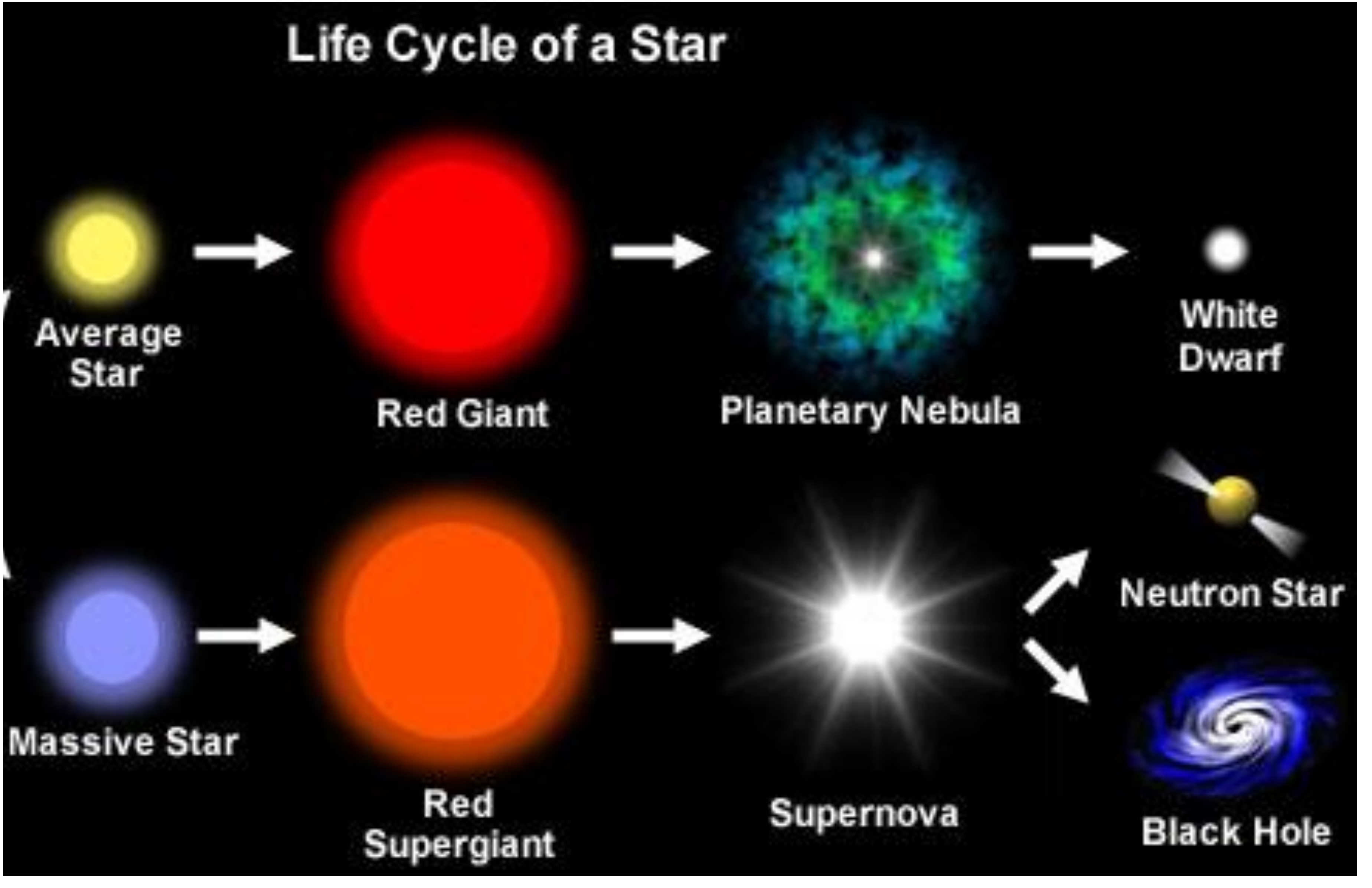
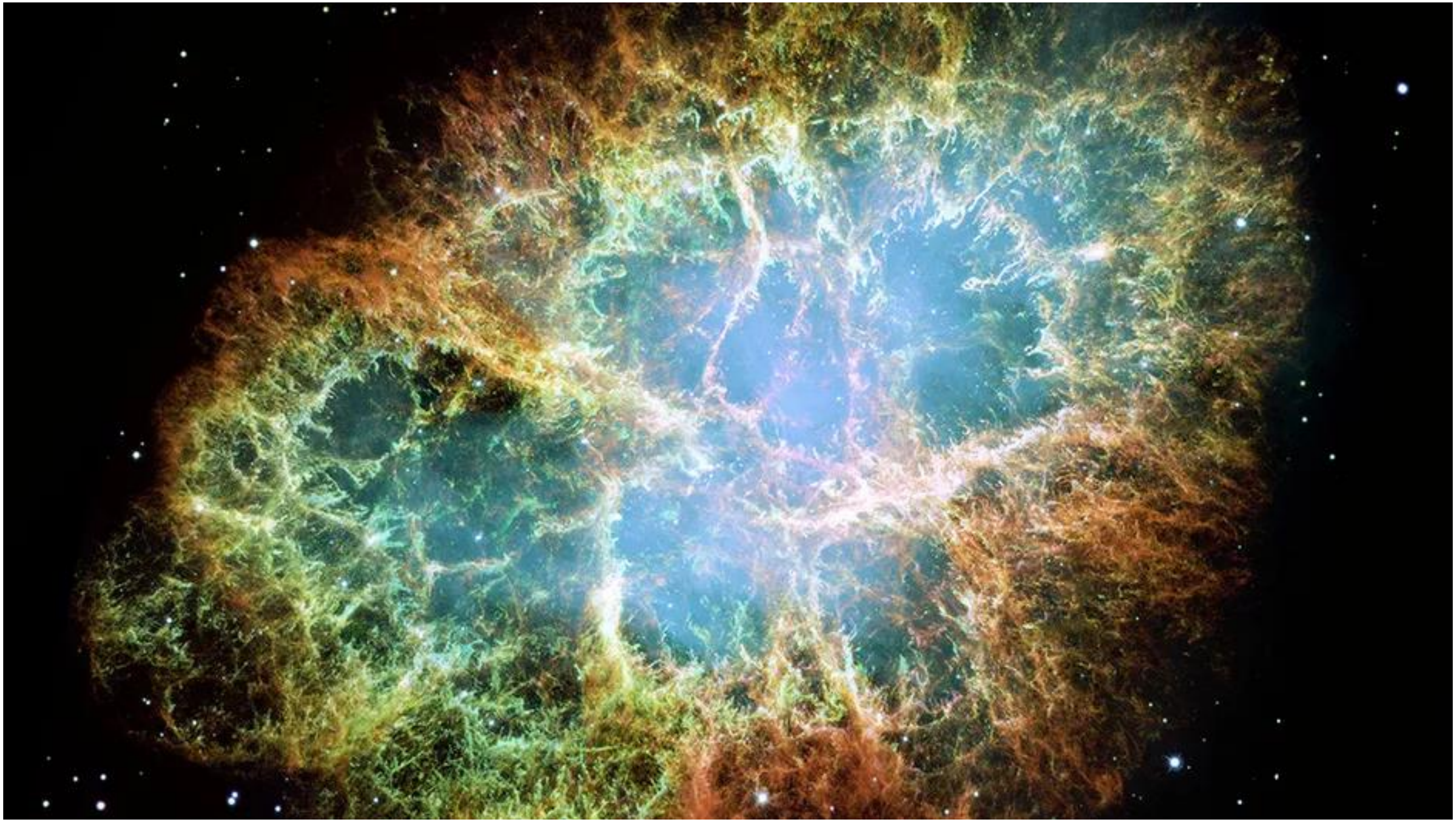
Stellar evolutionary pathway from Main Sequence



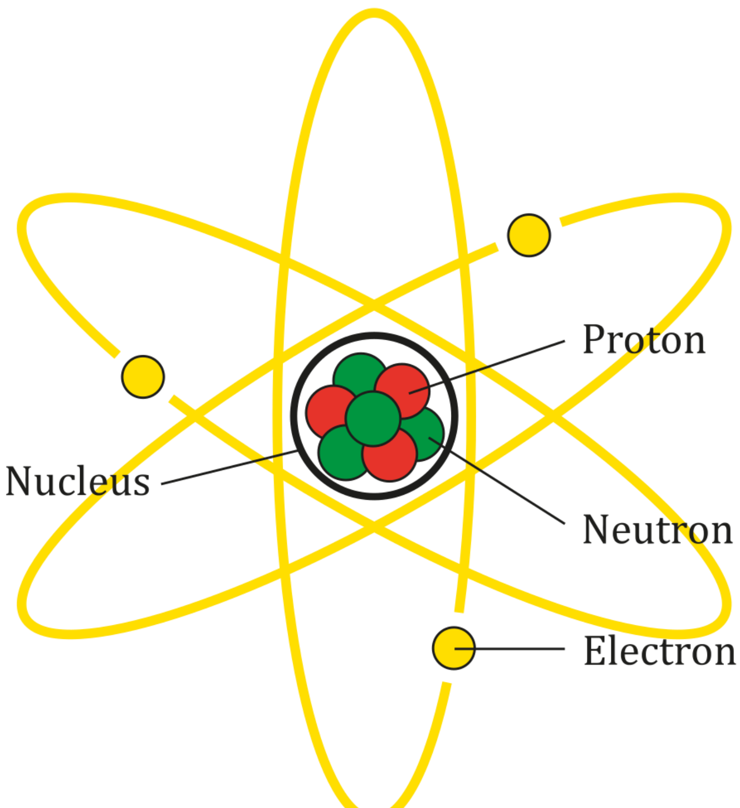
The high-star’s death stages will form a supernova remnant nebula and either a neutron star or black hole.

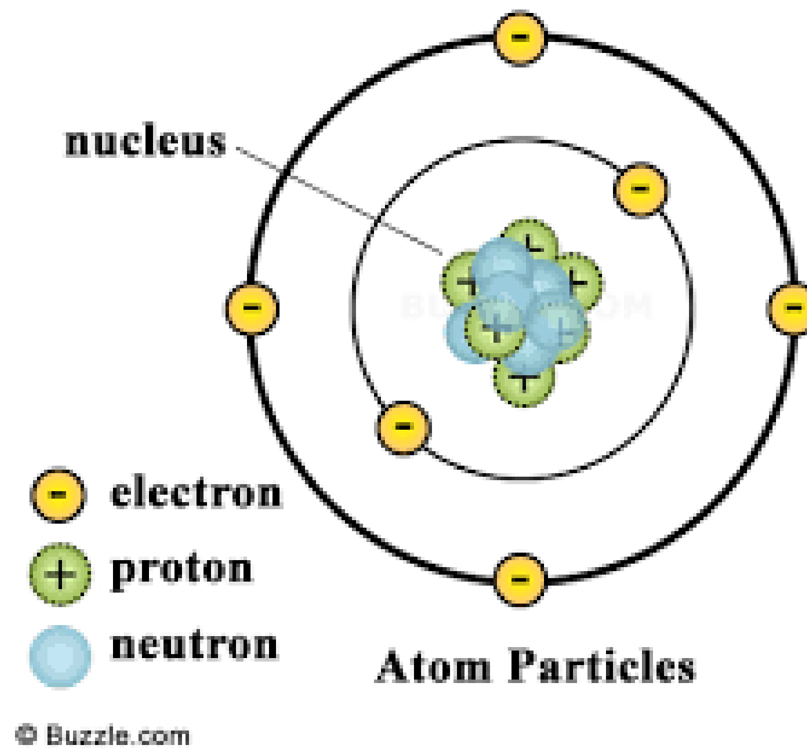


The models describe the components of an atom. Both models are simplified versions of the atom.

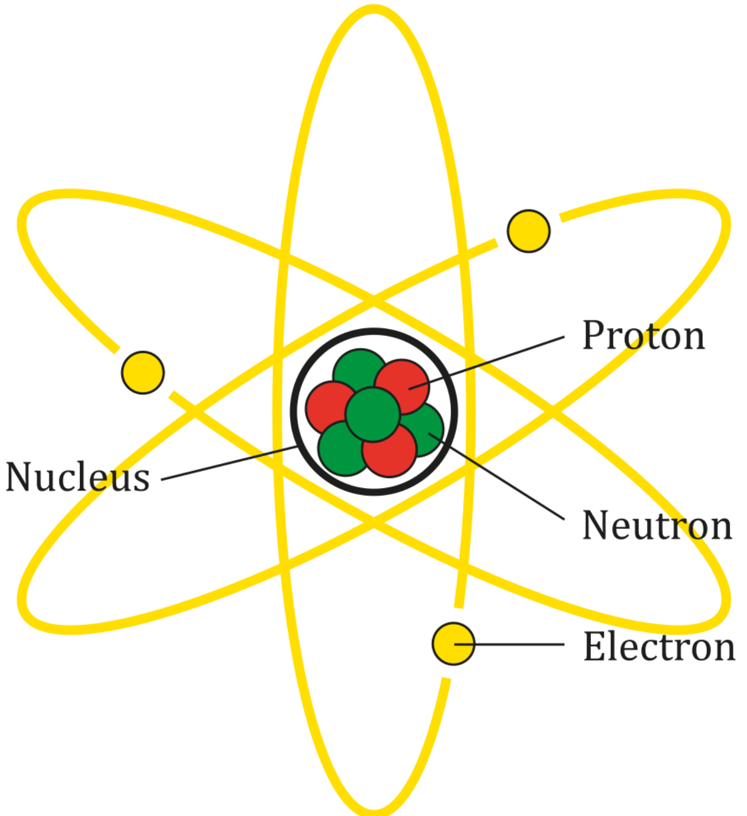
Nucleus: Protons and neutrons

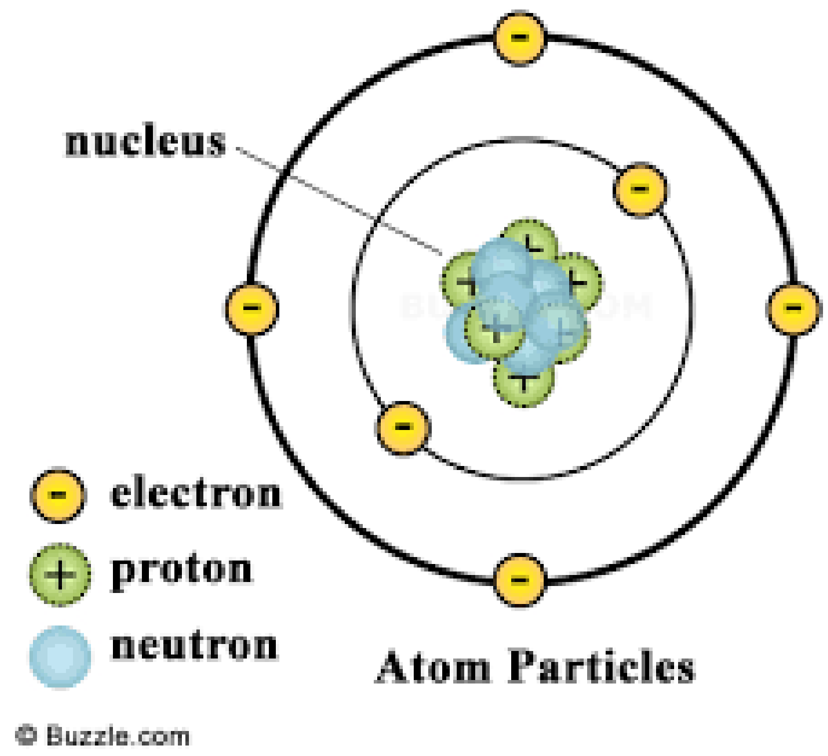
Electrons are in electron clouds around the nucleus.



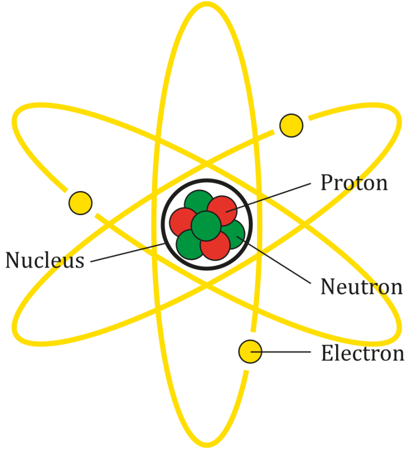


Most of the atom's volume is **empty space**. Electrons are negatively charged and repel each other—electrons are arranged spatially to minimize interactions between them. The nucleus is the very dense core of the of atom.





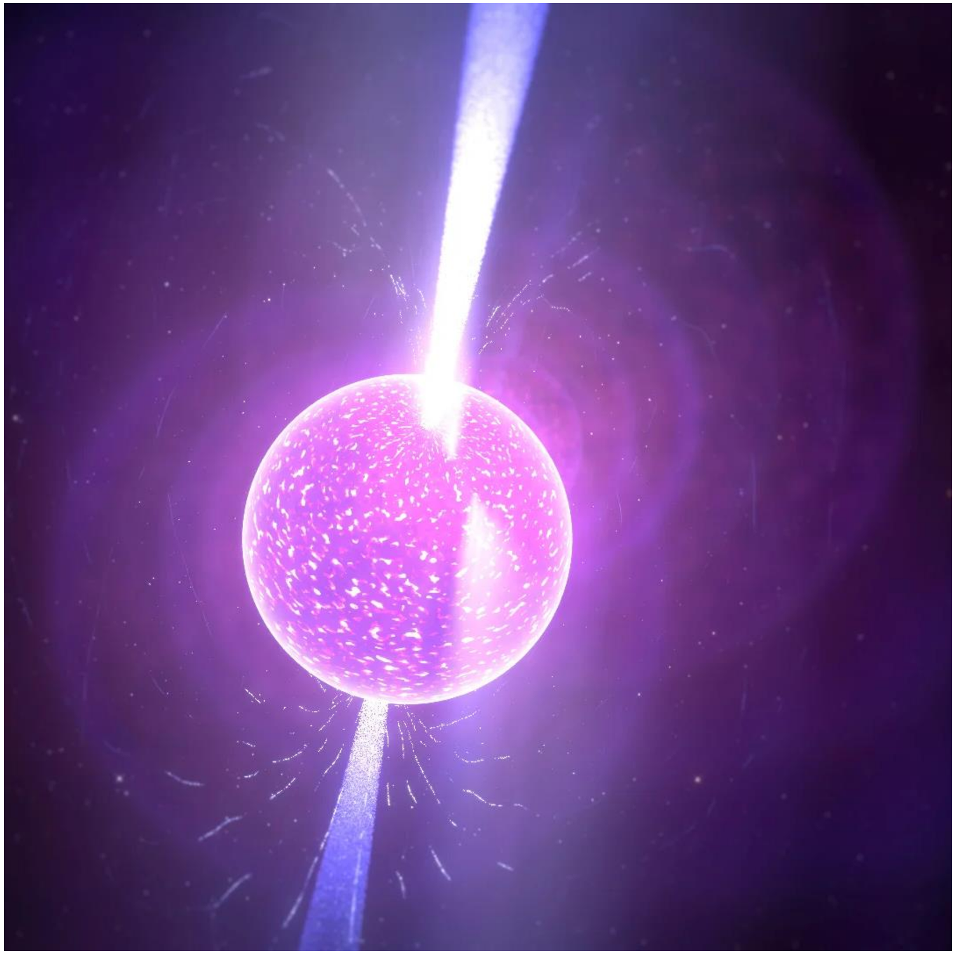
During the catastrophic inward collapse of the red supergiant star’s mass as iron (element 26) is formed in the core, the entire mass of star is crushing inward on the core.



The void space within the atoms in the core is crushed. Most of the electrons are forced into the nucleus and are annihilated by positrons in the protons.

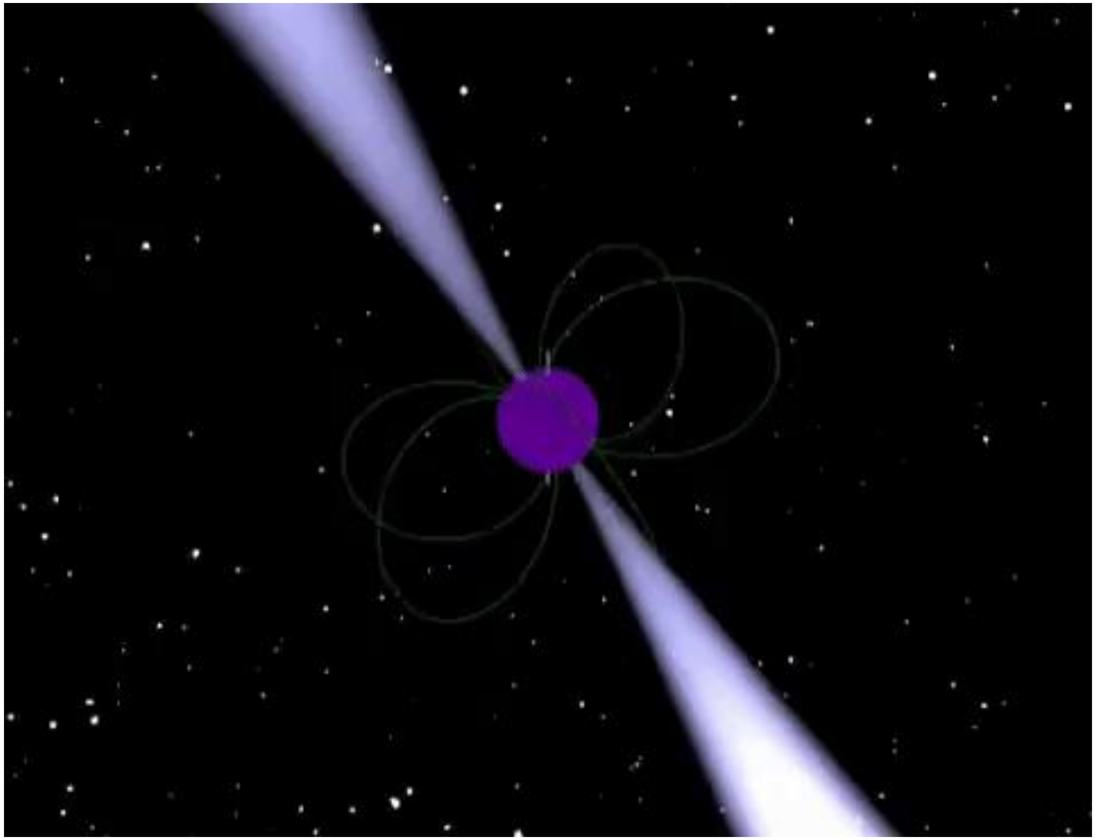
Bare nuclei (without electrons) are now pushed against other bare nuclei creating a huge ball of neutrons and some protons with no spacing between. This creates an astronomical amount of mass in a small volume.

The energy released by the rebound (bouncing back), annihilation, and the rapid neutron bombardment causes the explosion (the supernova).



Neutron stars are approximately 16-20 km in diameter but have 1.4-2 solar masses. They are one of the densest objects in our universe.

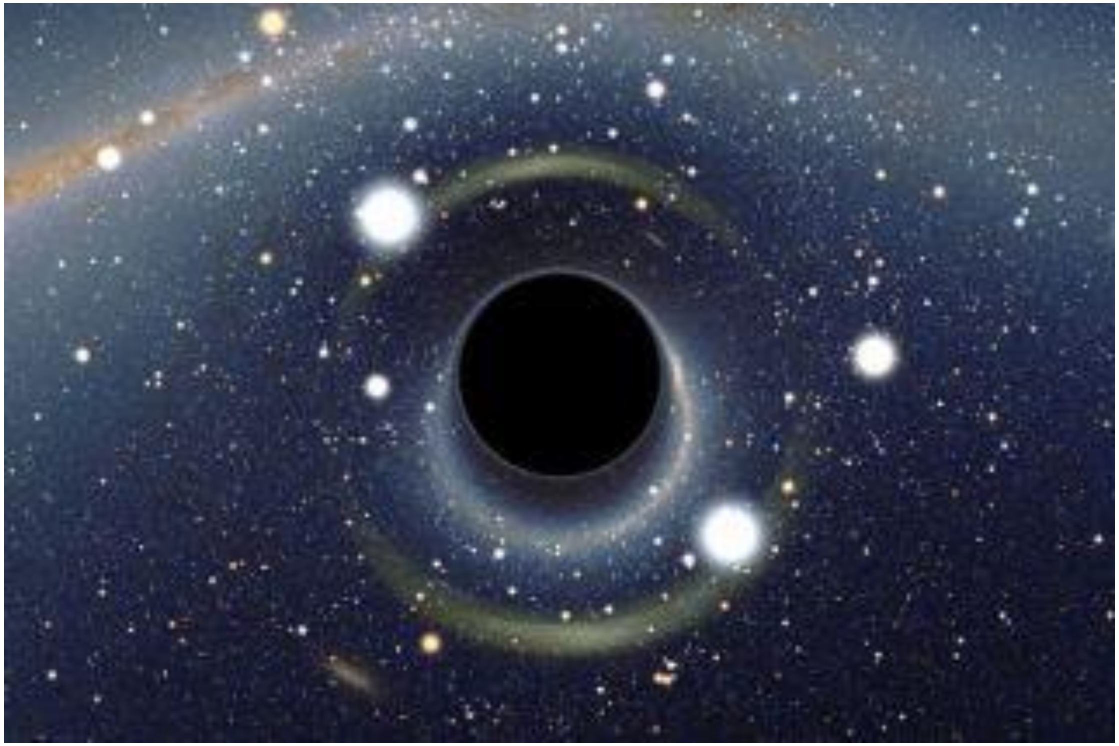
Neutron stars also rotate hundreds of times per second. They gained this fast rotation during the gravitational collapse of the red supergiant’s core.



Pulsars are fast spinning neutron stars that “appear to blink”. They tumble rather than rotate.

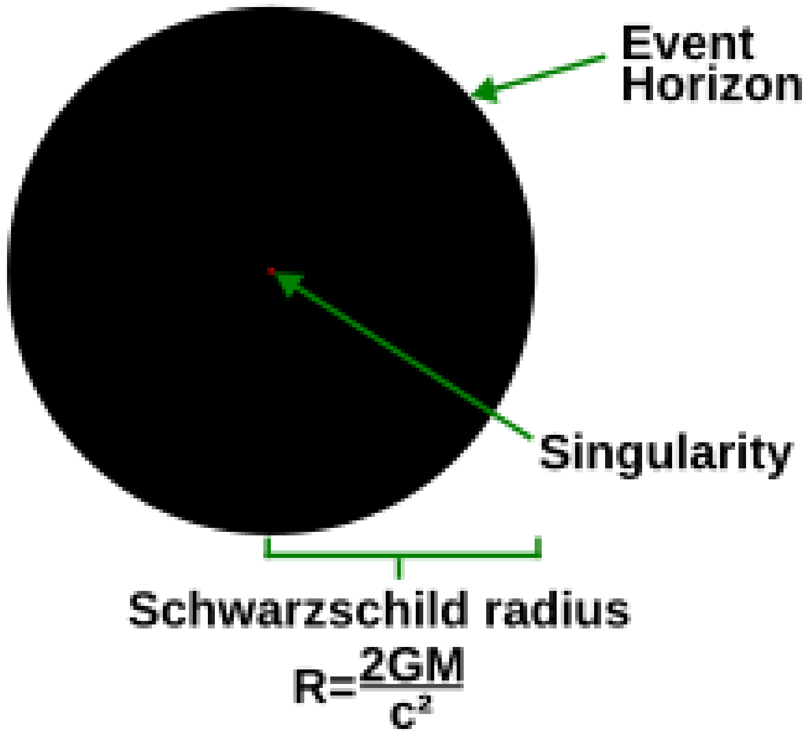
The neutron star emits two continuous streams of x-rays from its poles. On a regular period, the x-ray streams are rotated toward the Earth. X-ray observing telescopes observe the periodic “x-ray” streams that point towards the Earth.

Stellar Black Holes are created when the largest of the red supergiant stars undergo supernova.



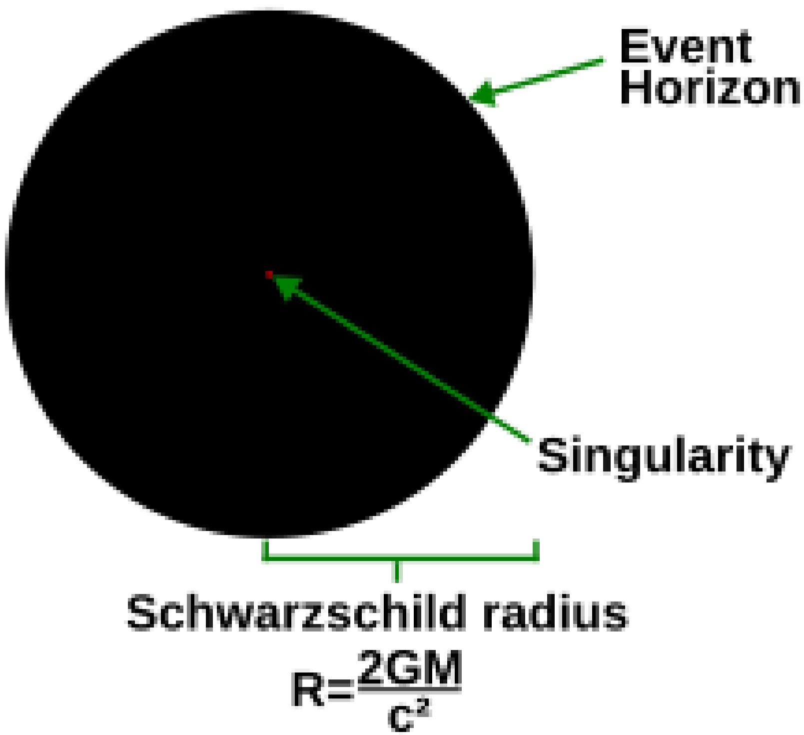
The black hole is not a “hole” in space. It appears as a black void in space because it does not reflect or produce light. Any light that passes within its **event horizon** will not escape.

The center of the stellar black hole is the singularity. **Singularity** an infinitely dense point in space where matter and energy have been compacted into infinite density



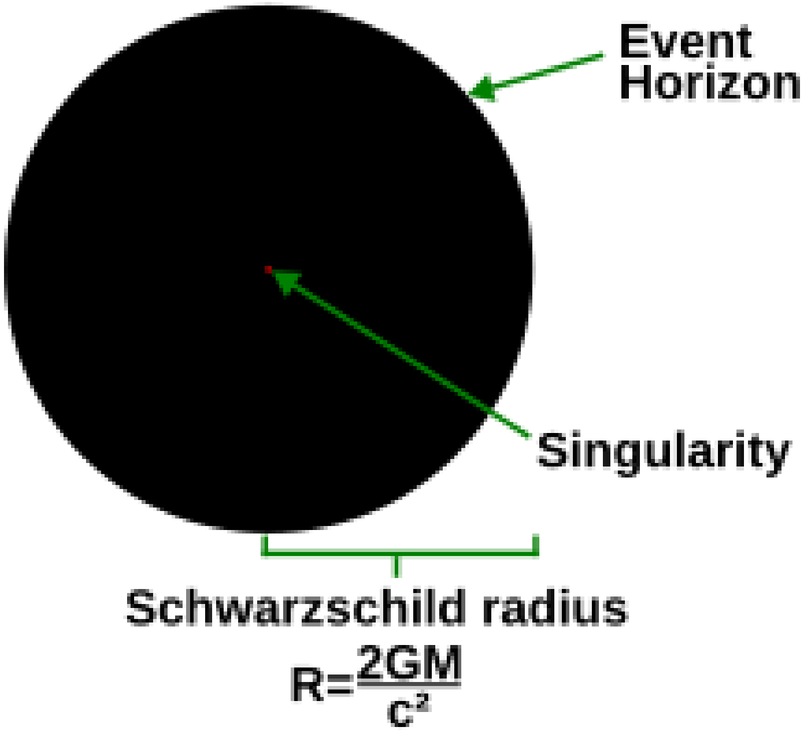
The actual "center mass" at the center of the black hole can range from 3 to 9 times the mass of the sun compressed into a "theoretical" point in space.

The **event horizon** is the "edge" of the black hole's gravitational zone at which if light enters it cannot escape the black hole's gravitational pull. The event horizon is the perimeter of the "black" of the black hole.



The **Schwartzchild radius** is the distance from the center of the singularity to the event horizon. It depends on the mass of the black hole.

Larger mass black holes will have a greater event horizon.

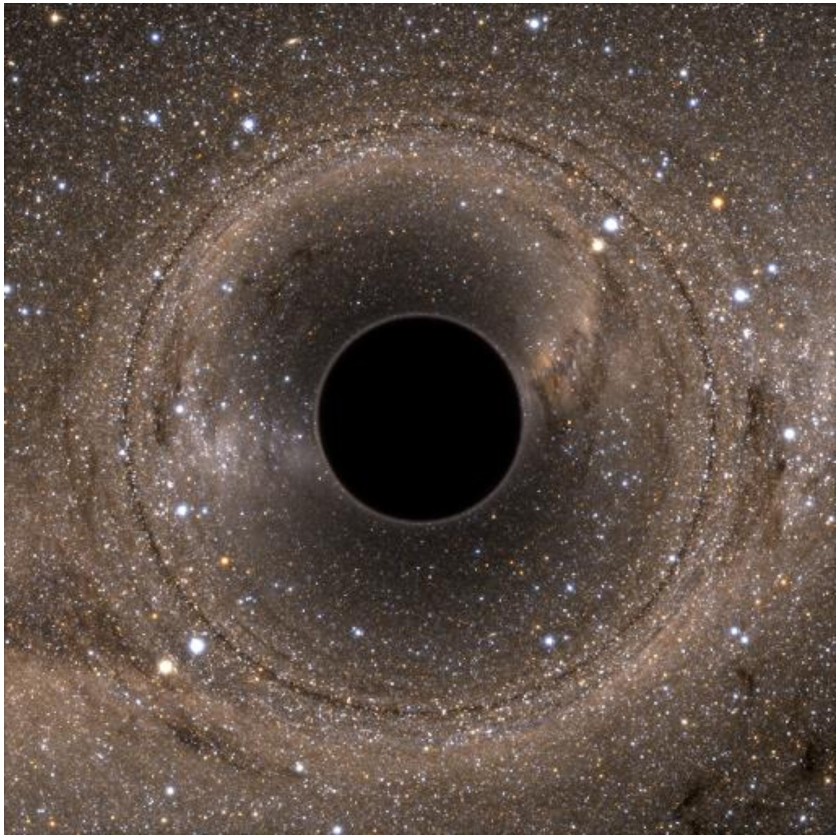


The Schwartzchild radius for a black hole with a mass of 5 solar mass is 14.67 km.
The diameter across would be 29.3 km

$$R = \frac{2 \cdot 6.67 \times 10^{-11} \cdot (5 \cdot 1.98 \times 10^{30})}{(3.00 \times 10^{8})} =$$

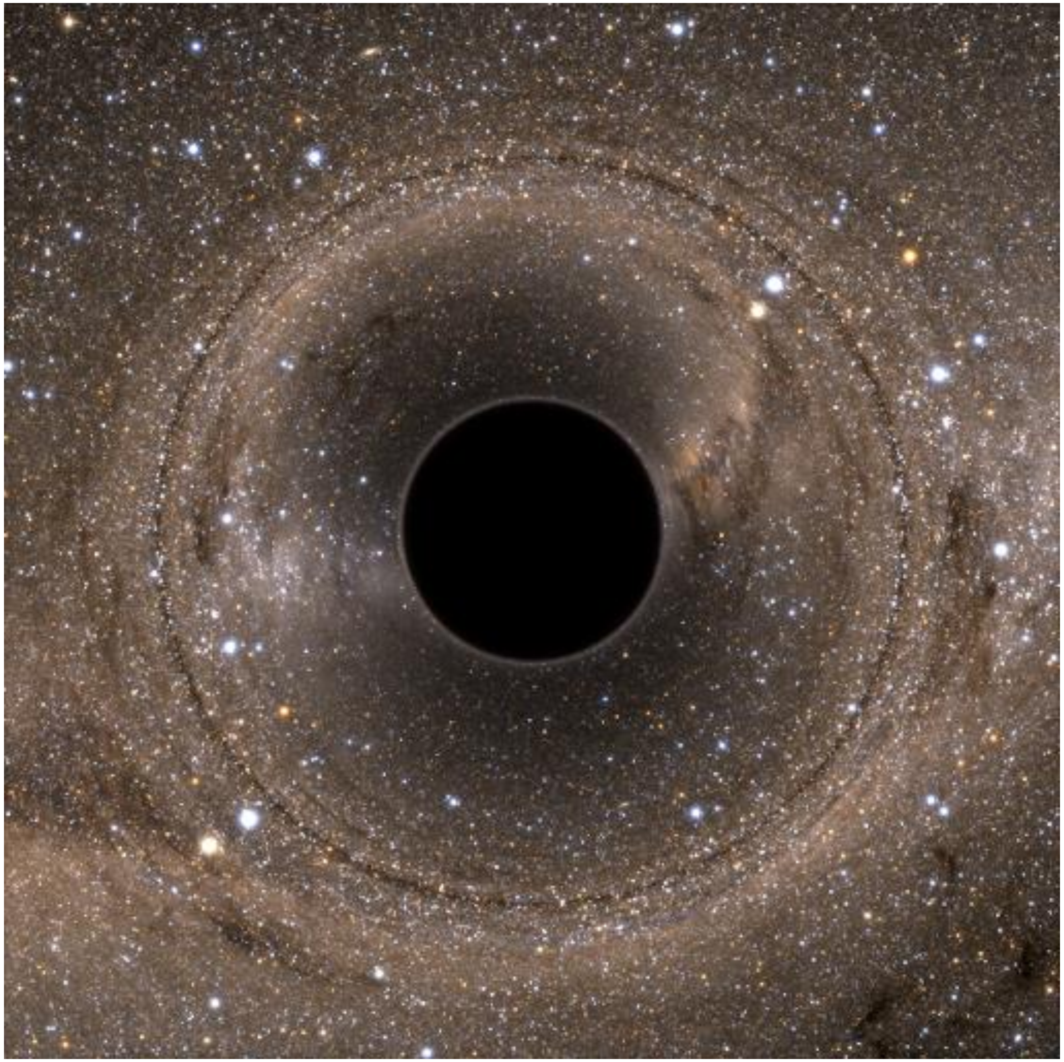
Radius = 14.67 km.
Diameter = 29.3 km

Any light that passes within the event horizon will be swallowed by the black hole never to return. Light that passes the black hole outside of the event horizon will be curved and bent by the distorted “space time”. This causes the **gravitational lensing** effect.



Light from stars or galaxies behind the black hole will curve around the black hole and be visible.

How are black holes seen if they are “black” and do not emit light?



They are observed indirectly by how other objects that emit light interact with them.

Because the light is bent around the black hole, the position of the object behind the black hole will appear to be in a different location in the sky than it actually is.

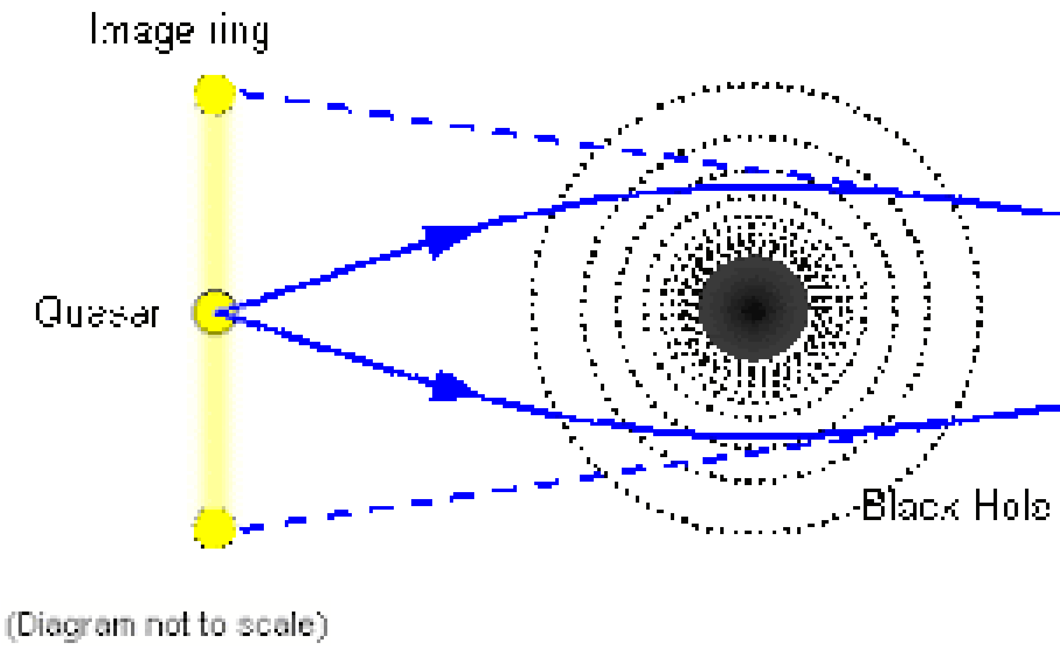
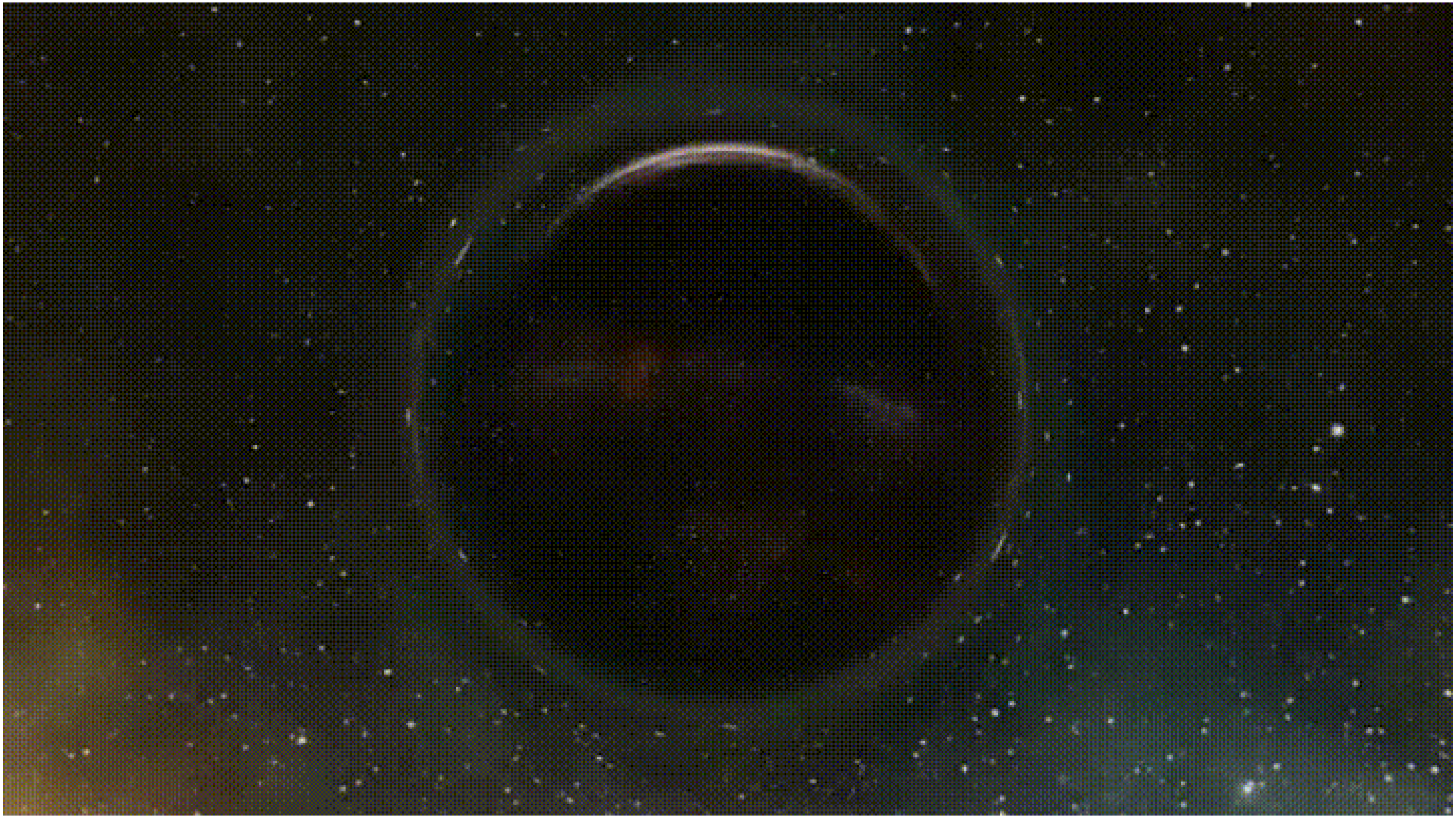
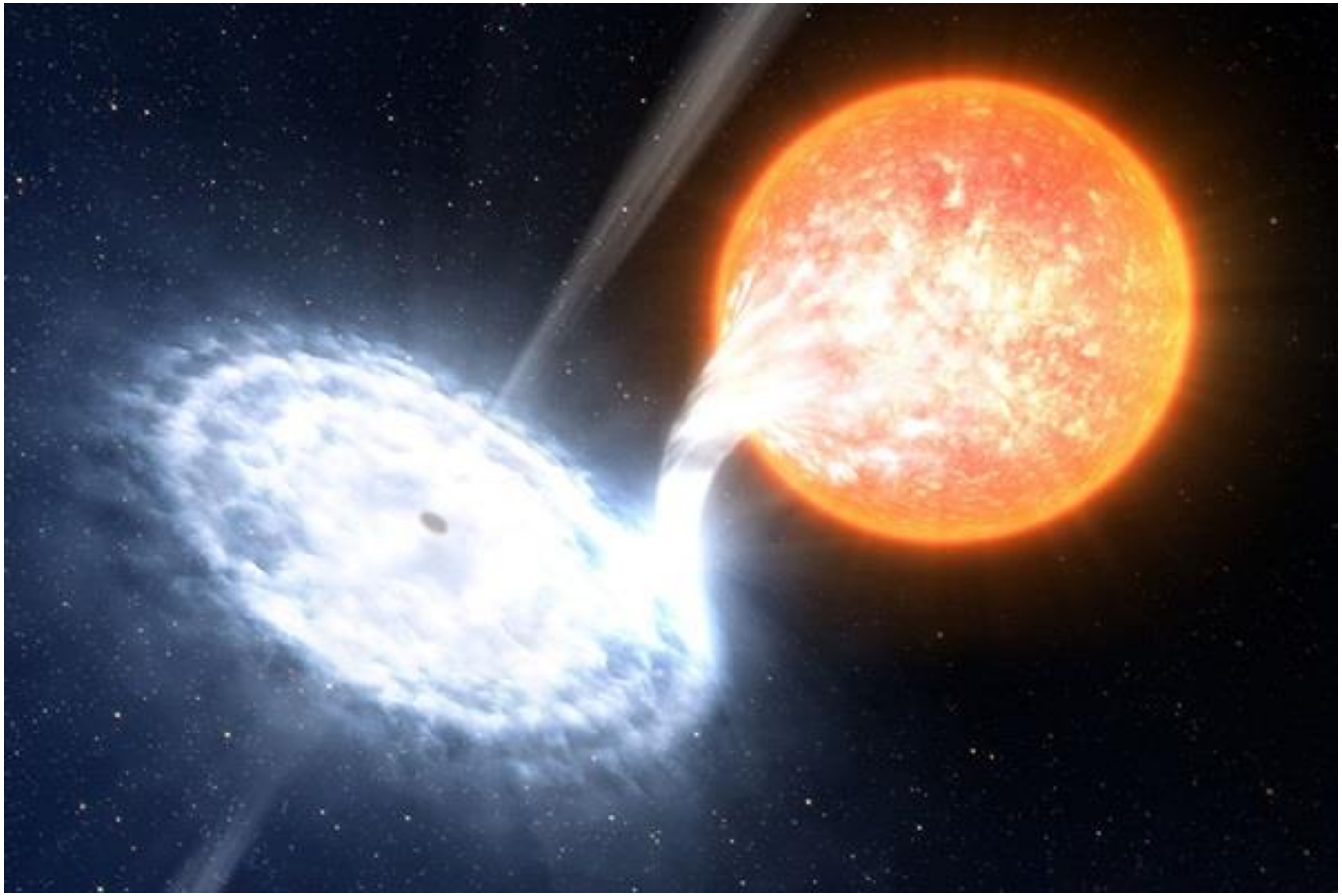


Figure 1

When the black hole moves way, the object appears again in its original position in the sky.



If the black hole is part of a **binary star system**, the companion star will orbit the black hole very fast. Astronomers will observe and measure radial velocity (moving in a circular path) of the star.



Accretion disks are layers of stellar gas and plasma being gravitationally pulled off the companion star that spirals around and inward to the black hole.

The companion star is being devoured by the black hole.

Accretion disks glow hotter and hotter and brighter and brighter the closer they spiral inward to the black hole. The gases become compressed by the gravity.

Relativistic jets are huge power jets of plasma and particles, as well as x-rays and gamma rays, that blast outward from the rotation axis of the black hole.

As stellar matter from the companion star is pulled into the black hole, it is compressed and heated as it moves faster and faster, approaching the speed of light. The material is compressed and heated so much, that it blasts outward.

Supermassive black holes are black holes in the **centers of galaxies.** They have masses millions of times greater than the sun. They form when stellar black holes merge with each other over billions of years. They migrate inward to the centers of galaxies.