AST 301
Introduction to Astronomy

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AST 301 (Lacy), course website

Topics for this week

How do we use the Hertzsprung-Russell diagram to make sense of the temperatures and luminosities of stars?

Describe the life stages of a low-mass star, like the Sun.

Use the HR diagram to show the evolution of a low-mass star graphically.

What happens inside of a star that makes it change from a main-sequence star into a red giant, then a planetary nebula and a white dwarf?

How do the life stages of a high-mass star differ, and why?

Describe the two types of supernovae

Spring AST courses

AST 309	**CURRENT TOPICS IN ASTRONOMY** 48265 · TTh 12:30-2 · WEL 3.502	GEBHARDT
AST 309N	**LIVES AND DEATHS OF STARS** 48270 · MWF 12-1 · WEL 3.502	WHEELER
AST 309S	**THE SOLAR SYSTEM** 48275 · TTh 11-12:30 · WEL 3.502	DODSON-ROBINSON

Combine parallax and brightness

Spica and Canopus emit about the same amount of power.

Spica has a parallax of .005 arcsec and Canopus has a parallax of .01 arcsec.

How do Spica and Canopus compare in apparent brightness?

Work it out and compare answers with your neighbors.

Hint: first figure out how they compare in distance, and then figure out how that affects their brightnesses.

Combine parallax and brightness

Canopus has twice the parallax of Spica.

Since distance α 1 / parallax, Spica must be at twice the distance of Canopus. (The numbers are 100 pc and 200 pc, but you don't need to know that.)

The more distant star (Spica) appears fainter.

Since it is twice as distant as Canopus, it appears 4 times fainter, or ¼ as bright.

We could use the magnitude system to describe how much fainter Spica is than Canopus, but I prefer to talk about fluxes instead of magnitudes.

Turn it around

If we measure the flux and distance of a star, we can calculate its luminosity.

Flux = Luminosity / (4 π distance^2), so

Luminosity = Flux x (4 π distance^2)

If two stars have the same flux, but one is twice as far away, how do their luminosities compare?

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:

$P^2 = a^3 / (M_1 + M_2)$

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

a is the size of the planet's orbit, measured in AU,

and $M_1 + M_2$ is the sum of the two masses, measured in solar masses.

Masses of stars

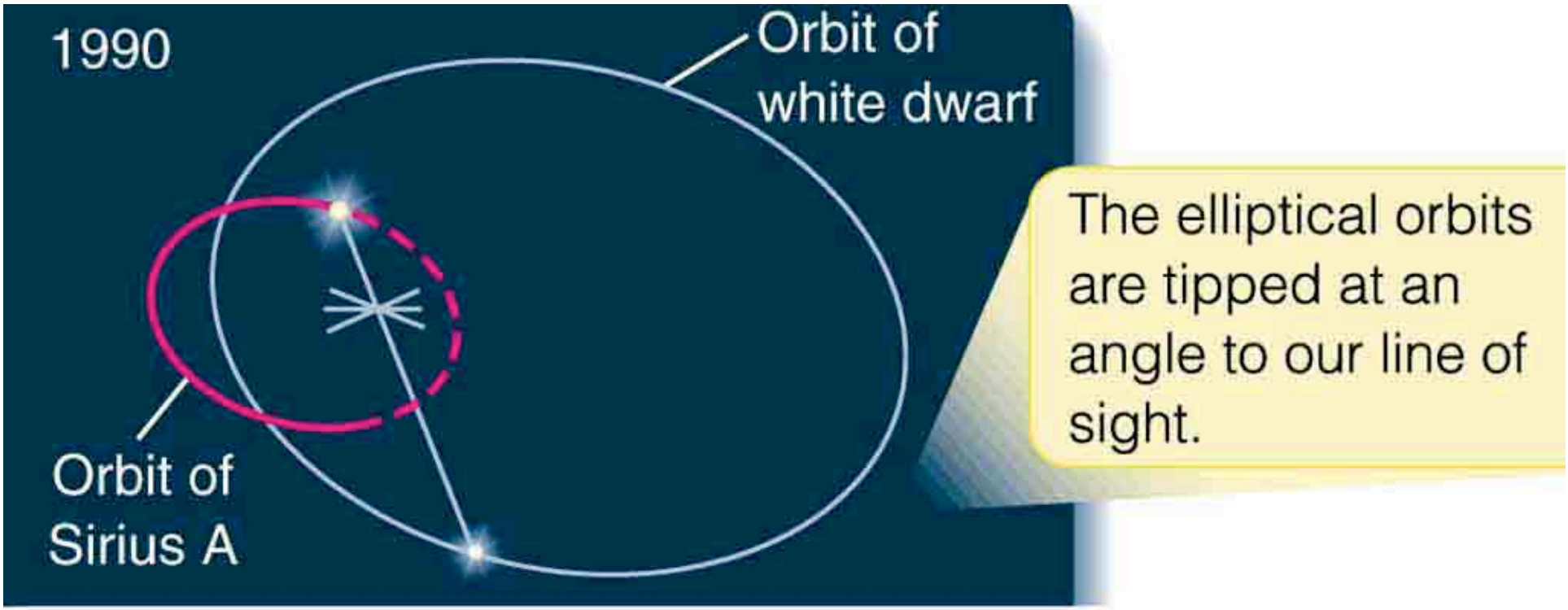
It is difficult to see planets orbiting other stars, but we can see stars orbiting other stars.

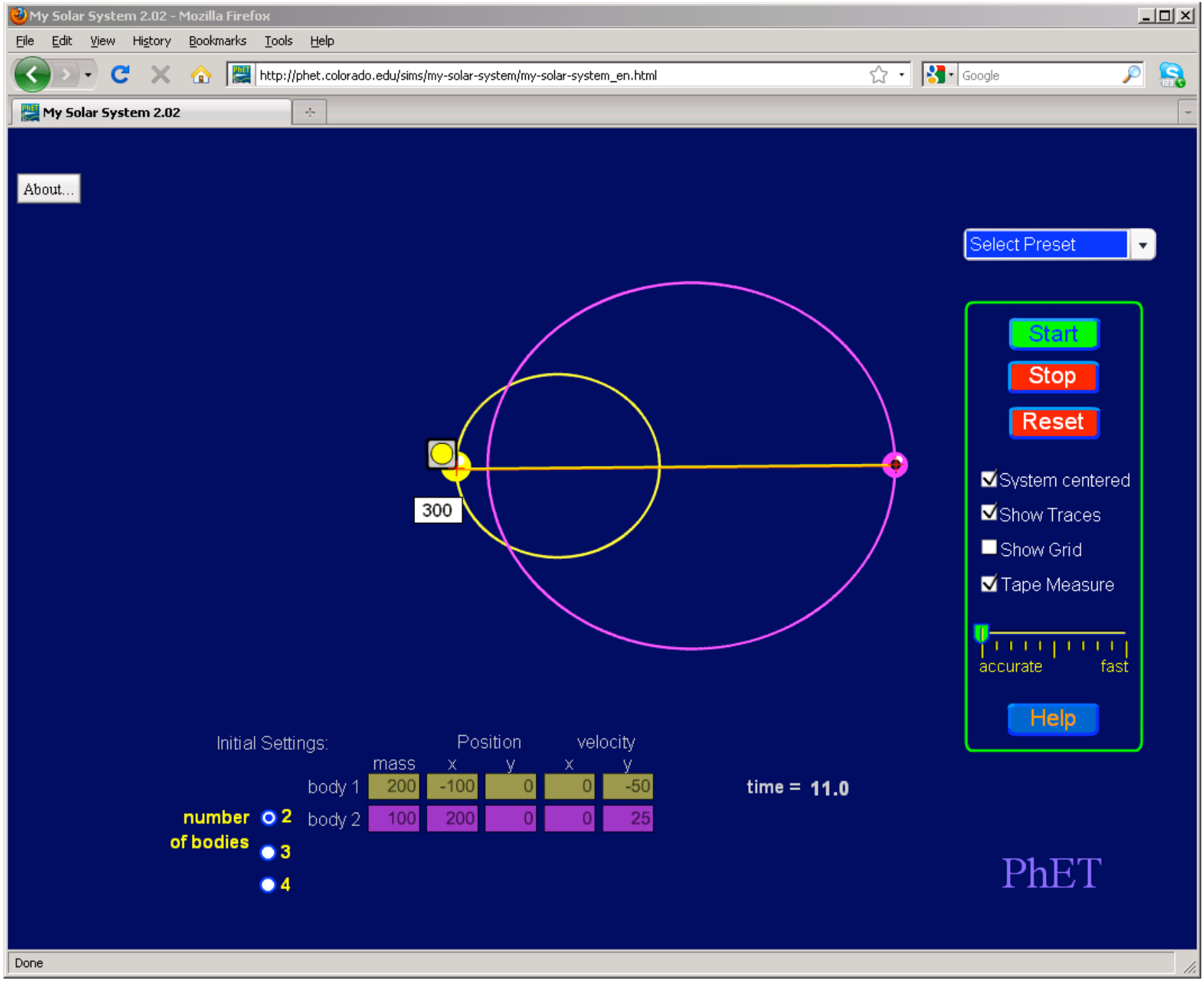
By measuring the periods and sizes of the orbits we can calculate the masses of the stars.

If $P^2 = a^3 / (M_1 + M_2)$, $M_1 + M_2 = a^3 / P^2$

This mass in the formula is 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.

a is the average distance between the two stars.

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About...
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Start
Stop
Reset
System centered
Show Traces
Show Grid
Tape Measure
accurate
fast
Help
300
Initial Settings:
Position
velocity
mass
x
y
x
y
body 1
200
-100
0
0
-50
body 2
100
200
0
0
25
number of bodies
2
3
4
time = 11.0
PhET
Done

What do we find?

We can measure:

- flux and distance, then calculate luminosity
- mass
- surface temperature from λ_{peak}

How can we make sense of what we find?

We could make a list of luminosities, masses, and temperatures of stars.

But a drawing is easier to understand.

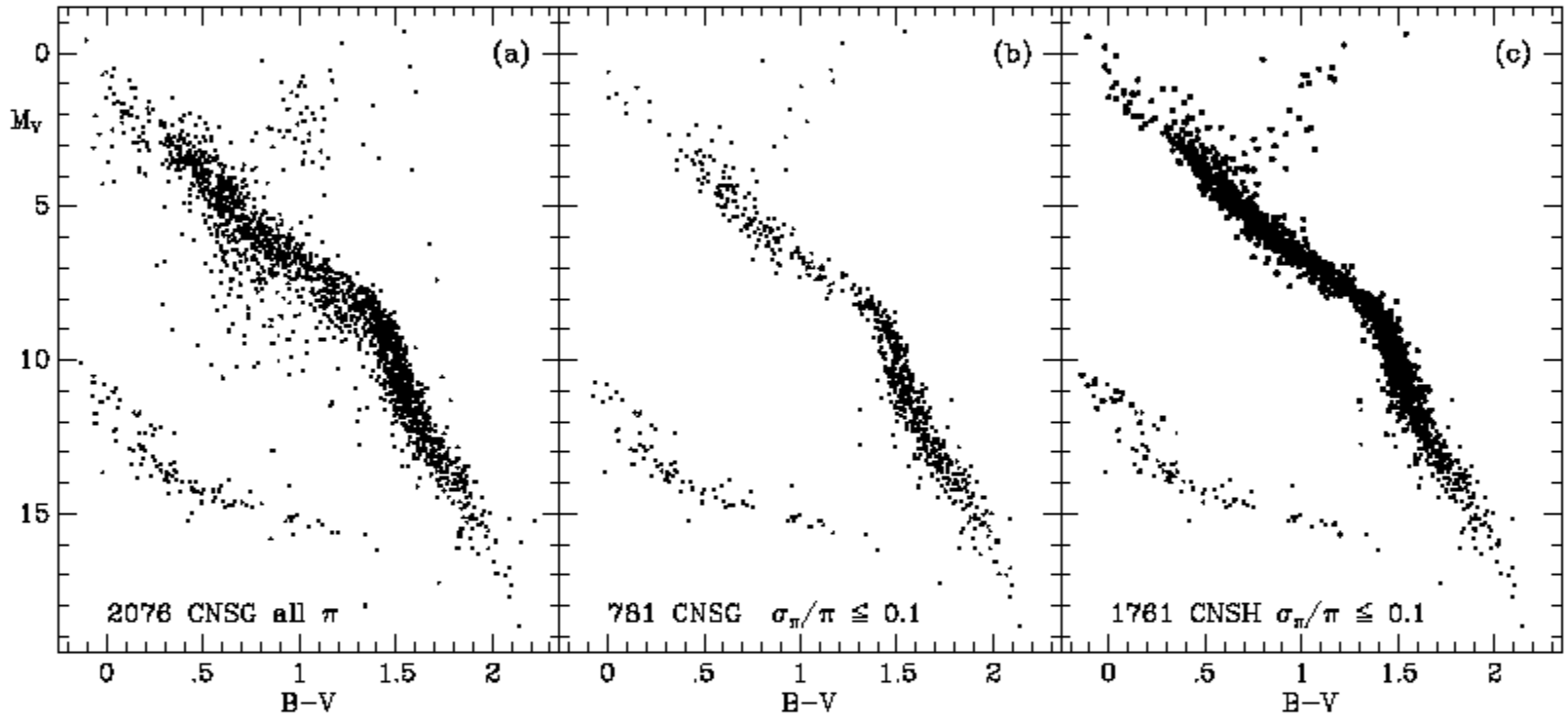


Figure 3. CM-diagrams for nearby stars ($r \leq 25$ pc): (a) all CNSG stars with trigonometric parallaxes; (b) all CNSG stars with relative parallaxes better than 10 per cent; (c) all CNSH stars with relative parallaxes better than 10 per cent.

Each dot is a star.

Blue stars are on the left, red stars on the right.

Luminous stars are at the top, faint stars at the bottom.

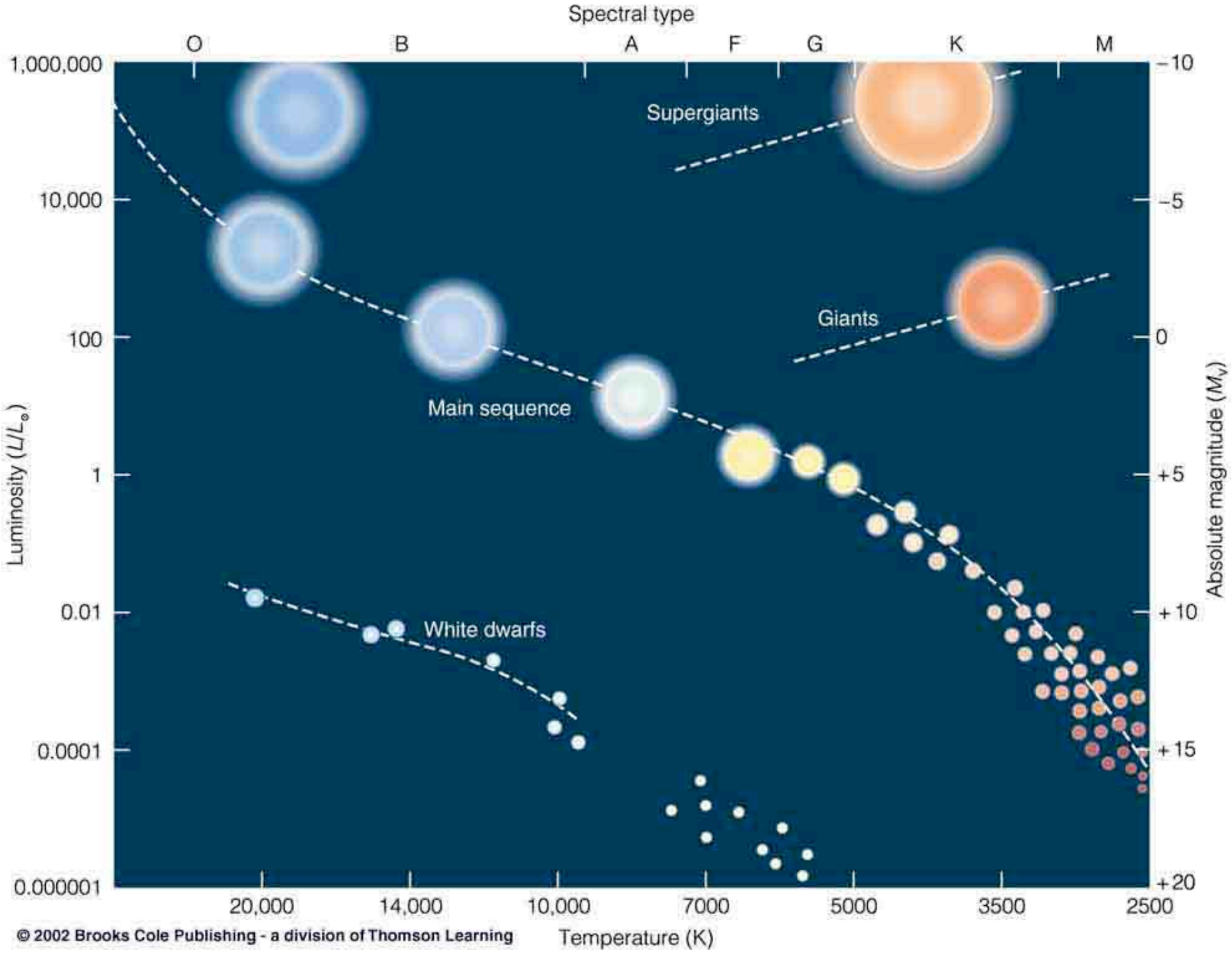
Temperature-Luminosity diagrams

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.



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).

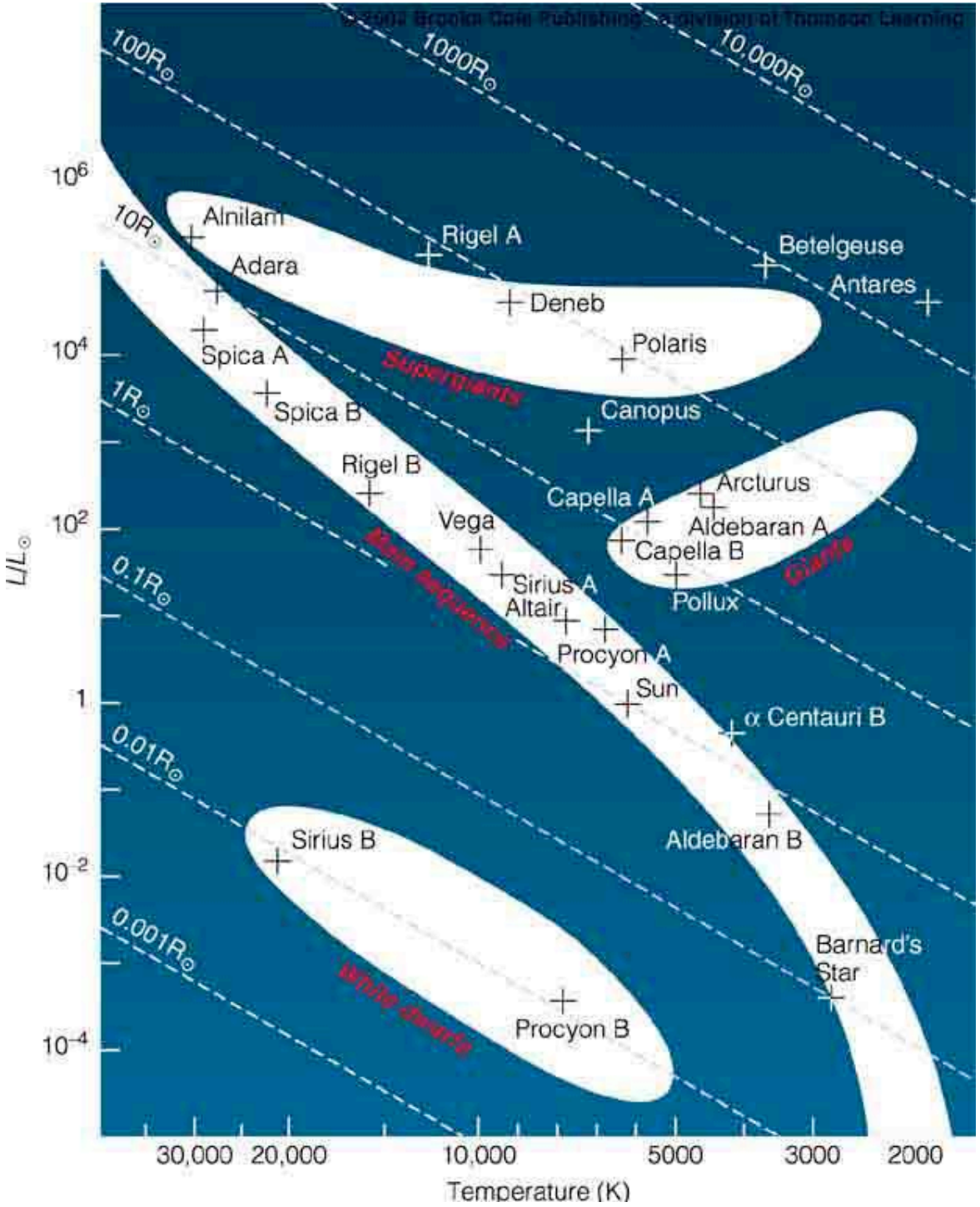
The Sun is one of these stars.

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?

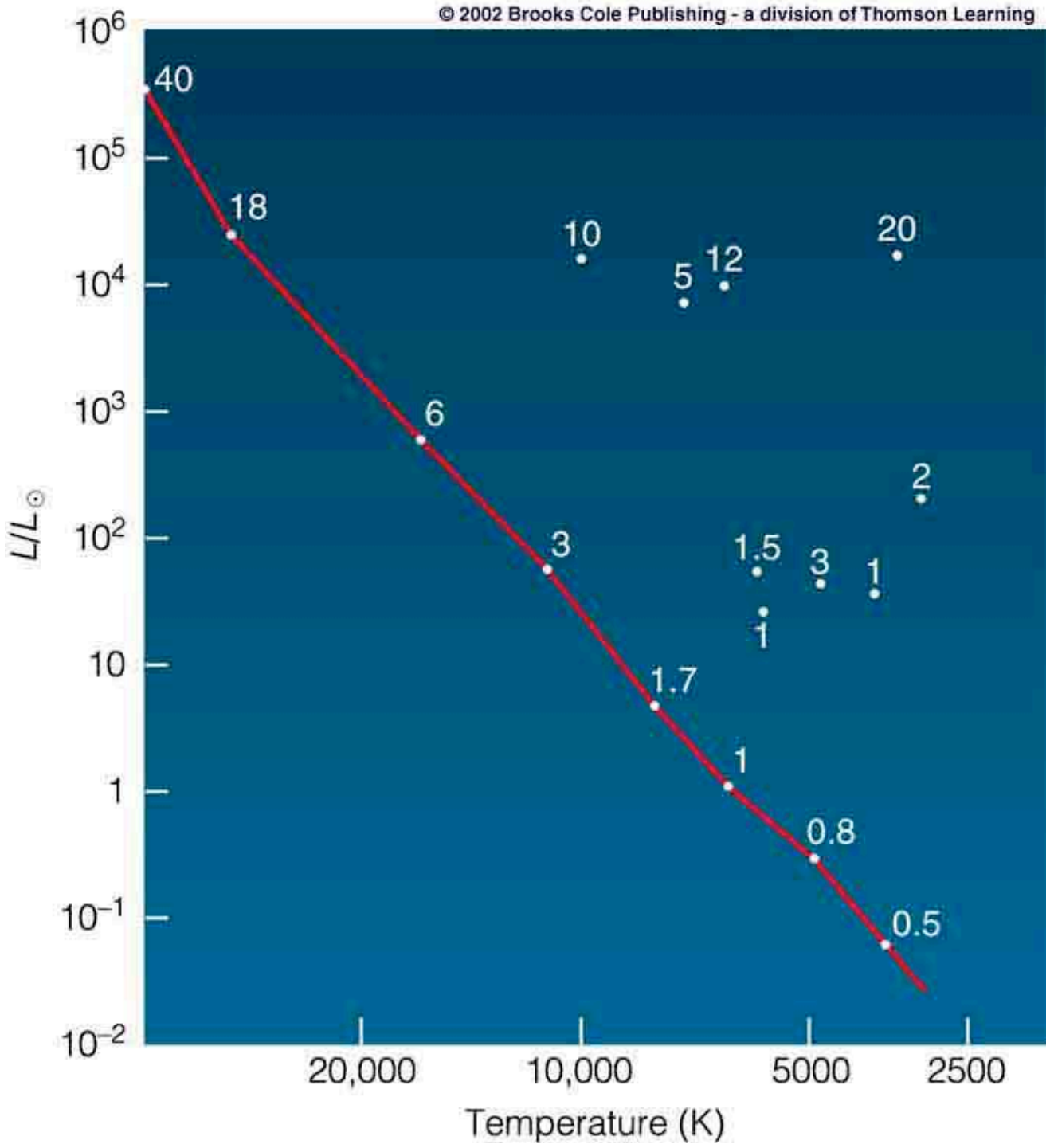

100R⊙
1000R⊙
10,000R⊙
10R⊙
1R⊙
0.1R⊙
0.01R⊙
0.001R⊙
Alnilam
Adara
Spica A
Spica B
Rigel A
Deneb
Betelgeuse
Antares
Polaris
Canopus
Rigel B
Capella A
Arcturus
Aldebaran A
Capella B
Vega
Sirius A
Altair
Procyon A
Pollux
Sun
α Centauri B
Aldebaran B
Sirius B
Procyon B
Barnard's Star
Supergiants
Main sequence
Giants
White dwarfs
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)

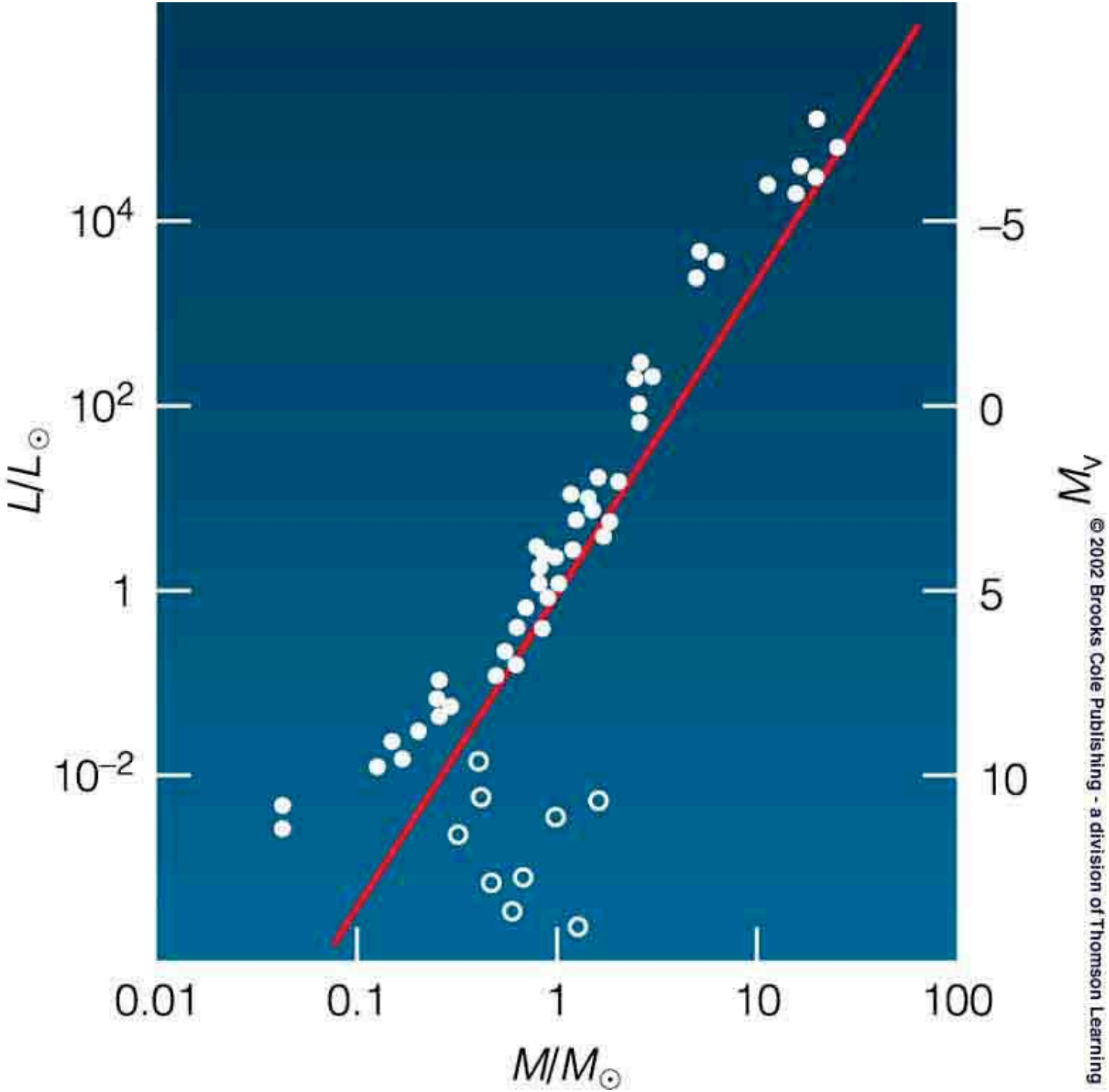
Mass – Luminosity Diagram

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.

Masses of stars on the H-R diagram





Groups of four

Choose a discussion leader and a scribe.

Read the graph:

What is the luminosity in solar luminosities of the Sun?

What is the luminosity of a 10 solar mass main sequence star? (Make an estimate.)

What is the relation between mass and luminosity?

$L \alpha M^x$

What is x? (Make an estimate.)