Hertzsprung-Russell Diagram

Astronomers have made surveys of the temperatures and luminosities of stars and plot the result on H-R (or Temperature-Luminosity) diagrams.

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

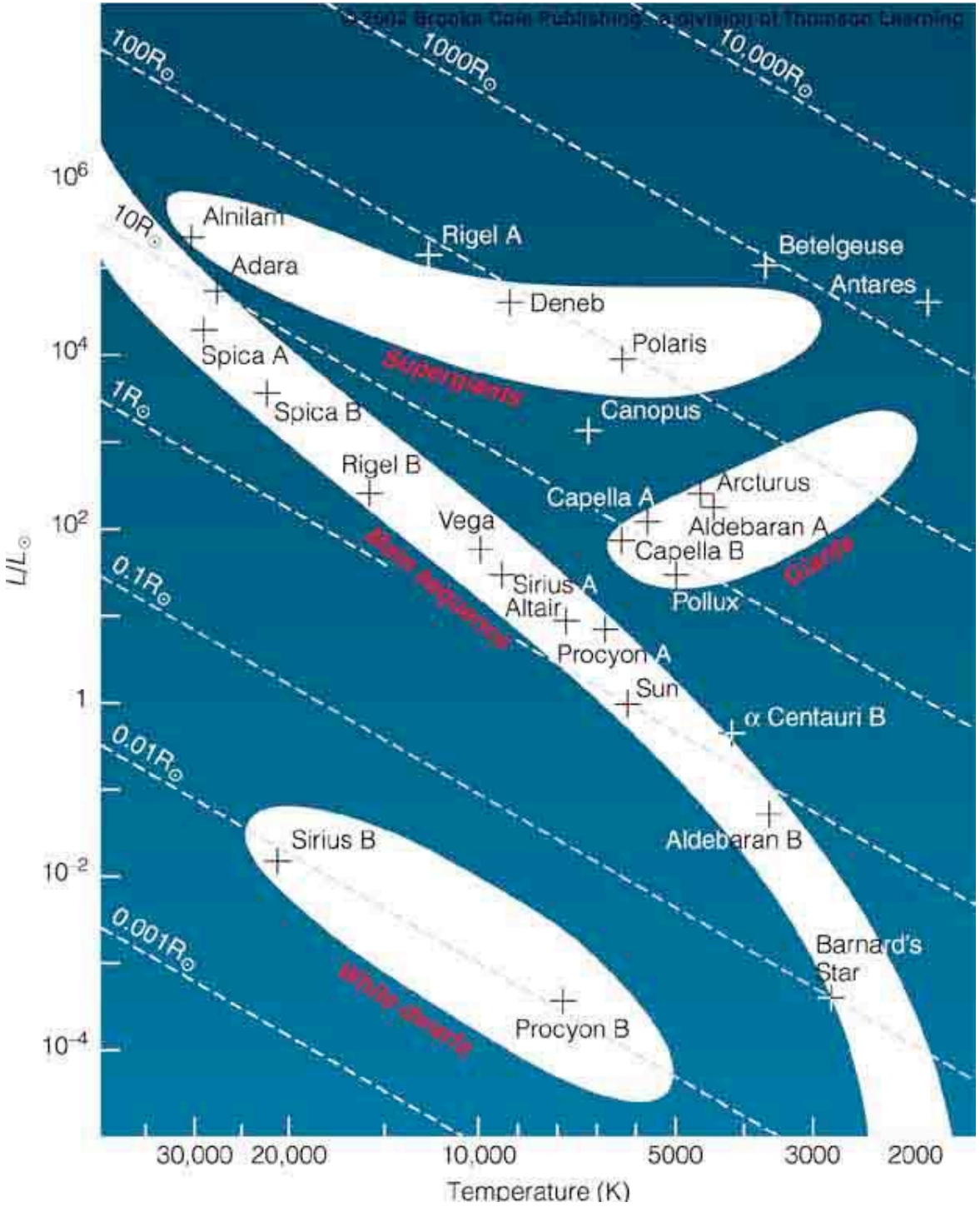
The Sun is one of these stars.

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
Pollux
Procyon A
Sun
α Centauri B
Aldebaran B
Sirius B
Barnard's Star
Procyon B
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)

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

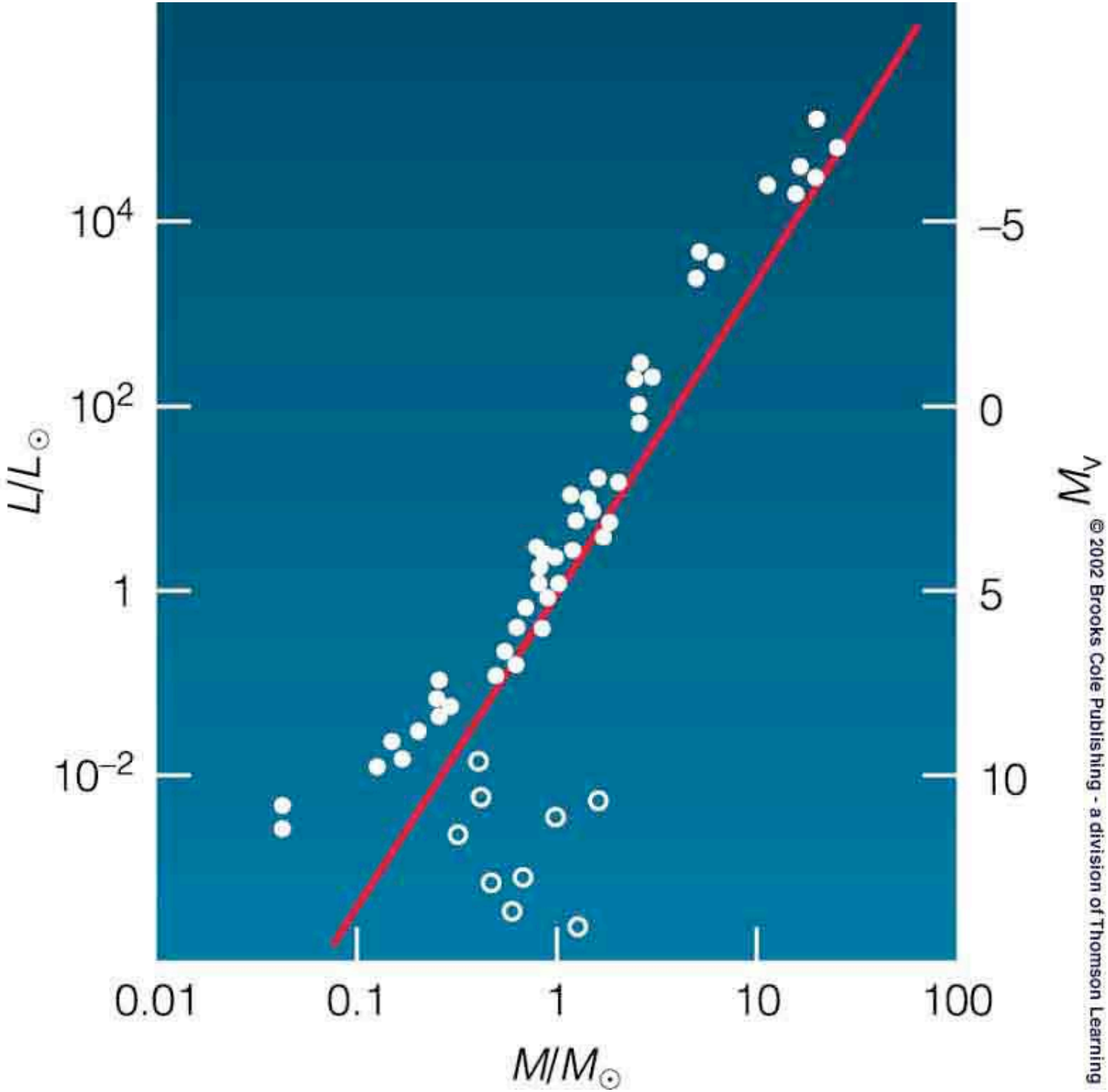
This mass in the formula is actually the sum of the masses of the two stars. If we observe the motions of both stars we can find out the mass of each star.

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.

(Although the luminosities of red giants and white dwarfs are not related to their masses, most red giants have masses similar to the Sun's or greater, whereas white dwarfs have masses similar to or less than the Sun's.)



What is the luminosity in solar luminosities of the Sun?

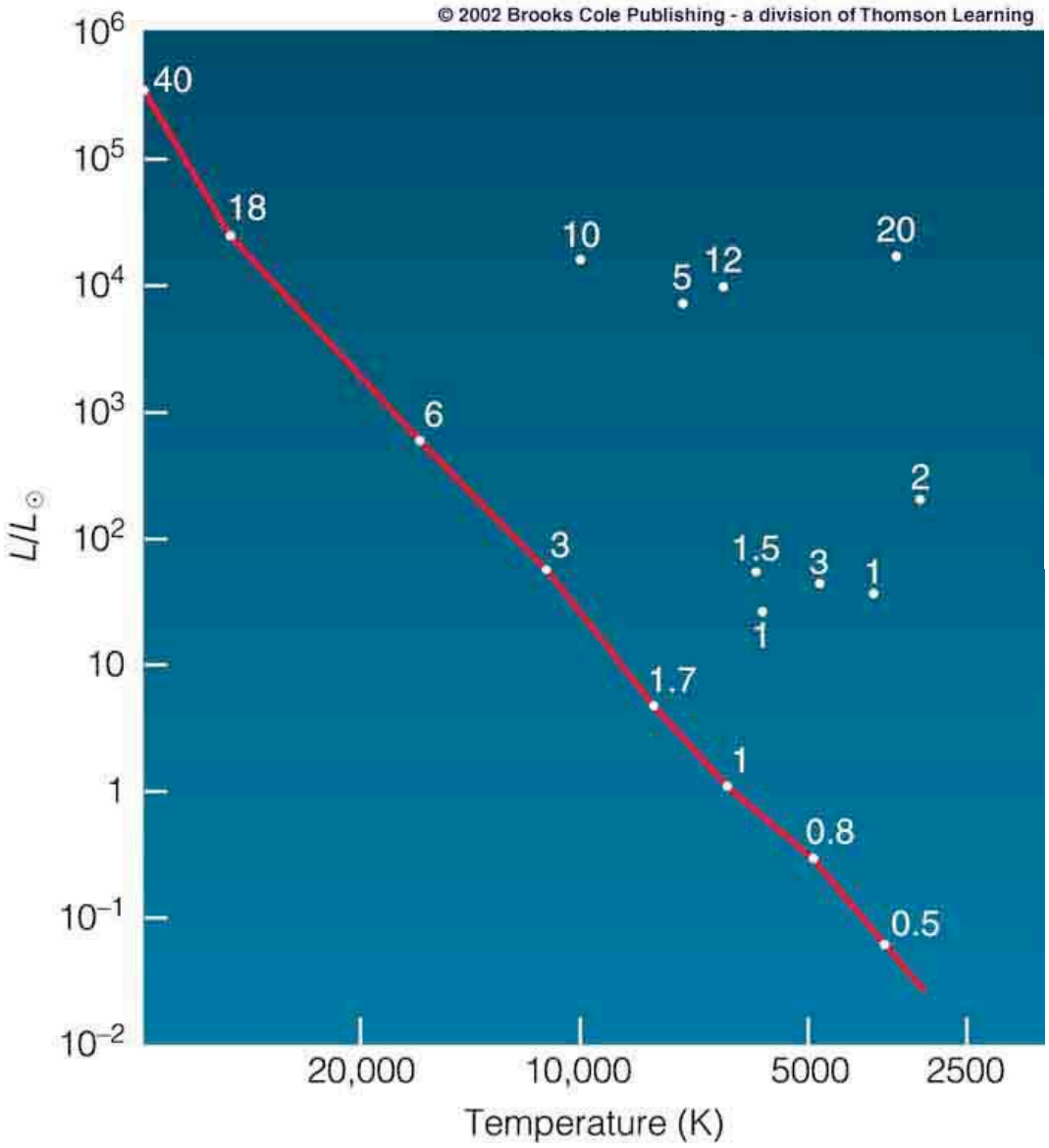
What is the luminosity of a 10 solar mass main sequence star? (Make an estimate.)

What is the relation between mass and luminosity?

We can write it as a proportion:
$L \propto M^x$

What is x? (Make an estimate.

Is luminosity proportional to mass? Or is it inversely proportional? Or does it vary more rapidly than proportional to mass?)



Mass-Luminosity Relation

1 solar mass	1 solar luminosity
10 solar masses	1000-10,000 solar luminosities

Increasing the mass by a factor of 10 makes the luminosity increase by a factor of 1000-10,000, or 10^3-10^4.

The rule must be L a M^3 or L a M^4.

L a $M^{3.5}$ is often used. (What does $M^{3.5}$ mean?)

Why are more massive stars more luminous?

You should find out this week.