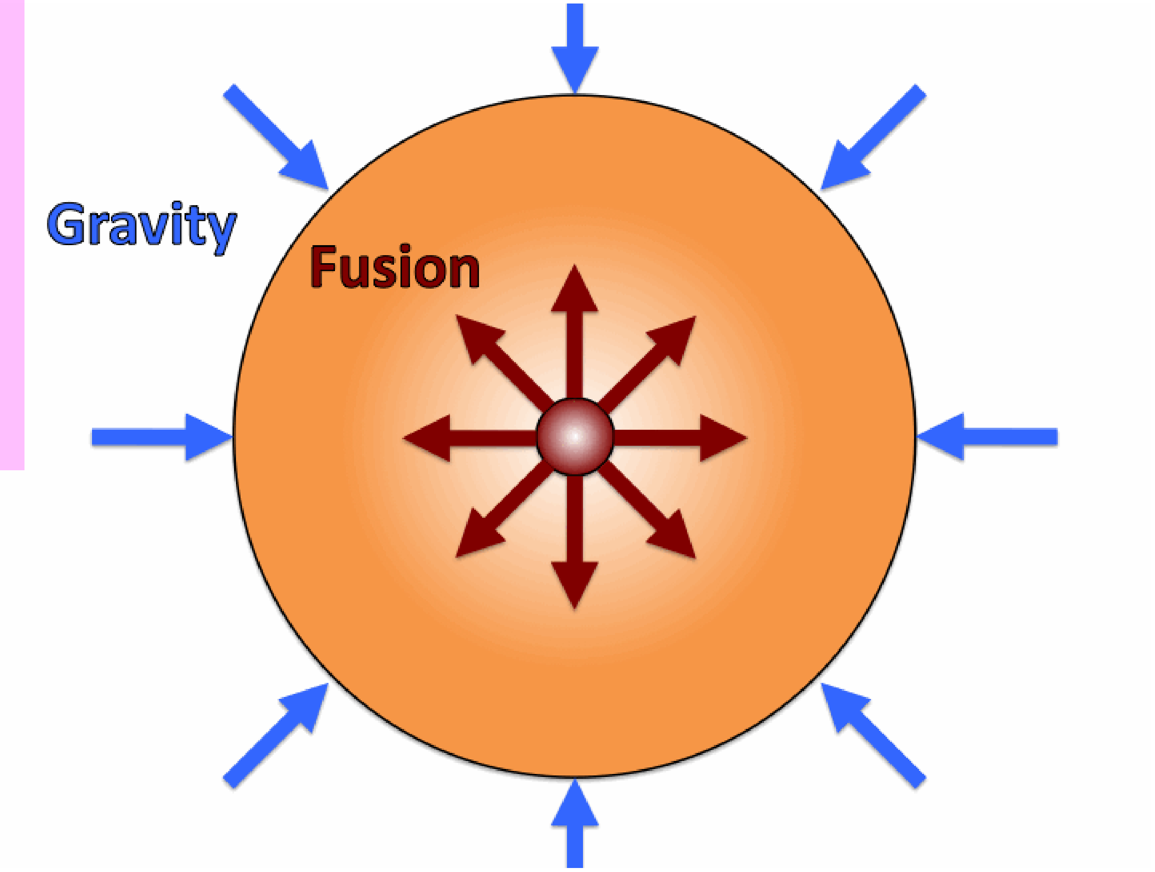
A star's **internal gravity** is proportional to the mass of the star. **More mass = more gravity** pulling gas molecules into the core making the core very dense and hot.

Hot core + high inward pressure of the gravity squeezing gas molecules together causes fusion.



Large mass stars

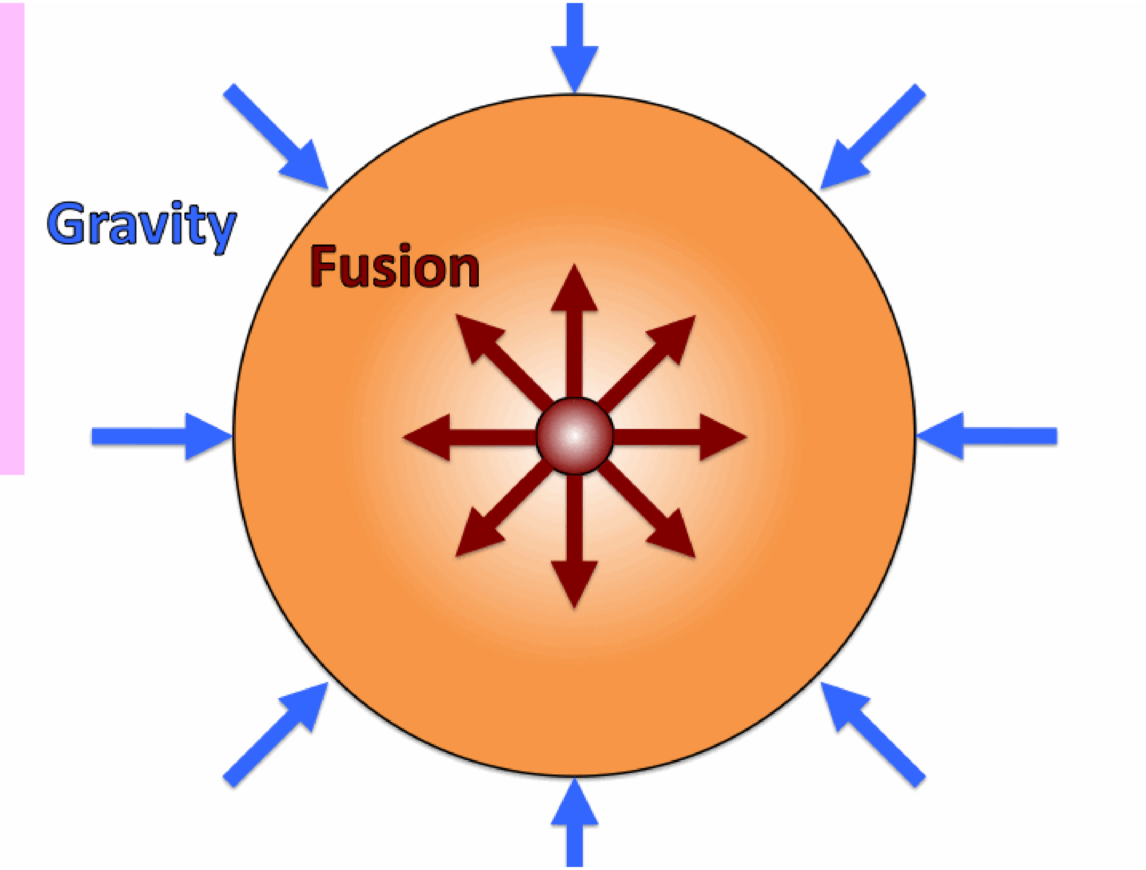
- Have a stronger inward gravity.
- Make more pressure and heat on the core
- Make fusion rate higher
- Make greater luminosity
- AND…they fuse their hydrogen so fast that they run out of available hydrogen sooner.

Low mass stars

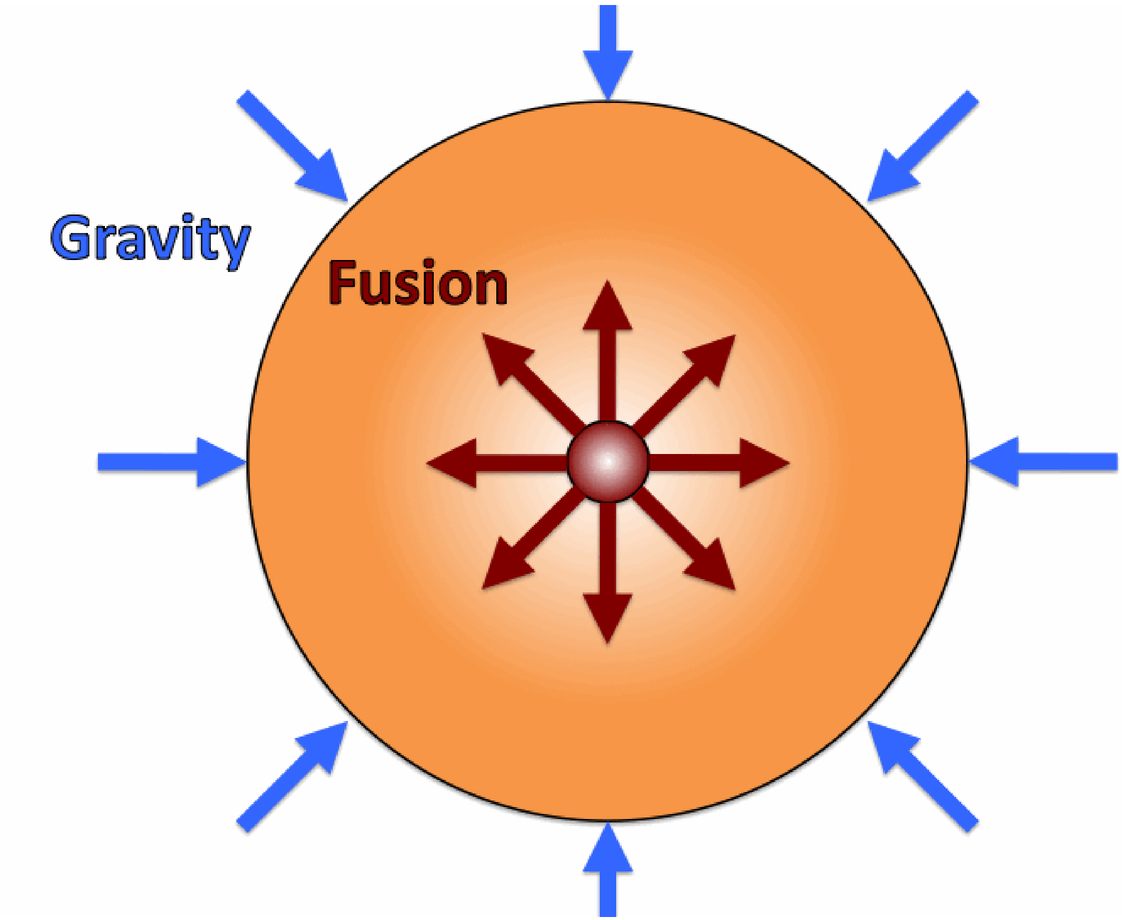
- Have a weaker inward gravity.
- Make less pressure and heat on the core
- Make fusion rate slower
- Make lower luminosity
- AND…they fuse their hydrogen much slower so it takes a longer time for them to run out of available hydrogen.

The fusion in the core, and the resultant generation of heat and energy, pushes the inner layers of the sun outward away from the core (through the radiative zone and convective zone).

Gravity pulls mass inward to the core. Fusion pushes mass outward away from core.

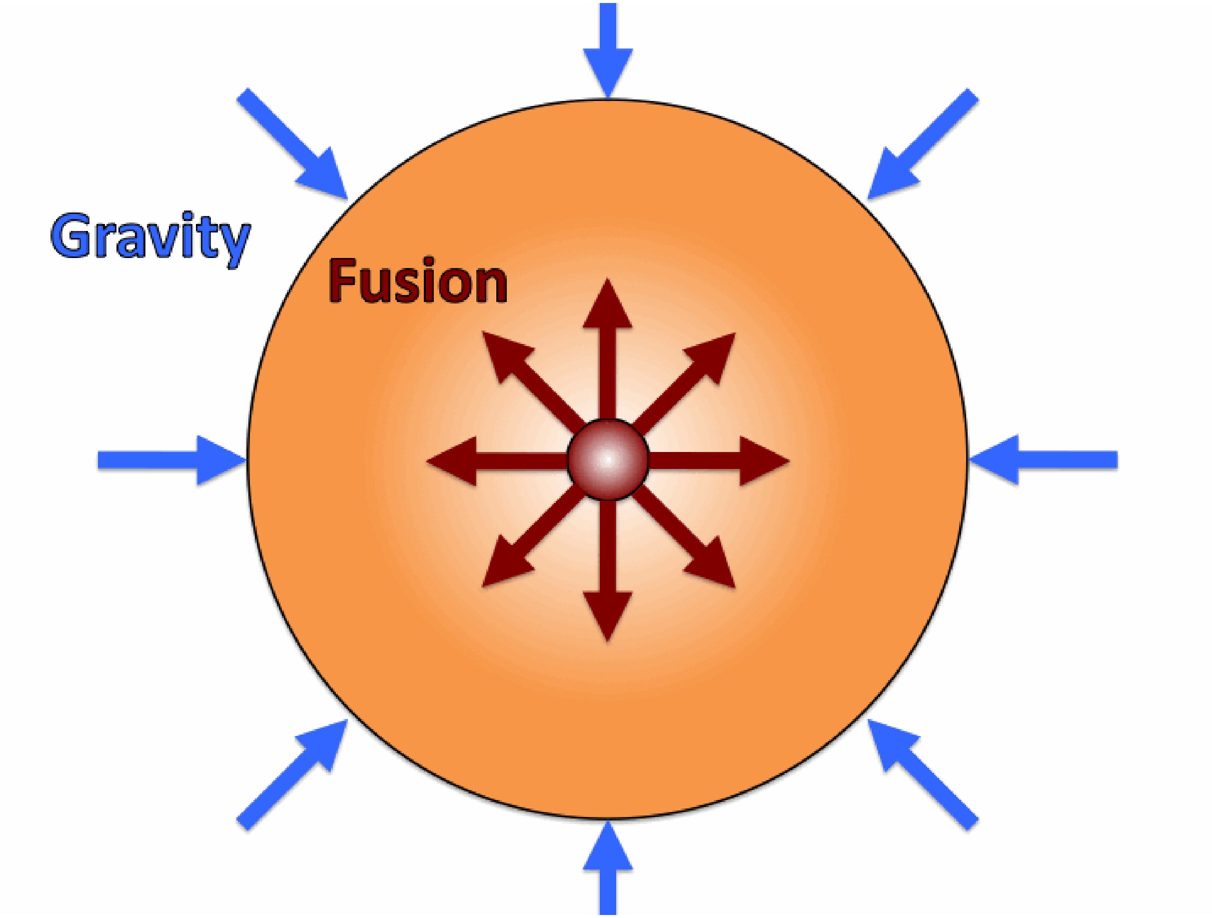


Hydrostatic equilibrium: The stable "balanced" state when the outward push force through a liquid or gas is equal in magnitude and opposite in direction to the inward pull force.

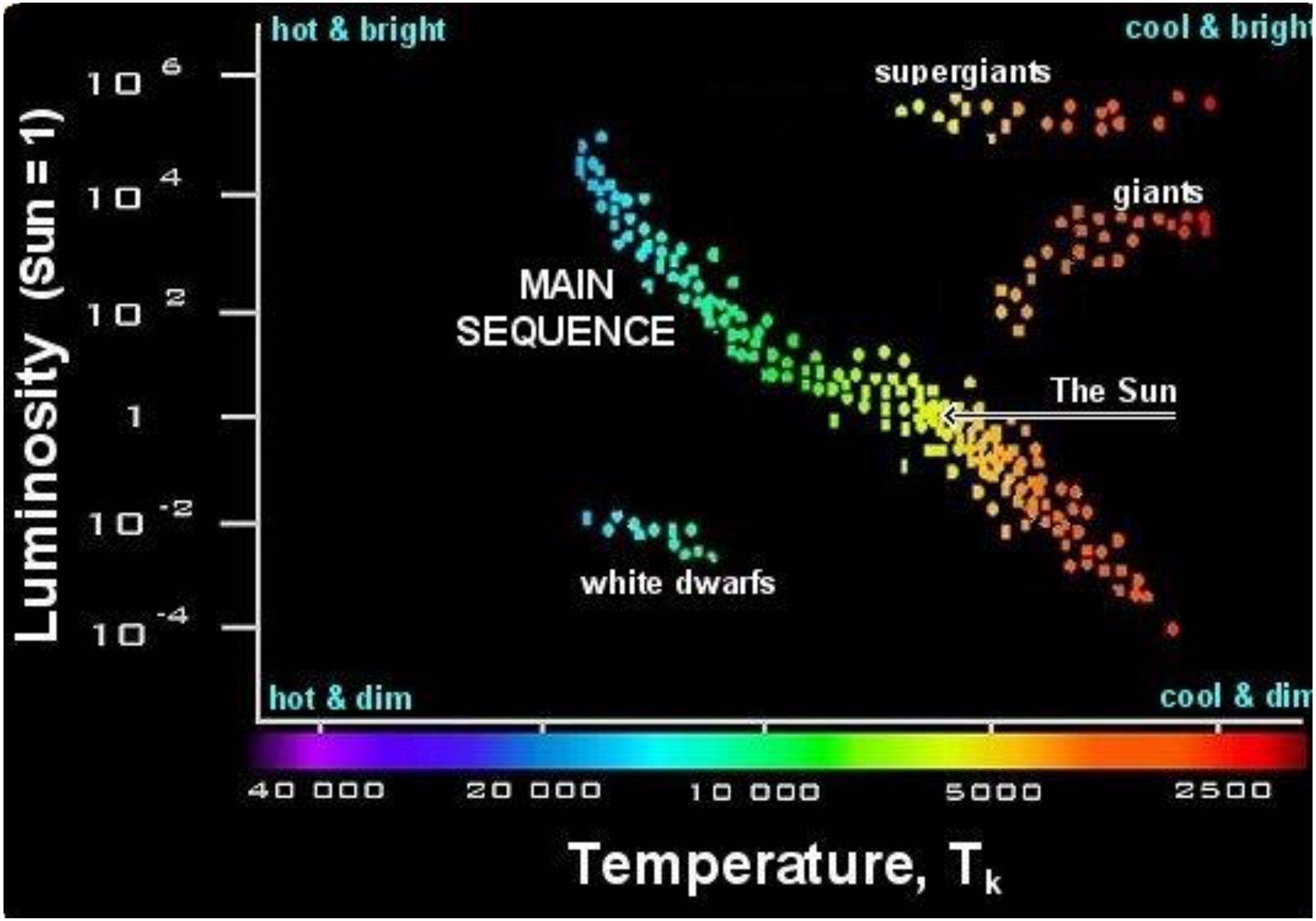


Main sequence stars keep a stable volume and radius when they are at a state of hydrostatic equilibrium.

As long as the **rate of fusion** in the core is at a certain level to make the outward push force that exactly balances the inward force of gravity, the star will maintain a stable radius and volume.



Hertzsprung Russell Diagram: A graph or plot of observable stars based on their luminosity and surface temperature.



Vertical axis (y-axis): **10-Log Luminosity ratio**

- The luminosity ratio is the luminosity of the star divided by the luminosity of the Sun.
- The scale is 10-Log units
- Compares the amount of star/light power released by a star relative to the Sun's star/light power.

- Luminosity ratio of 1 (10 Log = 0): Star has equal luminosity as to the Sun.
- Luminosity ratio of 10 (10 Log = 1): Star has 10-times the luminosity as the Sun.
- Luminosity ratio of 1000 (10 Log = 3): Star has 1000-times the luminosity as the Sun.
- Luminosity ration of 0.01 (10 Log = -2) Star has 1/100-times the luminosity as the Sun.

Horizontal axis (x-axis): **Surface temperature in Kelvin**

- The surface temperatures are for the Star's photosphere.
- The scale is Kelvin.
- Surface temperature controls the color of the star.

Red: 2500 K to 3500 K

Orange: 3500 K to 5000 K

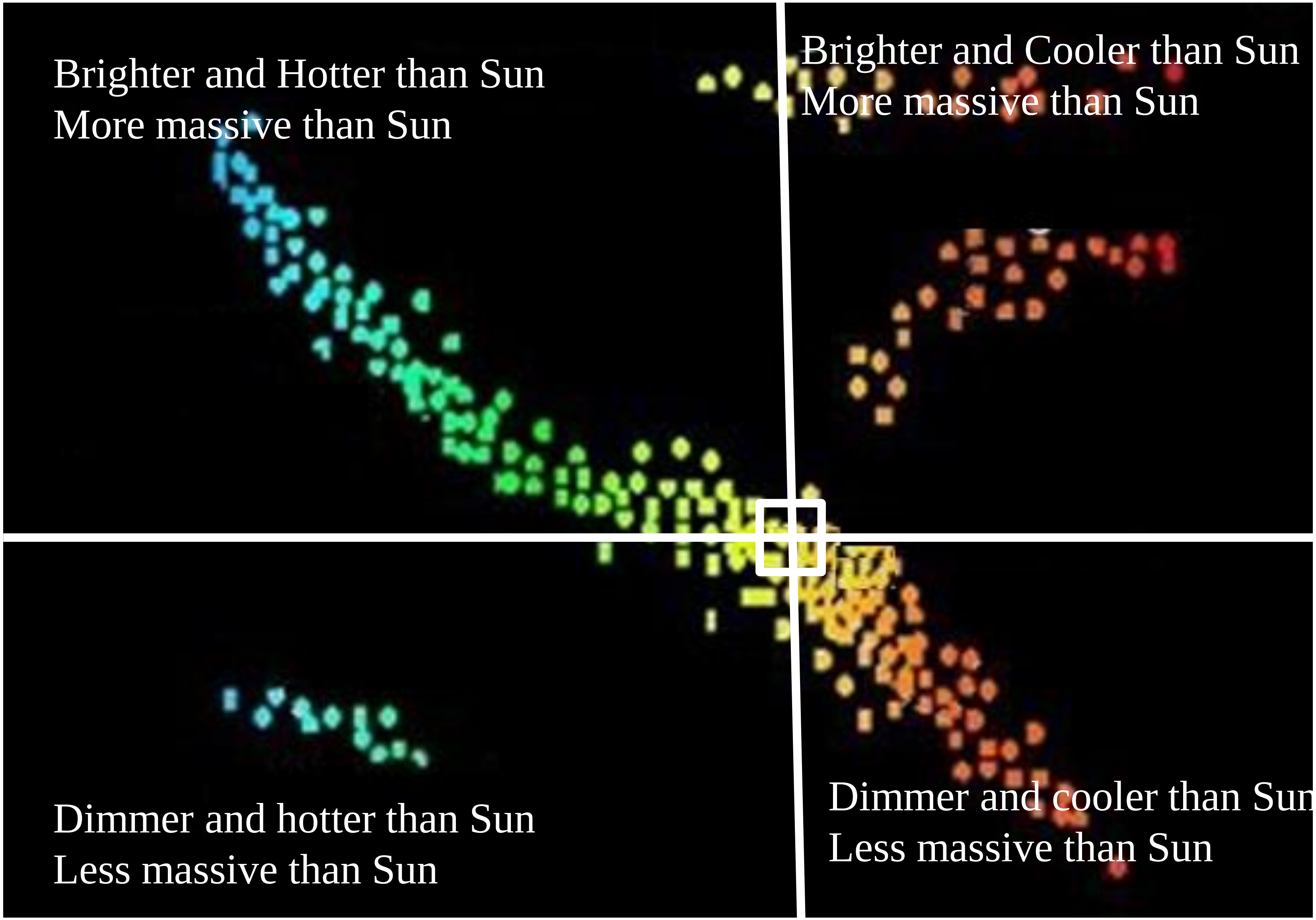
Yellow: 5000 K to 6000 K

Yellowish-white stars: 6000 K to 7500 K

White: 7500 K to 10,000 K

Blue: 10,000 K to 25,000 K

* There are no green stars.


Brighter and Hotter than Sun
More massive than Sun
Brighter and Cooler than Sun
More massive than Sun
Dimmer and hotter than Sun
Less massive than Sun
Dimmer and cooler than Sun
Less massive than Sun

Types of Main Sequence Stars

- Red dwarfs
- Orange dwarfs
- Yellow dwarfs
- White giants
- Blue giants
- Blue supergiants*

Main sequence stars are in the stable part of their lifespan. They are **actively fusing hydrogen to helium** in their cores. Their size and volume remains constant due to the constant rate of fusion.

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Types of Giant Stars

- Red giants
- Orange giants
- Yellow giants

Types of Supergiant Stars

- Red super giants
- Orange super giants
- White super giants
- Blue super giants

Giant stars lie outside of the Main Sequence. They are degenerating stars—going through the last stages of stellar evolution. They are in the process of dying.

White dwarf stars lie outside of the Main Sequence. They are very hot remnants of the cores of dead small-to-medium size stars.

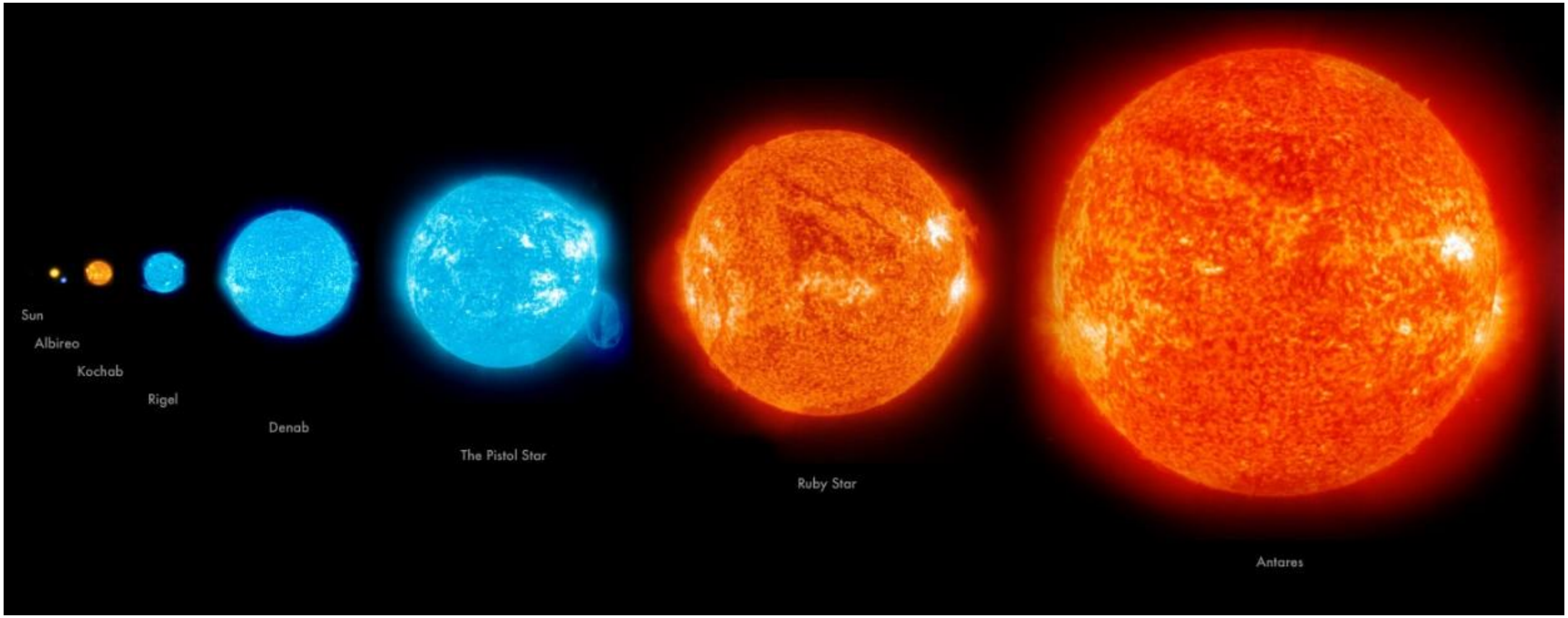
Lifespan of Main Sequence stars

Red dwarfs	M: 100 BY-1 TY
Orange dwarfs	K: 10 BY to 100 BY
Yellow & White	F-G: ~1 BY to 10 BY
Whitish giants	A: ~100 MY to 1 BY
Blue giants	B: ~10 MY to 100 MY
Blue supergiants	O: ~1 MY to 10 MY

Solar Masses of Main Sequence stars

Red dwarfs	M: 0.1-0.3 SM
Orange dwarfs	K: 0.3-0.8 SM
Yellow & White	F-G: 0.8-1.5 SM
Whitish giants	A: 1.5-3.0 SM
Blue giants	B: 3-10 SM
Blue supergiants	O: > 10 SM

Giant stars and supergiant stars are more massive and are much more luminous than the Sun.

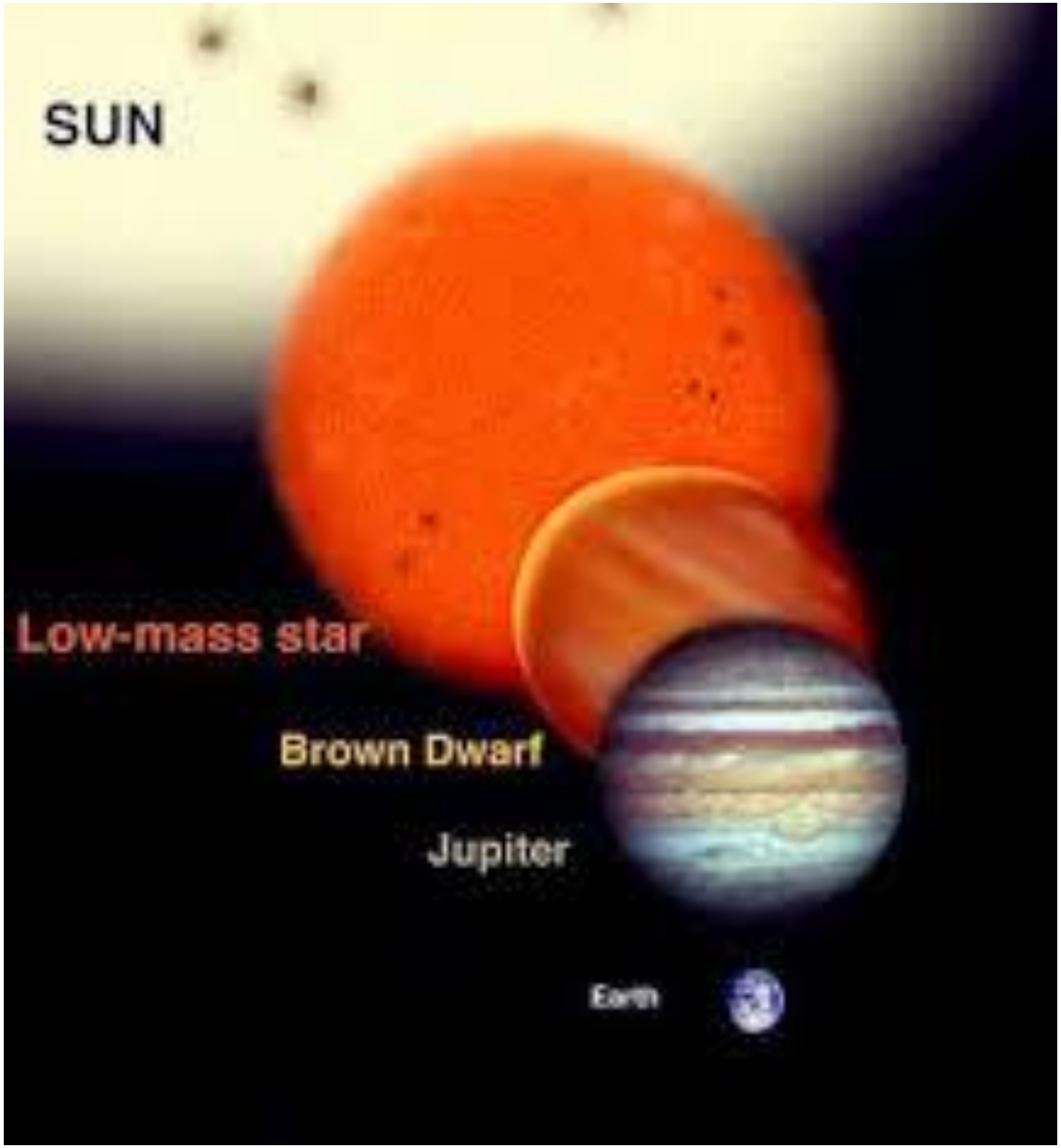


Red giants

Blue supergiants

Red supergiants

Low Mass Stars (Dwarf stars)



Red dwarf stars are the lowest mass "true star".

Brown dwarf stars are sometimes called "failed stars". They do not have enough mass and internal gravity to start fusion in their cores.

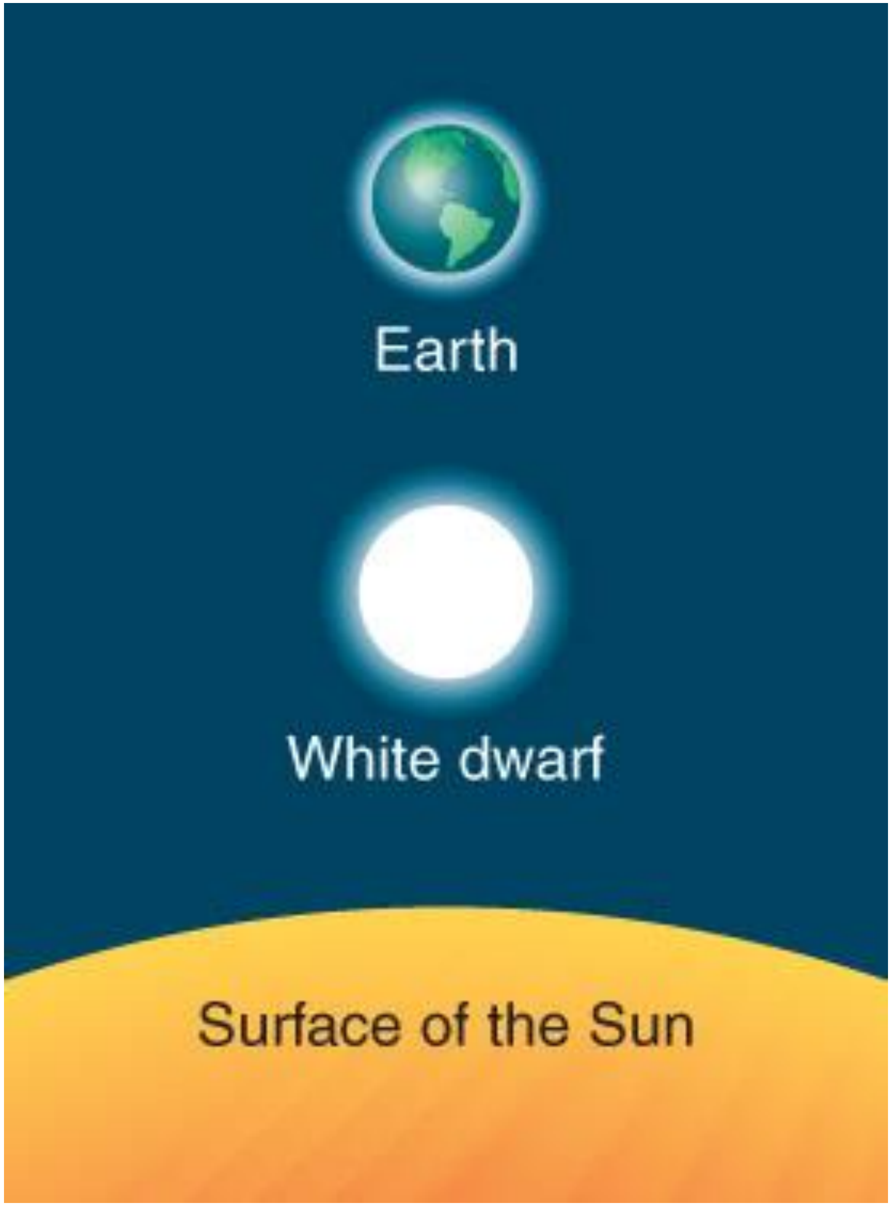
White Dwarf Stars

White dwarfs do not produce energy. They radiate away their leftover energy and simply fade away and become black dwarfs.

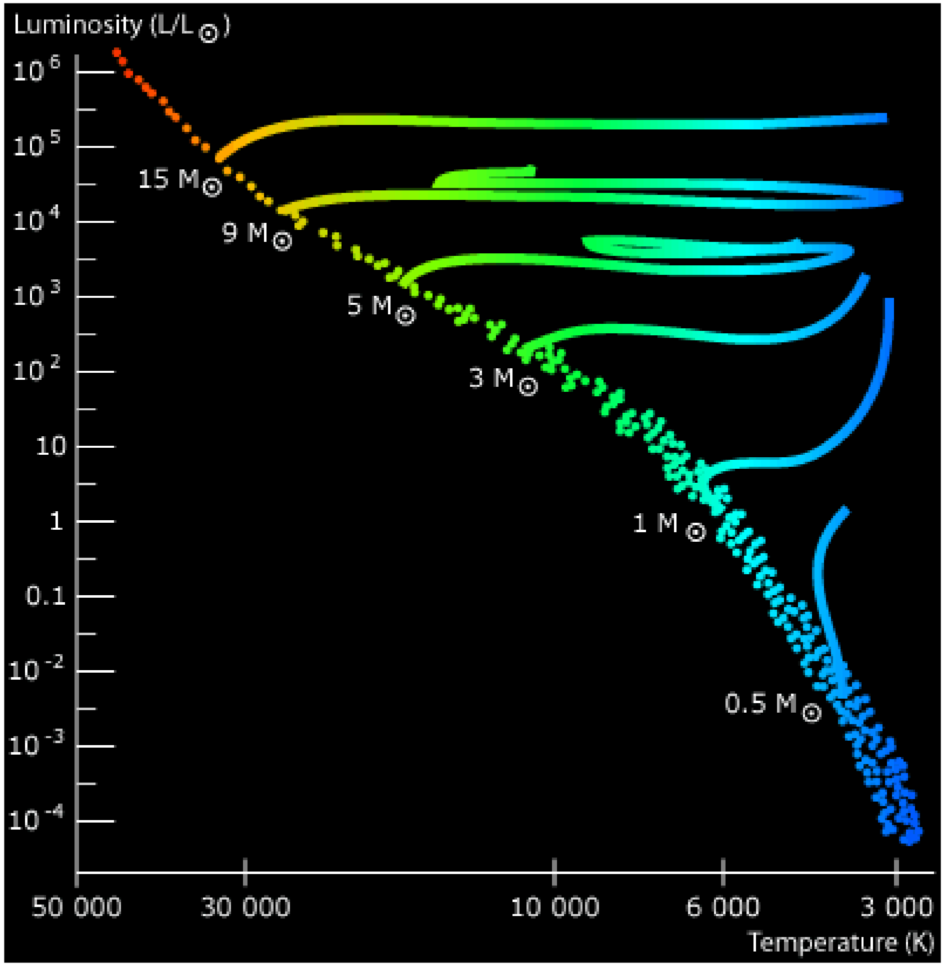
Black dwarf is the theorized final state of a star with a main sequence mass less than about 8 solar masses, in which all of its energy sources have been depleted so that it emits no radiation.

A typical white dwarf will have 0.8 solar masses, a diameter of 10,000 km (3/4 of Earth's), and a density of 10^6 g/cm^3.

A teaspoon of white dwarf material would weigh two tons.



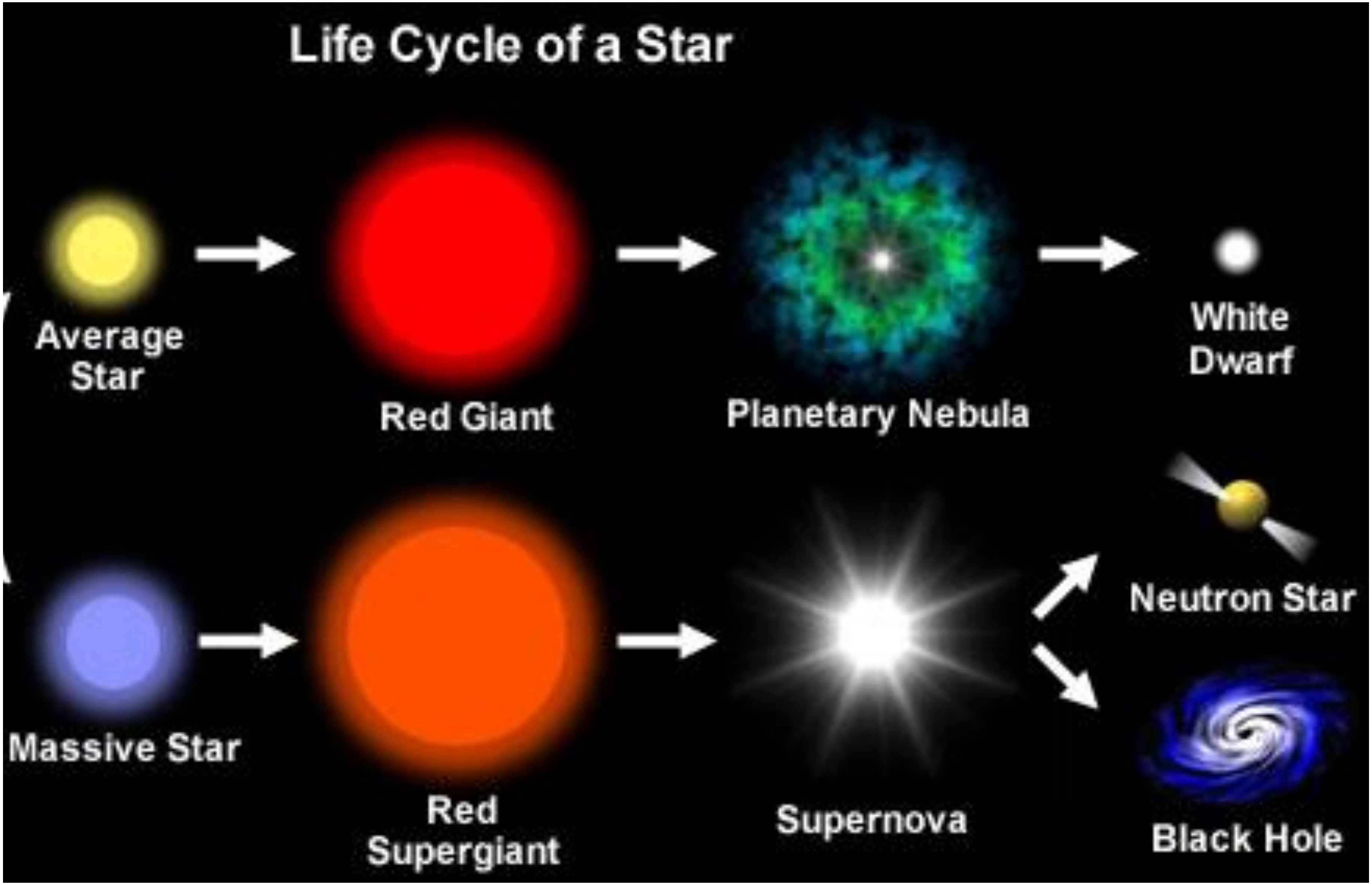
What happens to stars when they evolve out of their Main Sequence part of their lives?



Main sequence stars fuse hydrogen to helium.

Eventually the amount of hydrogen in the star's core decreases to a low enough threshold where the **helium in the core starts fusing to the element carbon.**

Stellar evolutionary pathway from Main Sequence

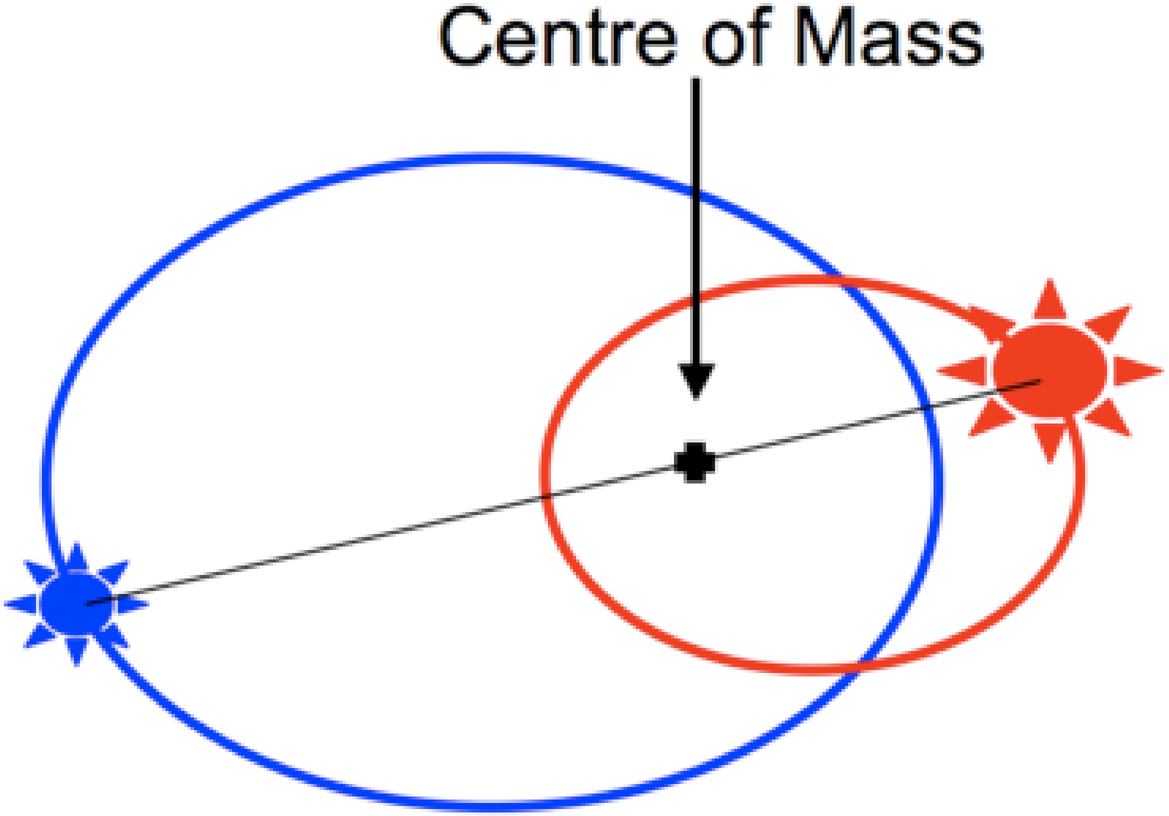


Binary Star Systems

- ~ 80% of stars exist in a binary star system
- Two **companion stars** that orbit each other around a common center of gravity, called the **barycenter**.

- Stars vary by size and possibly by age.
- One star is usually much larger and more luminous than the other. (Red dwarf and white giant)
- Condensed from the same nebular cloud.

The star with the larger mass orbits with a smaller radius around the barycenter (center of mass). The star with the smaller mass orbits with a greater radius around the barycenter.



Eclipsing Binary Stars

Two stars of a binary system with different luminosities will pass in front of each other, decreasing the amount of light viewed from Earth as a function of their orbiting each other.

If smaller dimmer star passes in front of larger, more luminous star—the star system will be much dimmer.

If smaller dimmer star is side-by-side with the larger more luminous star—the star system will be very bright.

If the larger, more luminous star passes in front of the smaller dimmer star—the star system will be slightly dimmer.

Astronomers can infer how fast the stars are orbiting each other, the luminosity differences between the stars, and the mass of the stars based on their obit distances.

Eclipsing Binary Stars

A smaller, less luminous star (e.g. red dwarf or yellow dwarf) passes in front of the larger, more luminous star (e.g., blue giant or white giant) as they orbit each other..

Smaller in front to larger—star system appears dimmer.

Larger in front of smaller—star system appears brighter.

The change in brightness of the eclipsed binary star. When brightness is plotted as a function of time, the orbit speed and luminosity differences can be determined.