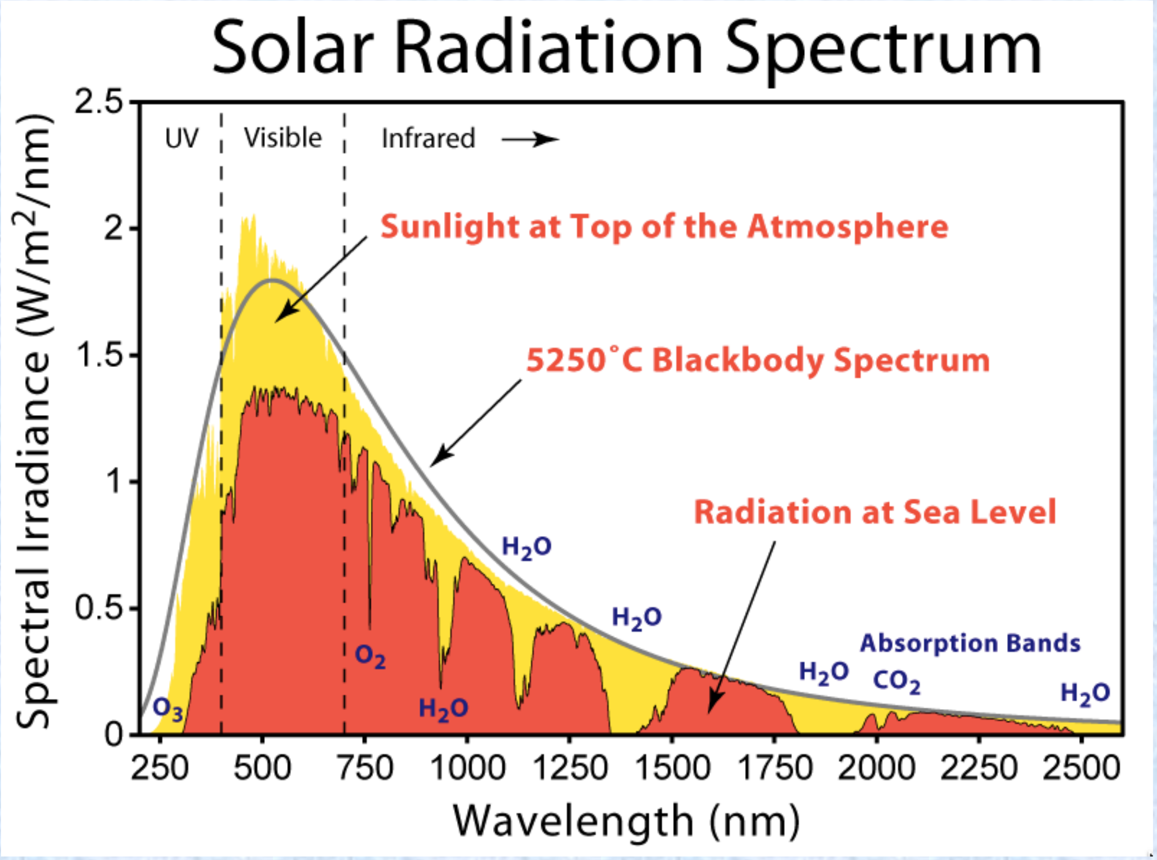
Astronomy 1 – Fall 2019



Announcement: See slide from last time about preparing for the midterm.

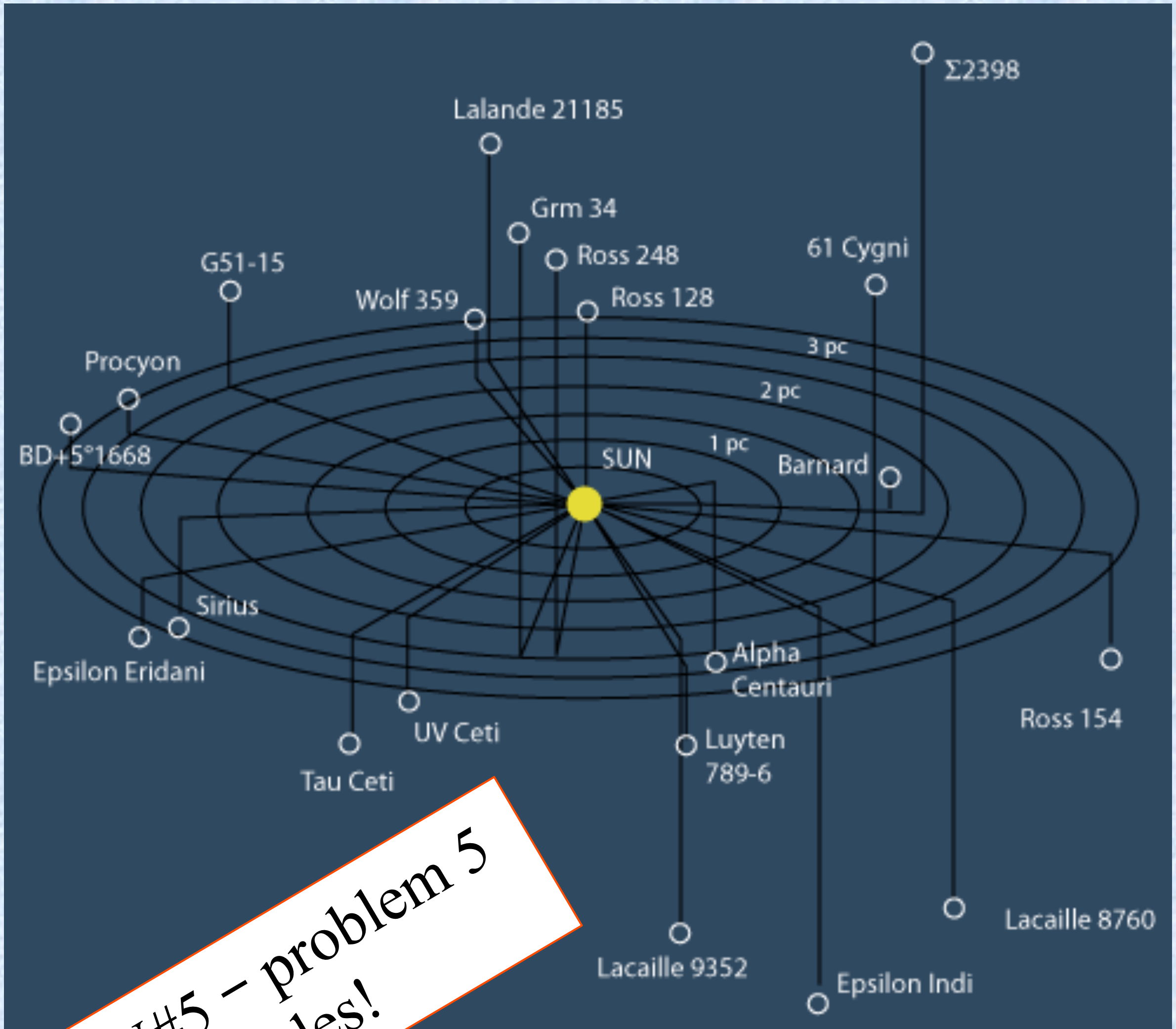
Previously on Astro-1

- What holds the Sun up?
- Why does the Sun shine?
- How long will it shine?
- How does the energy get out of the Sun?

Today on Astro 1

- The luminosity of a star can be measured two ways:
  - From its brightness and distance
  - From its surface temperature and radius
- Stars come in a wide variety of colors and sizes.
  - Color describes the surface temperature.
  - The surface temperature determines the spectral type.
  - Is our Sun a typical star?
- Stellar mass
  - Is measured from orbiting pairs of stars.
  - Determines the luminosity and lifetime of a star
  - The HR Diagram

The Closest Stars



HW#5 – problem 5 Magnitudes!

Put it in perspective.

Remember, distance determines luminosity after you measure intensity.

And ask how do we know the distance to these stars?

HW#5 – problem 4 (11.17.7) Proper motion of Kaptyen's star is 8.67 "/year

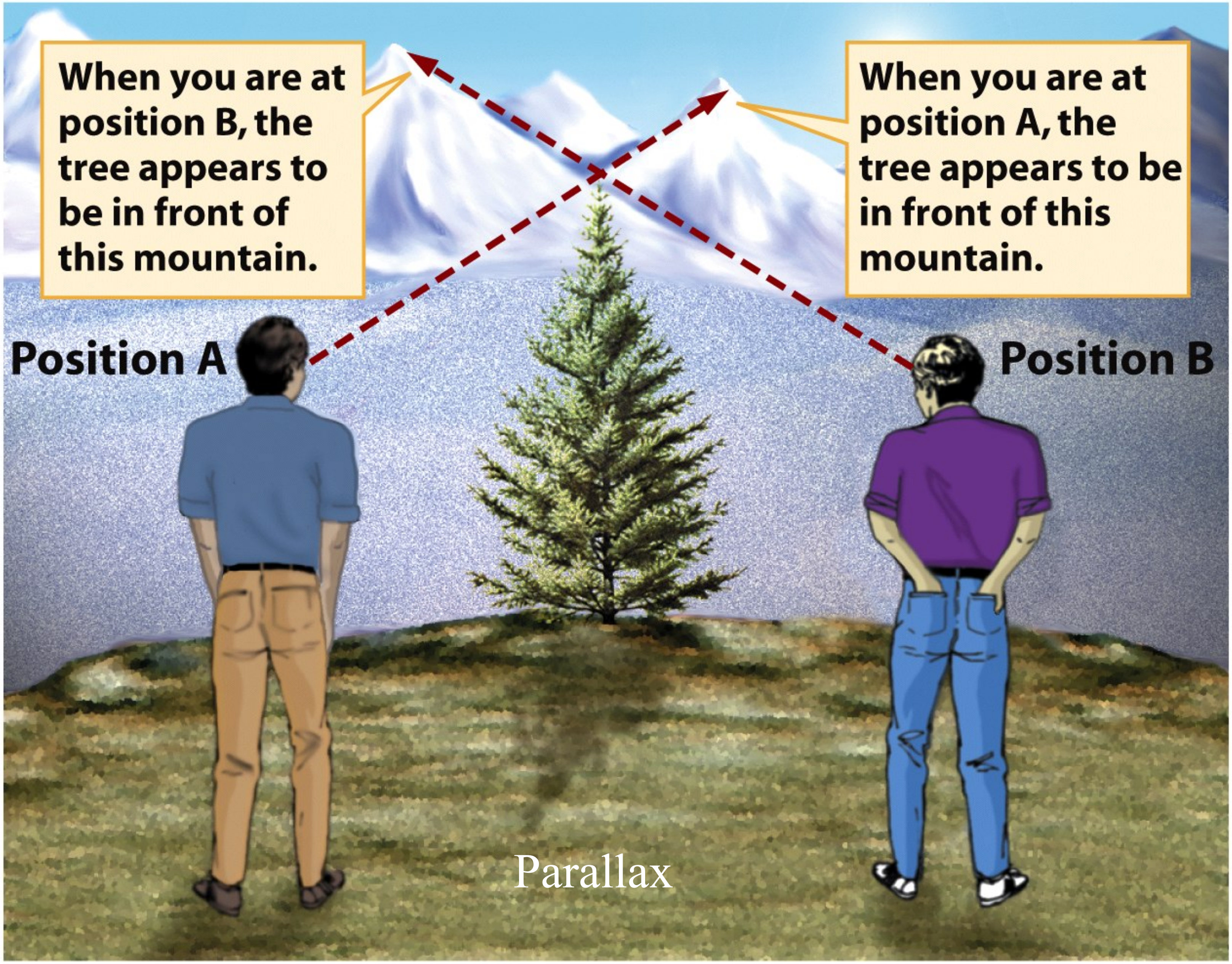
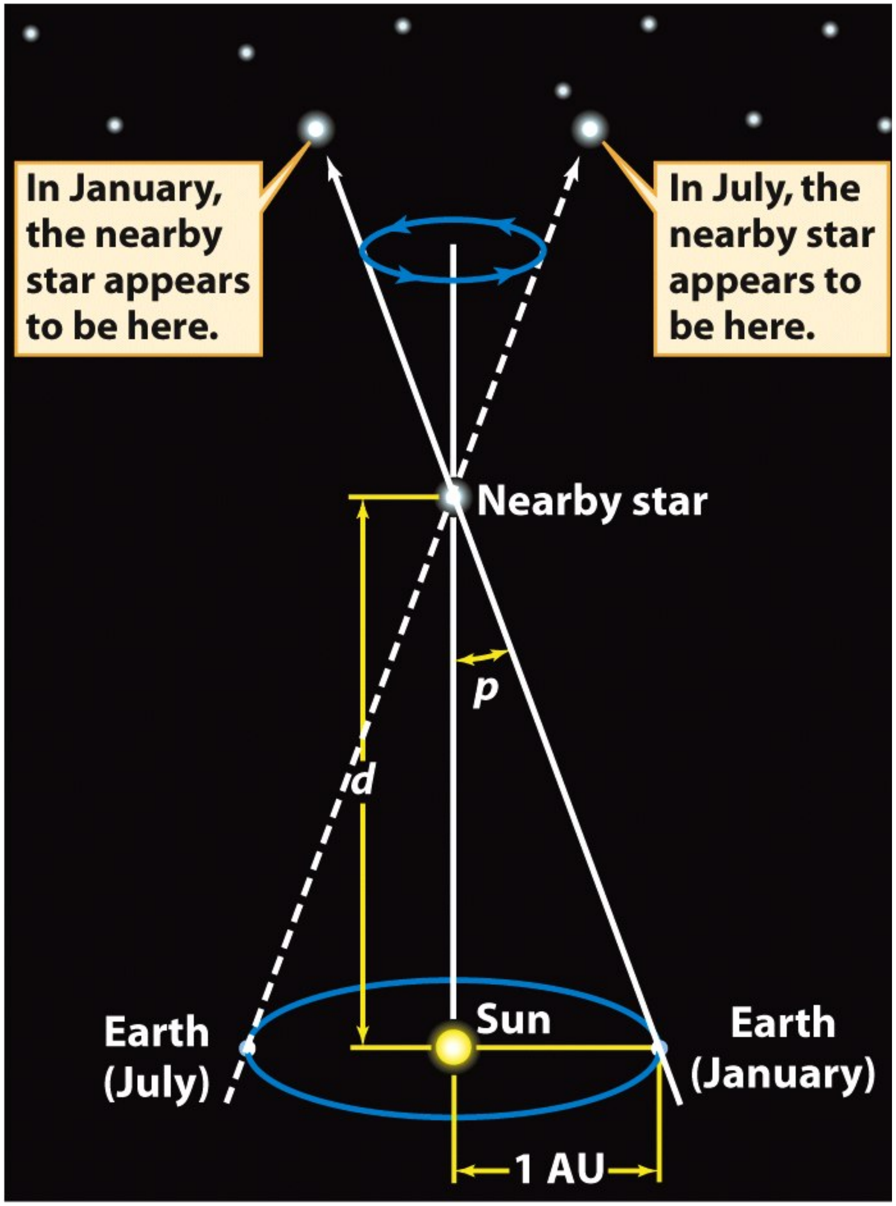
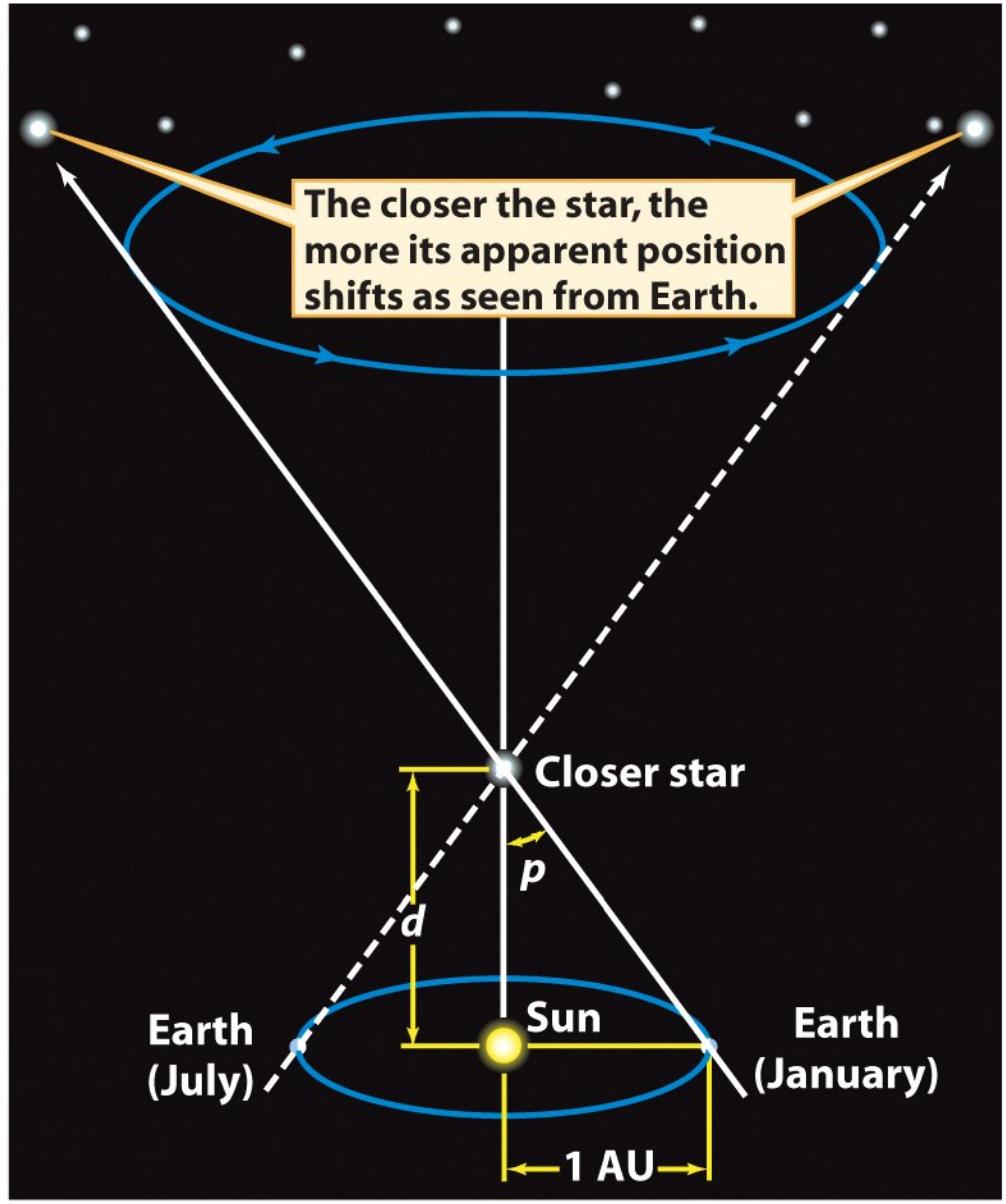


Figure 17-1
Universe, Eighth Edition



Parallax of a nearby star

Figure 17-2a
Universe, Eighth Edition

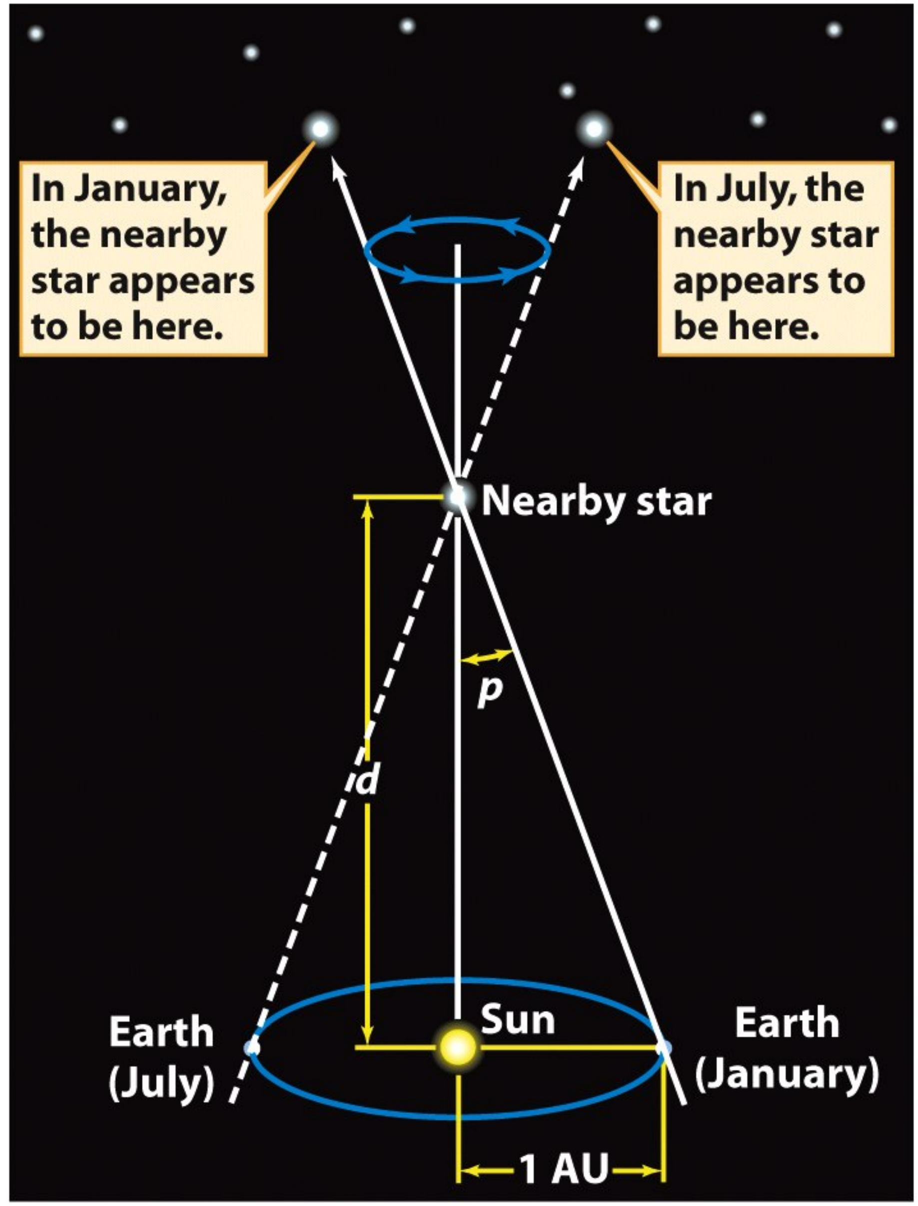


Parallax of an even closer star

Figure 17-2b
Universe, Eighth Edition

Remember 1 pc is the distance at which 1 AU subtends 1 arcsec

1 pc = 3.26 ly



Parallax of a nearby star

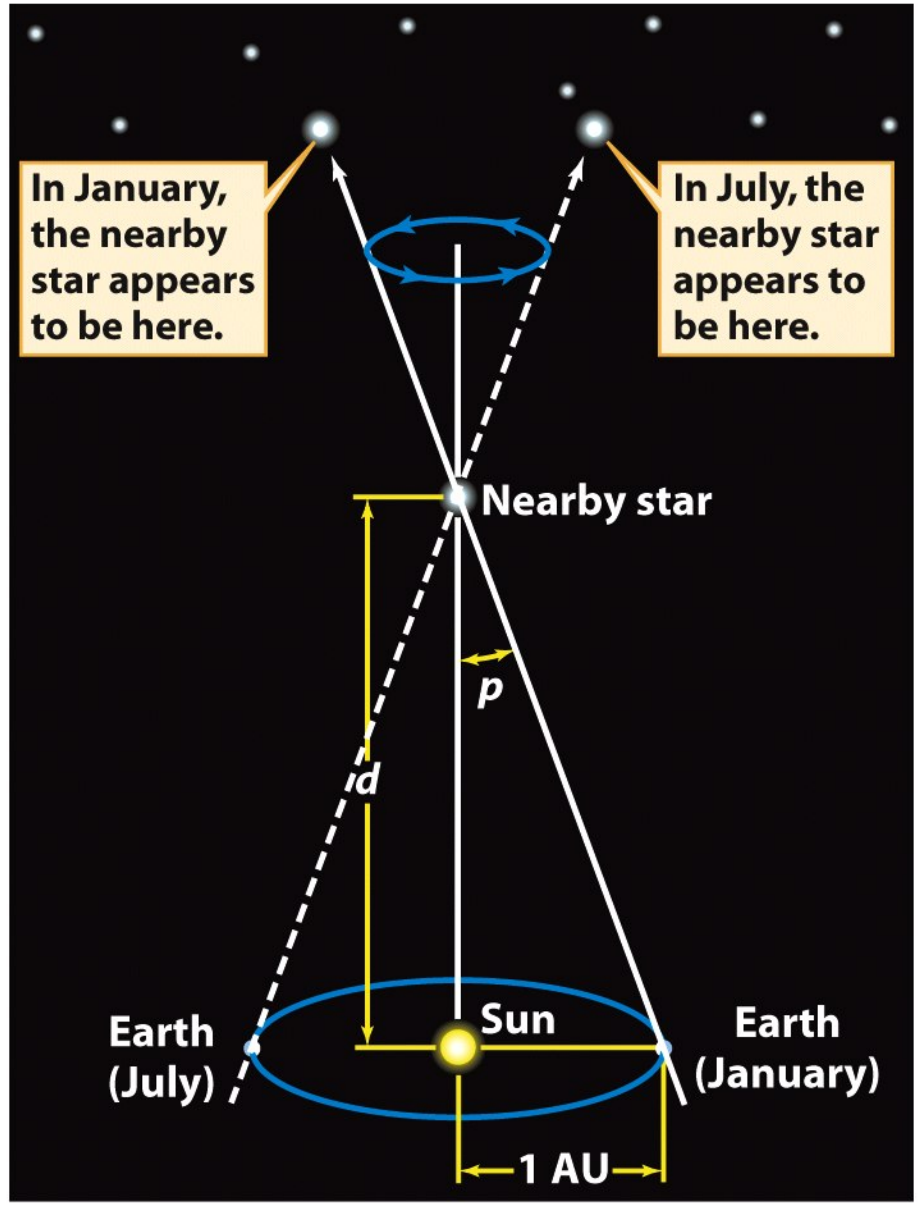
Figure 17-2a
Universe, Eighth Edition

Example: Measuring the distance to a star

A star has a parallax of 0.1”. What is its distance?

d = 1 pc / p (arcseconds)
p = parallax in arcsec
d = distance in parsecs

$$d = 1 \ / \ 0.1$$
$$= 10 \text{ pc}$$



Parallax of a nearby star

Figure 17-2a
Universe, Eighth Edition

Question (iclickers!)

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?

HINT: d = 1 pc / p (arcseconds)

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

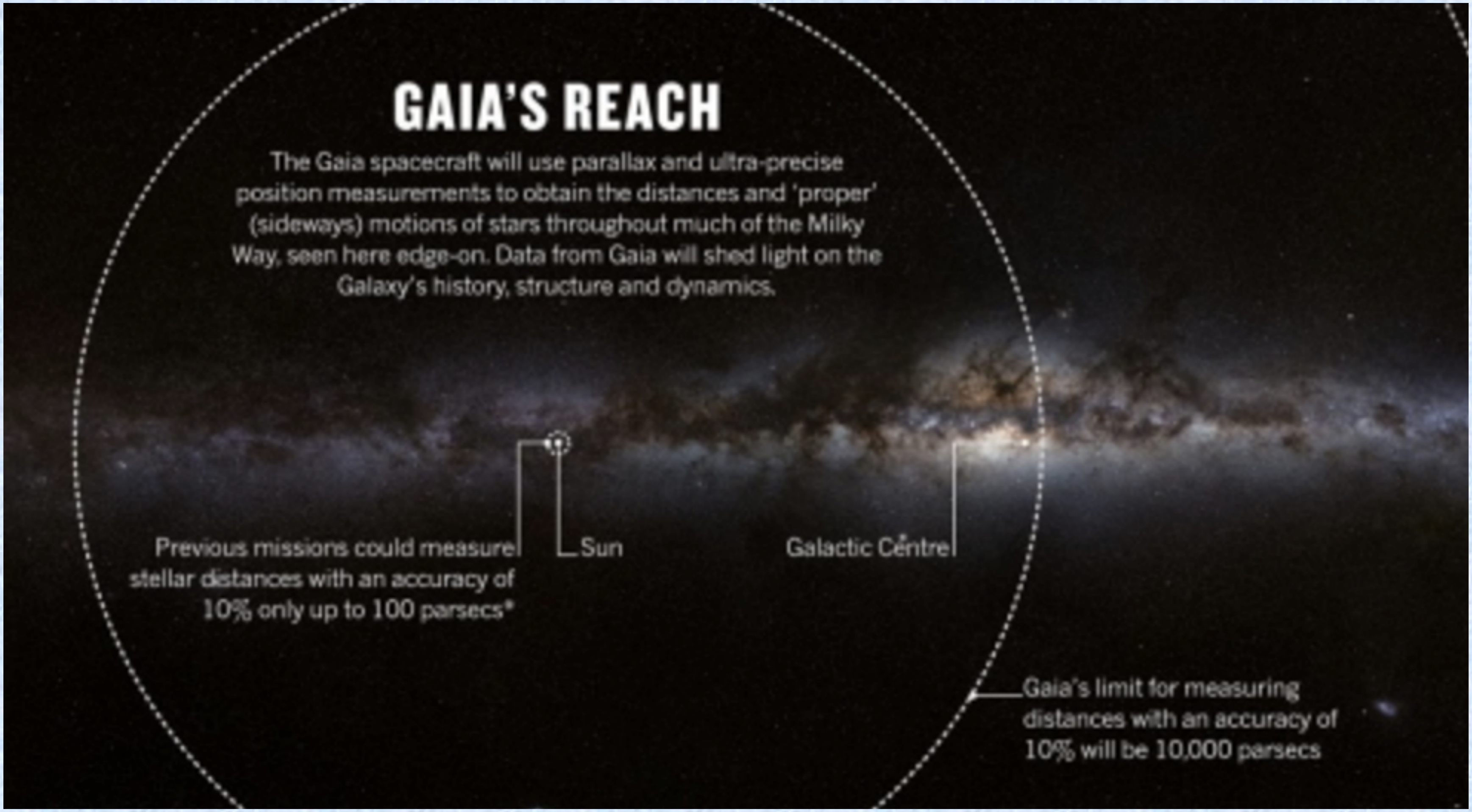
Question (iclickers!)

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?

HINT: d = 1 pc / p (arcseconds)

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

State of the Art Parallax Measurements: d = 10,000 pc OR p = 10^{-4} arcseconds



Question (iclickers!)

•At the distance of the Earth from the Sun (1 AU) the intensity of sunlight is 1370 watts/m^2. What is the intensity at the distance of Saturn from the Sun (10 AU)?

A. 13,700 watts/m^2

B. 1370 watts/m^2

C. 137 watts/m^2

D. 13.7 watts/m^2

Question (iclickers!)

- At the distance of the Earth from the Sun (1 AU) the intensity of sunlight is 1370 watts/m^2. What is the intensity at the distance of Saturn from the Sun (10 AU)?

A. 13,700 watts/m^2
B. 1370 watts/m^2
C. 137 watts/m^2
D. 13.7 watts/m^2

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 $d = 1$.

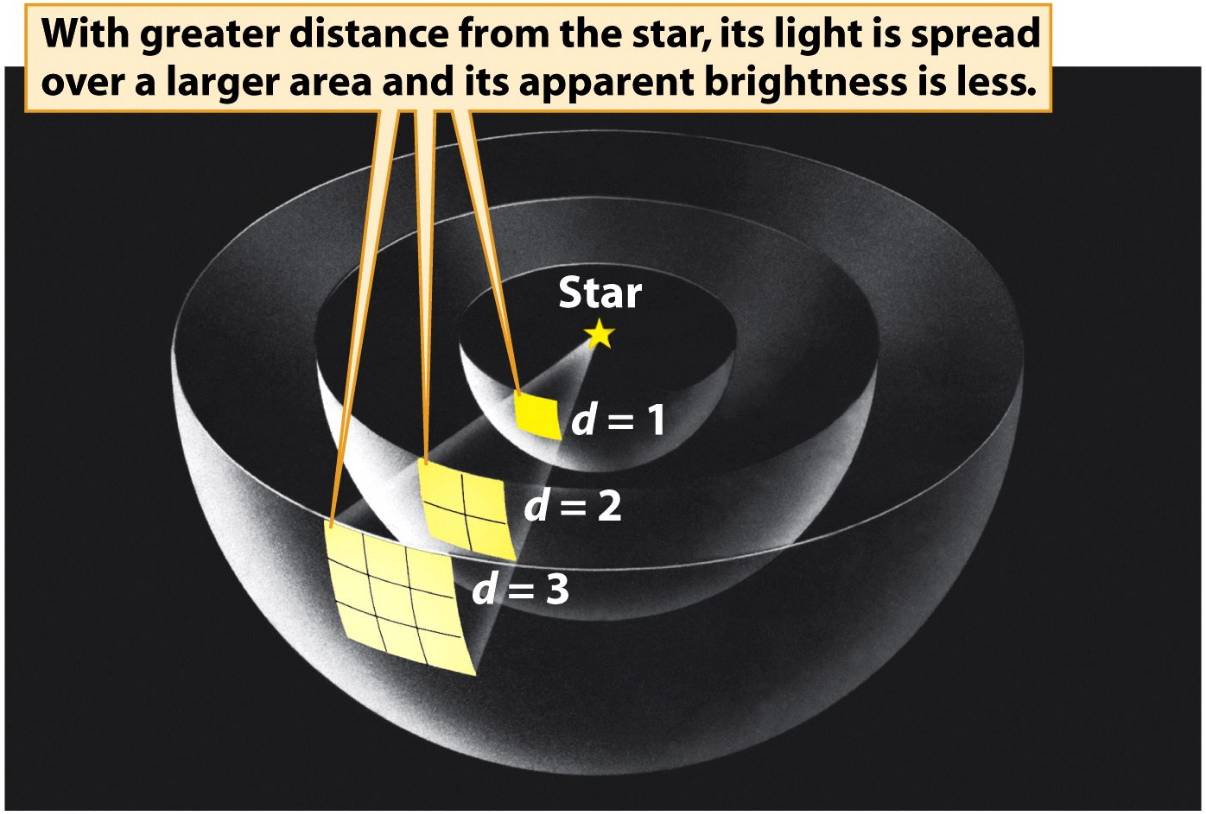


Figure 17-4
Universe, Eighth Edition

Measuring the luminosity of a star

- A star may appear faint because it emits little light, but a very luminous source at a great distance will also appear faint.
- Likewise, a flashlight is bright when held at the tip of your nose. And a supernova will be bright even it occurs on the other side of our Galaxy.
- Knowing the distance makes it possible to calculate luminosity from the observed brightness of the light.

$$\mathbf{L = 4\pi d^2 \times b}$$

b = brightness of star as we see it (joules per second per square meter)

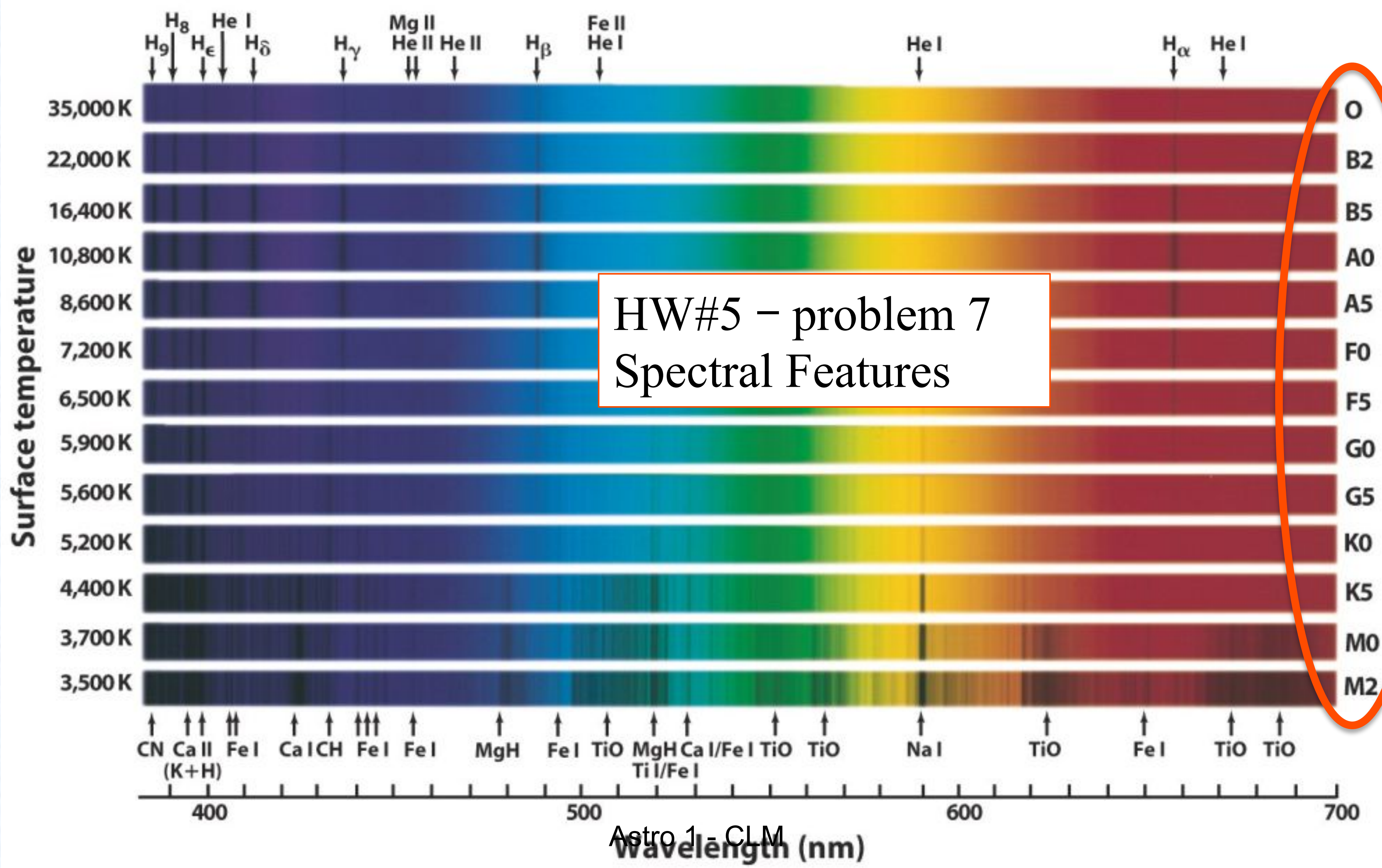
L = luminosity of star (watts, or joules per second)

d = distance to star (meters)

Effective Temperature

Measuring a star's surface temperature

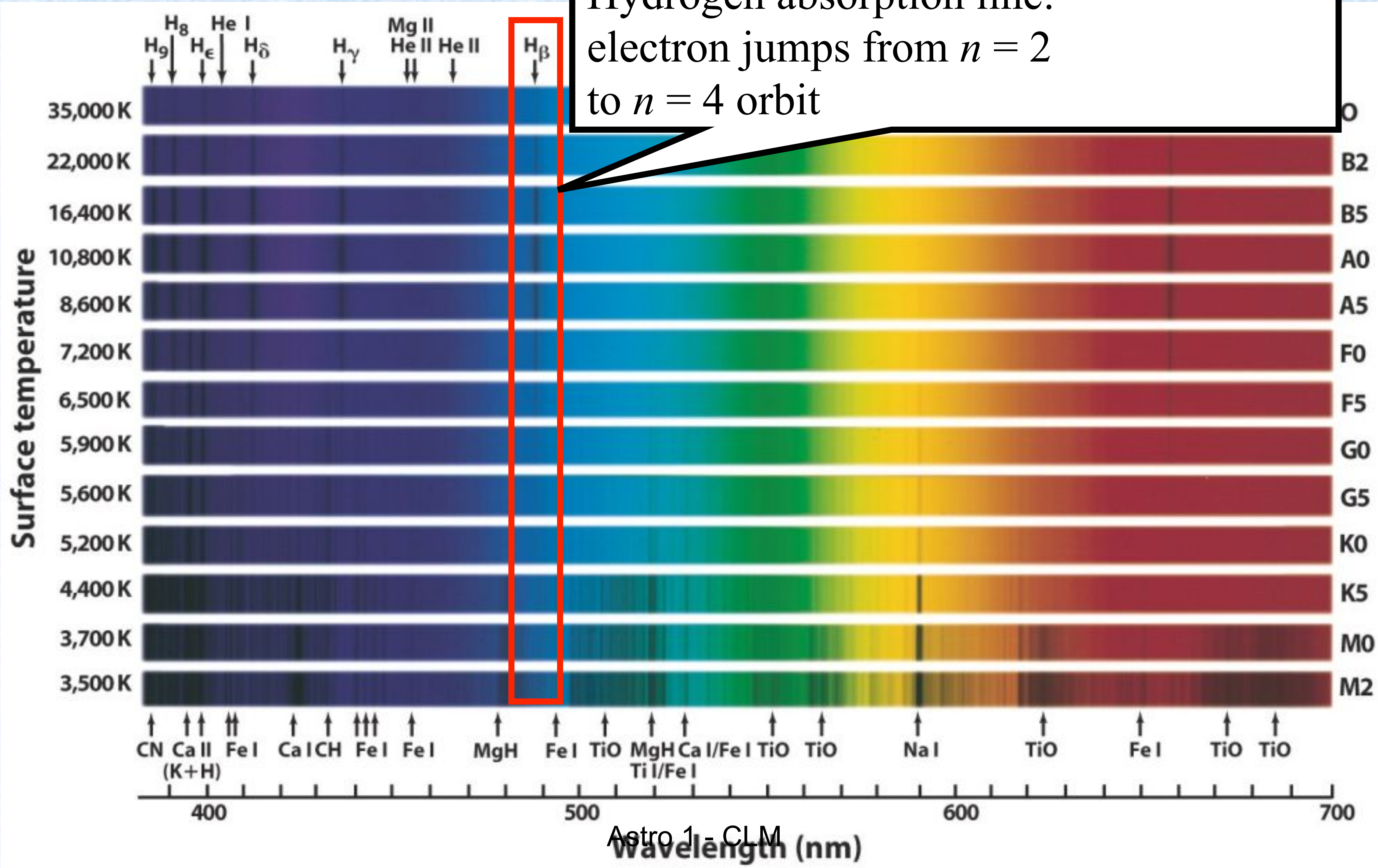
Spectral Type Maps to Surface Temperature



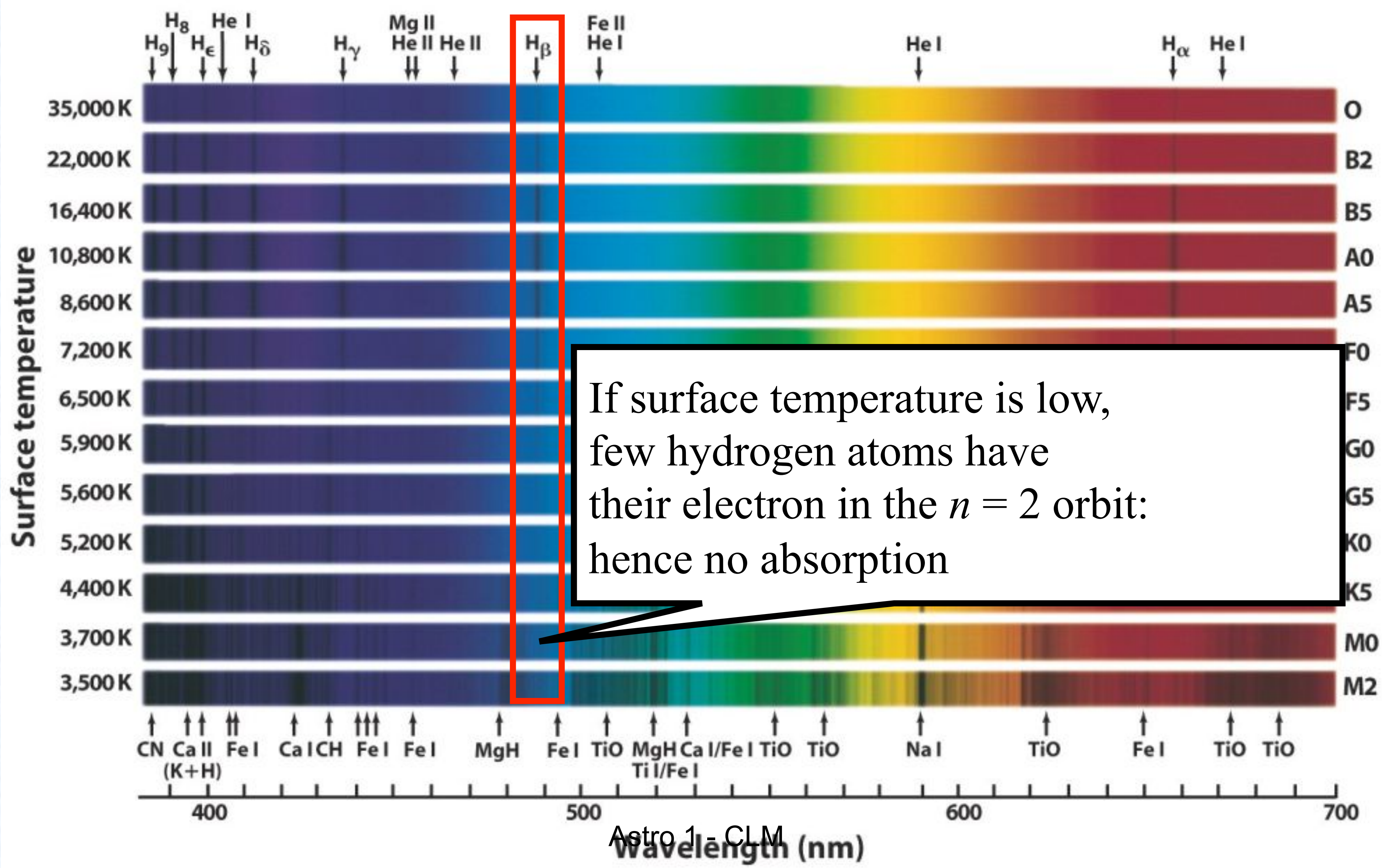
HW#5 – problem 7
Spectral Features

Spectra of stars with different surface temps

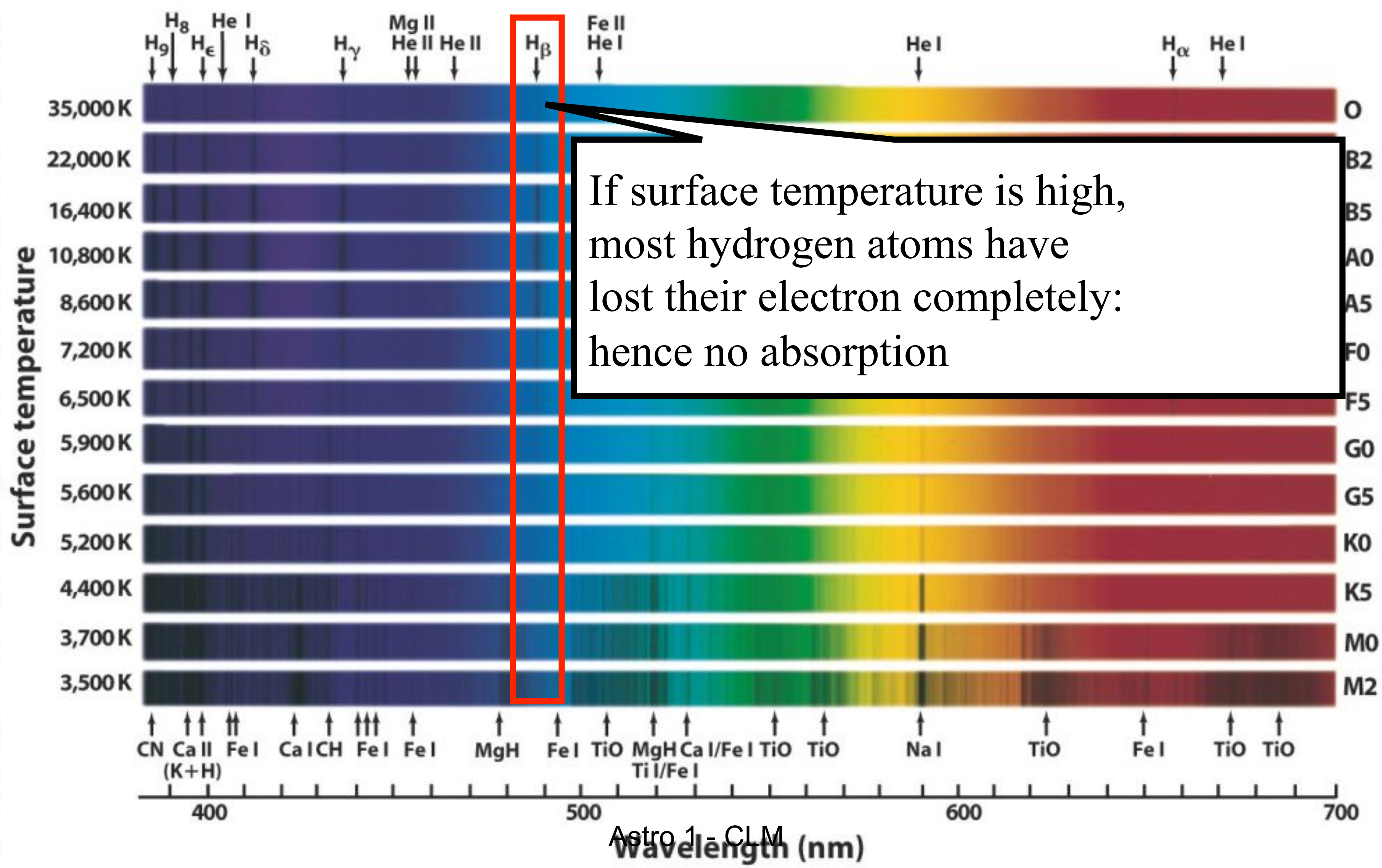
Hydrogen absorption line: electron jumps from $n = 2$ to $n = 4$ orbit



Spectra of stars with different surface temps

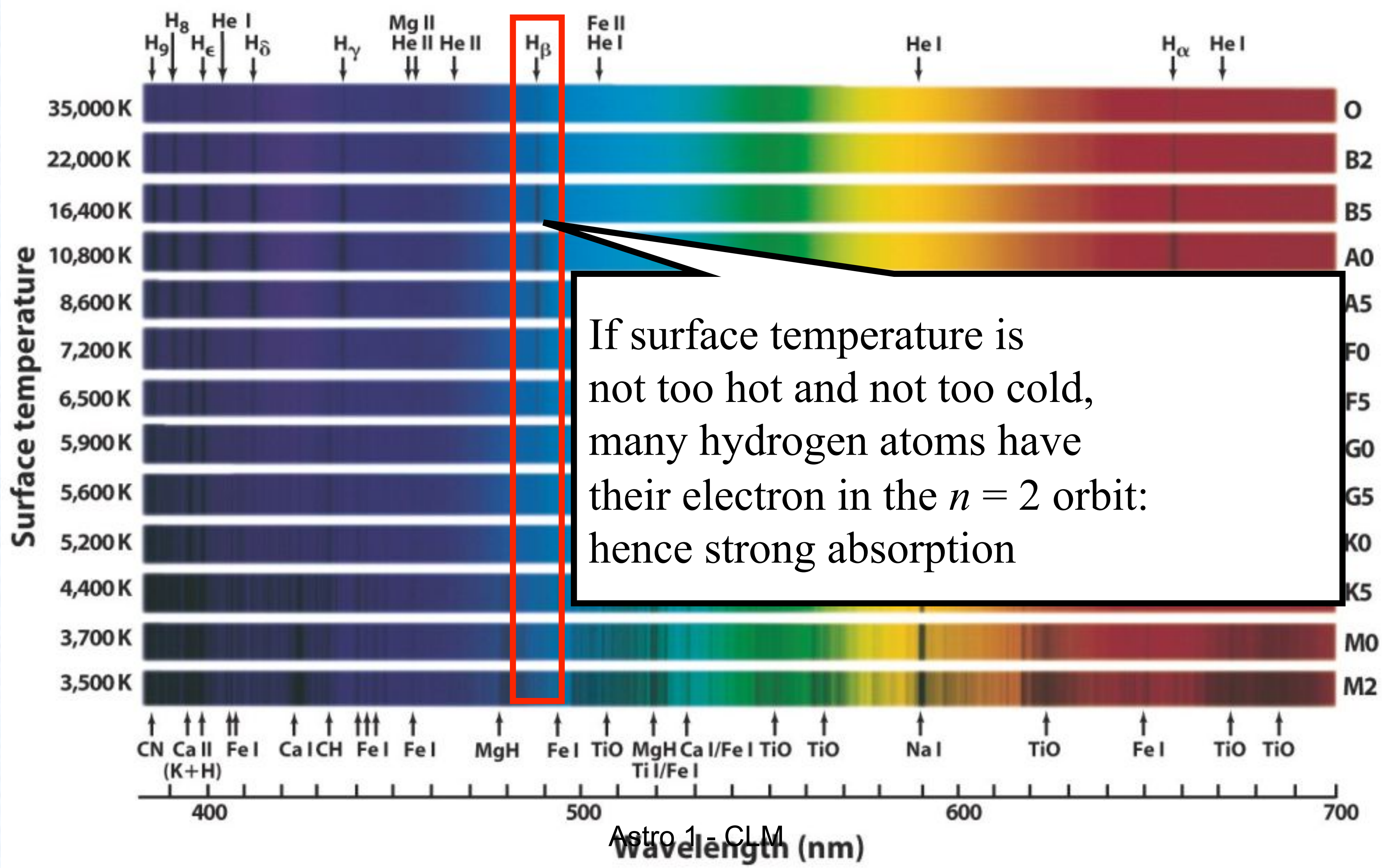


Spectra of stars with different surface temps



If surface temperature is high,
most hydrogen atoms have
lost their electron completely:
hence no absorption

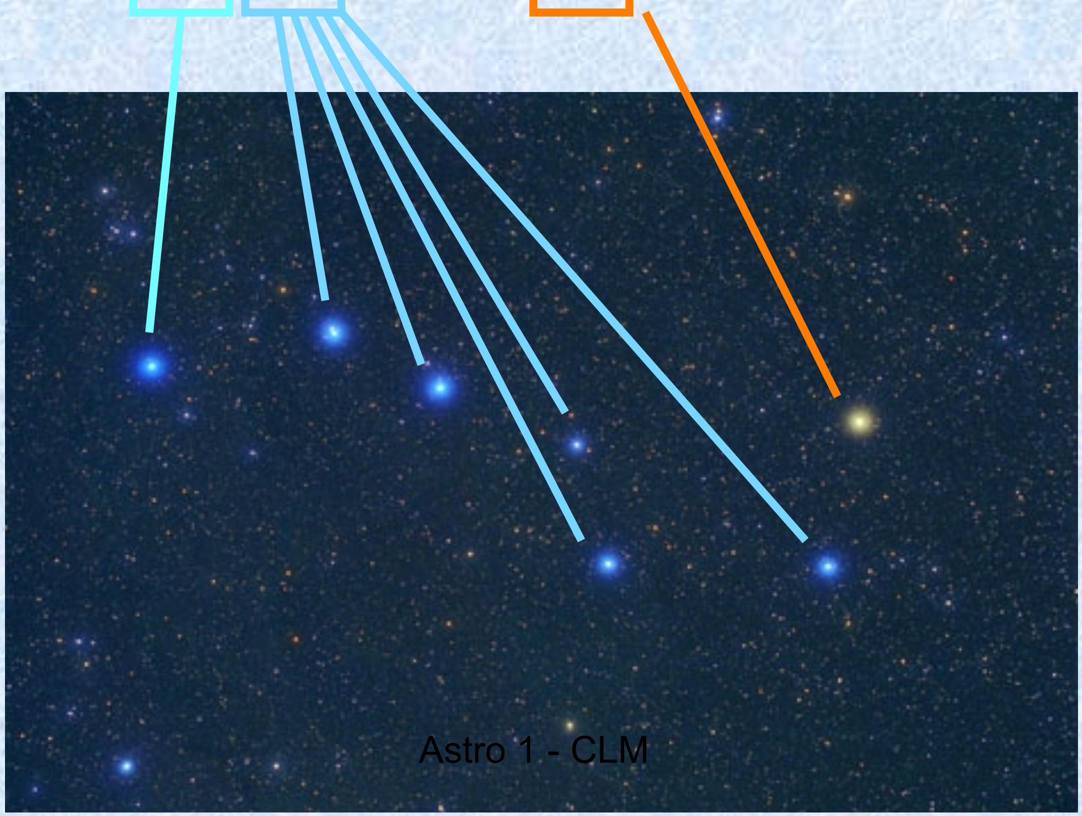
Spectra of stars with different surface temps



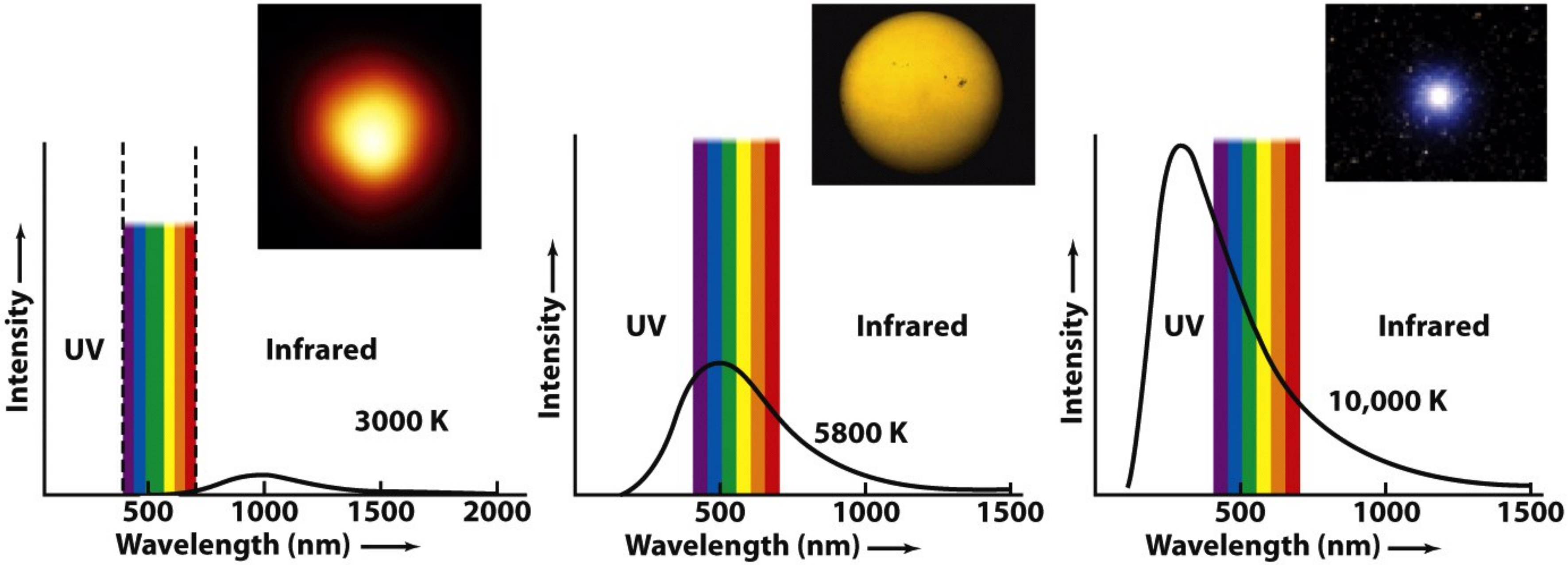
Spectral Types of Stars

Hot Cold

O B A F G K M L T



The Spectra of Stars Determine Their Color



(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 17-7
Universe, Eighth Edition

Colors: Very Low Resolution Spectra

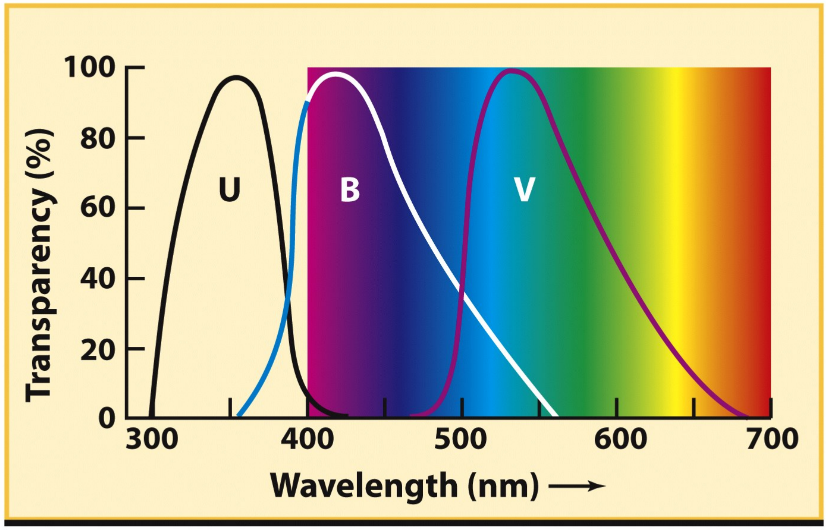


Figure 17-8
Universe, Eighth Edition

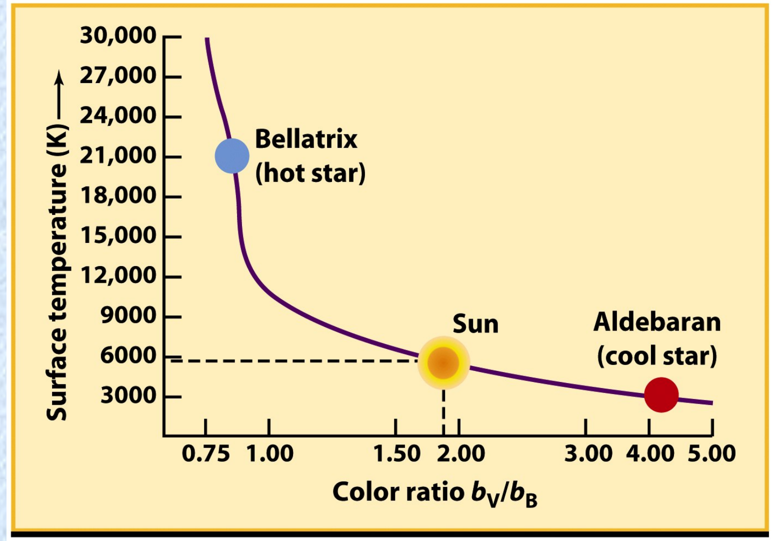


Figure 17-9

Table 17-1 Colors of Selected Stars

Star	Surface temperature (K)	b_V/b_B	b_B/b_U	Apparent color
Bellatrix (γ Orionis)	21,500	0.81	0.45	Blue
Regulus (α Leonis)	12,000	0.90	0.72	Blue-white
Sirius (α Canis Majoris)	9400	1.00	0.96	Blue-white
Megrez (δ Ursae Majoris)	8630	1.07	1.07	White
Altair (α Aquilae)	7800	1.23	1.08	Yellow-white
Sun	5800	1.87	1.17	Yellow-white
Aldebaran (α Tauri)	4000	4.12	5.76	Orange
Betelgeuse (α Orionis)	3500	5.55	6.66	Red

Source: J.-C. Mermilliod, B. Hauck, and M. Mermilliod, University of Lausanne

Table 17-1
Universe, Eighth Edition

HW#5 – problem 6
Colors of Stars

Sizes of Stars

How do we measure them?

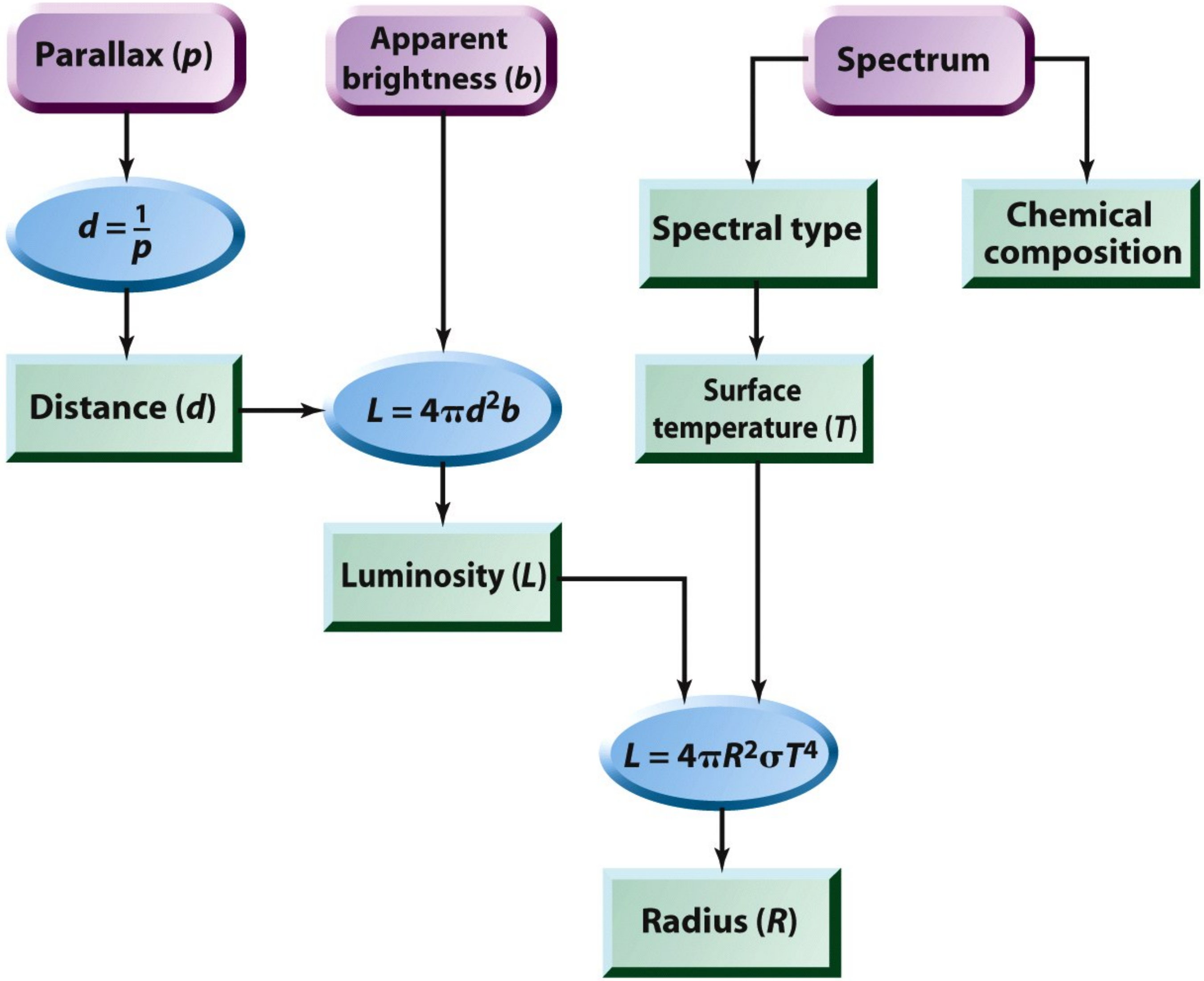
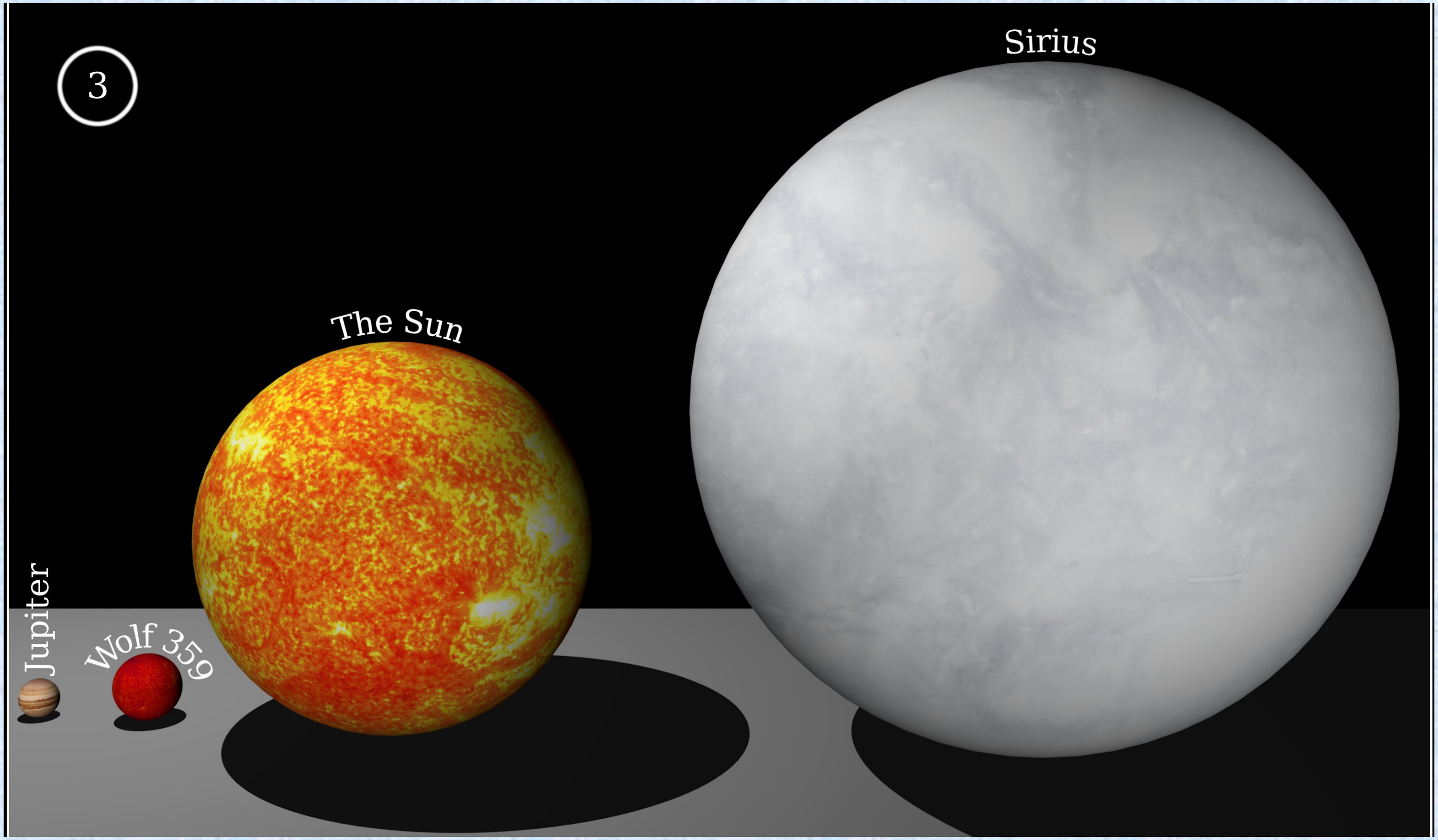
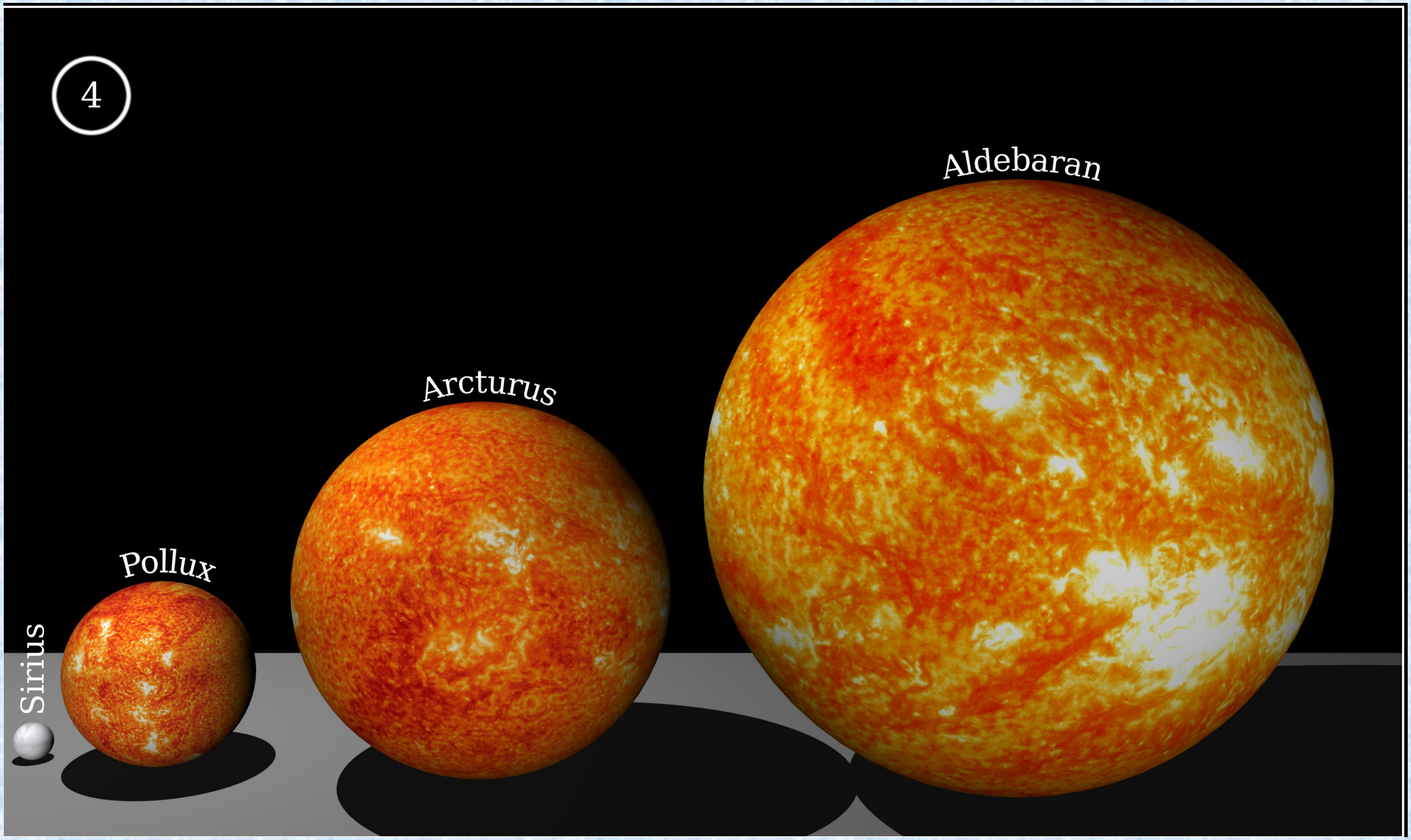


Figure 17-14
Universe, Eighth Edition

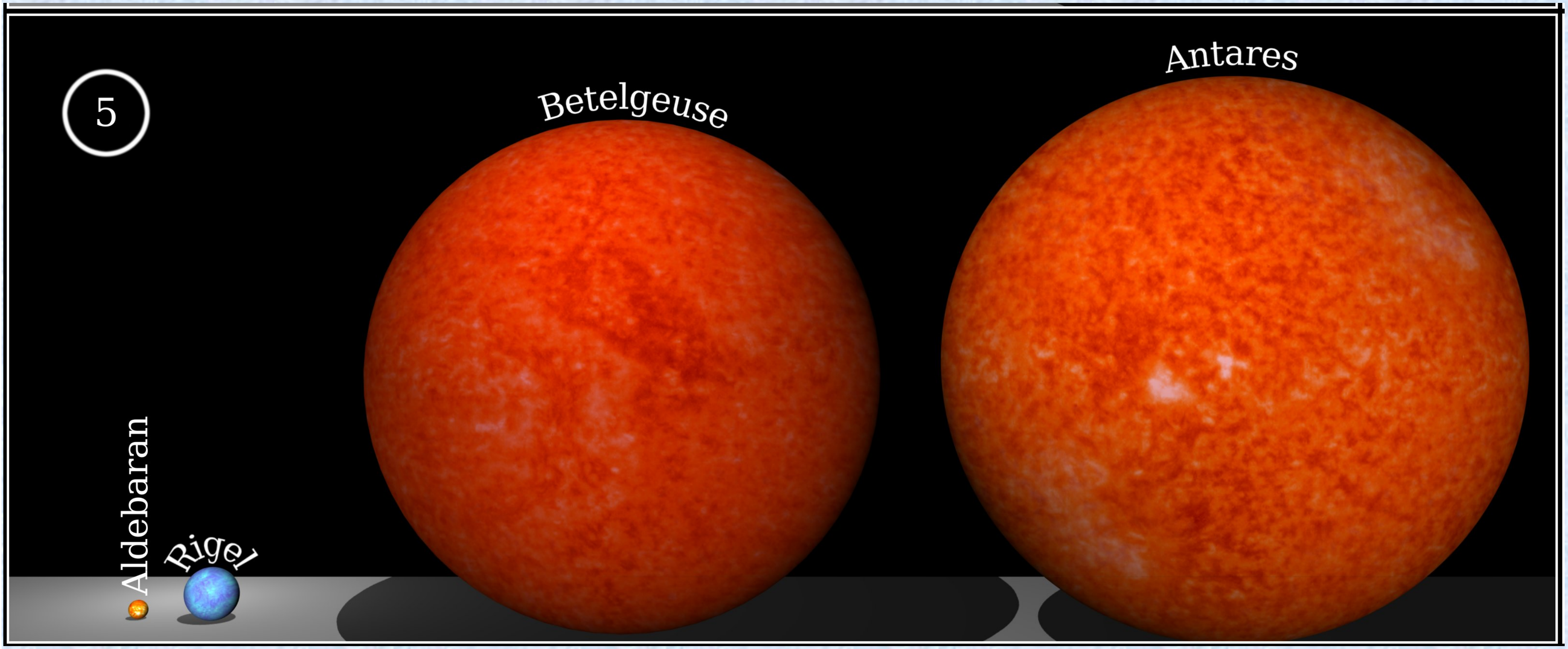
Dwarf Stars (Main Sequence Stars)



“Giants” (1-100 R_0)



Supergiants (~1000 R_0)



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

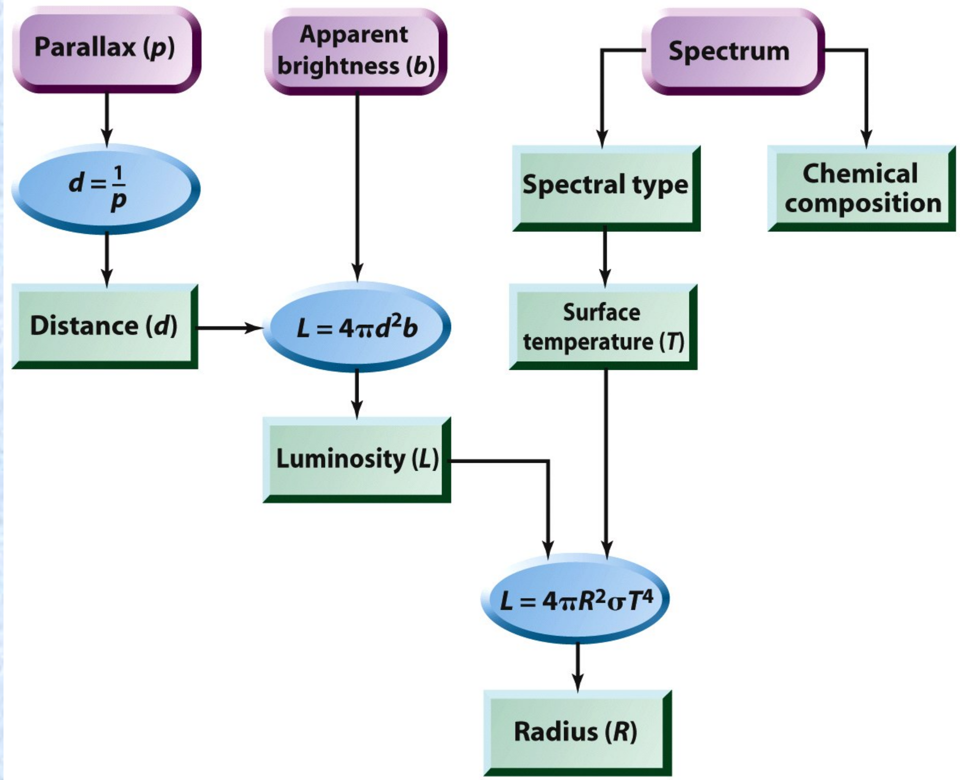


Figure 17-14
Universe, Eighth Edition

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

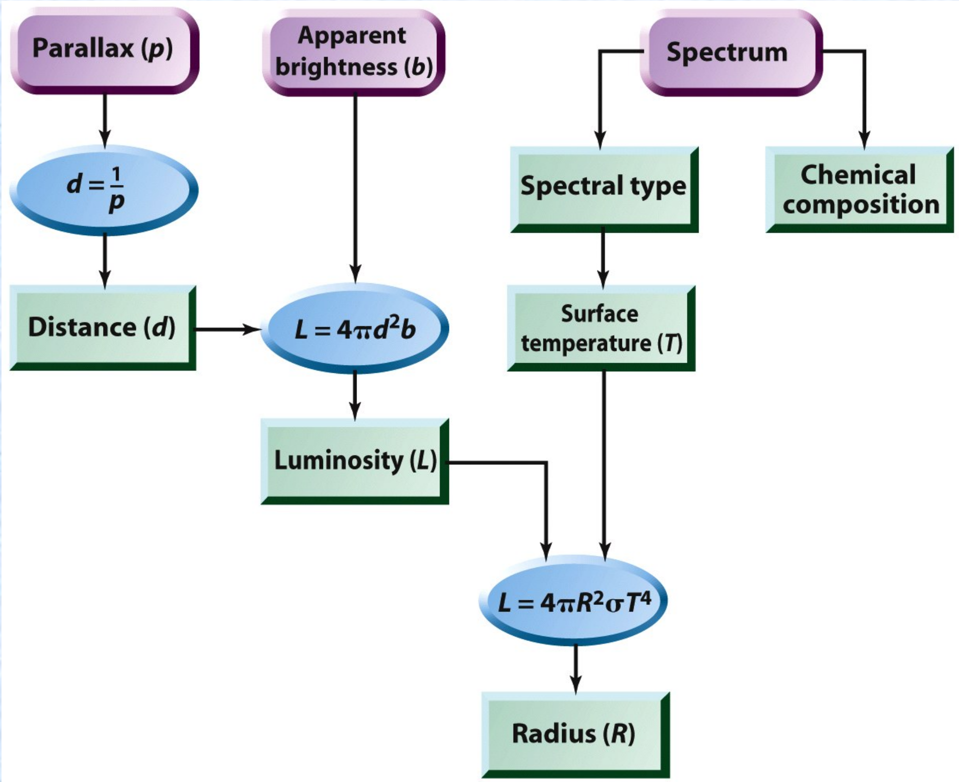
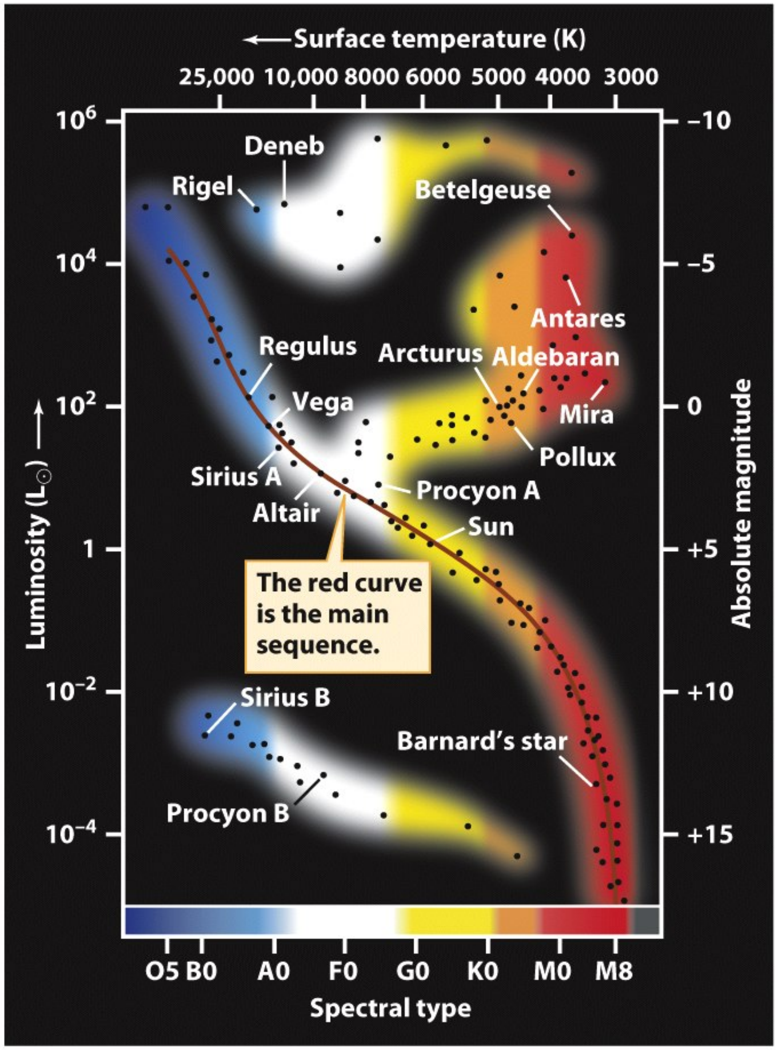


Figure 17-14
Universe, Eighth Edition

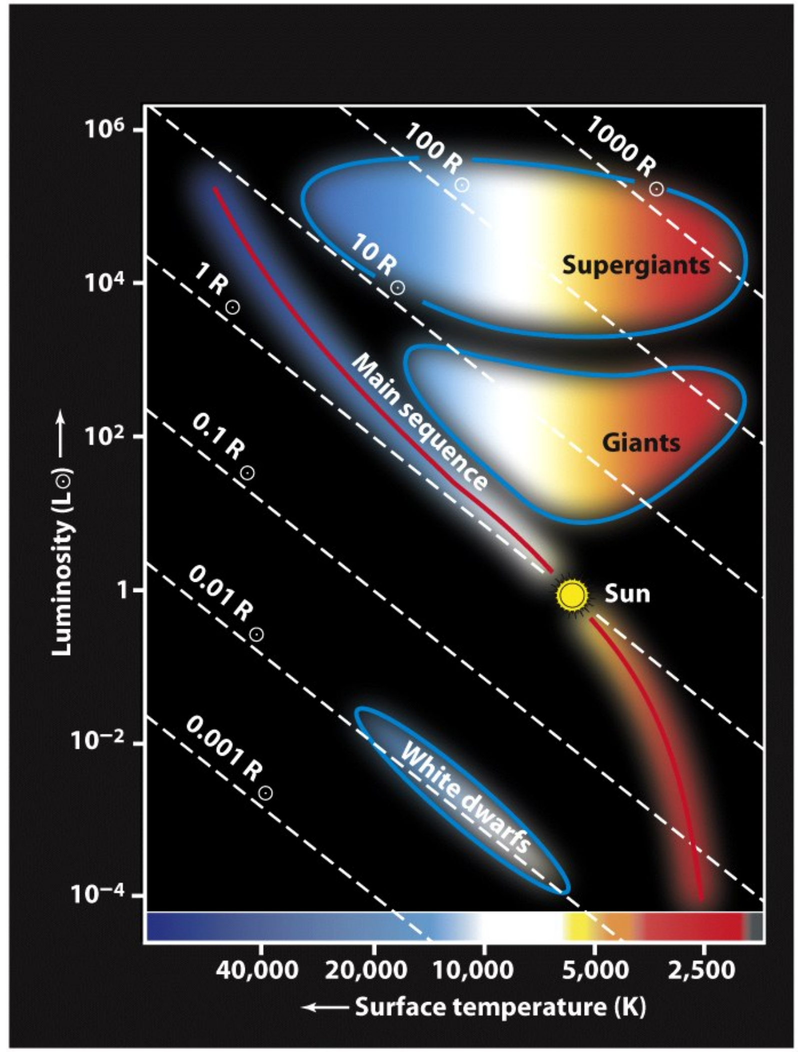
Astronomers found order in all this variety!

- The patterns reveal how stars work.
  - Gravity determines how high the central pressure needs to be.
  - Heat transport determines how long the energy takes to travel to the surface -- i.e., luminosity.
  - The nuclear energy generation in the core is sensitive to the central temperature, and the radius of the star must adjust to balance the energy radiated into space.
- We can "see it" in a simple diagram.

The Hertzsprung-Russell (HR) Diagram



(a) A Hertzsprung-Russell (H-R) diagram



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

Figure 17-15
Universe, Eighth Edition

Is the Sun a typical star?

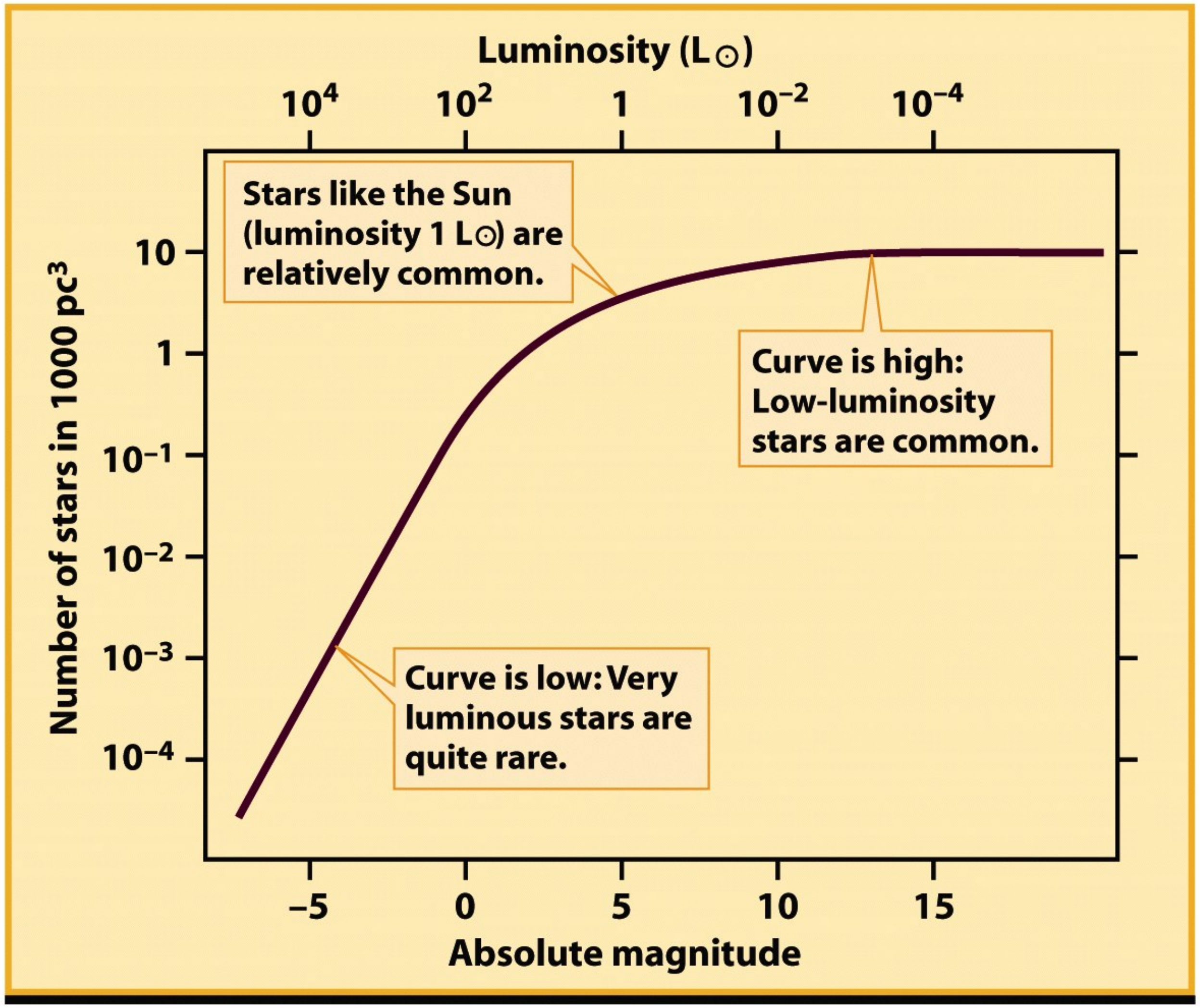


Figure 17-5
Universe, Eighth Edition

The masses of stars

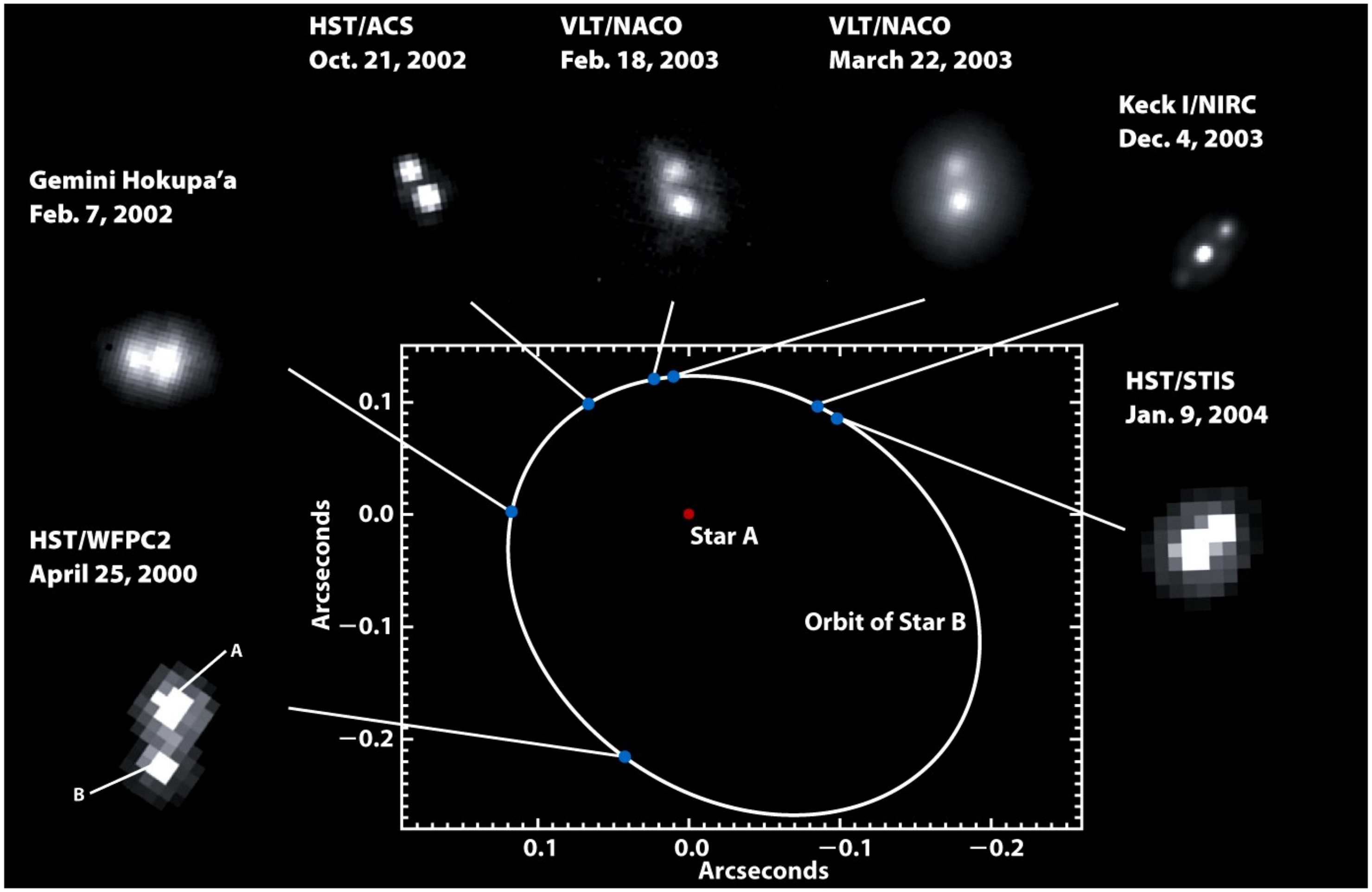
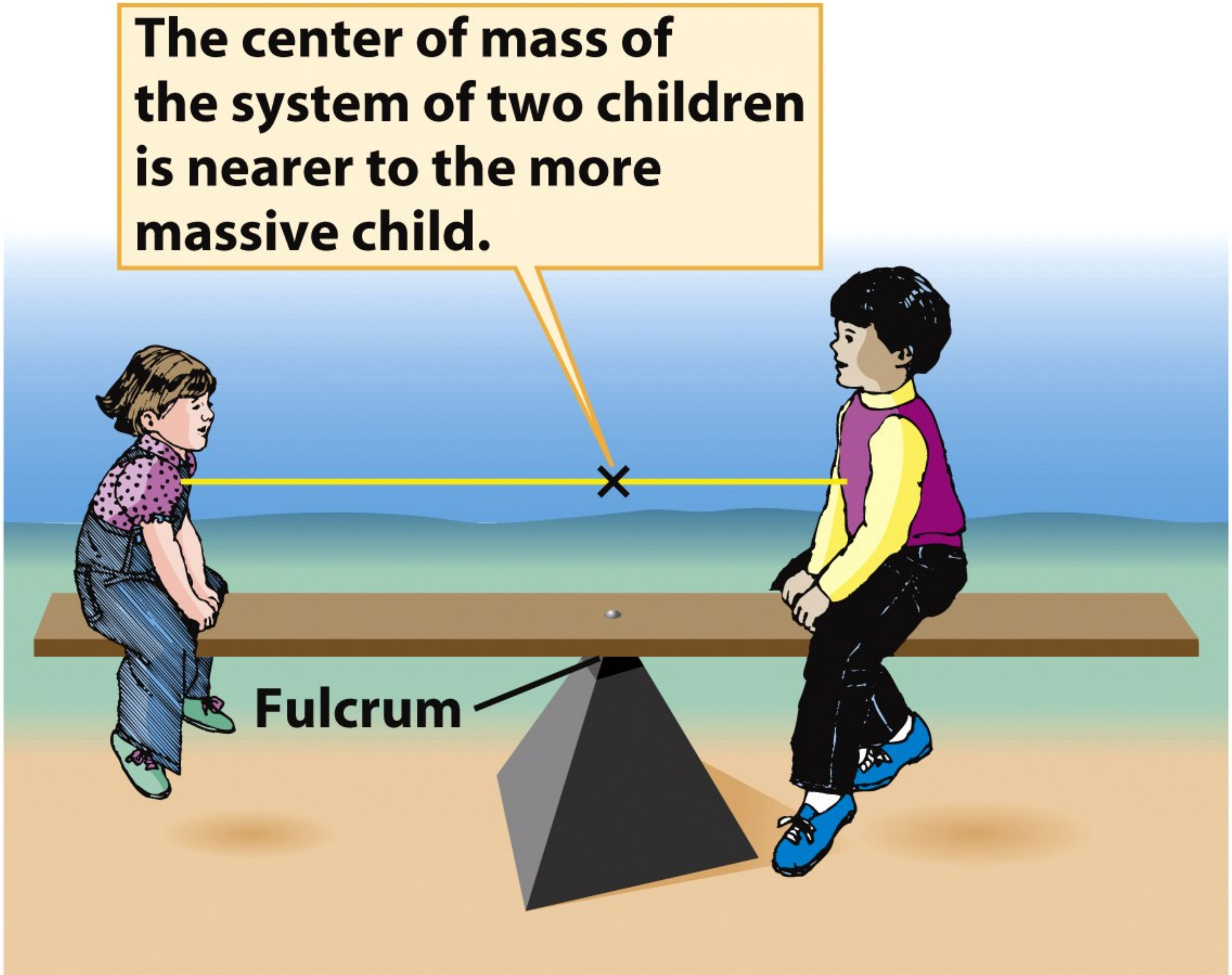


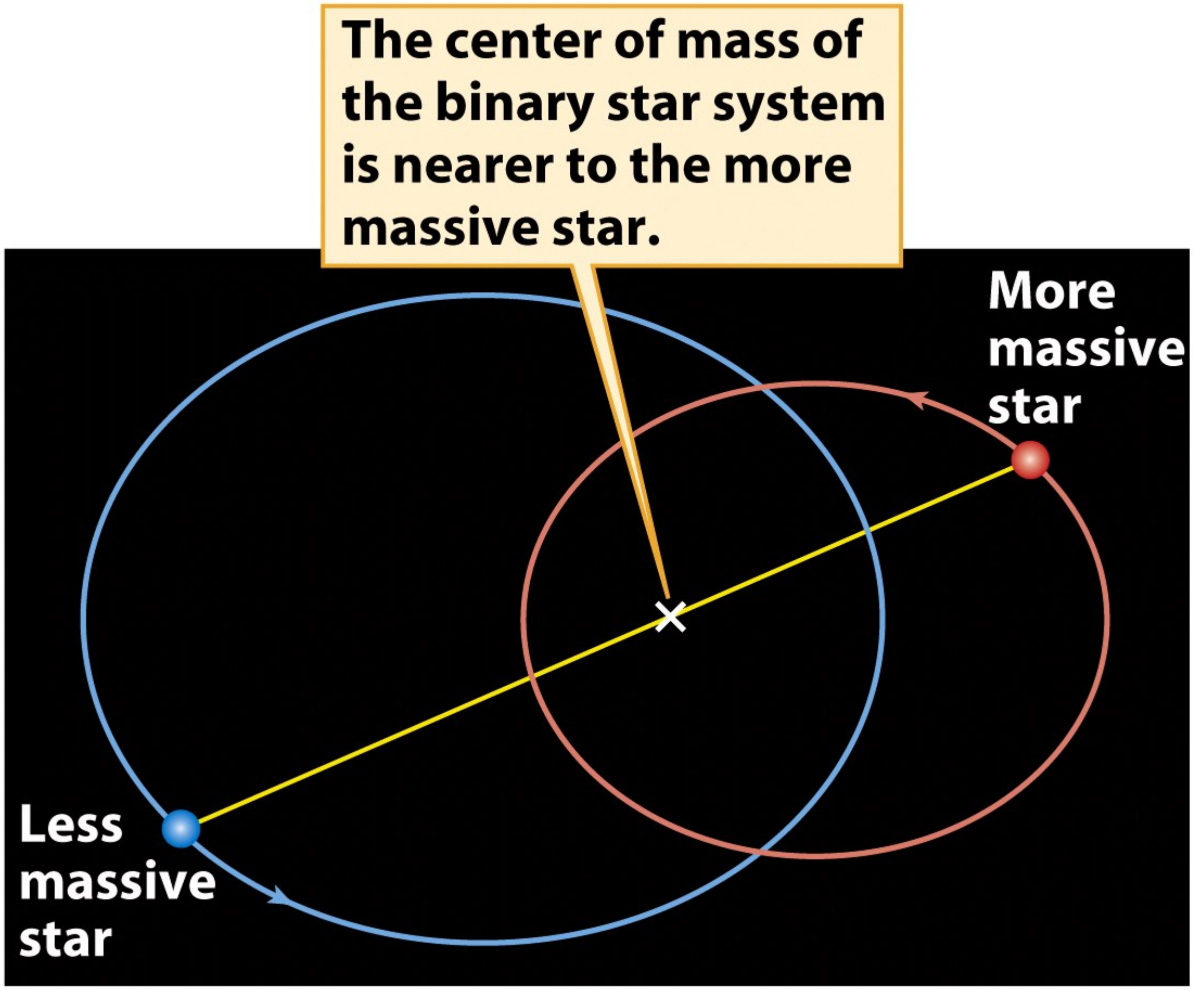
Figure 17-19
Universe, Eighth Edition

To determine stellar mases 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



A "binary system" of two children

Figure 17-20a
Universe, Eighth Edition



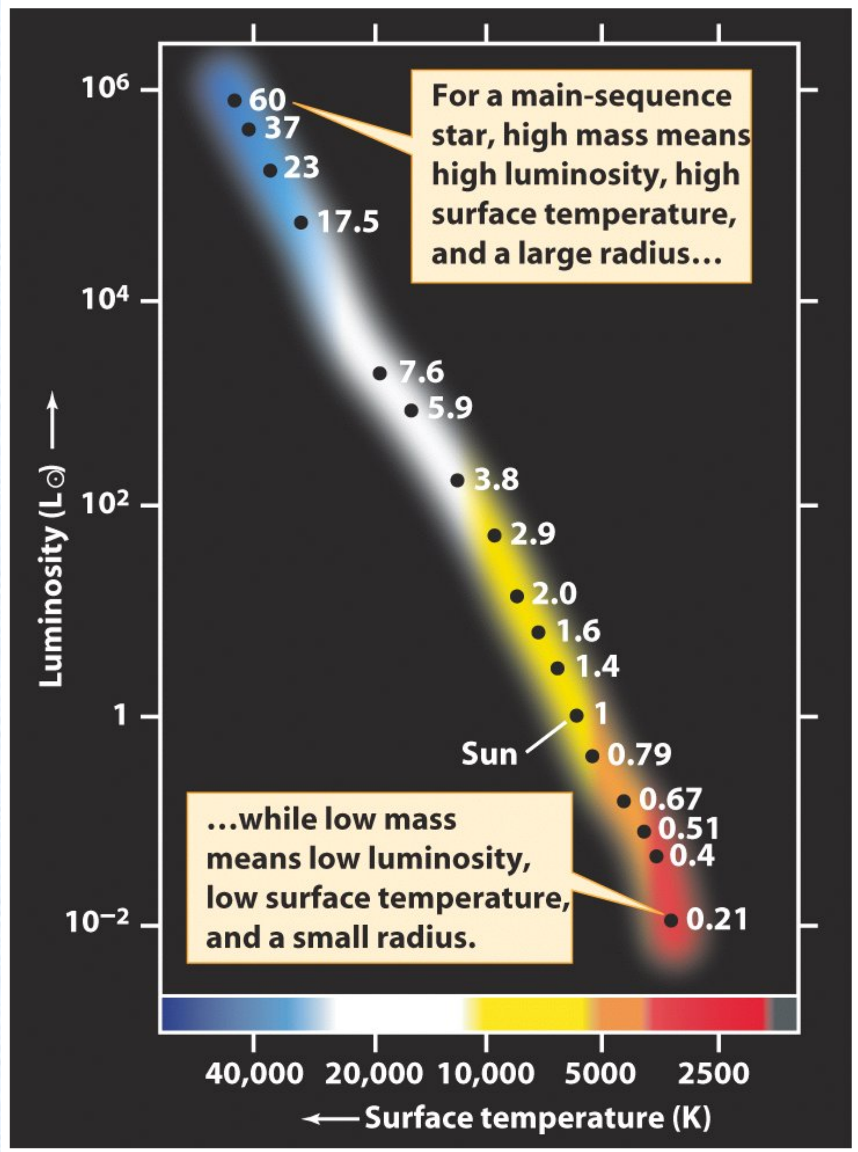
A binary star system

Figure 17-20b
Universe, Eighth Edition

http://astro.ph.unimelb.edu.au/software/binary/binary.htm

H-R diagram with masses

- The main sequence is a mass sequence!
- The mass of the star determines its luminosity.
- The combination of mass and luminosity determine the star's lifetime.



Summary

- Parallax is a tool to measure distances
- The Inverse-Square Law relates luminosity and brightness
- Spectra (or colors) provide an estimate of surface temperature.
- L and T ➔ stellar size (or radius)
- 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.
  - Masses can be determined for binaries. The main sequence is a mass sequence!!
- Low luminosity stars are more common than more luminous ones