

# Whirlpools of Light – Black Holes

## **Introduction**

Imagine for a moment a black hole. Most think of things like a huge black sphere, sucking up all the matter in the universe with no hope of escaping from it. Perhaps they think of a passage to another dimension, like the opening to a wormhole. Between Hollywood and science fiction novels, black holes have become one of the most misunderstood concepts in our universe. A true black hole is much more complex and fascinating, especially when one understands its unique properties and attributes.

## **Creation of Black Holes**

The creation process for black holes is just as spectacular as the black holes themselves. Astrophysicists have settled that most black holes were created by events called supernovas. To understand the significance of this creation, one must first understand what a supernova is. A supernova occurs when a relatively large star depletes all of the fuel it uses to sustain its fusion reaction. Throughout a star's life, two forces constantly fight each other. The explosive power of the fusion reaction that takes place inside is constantly trying to expand, but the sheer size of the star creates a field of gravity that pulls against the pressure created by the fusion reaction. However, fusion reactions run on a depletable fuel while the force of gravity is forever. At the inevitable moment when the star runs out of fuel to sustain the fusion reaction, the force of gravity forces the core of the star to collapse in on itself and results in the creation of a singularity in roughly a fraction of a second. The creation of the singularity results in the star's outer layers being expelled in a huge explosion, which we call a supernova. Another theory on the creation of black holes is one by renowned astrophysicist, Stephen Hawking. He imagined a long process and idea known as Hawking Radiation which essentially is detectable radiation given off by very small black holes. We haven't detected any of this radiation yet, but if we were to find it in our universe, it would mean that 'mini' black holes have been giving off this radiation for millions of years. In fact, the process to create enough radiation that we can detect takes so long that the birth year of these mini black holes would be at the time of the big bang, meaning that some of these black holes were created by the explosion that allegedly created our universe.

## Properties of Black Holes

The properties of black holes are what mislead most people. The idea that a black hole sucks up everything in a radius of thousands of miles is probably the myth that is farthest from the truth. A black hole created by a supernova is much smaller than the star that created it. In fact, the radius of a black hole created by our sun would be only 3 km compared to its original radius of 700,000 km. Additionally, the only things that a black hole will absorb are the things that lie within or cross the event horizon.

The event horizon is like an atmosphere, a sphere around the singularity of the black hole where the escape velocity is greater than the speed of light. To understand how this makes a black hole a phenomenon of nature, one must first understand what an escape velocity is and the significance of it. If an object were to launch itself away from the planet with the intent of breaking free of the Earth's gravitational pull, the speed at which this object must travel to escape the gravity is known as the escape velocity for that planet. In a black hole, the escape velocity is the speed of light and since nothing in the known universe is faster than the speed of light, anything including light that passes through the event horizon is pulled into and crushed by the singularity. No has any photographs of a true black hole, but Fig.1 shows a theorized image of what a black hole would look like.

However, the event horizon also has another name, the Schwarzschild radius. The event horizon itself was discovered by a man named Karl Schwarzschild but due to obvious issues with the name, the name was changed to the much simpler term, event horizon.

The singularity is the epicenter of the black hole. It is a point in space smaller than an atom where the volume and density are limitless, creating a point that cannot be created through any other means. A point like this is impossible to imagine, since as humans and beings that dwell in the third dimension, we cannot imagine a single point of limitless mass and volume. This point is located where the core of the star was formed when the force of

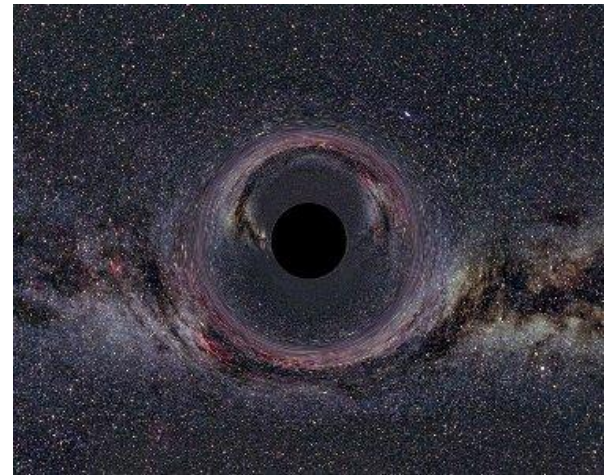


Figure 1: A theorized image of a black hole. There are no legitimate up-close pictures of a black hole, so this image conveys what a black hole might look like ("Black Holes").

gravity overcame the power of the fusion process and crushed the singularity into this infinitesimal speck. A common misconception about black holes is that if an object were to be pulled into the singularity, it would not be crushed but instead would be passed through a kind of wormhole, or connection to another place. What this other place may be is anyone's guess, from another point in our galaxy to another dimension. However, such a wormhole would be impossible to sustain and would, in theory, be unstable to the point that if any object were to pass through it, it would collapse (Bunn).

The next topic to mention is the theory of Hawking Radiation, a concept proposed by renowned physicist Stephen Hawking in the year 1974. Using extremely complicated quantum mechanical equations and experiments, physicists have discovered that the law of conservation of mass which states that matter can neither be created or destroyed, can in fact be violated so long as the created matter is destroyed very quickly. In other words, through an event known as a vacuum fluctuation, two particles can be created from literally nothing, a regular particle and an antiparticle. These two particles will destroy each other on contact, however, restoring the balance. Hawking theorized that these vacuum fluctuations occur just outside of the event horizon of a black hole but instead of the particles annihilating each other, the antimatter is pulled across the event horizon while the normal particle escapes. All observers will see is that apparently empty space just emitted a particle of energy (Bunn).

These vacuum fluctuations would occur all over the event horizon and would seem to the observer that the black hole was emitting a steady stream of energy/radiation. As the amount of radiation released increases, the negative energy absorbed by the black hole decreases its energy and according to the theory of relativity, it also loses mass (Jones). The theory also states that as the mass of the black hole decreases, the process of emitting radiation speeds up, so that the black hole shrinks at a constantly accelerating rate until the black hole either vanishes completely or leaves a tiny remnant behind. However, we currently do not have enough information to say what honestly happens to the black hole after the radiation process ends (Bunn).

## How Do We Know They Exist?

But the most important answer to be explained about black holes is, how do we know they exist? This could all just be a well thought out joke. But no, there are multiple ways to detect black holes and prove their existence. Unfortunately, we can not say that we have detected Hawking Radiation from any black holes; the very idea of Hawking Radiation is still only a theory. So far scientists have not discovered any particles of energy being emitted from apparently empty space, but thankfully there are other ways to prove the existence of black holes.

The main way of proving their existence is by observing the effects they have on nearby stars in space. The most obvious effect that a black hole may have on stars is the fact that the stars may begin to orbit the black hole. When astronomers chart a star and realize that it appears to be orbiting nothing at all, they assume that the “nothing” that the star is orbiting is actually a black hole (Miller). Also, due to the intense gravitational pull from black holes, they may pull in particles from nearby sources, whether they are any of the random floating particles in space or from a nearby star. As these materials are pulled into the black hole, they accelerate to very high speeds and their temperature rises to millions of degrees Kelvin. These heated particles emit X-rays as they spin around and around the black hole, and these X-rays are in quantities great enough to be picked up by X-ray telescopes here on Earth. The process is illustrated in

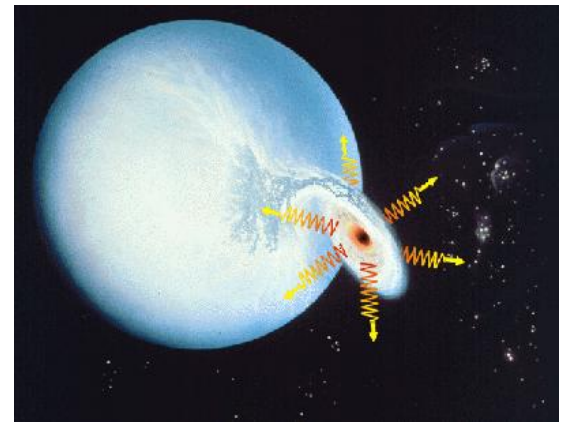


Figure 2: This diagram depicts particles being pulled into the black hole and releasing X-rays due to the heat being generated by spinning so fast (Freudenrich).

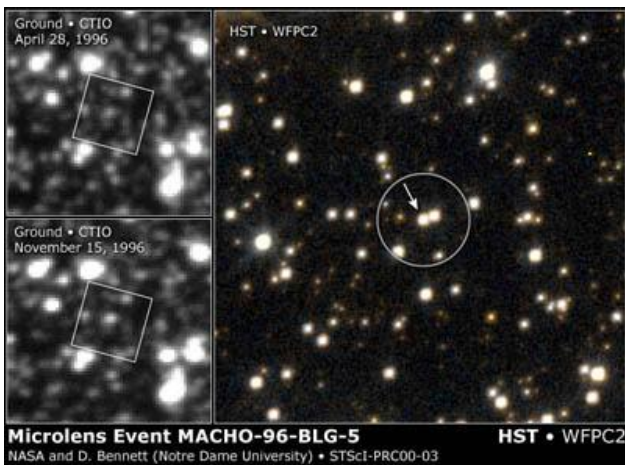


Figure 3: Pictures from the Hubble Space telescope showing two images of one object, indicating the presence of a gravitational lens (Freudenrich).

figure 2, which depicts the particles being pulled into the black hole and emitting the X-rays.

A final way to both prove that black holes exist is the presence of gravity lenses in space. According to Einstein’s theory of general relativity, gravity has the ability to bend space, and after an experiment involving charting the position of a star before, during and

after a solar eclipse, it was proved to be correct. Astronomers found that when an object with an immense gravitational pull passes between the earth and an object, the object with the strong gravitational pull could actually bend the light and bring the other object into a focus. This effect is similar to the functioning of a lens and is therefore called a gravitational lens. In 1996, the Hubble Space Telescope had pictures that showed two images of a single object close together as shown in figure 3. This phenomenon indicated that a gravitational lens had taken place, but the object that had caused it couldn't be seen. The only conclusion to be drawn was that a black hole had just passed between the object and the Earth.

## **Conclusion**

As fascinating as they may sound, black holes are not the stuff of science fiction. They are nowhere near as potent as they are often described. They are the most powerful and awe-inspiring forces of the cosmos; their mechanics defy conventional logics. The point of singularity is a place that exists only in the dreams of scientists and formulas of quantum mechanics and the idea of a field of gravity so strong that not even light waves can escape is a source of galactic wonder. They bind the universe together and must be better understood if we are to understand the cosmos.

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