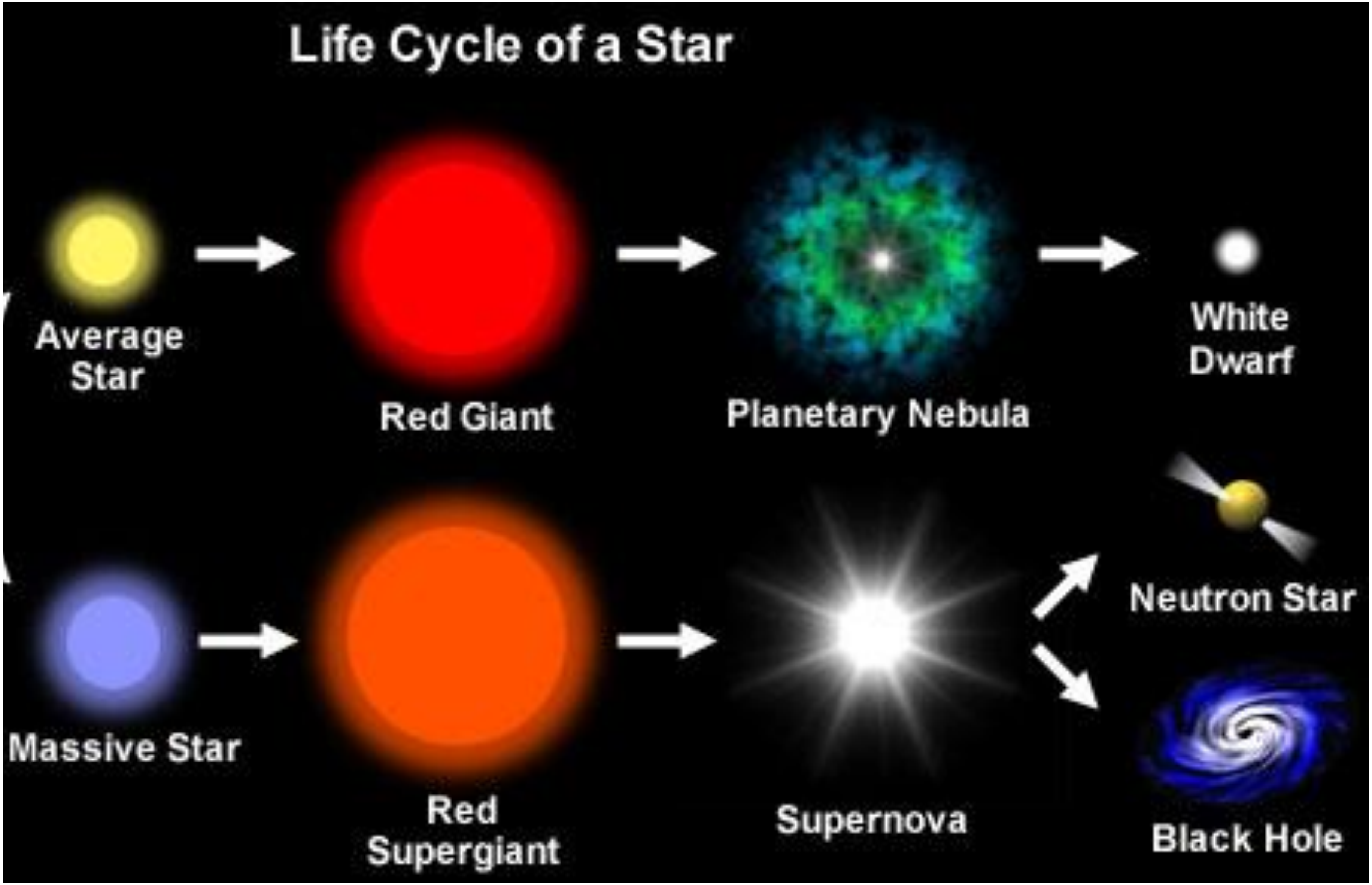
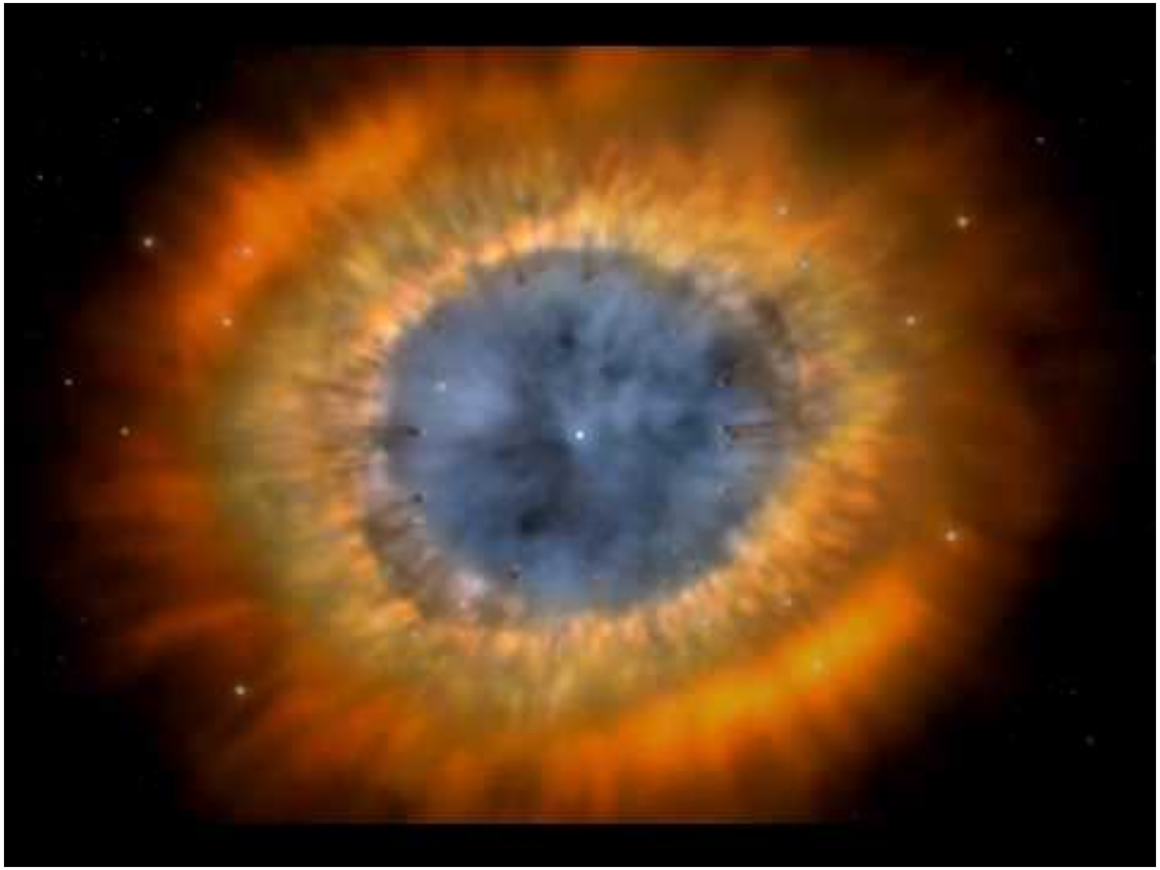
Stellar evolutionary pathway from Main Sequence



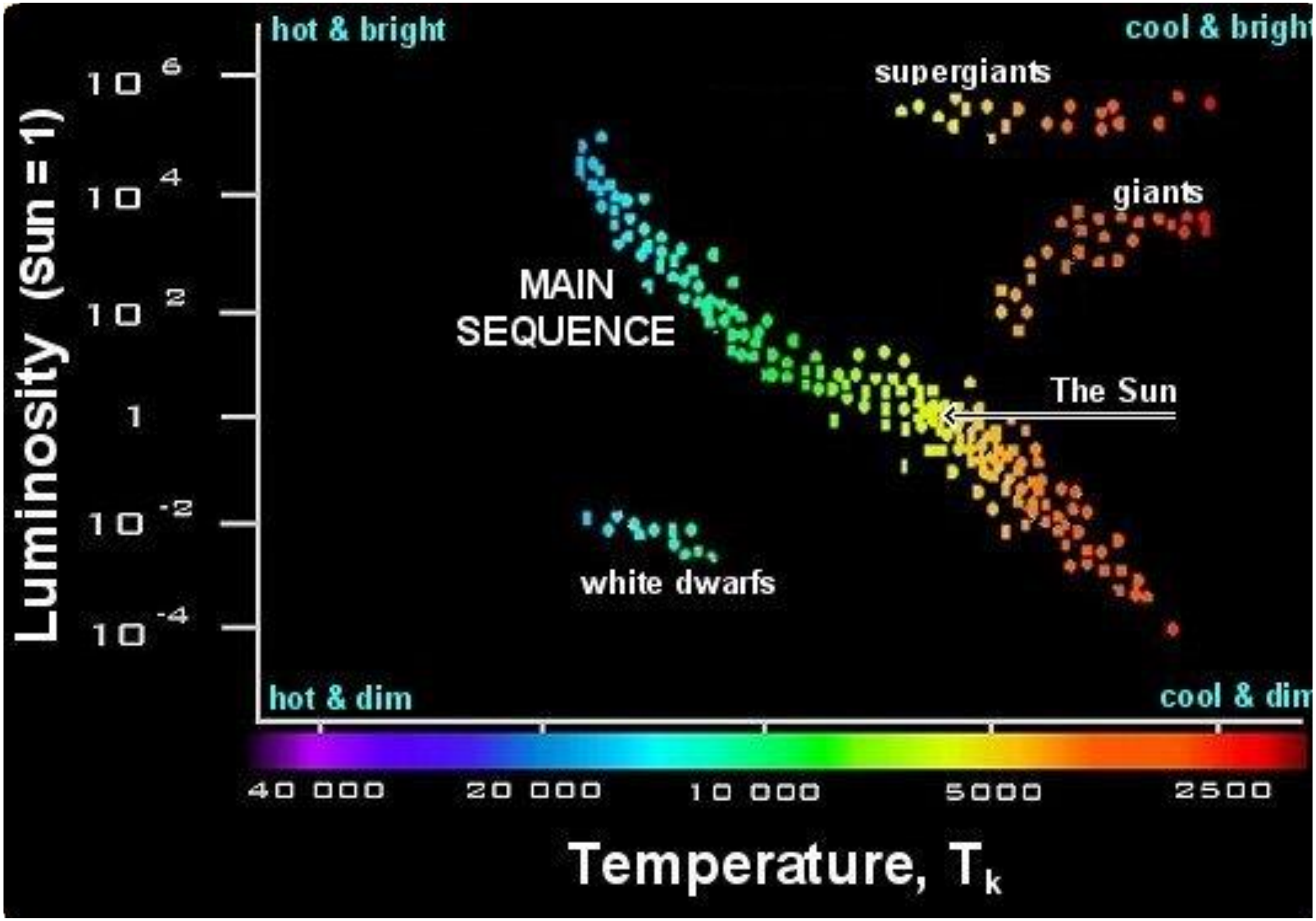
The low-mass star’s death stages will form both the planetary nebula and the white dwarf star.

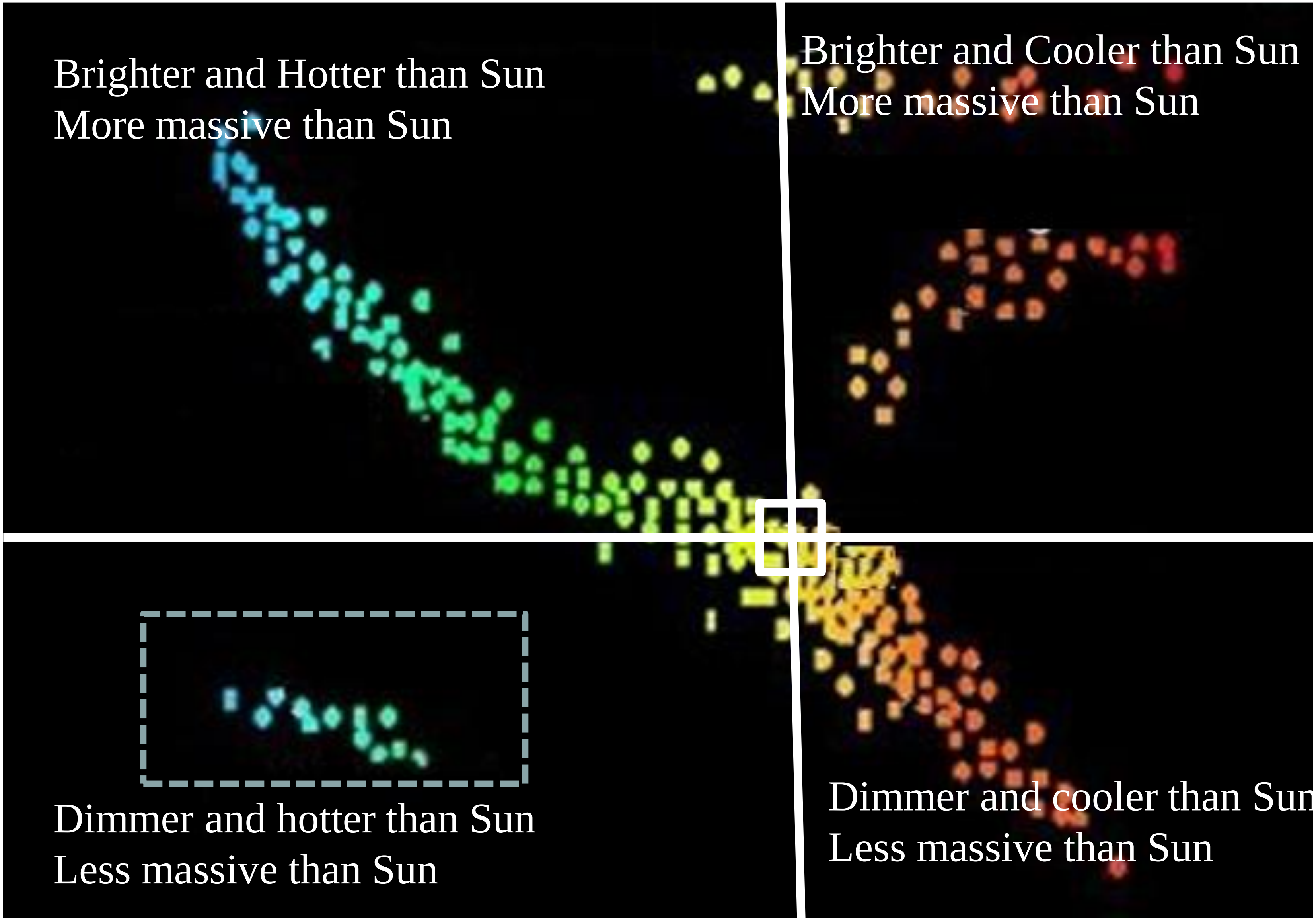


In thousands to millions of years, the nebular gases and dust will cool and no longer produce light. The planetary nebula will become a dark nebula.

The white dwarf star will outlive the nebula by billions of years.

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





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

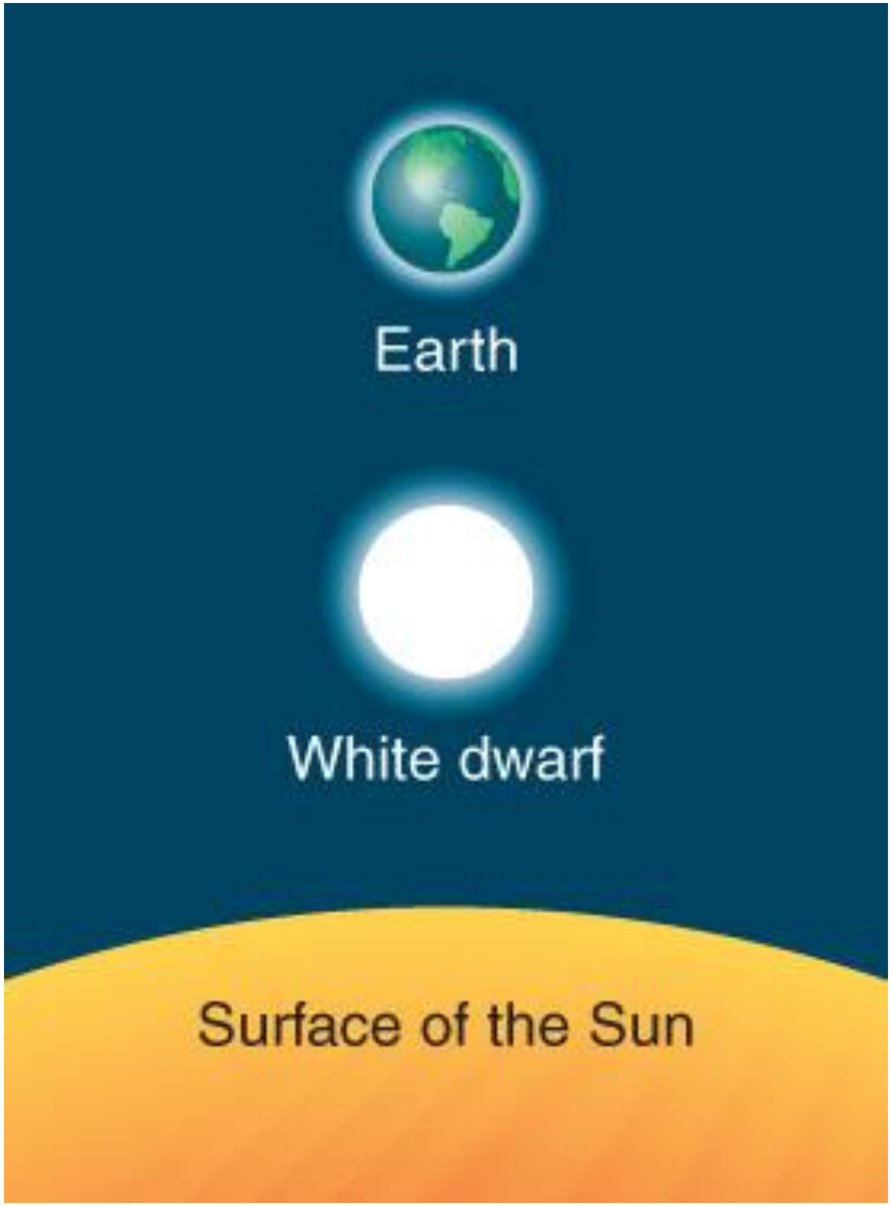
White dwarfs are made of very hot carbon and oxygen, the last two elements created by fusion in low-mass main sequence stars before the star’s fusion stops.

There is no fusion. It has not core. It glows because it is “white hot”. The white dwarf is radiating away its remaining heat for the next 20-100 billion years.

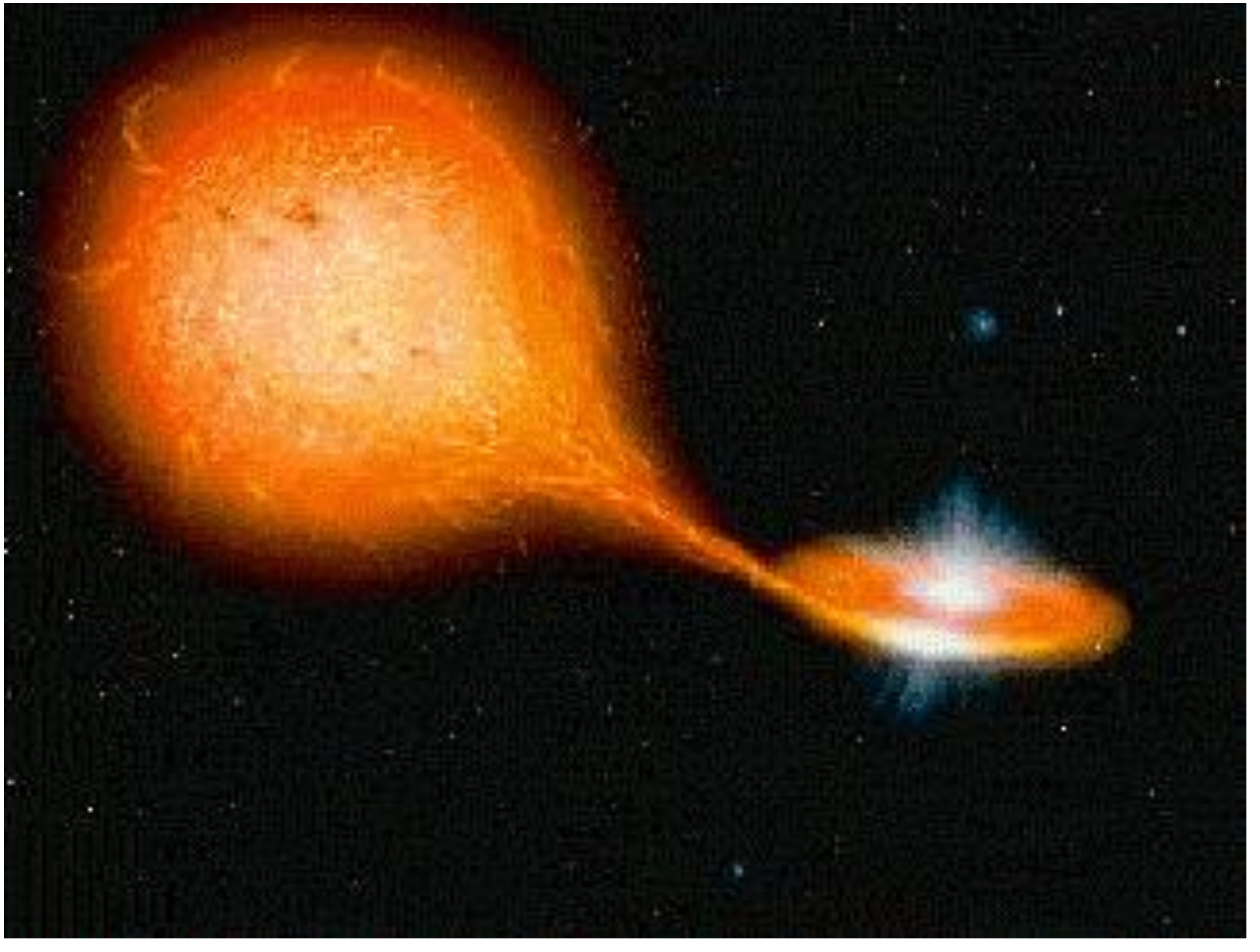
A typical white dwarf will have 0.8 solar masses, a diameter of 10,000 km (3/4 of Earth's), and a density of 10^6 g/cm^3.

A teaspoon of white dwarf material would weigh two tons.

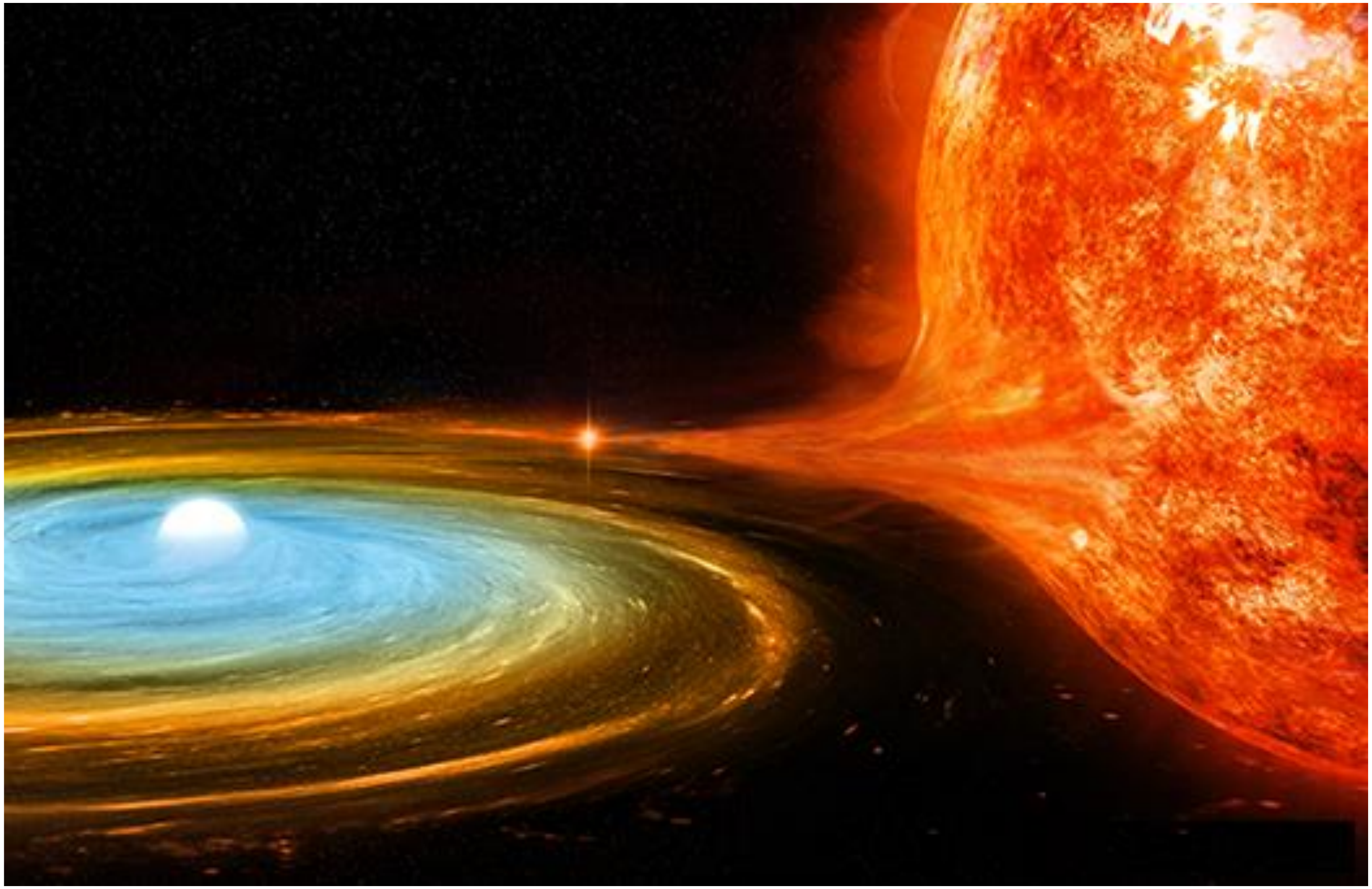
This extremely high density in a small body gives the white dwarf star a very strong gravity field.



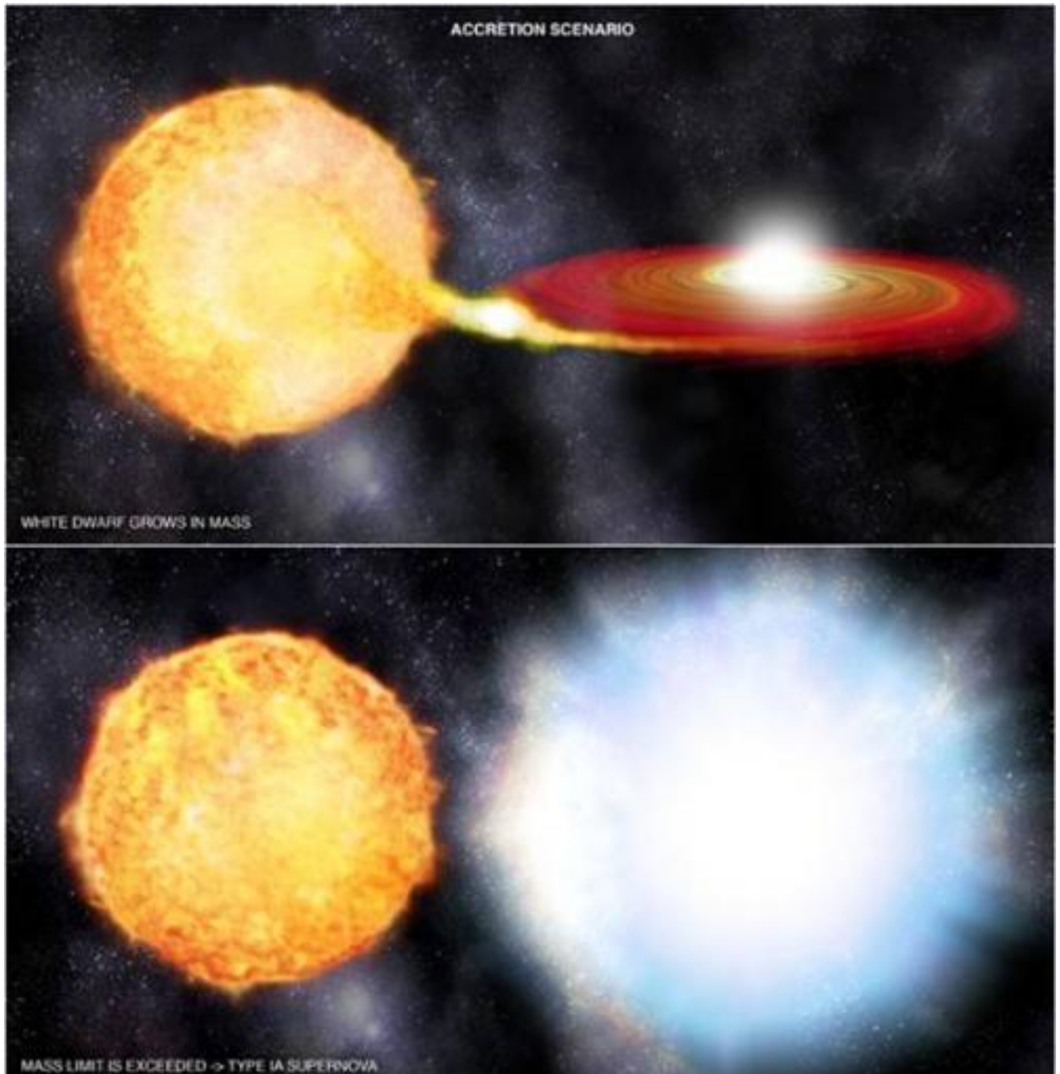
The situation for white dwarf stars gets interesting if the white dwarf is in a binary star system (2 stars) with a main sequence star or giant star as the other star.



If the white dwarf orbits close enough to the larger companion star, it can become a **vampiric white dwarf**. The white dwarf’s stronger gravity field will pull plasma and gas from the larger star that will accumulate into an **accretionary disk** around the white dwarf.



The matter in the accretionary disk eventually flows onto the white dwarf star, increasing its mass and increasing its heat and gravity strength.



If the increasing mass of the white dwarf reaches the **Chandrasekhar Limit**, the white dwarf star will **detonate** (explode) in a **Type 1a supernova**.

The **Chandrasekhar Limit** is the critical mass limit for a white dwarf star.

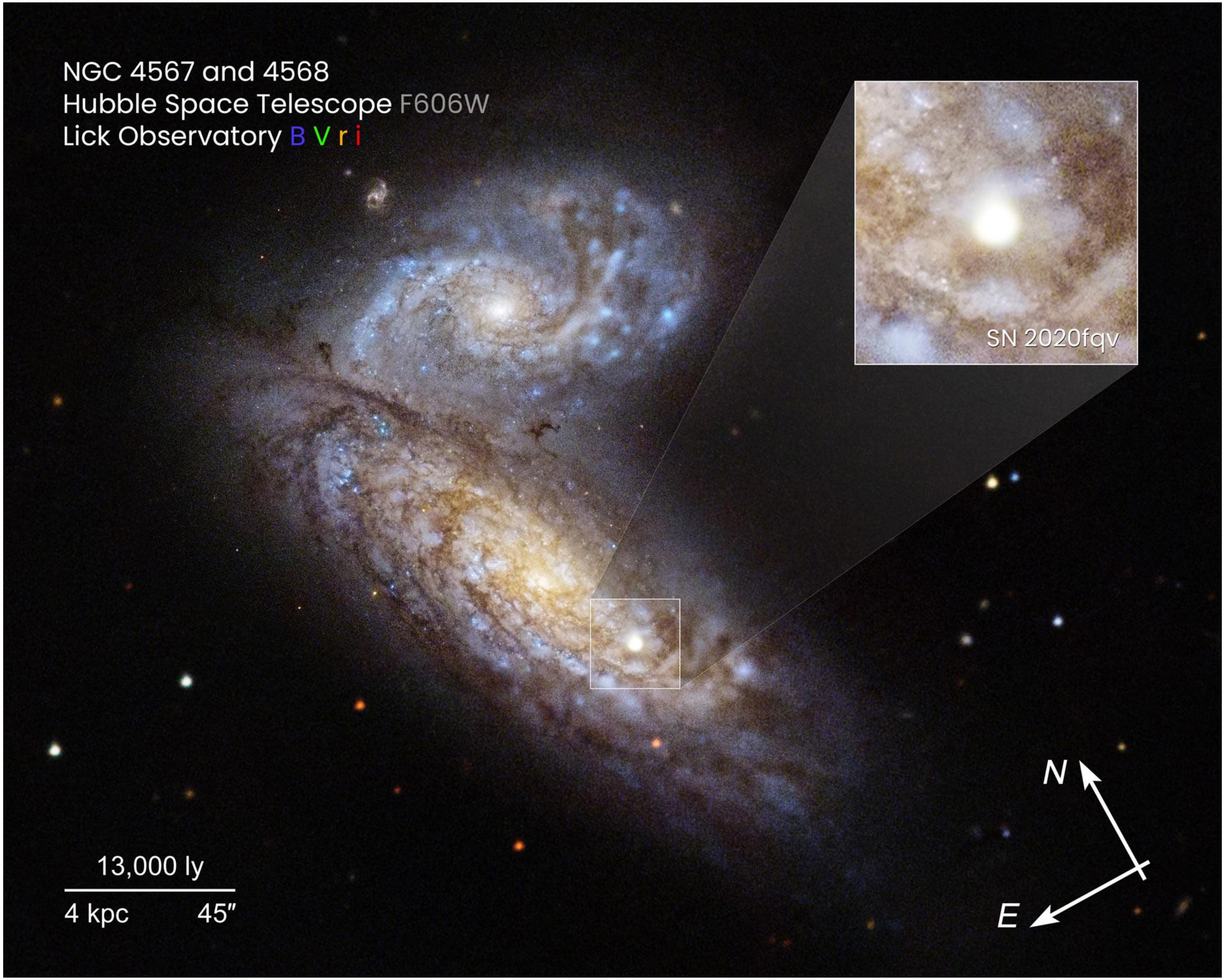
- A white dwarf star that has a mass lesser than the Chandrasekhar limit will remain a glowing white dwarf star.
- A white dwarf star that gains enough extra mass surpass the Chandrasekhar limit will detonate as a **Type 1a supernova.**

The Chandrasekhar Limit is **1.4-times the mass of the Sun**. Any white dwarf that accretes mass to exceed 1.4 solar masses will detonate.

At 1.4 solar masses, the inward gravity of the white dwarf's mass will start runaway **carbon and oxygen fusion**, which rapidly produces heavier atoms and heavier elements.

The astronomical amount of heat and energy released by this sudden flash of fusion causes the white dwarf star to explode.

Type 1a supernova in the Galaxy NGC 4567



What is important about Type 1a supernovae?

- All white dwarf stars are the same size and same mass, more or less.
- The mass of the white dwarf at detonation (the Chandrasekhar limit) will always be 1.4 solar masses.
- Therefore, the amount of light (luminosity) and duration of the event will be the same for any exploding white dwarf star.

This important because *all two Type 1a supernova have the same luminosity. If they have different brightness, they are different distances away from Earth.*

This is called **Standard Candle Method** of determining distances to galaxies.

- Brighter detonations mean the galaxy is closer to Earth.
- Dimmer detonations mean the galaxy is farther from Earth.
- Both detonations release the same amount of light energy regardless of distance.

The headlights of the same car have different brightness depending on the distance away from the camera. Closer to the camera, much brighter (right). Farther from the camera, much dimmer (left).