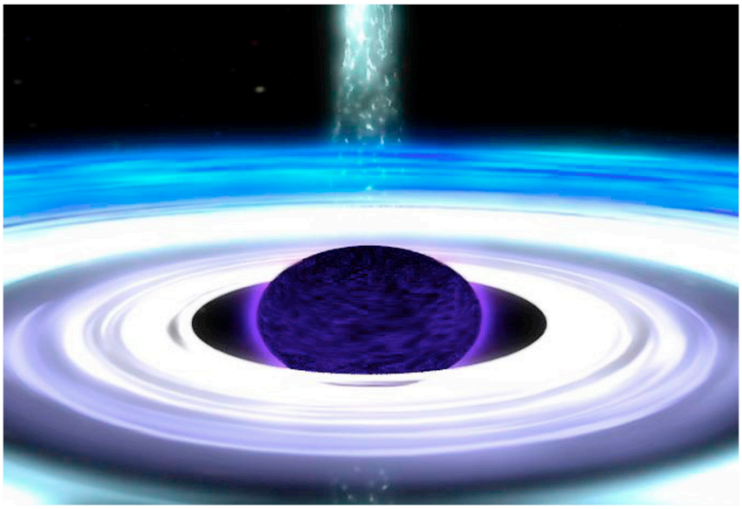
Session 10: Black Holes



This presentation supports the "Background" material in Session 10 of the Afterschool Universe program. This session is about black holes.

The Main Concepts…

1. Black holes are the end points of stellar evolution for the very massive stars
2. The idea of escape velocity
3. Black holes are objects where the escape velocity exceeds the speed of light

Let us summarize the main concepts in this Session. We will discuss these in the rest of this presentation.

Escape Velocity

On the surface of the Earth, the faster you throw something upwards, the higher it goes before coming down.

If you throw something up at 25,000mph (7 miles per second) or more, it can leave the Earth's gravitational pull entirely and travel freely into space.

This speed is called the **escape velocity**; objects with a stronger gravitational pull than the Earth have a larger escape velocity.

Let us start by explaining the idea of escape velocity.

We all know that the faster you throw a ball into the air, the higher it will go before coming back down. In fact, if an object was thrown upwards from the Earth's surface at 25,000 miles per hour (7 miles per second) or more, it would never come down… it would have escaped the Earth's gravity and would keep on traveling into the space. This special speed is called the escape velocity.

The escape velocity is higher for planets that have higher gravity (are more massive or denser).

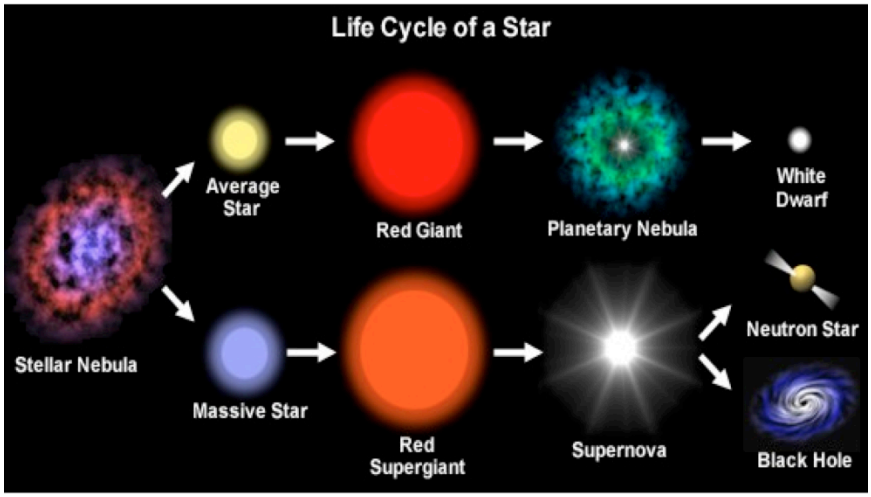
Black Holes

- A black hole is an object with such strong gravity that the escape velocity is the **speed of light**.
- Since light cannot escape, black holes appear black!
- Also, since nothing can travel faster than light, **nothing can escape from a black hole**.

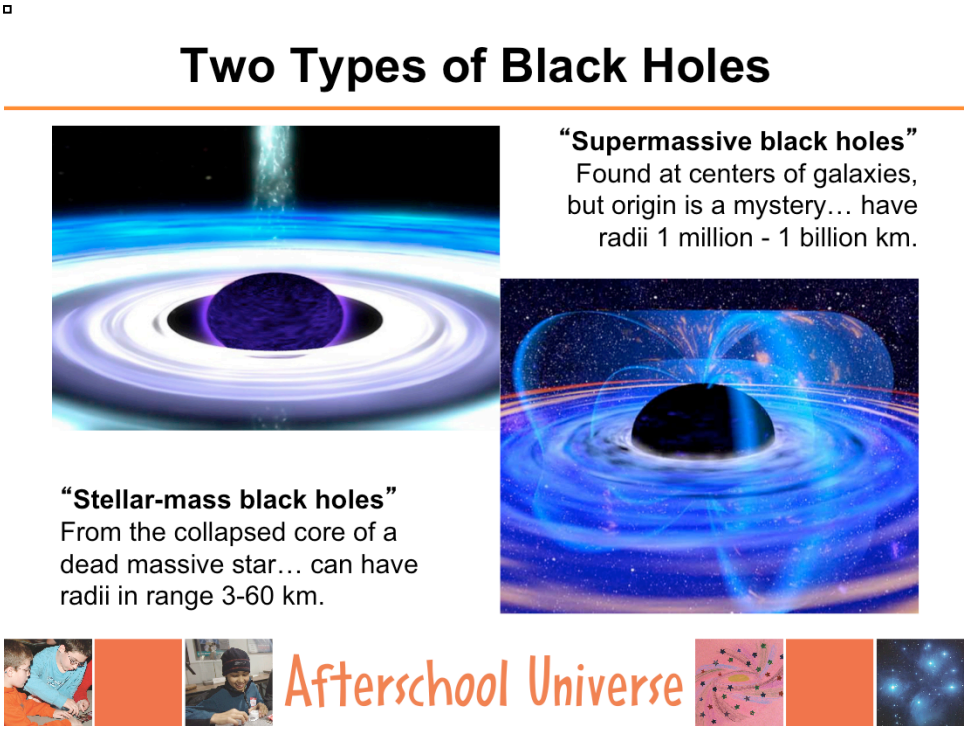
Now imagine an object that is so massive and dense, and has such strong gravity, that the escape speed is the speed of light. In this case, not even a light beam could leave the object. It would appear dark. This is the basic idea of a black hole.

Einstein deduced that nothing can move faster than the speed of light. So, in fact, nothing can escape from a black hole.

Life Cycle of a Star



Recall the life cycle of a massive star that leads to a black hole (bottom track)

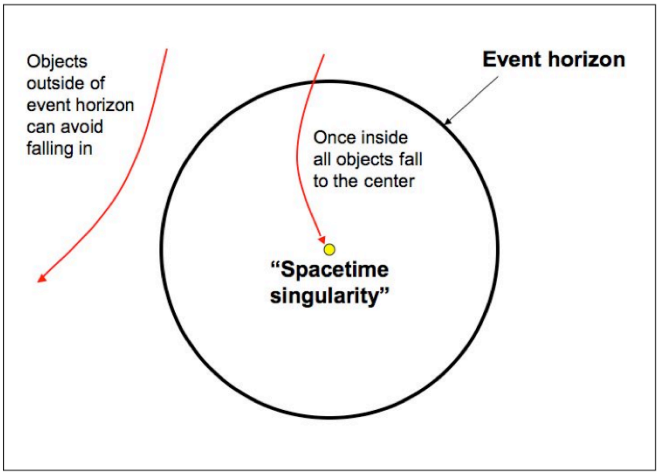


There are two general types of black holes that we know about in the Universe.

The first kind are called "stellar-mass black holes", and have masses in the range 3-20 times the mass of the Sun and radii in the range of 3-60 kilometers. So they are enormously dense! This is the type of black hole that is formed when the most massive stars in the Universe explode in in a supernova explosion. The black hole results form the catastrophic collapse of the dead star's core.

The other type of black holes are the "supermassive black holes" that are found at the centers of galaxies. It is unknown exactly how they formed, but it is known that they are very very old (likely forming in the first billion years or so of the Universe's lifetime). They have radii in the millions to billions of kilometers (with masses of millions to billions times that of the Sun).

Structure of a Black Hole

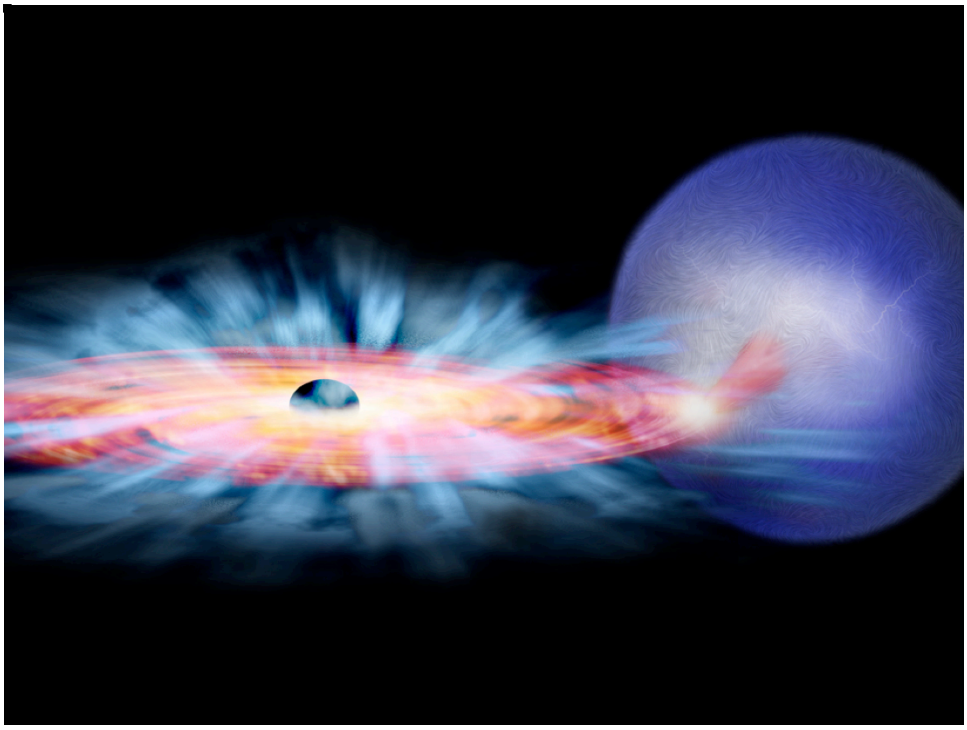


What is the structure of a black hole?

All of the actual "stuff" (the matter and energy) is contained in a central point of unimaginably high density which is often called the "spacetime singularity". Scientists believe that our current understanding of the laws of physics becomes invalid at this point.

Surrounding this is a sphere known as the event horizon. This is the place of no return. Outside of the event horizon, objects (stars, planets, rocket-ships) can fly by the black hole without being pulled in. In fact, at large distances, the gravitational pull of a black hole is completely "normal" and the same as any other object of comparable mass.

But once an object wonders inside the event horizon, it is doomed. It is forced to fall towards the spacetime singularity where it will eventually be destroyed.



Because they are black (and space is black!), a black hole can be very hard to find and study.

Exceptions are when there's a nearby source of gas (such as a nearby star). Gas can then be pulled into orbit about the black hole. The swirling gas becomes very hot and emits X-rays. Special telescopes (X-ray telescopes) can then see the emission from this swirling gas. This is one of the main ways that astronomers study black holes.