# Friday, Oct. 10

Syllabus, class notes, and homeworks are at: www.as.utexas.edu → courses → AST 301, Lacy

Reading for next week: chapter 9

The Wednesday help session is in GRG 424 at 5:00 (for the entire semester).

# Topics for this week

How do astronomers use parallax to measure the distances to stars? Why does parallax vary inversely with distance?

Describe and explain the relationship between a star's apparent brightness (or flux), its absolute brightness (or luminosity), and its distance from us.

Describe and explain the relationship between a star's luminosity, its radius, and its temperature, and how this relationship is used to measure radii of stars.

Sketch an H-R diagram, showing the location of main sequence stars, red giants, and white dwarfs.

Explain how astronomers measure masses of stars.

Describe how the luminosities of main sequence stars are related to their masses.

# Parallax and Distance

You judge the distance to objects (depth perception) from the fact that your two eyes view an object from two different locations, so have to look in different directions to look at an object.

The different direction to an object from different positions is called parallax.

Astronomers use the change in the direction to a star during a year, as the Earth orbits around the Sun, to judge the distance to the star.

Nearer stars have bigger parallaxes, or

parallax a 1 / distance

# Apparent brightness

How bright a star appears is determined by how much light from that star enters your eye.

That is given by the product of the area of your pupil and the light power per unit area reaching you from the star.

We refer to the power per unit area as the flux or apparent brightness of the star.

Flux = Power / Area

You can calculate the flux of light from a star by dividing the power emitted by the star by the area it has spread over by the time it gets to you.

Because all areas vary as the square of the size of the object, the area the light has spread over varies as the square of the distance it has traveled.

# Flux or Apparent Brightness

In traveling a distance of 1 pc from a star, light spreads out over some area.

When the light has traveled a distance of 2 pc from the star, it has spread out over 4 times as much area.

Since the flux of starlight is the power emitted divided by the area it has spread over, the flux is 4 times smaller 2 pc from the star than it is at 1 pc.

The formula is: Flux a 1 / distance$^2$

Or if the stars we are comparing have different luminosities (power emitted), the formula becomes:

Flux a Luminosity / distance$^2$

# Absolute Magnitude

We won’t use absolute magnitude much, but you should know that it is a a way of expressing the amount of light a star puts out (rather than the amount that hits your eye).

Like the apparent magnitude system, each increase of one magnitude means a decrease in light by a factor of 2.5

The Sun has an absolute magnitude of about 5.

A star with an absolute magnitude of 6 emits about 2.5 times less light than the Sun does.

A star with an absolute magnitude of 0 (that’s 5 magnitudes smaller than the Sun) emits about 2.5x2.5x2.5x2.5x2.5 (or 100) times as much light as the Sun.

Remember: smaller magnitudes mean more light.

# Temperature-Luminosity diagrams

Astronomers measure the temperatures and luminosities of many stars and plot them on a diagram called the Hertzsprung-Russell (or H-R) diagram.

For historical reasons they plot temperatures increasing to the left (not right) and luminosities increasing upward.

They also sometimes plot colors instead of temperatures and absolute magnitudes instead of luminosities.

They find that stars cluster in 3 groups.

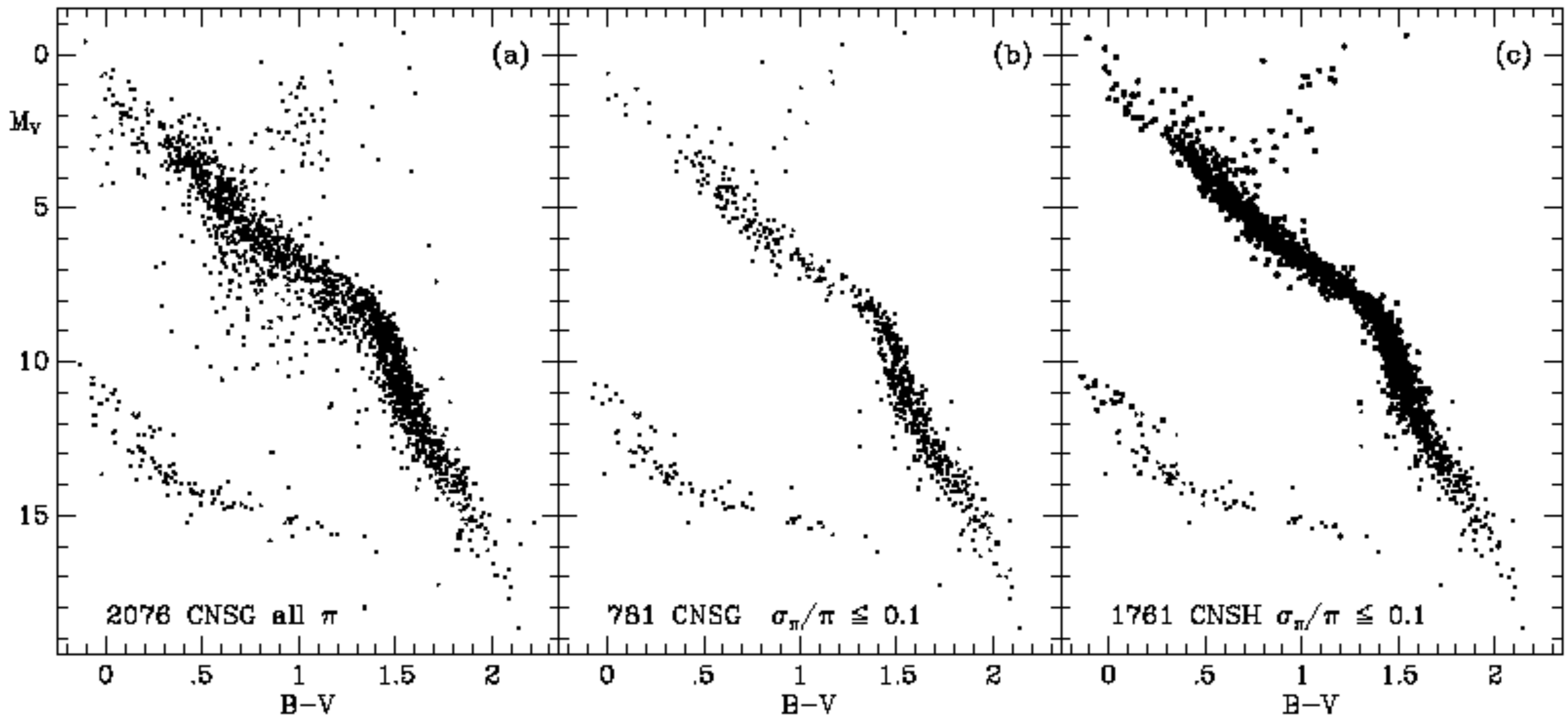



*Figure 3. CM-diagrams for nearby stars ($r \leq 25$ pc): (a) all CNSG stars with trigonometric parallaxes; (b) all CNSG stars with relative parallaxes better than 10 per cent; (c) all CNSH stars with relative parallaxes better than 10 per cent.*

# Star survey results

Many stars fall on a diagonal line running from the upper left (hot and luminous) to the lower right (cool and faint).

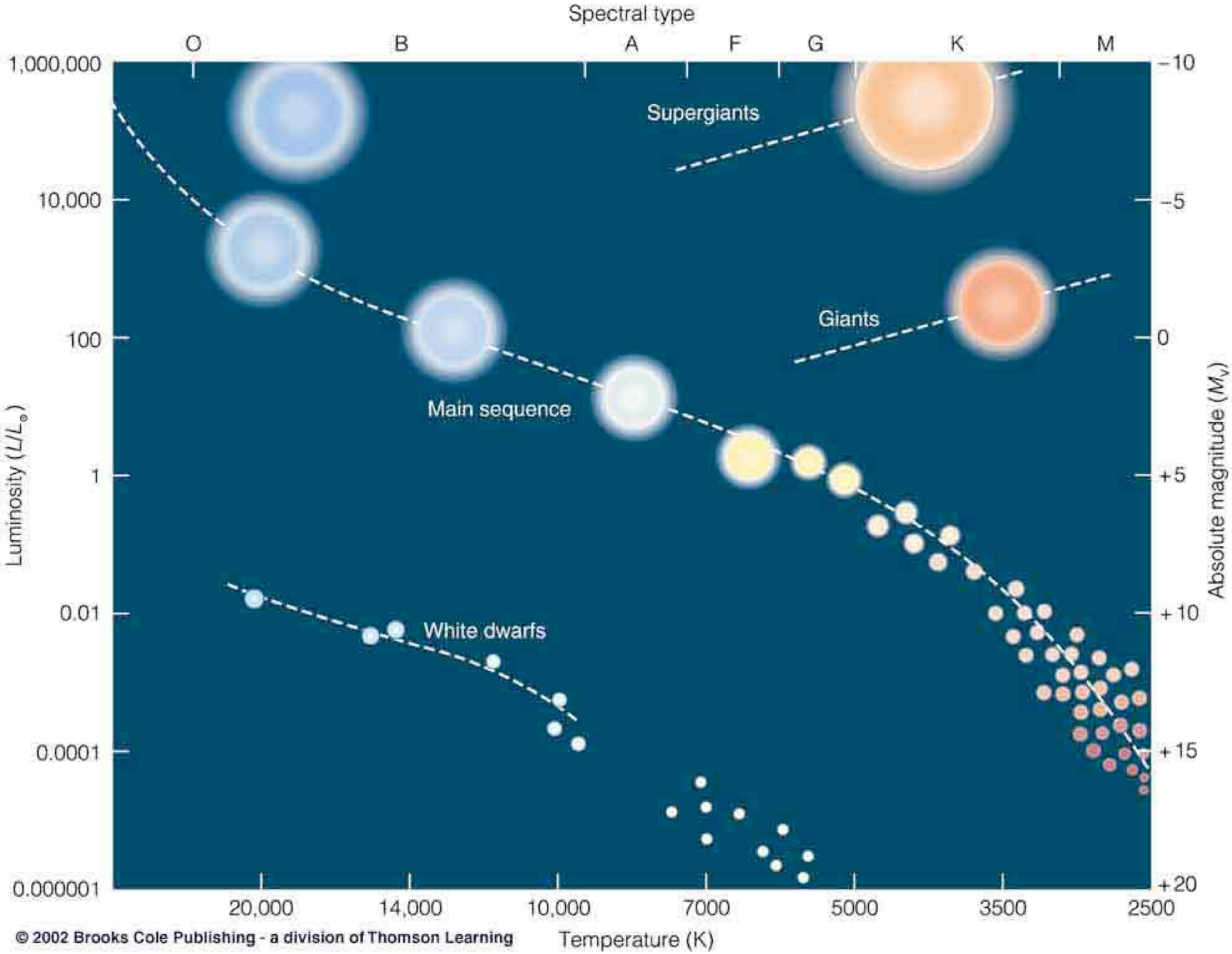
The Sun is one of these stars.

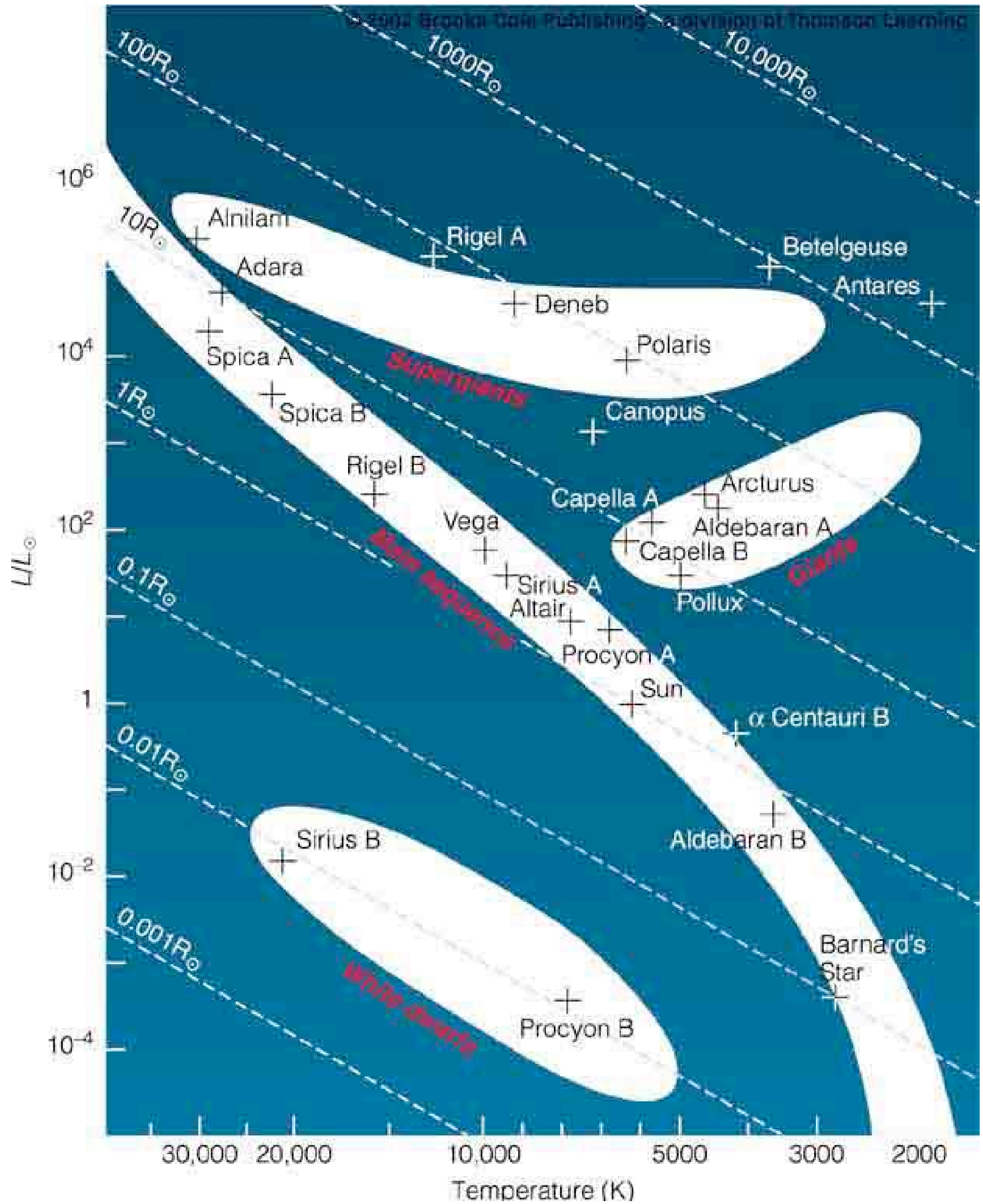
But some fall in the upper right (cool and luminous) and some fall toward the bottom of the diagram (faint).

What can we say about the stars in the upper right?

What can we say about the stars toward the bottom?

If all stars had the same size, what pattern would they make on the diagram?


Spectral type
O
B
A
F
G
K
M
1,000,000
10,000
100
1
0.01
0.0001
0.000001
Luminosity ($L/L_{\odot}$)
−10
−5
0
+5
+10
+15
+20
Absolute magnitude ($M_V$)
Supergiants
Giants
Main sequence
White dwarfs
20,000
14,000
10,000
7000
5000
3500
2500
Temperature (K)


100R☉
1000R☉
10,000R☉
10R☉
1R☉
0.1R☉
0.01R☉
0.001R☉
Alnilam
Adara
Spica A
Spica B
Rigel A
Deneb
Polaris
Betelgeuse
Antares
Supergiants
Canopus
Rigel B
Capella A
Arcturus
Aldebaran A
Capella B
Giants
Vega
Main sequence
Sirius A
Altair
Procyon A
Pollux
Sun
α Centauri B
Aldebaran B
Sirius B
Barnard's Star
White dwarfs
Procyon B
$10^6$
$10^4$
$10^2$
1
$10^{-2}$
$10^{-4}$
$L/L_\odot$
30,000
20,000
10,000
5000
3000
2000
Temperature (K)

# Masses of Stars

The gravitational force of the Sun keeps the planets in orbit around it.

The force of the Sun's gravity is proportional to the mass of the Sun, and so the speeds of the planets as they orbit the Sun depend on the mass of the Sun.

Newton's generalization of Kepler's 3rd law says:

$P^2 = a^3 / M$

where P is the time to orbit, measured in years,

a is the size of the orbit, measured in AU,

and M is the sum of the two masses, measured in solar masses.

# Masses of stars

It is difficult to see planets orbiting other stars, but we can see stars orbiting other stars.

By measuring the periods and sizes of the orbits we can calculate the masses of the stars.

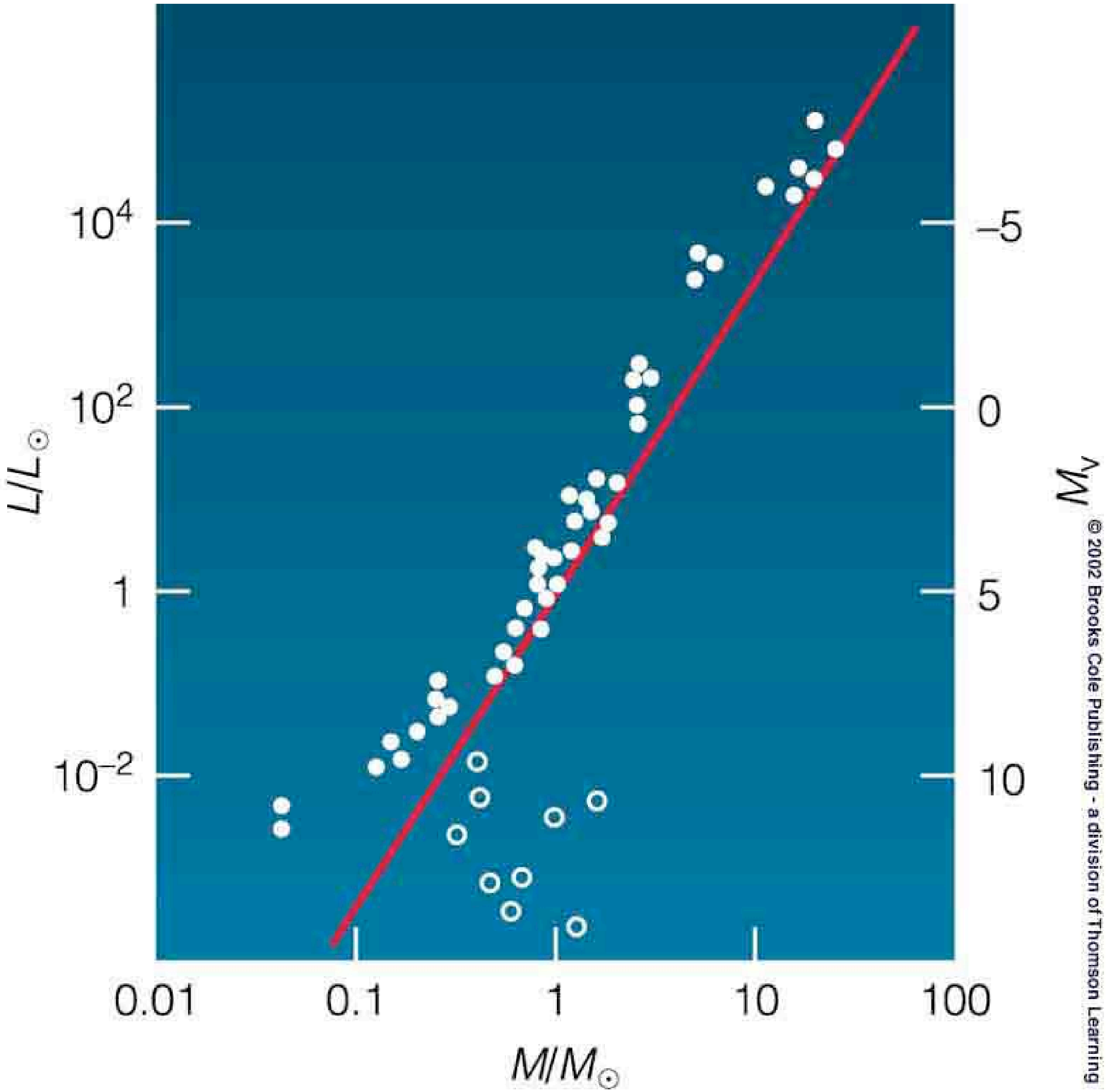
If $P^2 = a^3 / M$, $M = a^3 / P^2$

This mass in the formula is actually the sum of the masses of the two stars. If we observe the motions of both stars we can find out the mass of each star.

# Mass – Luminosity Diagram

We can plot the masses and luminosities of stars on a diagram like the H-R diagram.

Red giant and white dwarf stars follow no pattern, but main sequence stars fall along a line with luminosity increasing with mass.


$10^4$
$10^2$
1
$10^{-2}$
$L/L_\odot$
–5
0
5
10
$M_V$
0.01
0.1
1
10
100
$M/M_\odot$