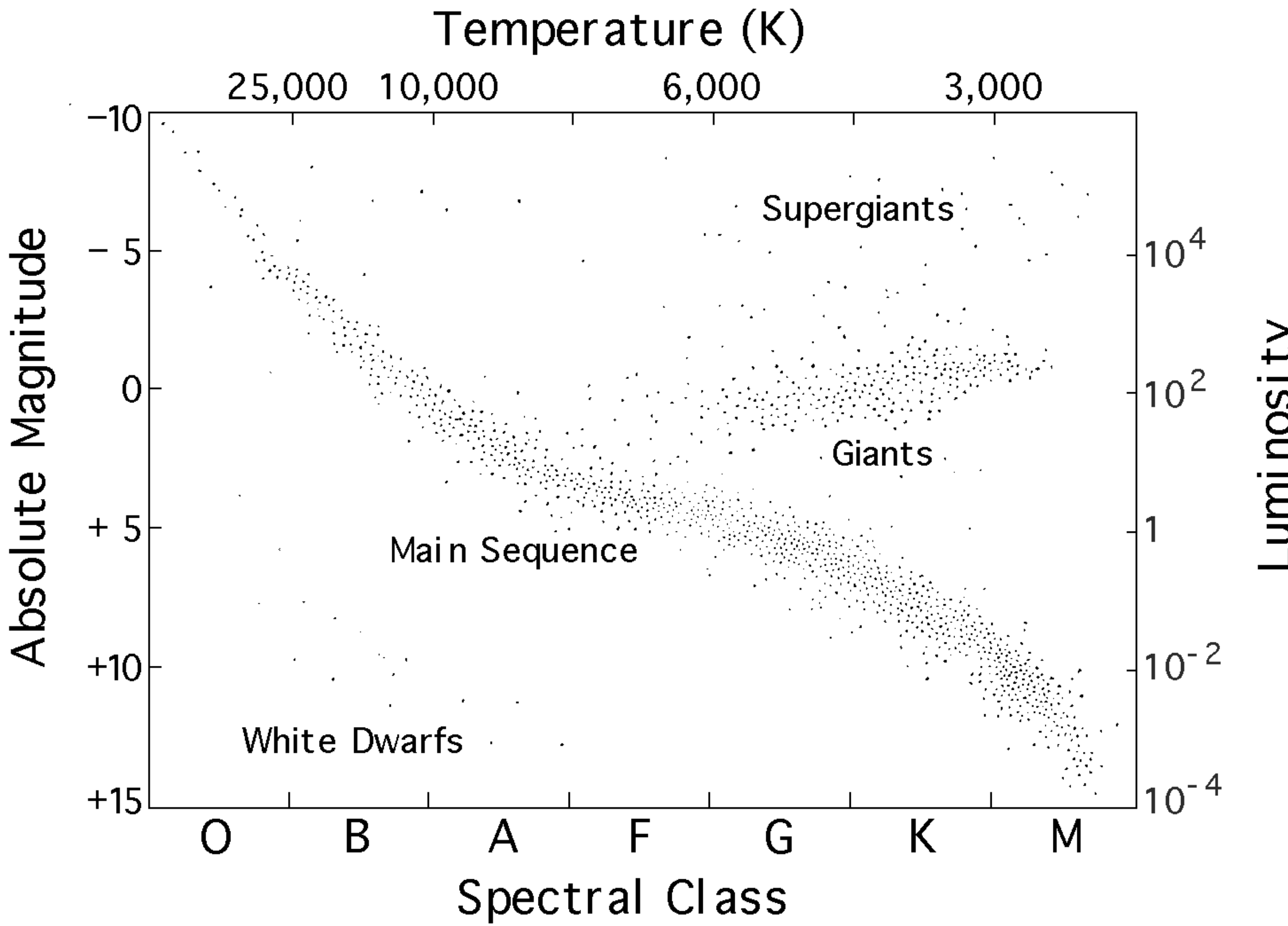
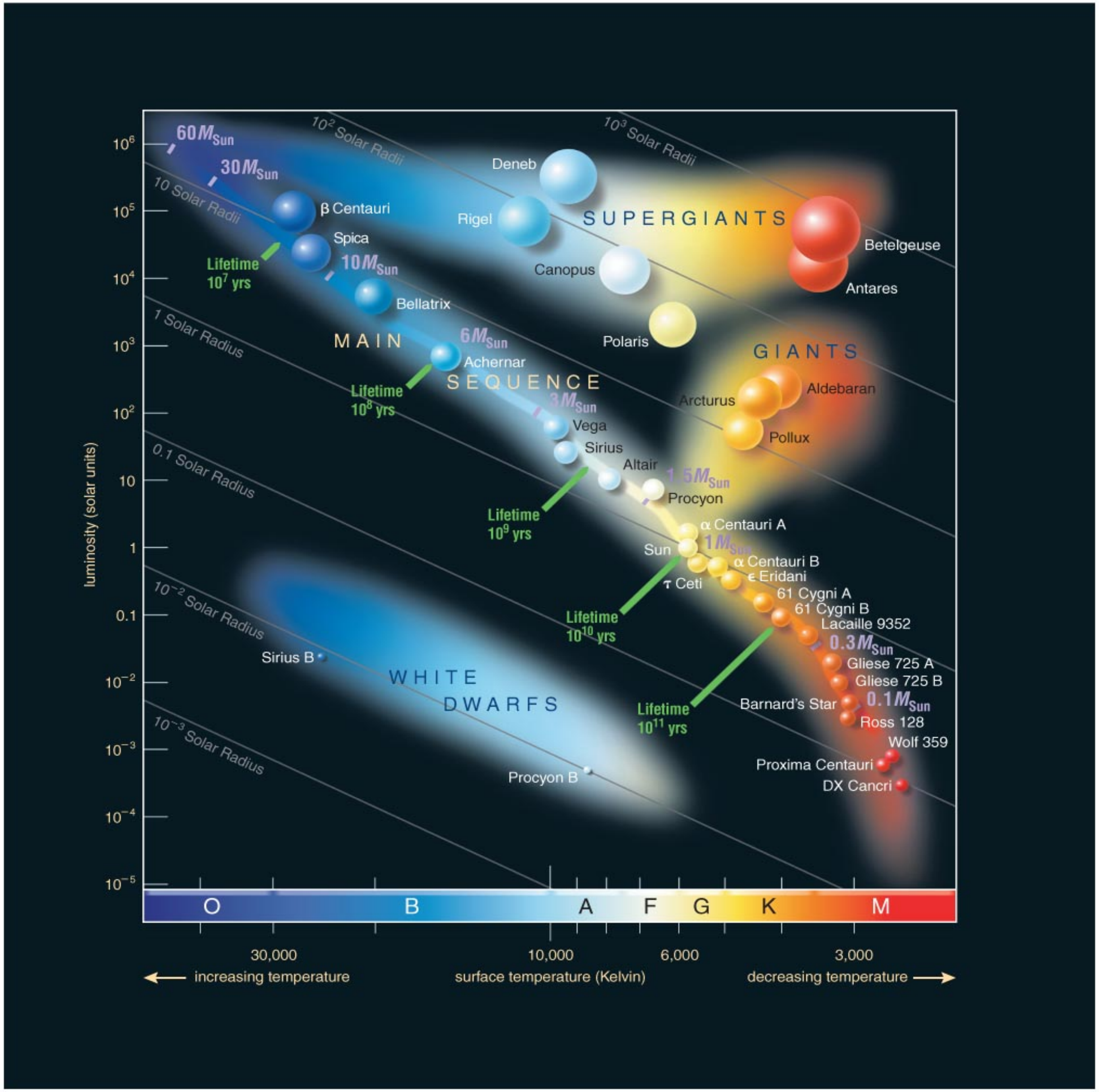
What tool do astronomers use to understand the evolution of stars?

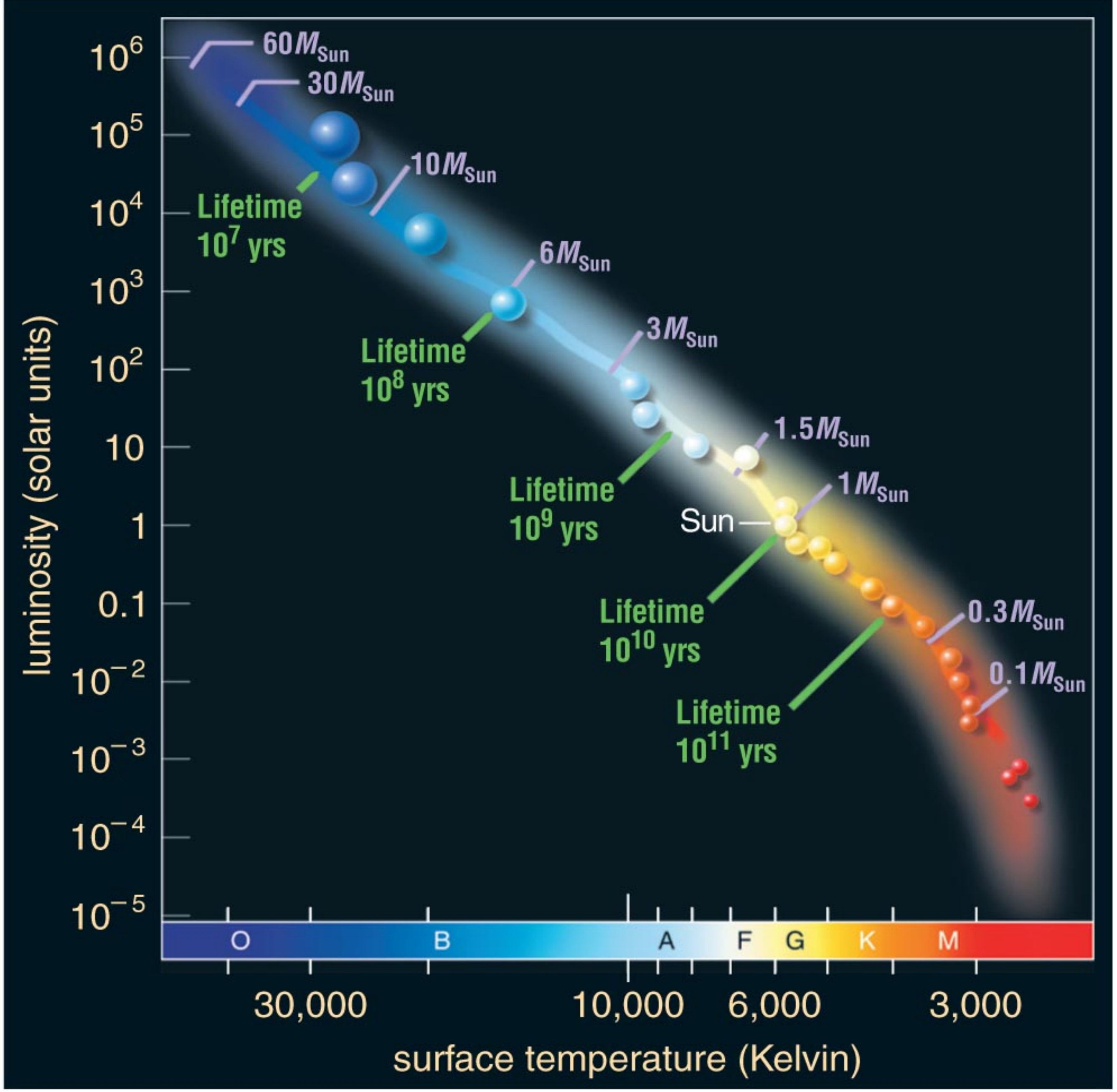


Groups indicate types of stars or stages in their evolution.

- What is plotted?
- How does an individual star move around the diagram?
- What causes a star to move around the diagram?



Main sequence is when a star is burning hydrogen in its core.
The luminosity and temperature of a main-sequence star are set by its mass.
More massive means brighter and hotter.



Stellar evolution

The evolution of a star is determined primarily by its

A) mass and chemical composition

B) mass and temperature

C) luminosity and chemical composition

D) luminosity and temperature

Star cluster age

The most massive star on the main sequence in a star cluster has a mass of 5 solar masses. Approximately how old is the cluster?

A) 1 Myr

B) 10 Myr

C) 100 Myr

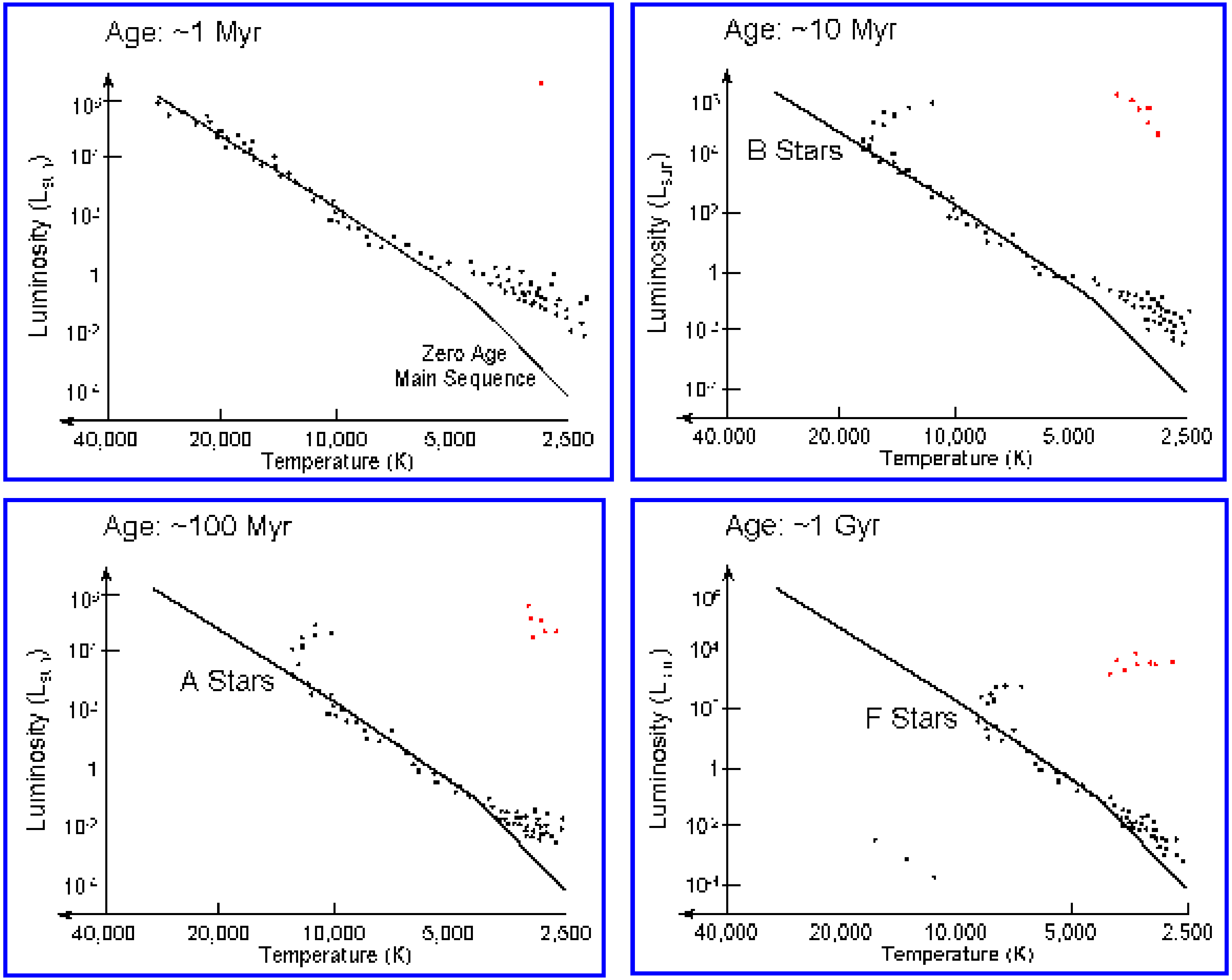
D) 1 Gyr

Star cluster age

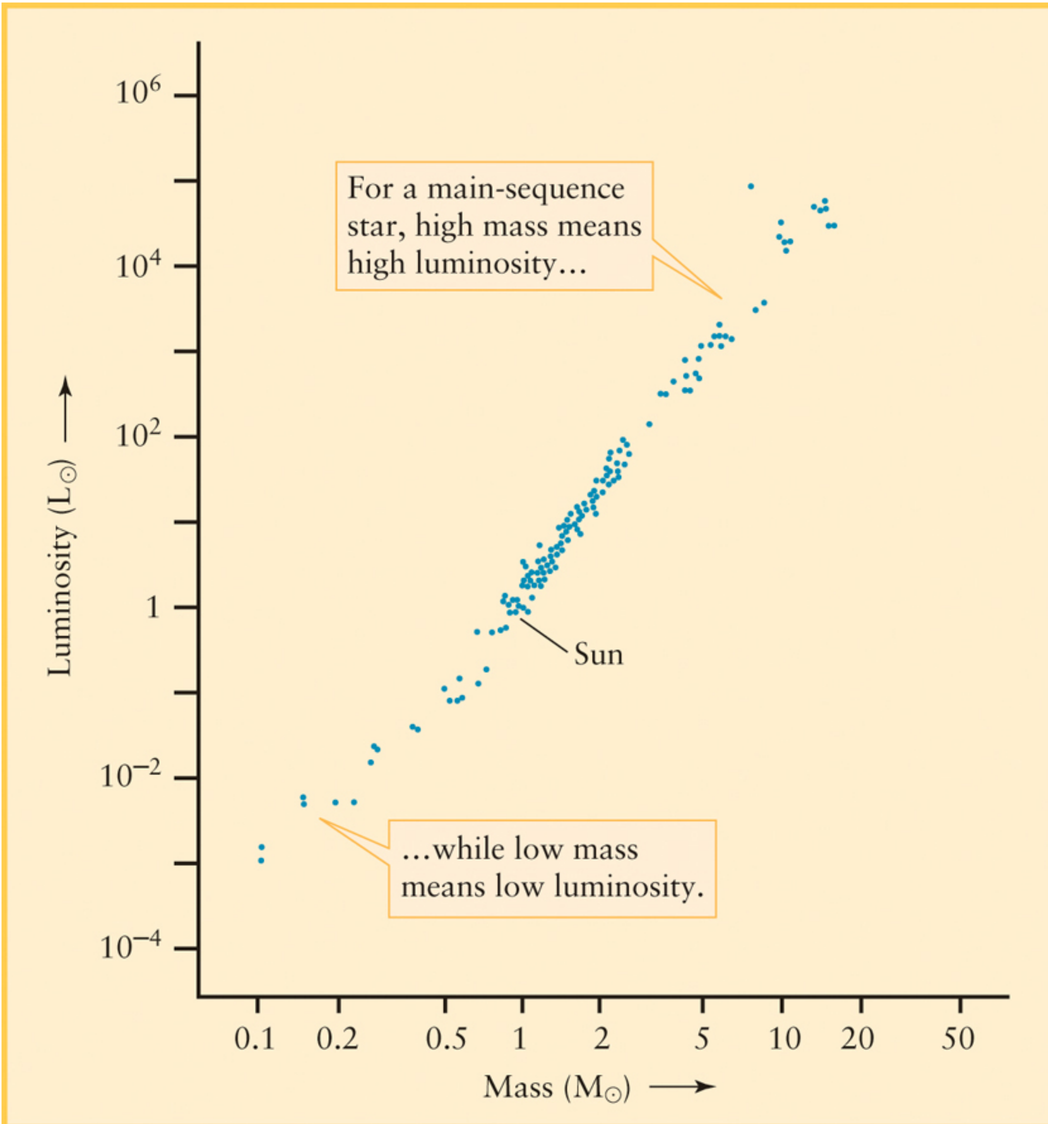
The age of a star cluster can be found by:

determining the turnoff point on the main sequence of its H-R diagram. (90.4 %)

Turn-off point of cluster reveals age



Mass-Luminosity relation on the main sequence



$$\frac{L}{L_\Theta} \approx \left(\frac{M}{M_\Theta}\right)^{3.5}$$

Mass-Lifetime relation

- The lifetime of a star (on the main sequence) is longer if more fuel is available and shorter if that fuel is burned more rapidly
- The available fuel is (roughly) proportional to the mass of the star
- From the previous, we known that luminosity is much higher for higher masses
- We conclude that higher mass star live shorter lives

A 5 solar mass star has about 5 times the sun's supply of nuclear energy. Its luminosity is about $5^{3.5} = 300$ times that of the sun. How does the lifetime of the star compare with that of the sun?

A) 5 times as long
B) the same
C) 5/300 as long
D) 1/300 as long

A five solar mass star has about 5 times the sun's supply of nuclear energy. Its luminosity is 300 times that of the sun. How does the lifetime of the star compare with that of the sun?

$$\frac{t_A}{t_B} = \frac{M_A}{M_B}\frac{L_B}{L_A} = \frac{5}{1}\frac{1}{300} = \frac{5}{300} = \frac{1}{60}$$

Sun's lifetime ~ 10 billion years = 10^{10} yr = 10 Gyr.

Lifetime of 5 solar mass star is 10^{10} yr/60 ~ $10^{10}/10^{2}$ yr = 10^{8} yr = $10^{2}\times10^{6}$ yr = 100 million yr = 100 Myr

This is the age of the star cluster.

Star cluster age

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Luminosity, temperaure, radius

Two stars are found to have the same luminosity. However, one star has twice the surface temperature of the other. From this information, what can you determine about their radii?

A) The hotter star has half the radius of the cooler star.

B) The cooler star has half the radius of the hotter star.

C) The hotter star has a quarter the radius of the cooler star.

D) Nothing can be determined about the radii from this information.

Luminosity Law

$$\frac{L_A}{L_B} = \frac{R_A^2 T_A^4}{R_B^2 T_B^4}$$

$$R_A^2 T_A^4 = R_B^2 T_B^4$$

$$R_A^2 T_A^4 = R_B^2 T_B^4$$

Set $T_A = 2$ and $T_B = 1$

$$R_A^2 2^4 = R_B^2 1^4$$

$$R_A = \frac{R_B}{2^2} = \frac{R_B}{4}$$

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Protostars

Compared to our Sun, which of the following does NOT describe the protostar out of which it formed?

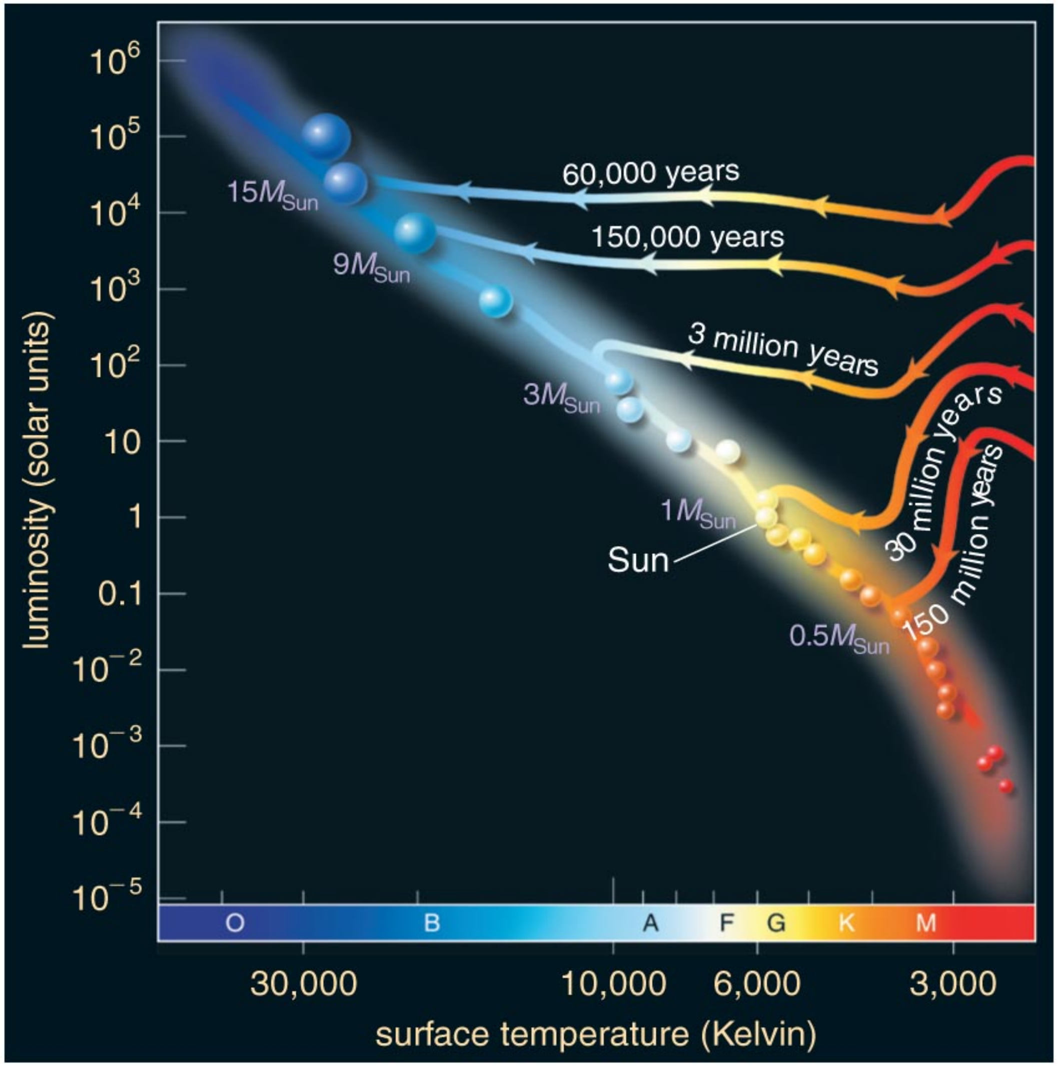
A) It was bigger than our Sun.

B) It was cooler than our Sun.

C) It was more luminous than our Sun.

D) All of the above statements describe the protostar.

Protostars on HR diagram



- Luminosity?
- Temperature?
- Radius?

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Spectra

Suppose we observe a cloud of cool gas with a star behind it. The combined spectrum will be

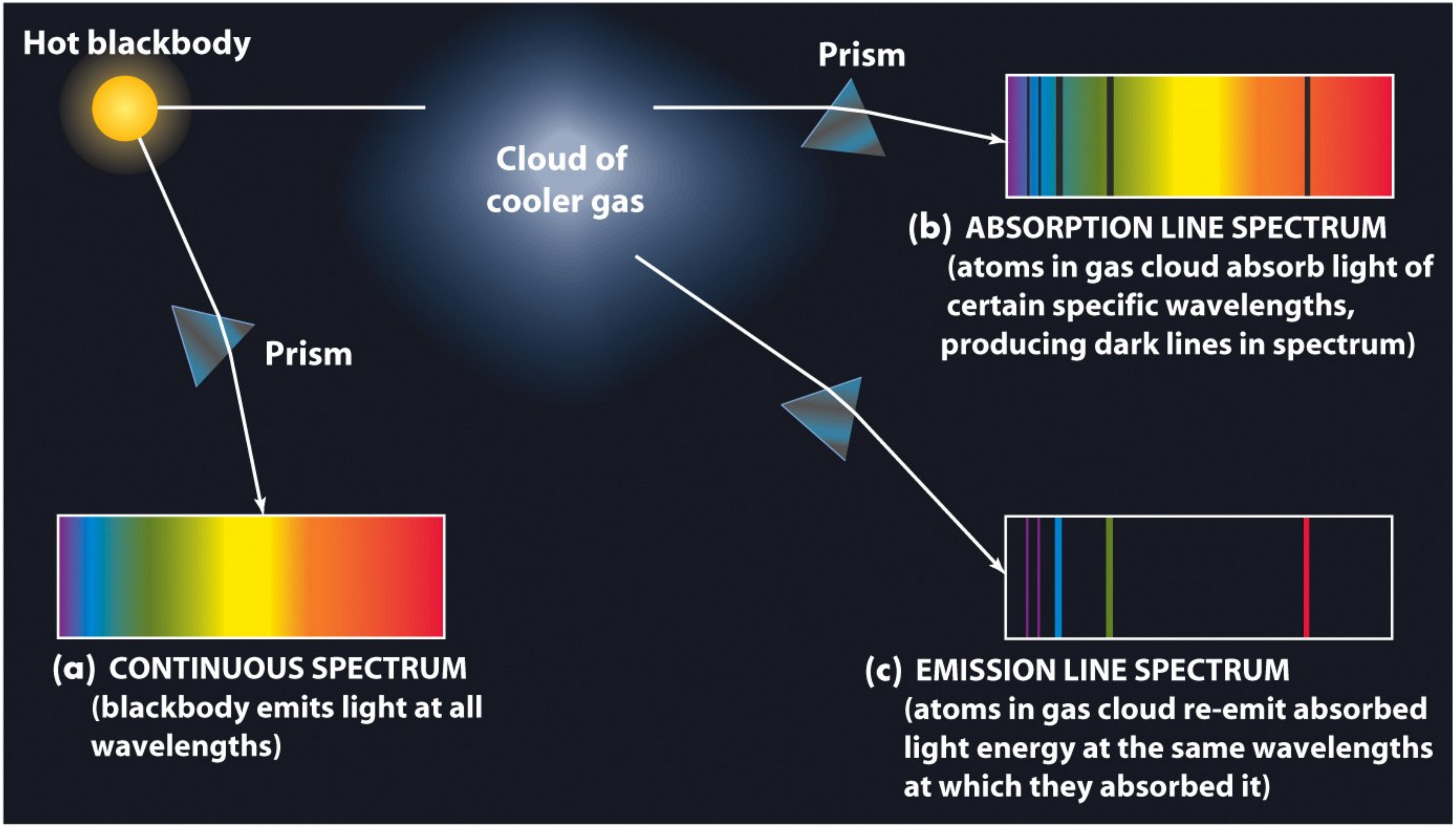
A) absorption lines only

B) continuous radiation only

C) continuous radiation with emission lines superimposed

D) continuous radiation with absorption lines superimposed

Lines can be emitted or absorbed



Spectra

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D) continuous radiation with absorption lines superimposed

Emission of photons

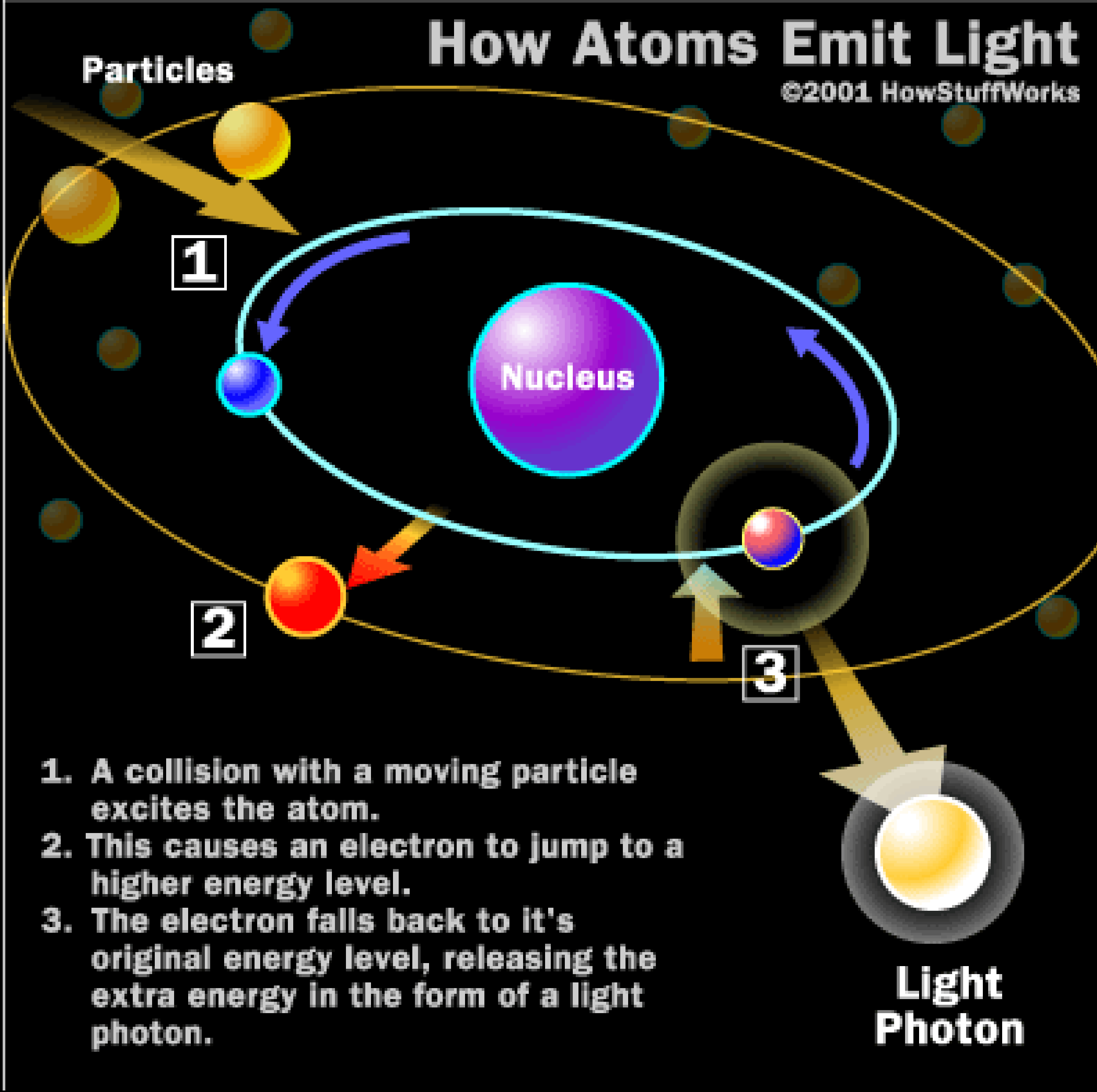
Which of the following processes will result in the emission of a photon?

A) the electron in an atom jumping to a higher energy level

B) the electron in an atom jumping to a lower energy level

C) an atom becoming ionized

D) the electron in an atom remaining in the ground state


How Atoms Emit Light
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Particles
1
Nucleus
2
3
1. A collision with a moving particle excites the atom.
2. This causes an electron to jump to a higher energy level.
3. The electron falls back to it's original energy level, releasing the extra energy in the form of a light photon.
Light Photon

Emission of photons

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Equation Sheet

Some useful numbers:

Radius	Distance
Moon = 1.7×10^{6} m	Earth-Moon = 3.8×10^{8} m
Earth = 6.4×10^{6} m	Sun-Earth = 1.5×10^{11} m
Sun = 7.0×10^{8} m	Sun-Alpha Centauri = 4.1×10^{16} m

1 light-year = 9.5×10^{15} m

1 parsec = 3.26 light-years = 3.086×10^{16} m

Parallax formula: $d = 1/p$ for d in pc, p in arcseconds

Small angle formula $S = \frac{\alpha \cdot d}{206265}$ for S, d in meters, α in arcseconds

Schwarzschild radius = 3 km (M/M_{Sun})

$$\frac{\text{Flux}_A}{\text{Flux}_B} = \frac{\text{Luminosity}_A}{\text{Luminosity}_B}\left(\frac{\text{Distance}_B}{\text{Distance}_A}\right)^2$$

$$\frac{L_A}{L_B} = \frac{R_A^2 T_A^4}{R_B^2 T_B^4}$$