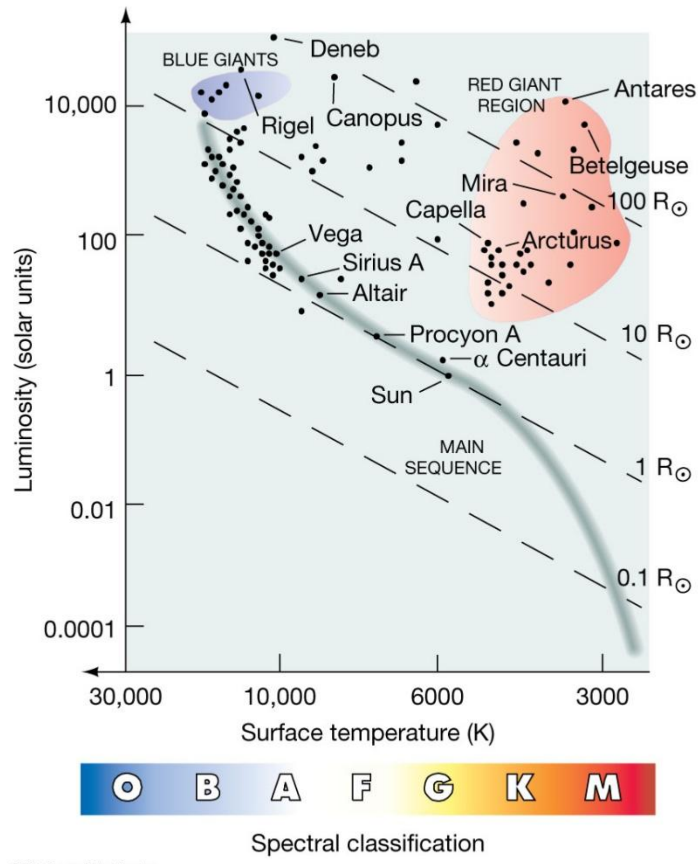


# 17.5 The Hertzsprung–Russell Diagram

An H–R diagram of the 100 brightest stars looks quite different.

These stars are all more luminous than the Sun. Two new categories appear here—the red giants and the blue giants.

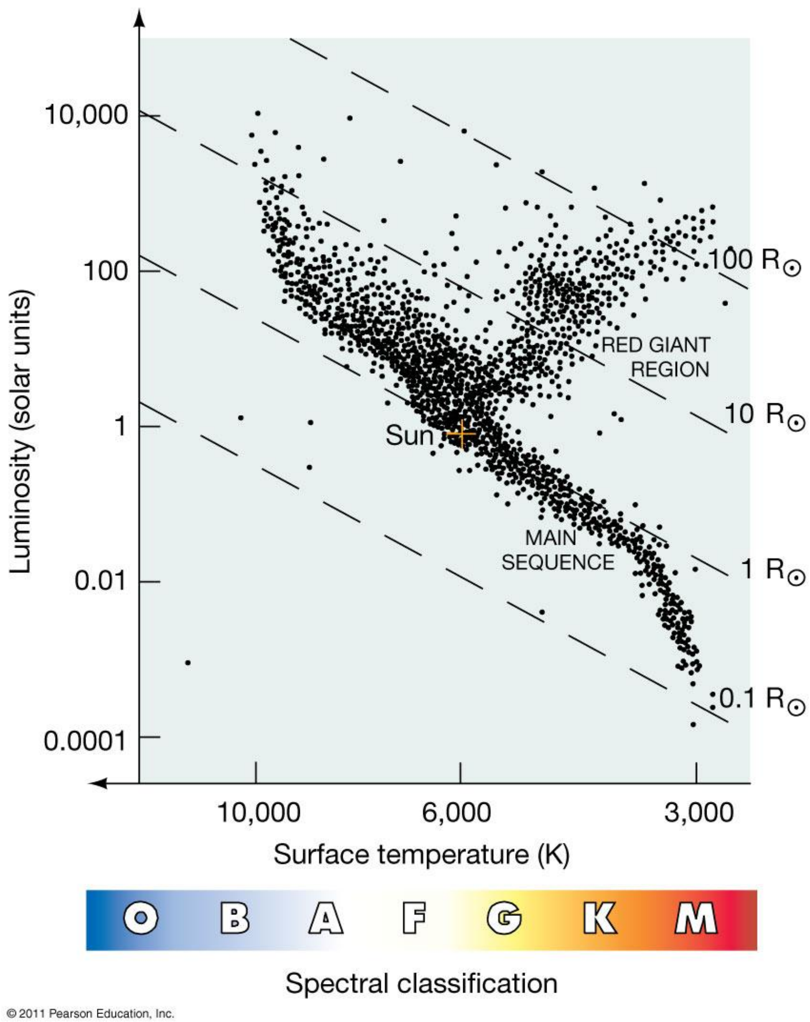
Clearly, the brightest stars in the sky appear bright because of their enormous luminosities, not their proximity.



# 17.5 The Hertzsprung–Russell Diagram

This is an H–R plot of about 20,000 stars. The main sequence is clear, as is the red giant region.

About 90% of stars lie on the main sequence; 9% are red giants and 1% are white dwarfs.



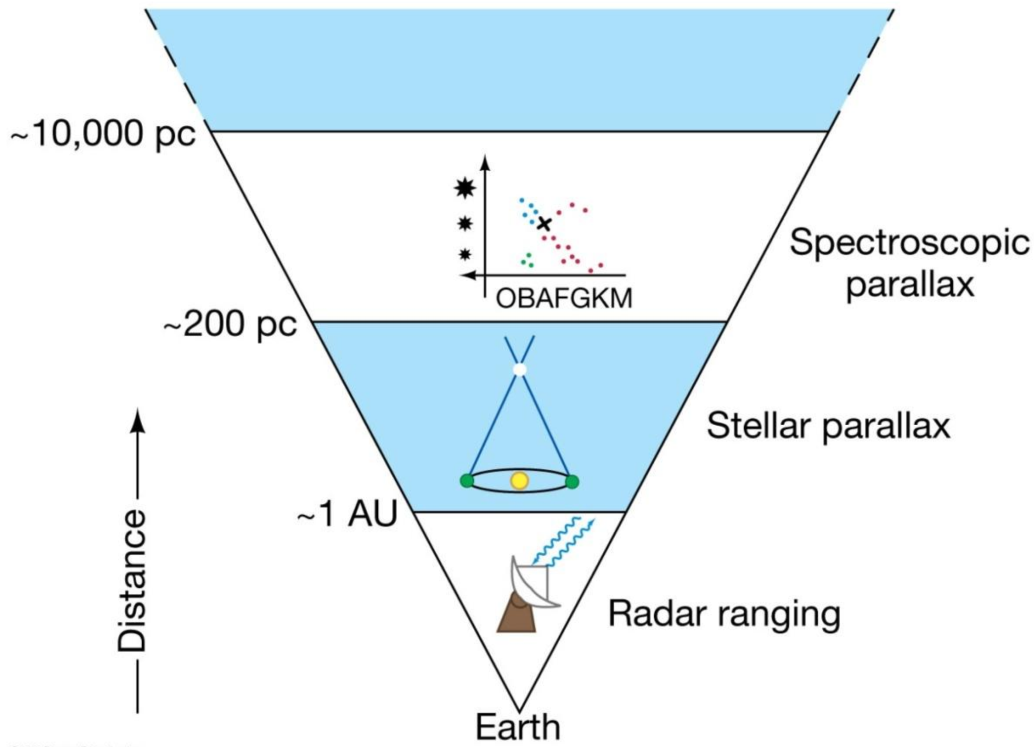
# 17.6 Extending the Cosmic Distance Scale

Spectroscopic parallax: Has nothing to do with parallax, but does use spectroscopy in finding the distance to a star.

1. Measure the star's apparent magnitude and spectral class
2. Use spectral class to estimate luminosity
3. Apply inverse-square law to find distance

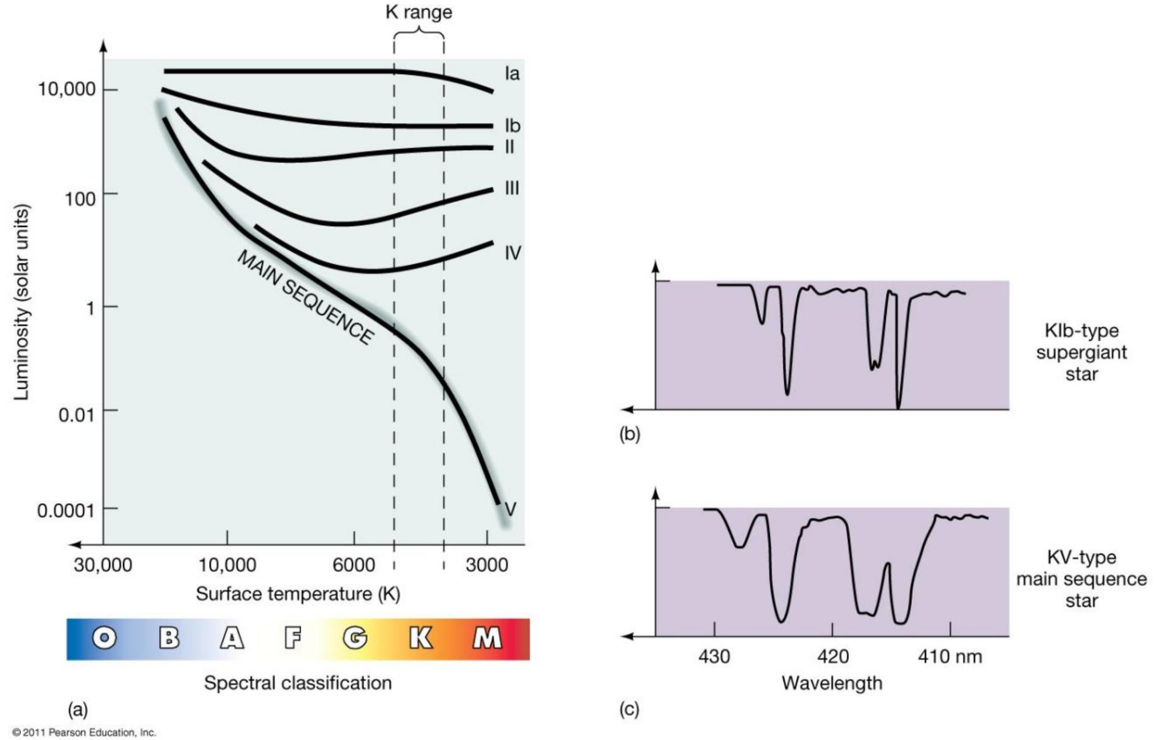
# 17.6 Extending the Cosmic Distance Scale

Spectroscopic parallax can extend the cosmic distance scale to several thousand parsecs



# 17.6 Extending the Cosmic Distance Scale

The spectroscopic parallax calculation can be misleading if the star is not on the main sequence. The width of spectral lines can be used to define luminosity classes.



# 17.6 Extending the Cosmic Distance Scale

In this way, giants and supergiants can be distinguished from main-sequence stars

**TABLE 17.4 Variation in Stellar Properties within a Spectral Class**

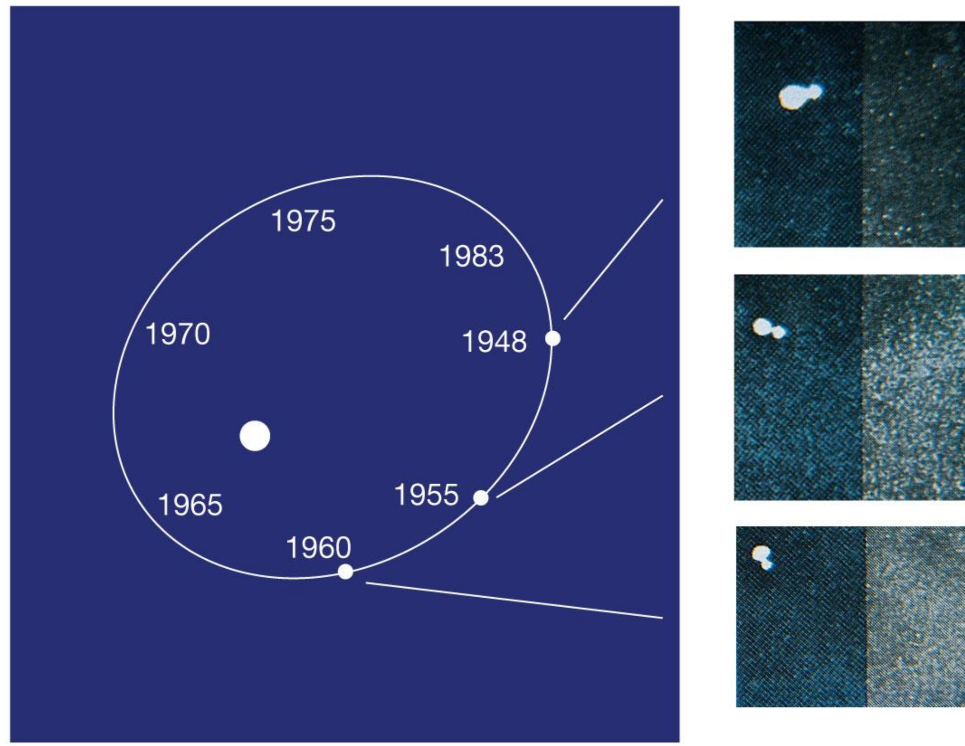
| Approximate Surface Temperature (K) | Luminosity (solar luminosities) | Radius (solar radii) | Object | Example |
|---|---|---|---|---|
| 4900 | 0.3 | 0.8 | K2V main-sequence star | ε Eridani |
| 4500 | 110 | 21 | K2III red giant | Arcturus |
| 4300 | 4000 | 140 | K2Ib red supergiant | ε Pegasi |

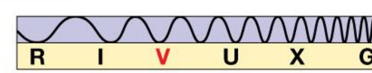
# 17.7 Stellar Masses

Determination of stellar masses:

Many stars are in binary pairs; measurement of their orbital motion allows determination of the masses of the stars.

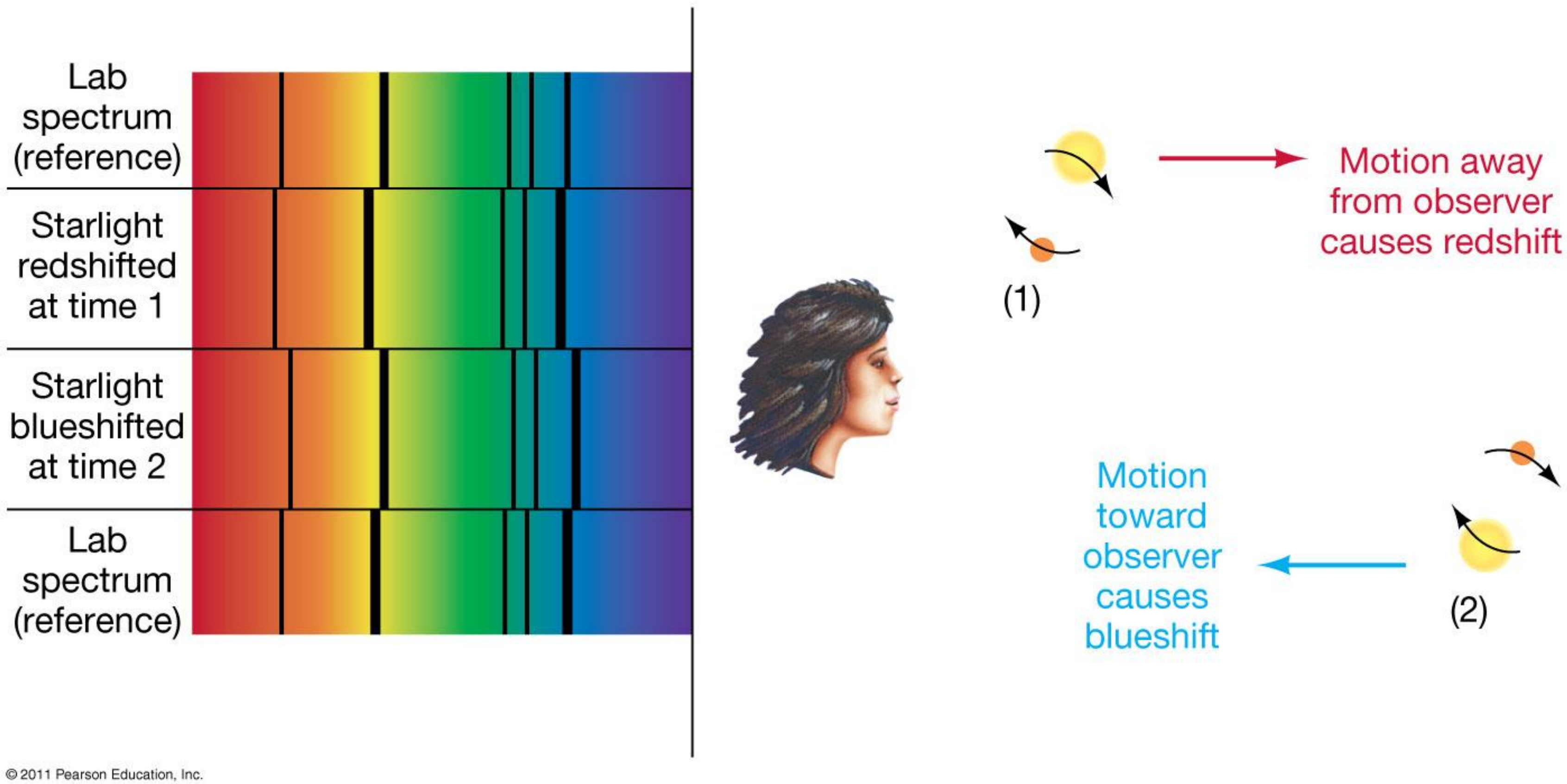
Visual binaries can be measured directly. This is Kruger 60.



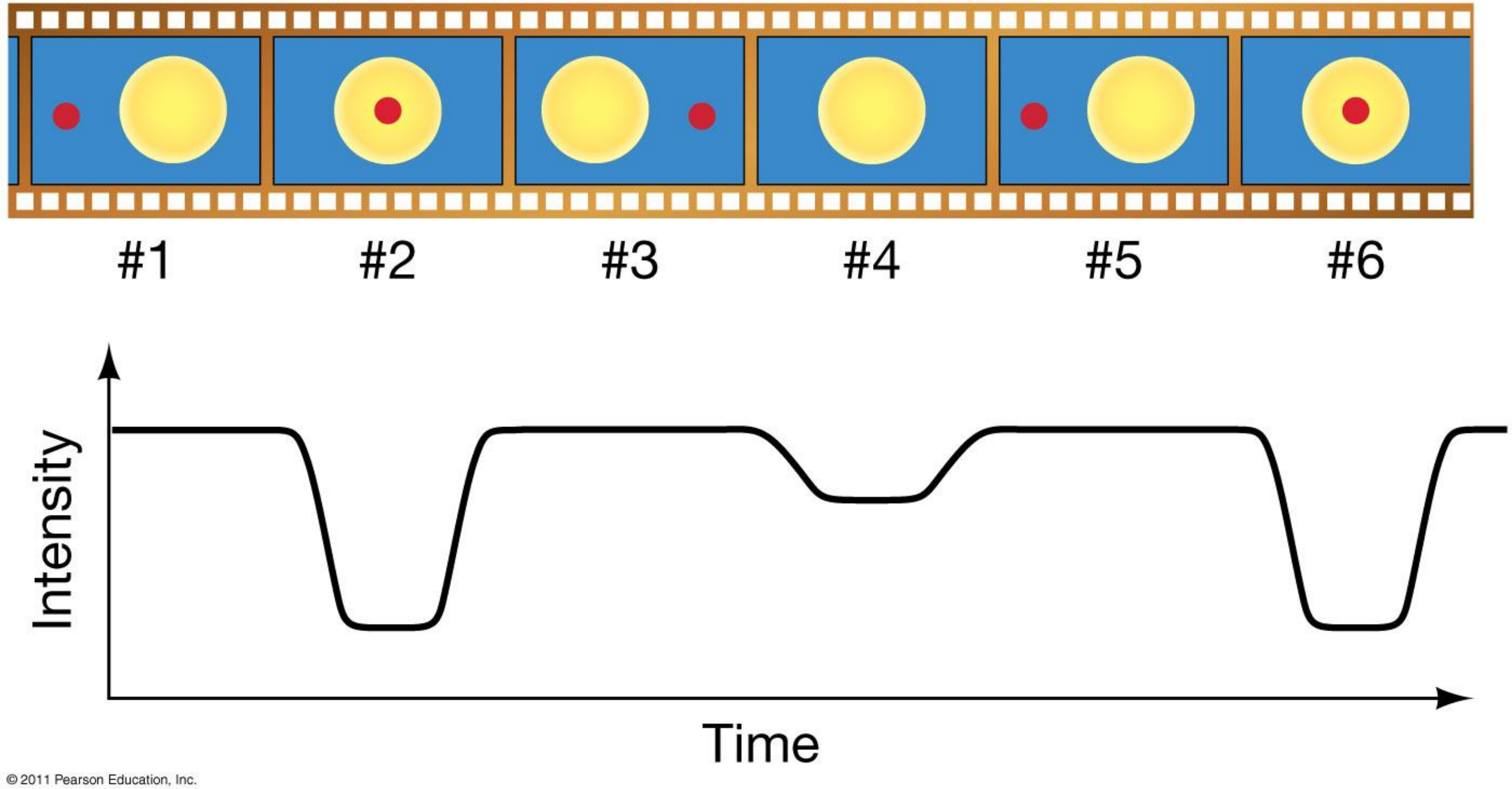
# 17.7 Stellar Masses

Spectroscopic binaries can be measured using their Doppler shifts



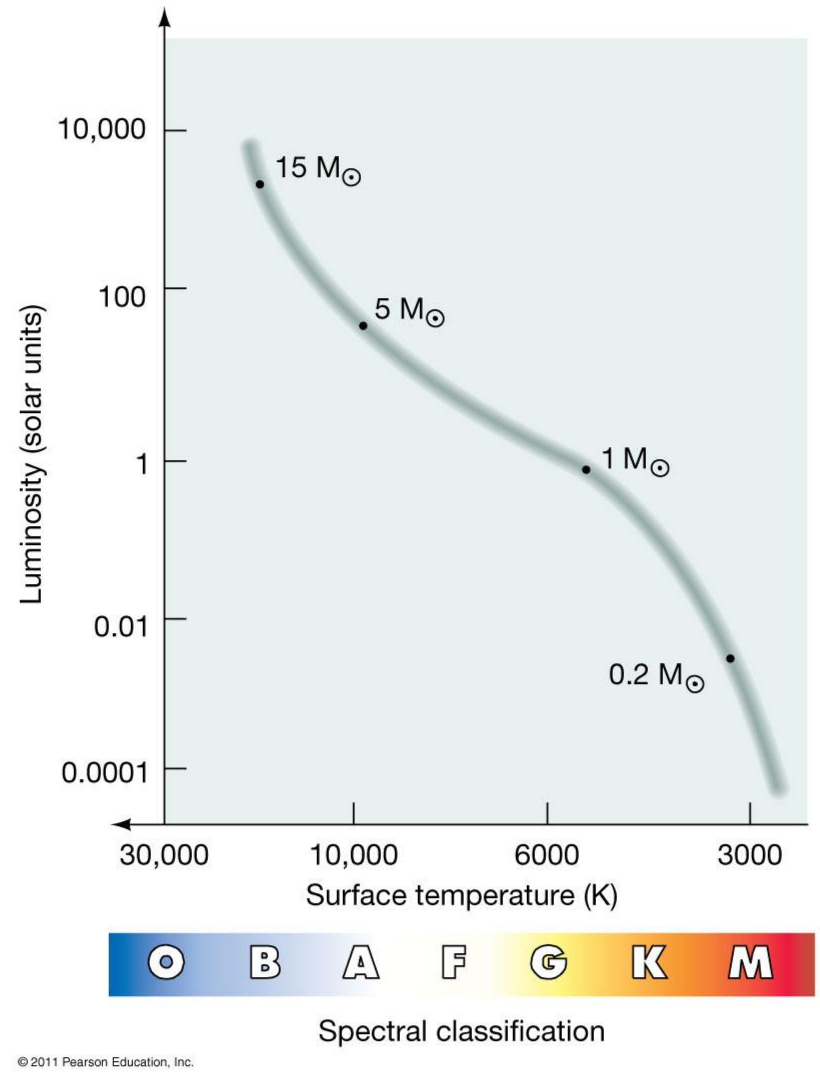
# 17.7 Stellar Masses

Finally, eclipsing binaries can be measured using the changes in luminosity



# 17.7 Stellar Masses

Mass is the main determinant of where a star will be on the main sequence

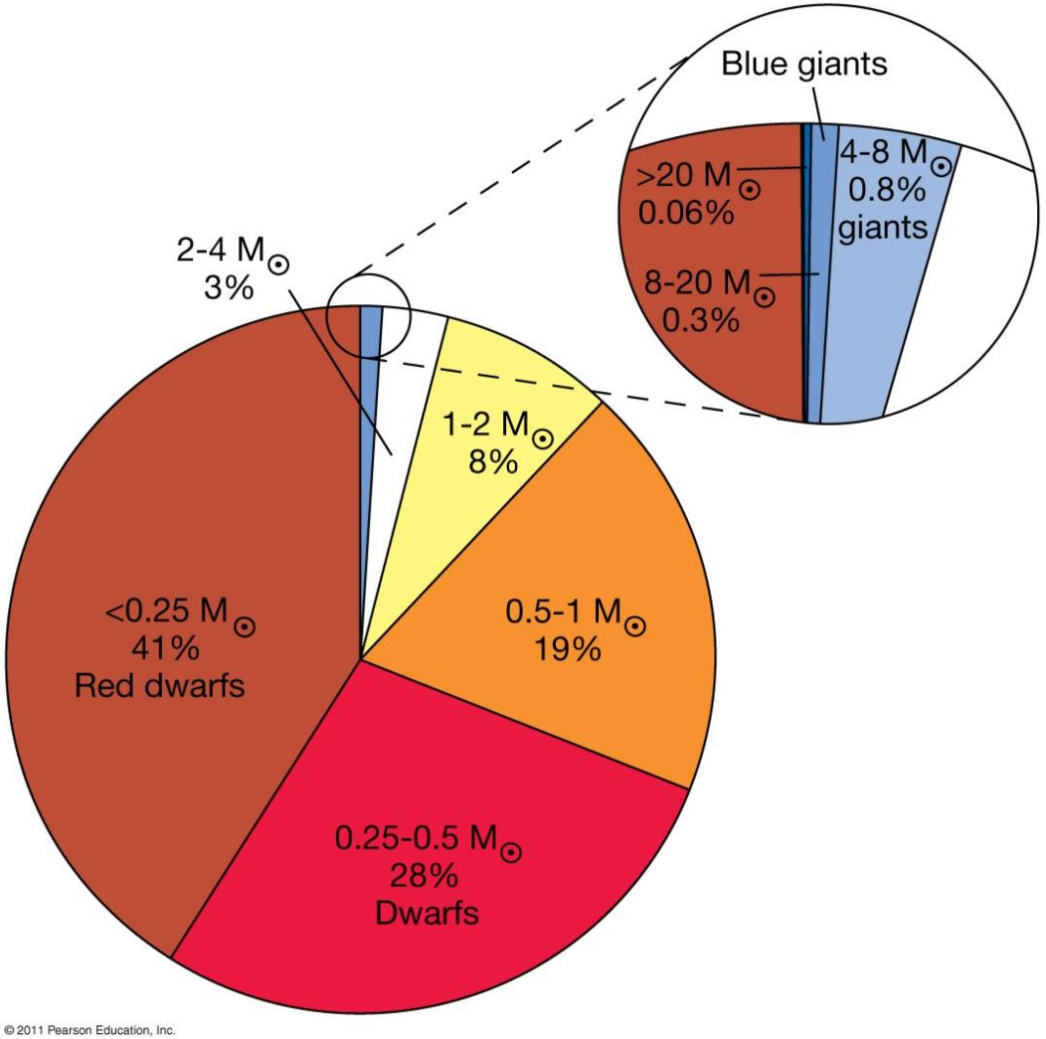


# More Precisely 17-3: Measuring Stellar Masses in Binary Stars

In order to measure stellar masses in a binary star, the period and semimajor axis of the orbit must be measured. Once this is done, Kepler’s third law gives the sum of the masses of the two stars. Then the relative speeds of the two stars can be measured using the Doppler effect; the speed will be inversely proportional to the mass. This allows us to calculate the mass of each star.

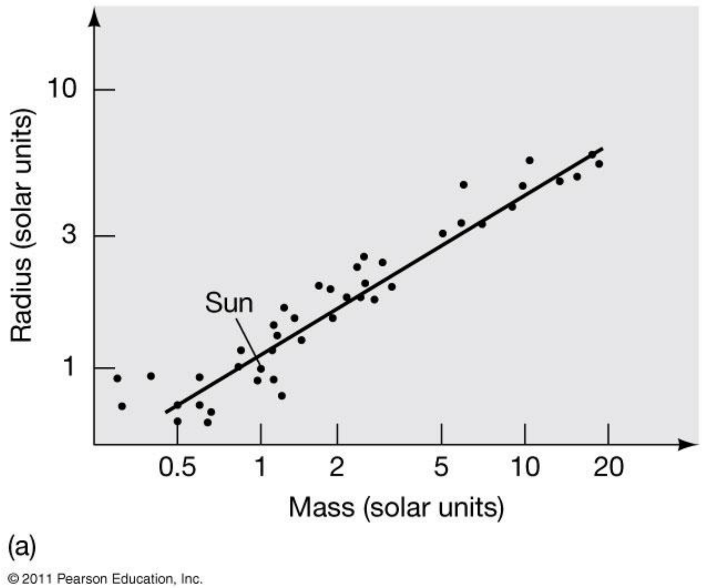
# 17.8 Mass and Other Stellar Properties

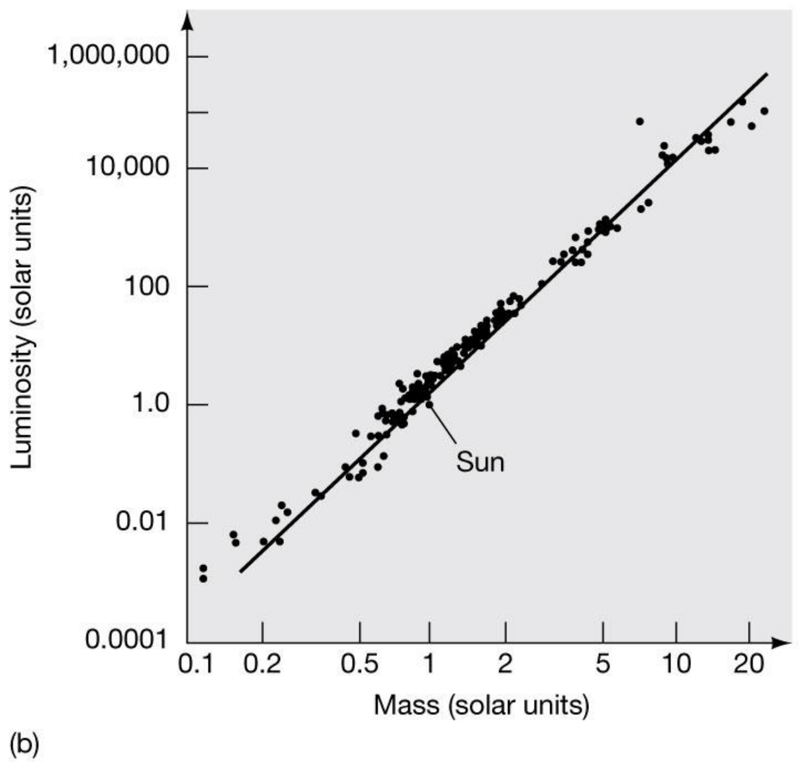
This pie chart shows the distribution of stellar masses. The more massive stars are much rarer than the least massive.



# 17.8 Mass and Other Stellar Properties

Mass is correlated with radius and is very strongly correlated with luminosity



# 17.8 Mass and Other Stellar Properties

Mass is also related to stellar lifetime

$$\text{stellar lifetime} \propto \frac{\text{stellar mass}}{\text{stellar luminosity}}.$$

Using the mass–luminosity relationship

$$\text{stellar lifetime} \propto \frac{1}{(\text{stellar mass})^3}.$$

# 17.8 Mass and Other Stellar Properties

So the most massive stars have the shortest lifetimes—they have a lot of fuel but burn it at a very rapid pace.

On the other hand, small red dwarfs burn their fuel extremely slowly and can have lifetimes of a trillion years or more.

# Summary of Chapter 17

- Can measure distances to nearby stars using parallax
- Apparent magnitude is related to apparent brightness
- Absolute magnitude is a measure of the power output of the star
- Spectral analysis has led to the defining of seven spectral classes of stars
- Stellar radii can be calculated if distance and luminosity are known

# Summary of Chapter 17 (cont.)

- In addition to “normal” stars, there are also red giants, red supergiants, blue giants, blue supergiants, red dwarfs, and white dwarfs
- Luminosity class can distinguish giant star from main-sequence one in the same spectral class
- If spectrum is measured, can find luminosity; combining this with apparent brightness allows distance to be calculated

# Summary of Chapter 17 (cont.)

- Measurements of binary-star systems allow stellar masses to be measured directly

- Mass is well correlated with radius and luminosity

- Stellar lifetimes depend on mass; the more the mass, the shorter the lifetime