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Class Challenge IV

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There is evidence that black holes could be used for space and time travel. Black holes are areas in space where space-time is warped due to gravity being quite dense. They form when a star dies and explodes. As of right now, black holes can not be used as wormholes but could be used as a gravitational slingshot to help propel a spacecraft through space faster. Black holes can be used as time machines thanks to them being super dense. Hopefully, black holes will be a means of space-time travel in the future when our technology becomes better.

Black Holes have an extreme gravitational pull that warps the fabric of space-time, making it possible to use them as a means of Space-Time travel.

Have you ever wondered what it would be like to be able to go and explore the universe, or to be able to go to a planet that is on the other side of the universe? The only thing stopping you is billions of light-years and a need for more technology to create a ship capable of getting you there. Maybe you have thought about time traveling, going to the future, or visiting the dinosaurs. Unfortunately, this cannot happen without a time machine.

Black holes can be used for space and time travel. There are three areas to be considered to understand how this is possible. First, it is very important to understand what a black hole is and how it is formed. Then, it needs to be determined whether or not black holes can actually be

used for space travel. Finally, consideration can be taken as to whether a black hole can be used as a time machine.

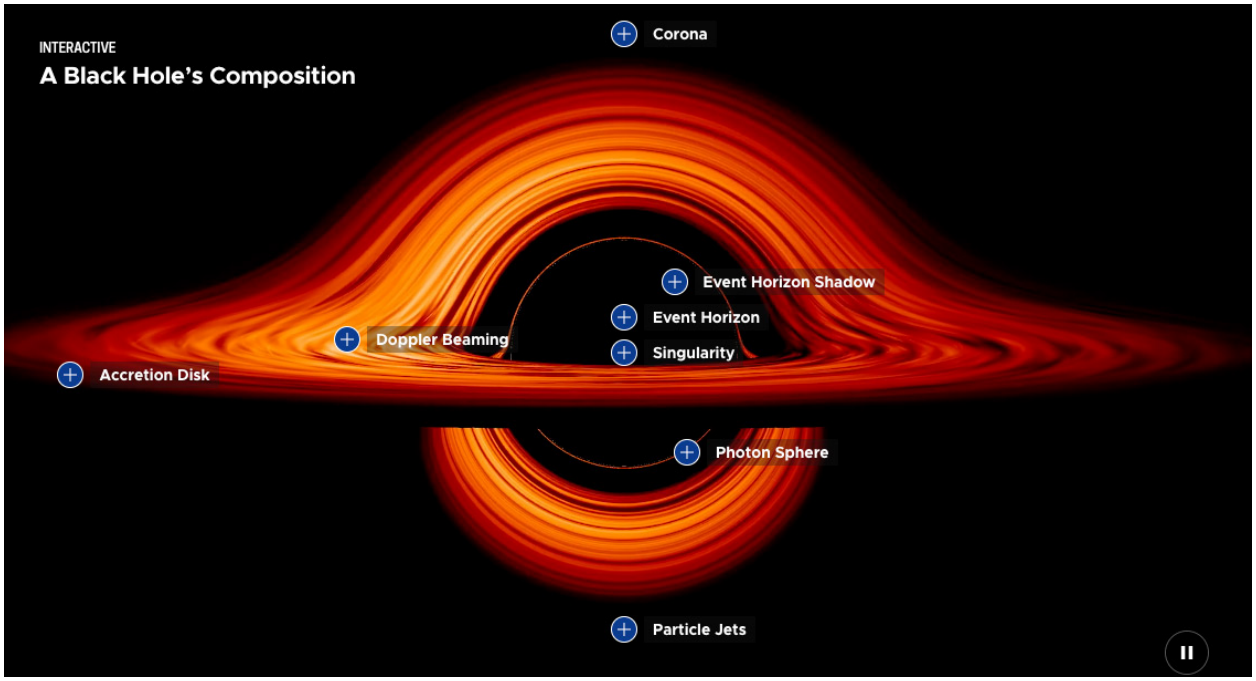
What is a black hole, and how does it form?

Black holes are areas in space where gravity is so dense that nothing can escape from its grasp, including light. There are two categories of black holes, stellar and supermassive. The way scientists determine what type of black hole it is is by figuring out how much mass it has. For example, Stellar black holes are about eight times the sun's mass and form when a star that is about to collapse in on itself and is twenty times the sun's mass dies and explodes. If it is under twenty times the sun's mass, it creates a neutron star. Supermassive black holes form the same way as the stellar ones do. The only difference is their mass. Supermassive black holes can be anywhere from hundreds to thousands of the sun's mass.

Black holes can form in one of three ways. The first way is from a star. When the star is about to die and cannot support itself anymore, it collapses in itself, creating a supernova. That supernova then tears a hole in the fabric of spacetime. The second way a black hole is formed is when two neutron stars collide. Neutron stars form when stars that are multiple times the mass of the sun collapses in on itself and explodes resulting in the birth of a neutron star. The third way a black hole forms is similar to the first, except there is no huge explosion that creates the supernova. It is called a failed supernova. Scientists might have witnessed this phenomenon between 2007-2015. They were watching star N6946-BH1 in a distant galaxy, and suddenly the star disappeared. Scientists believe they witnessed a failed supernova that created a black hole.

However, they are not entirely sure. Currently, scientists are still trying to figure out if a black hole was created.

Once a black hole forms, it can be divided into 8 parts: the event horizon, Accretion disk, Event Horizon Shadow, Photon Sphere, Doppler Beaming, Corona, Particle Jet, and singularity. (See picture Below)



Credit: NASA's Goddard Space Flight Center/Jeremy Schnittman - "Anatomy of a Black Hole." *NASA Science Universe Exploration*, Nasa, universe.nasa.gov/black-holes/anatomy/.

Event Horizon

An event horizon is what makes a black hole black due to it being unable to emit or reflect light. The event horizon is similar to being a surface of a black hole, although it is not

solid. If an object were to go inside the event horizon there would be no escape due to the fact that in order to escape, that object would have to travel faster than the speed of light. That is not possible because nothing travels faster than the speed of light. Therefore, nothing can escape the event horizon, not even light.

Event Horizon Shadow

The event horizon stops all light from entering the black hole, which then makes the light get redirected due to the gravitational lensing of the black hole. This creates a dark zone which is called the event horizon shadow, and it is twice as big as the black hole.

Accretion Disk

The Accretion Disk is what gives off light which in turn allows us to be able to see the black holes. Black holes feed off of matter, which helps them grow. They will consume anything, including other black holes. Due to the black hole's strong gravitational pull, the matter will rotate around in the accretion disk, starting from the outside and working its way toward the event horizon. Eventually, the matter falls into the black hole. When a black hole has nothing around it to consume, the accretion disk will cease to exist. This makes it near impossible for astronomers to locate it. The Photon Sphere and the Doppler beaming are part of the accretion disk. When looking closely, there would probably be a noticeably interesting shape from almost any angle. The reason it has such a unique shape is that the black hole's gravitational field warps space-time around it; the light has to follow this warped path.

> Astronomers call this process gravitational lensing. Light coming to us from the top of the disk behind the black hole appears to form into a hump above it. Light from beneath the far side of the disk takes a different path, creating another hump below. The humps' sizes and shapes change as we view them from different angles, and we see no humps at all when seeing the disk exactly face on (Anatomy of a Black Hole)

Photon Sphere

No matter what angle the black hole is observed from, there is a thin line of light at the edge of the event horizon's shadow; this is called the photon sphere. As previously mentioned, the photon sphere is a part of the accretion disk. It is just matter orbiting around the black hole, working its way to the event horizon. The closer the photon sphere gets to the event horizon, the thinner and fainter the rings look because the matter is falling into the black hole.

Doppler Beaming

When looking at the accretion disk on a certain side, it will look brighter than the other sides. The closer the matter gets to the black hole, the faster it spines. "This is the optical equivalent of an everyday acoustic phenomenon, where the pitch and volume of a sound – such as a siren – rise and fall as the source approaches and passes by. The black hole's particle jets show off this effect even more dramatically"- (Anatomy of a Black Hole.) Light from the part of the disk that is spinning toward Earth is brighter with a blue color. The light that is spinning away from Earth is a lot dimmer with a red color. This is called Doppler beaming.

Corona

Corona is one of the most extreme environments in the entire universe. The magnetic fields go through the inner accretion disk and then back out of it. This creates a weak, turbulent billion-degree cloud of particles that orbits around the Accretion Disk at a speed that can reach the speed of light. "It's a source of X-rays with much higher energies than those emanating from the accretion disk, but astronomers are still trying to figure out its extent, shape, and other characteristics."(Anatomy of a Black Hole.)

Particle Jet

Every type of black hole can have a particle jet. Particle jets occur at the inner edge of the accretion disk. They form when a small number of particles are about to fall into the black hole but get rerouted, causing them to be shot out on opposite sides. The light that is shot out can reach speeds up to the speed of light. Supermassive black hole particle jets can reach lengths of up to hundreds of thousands of light years in length.

Singularity

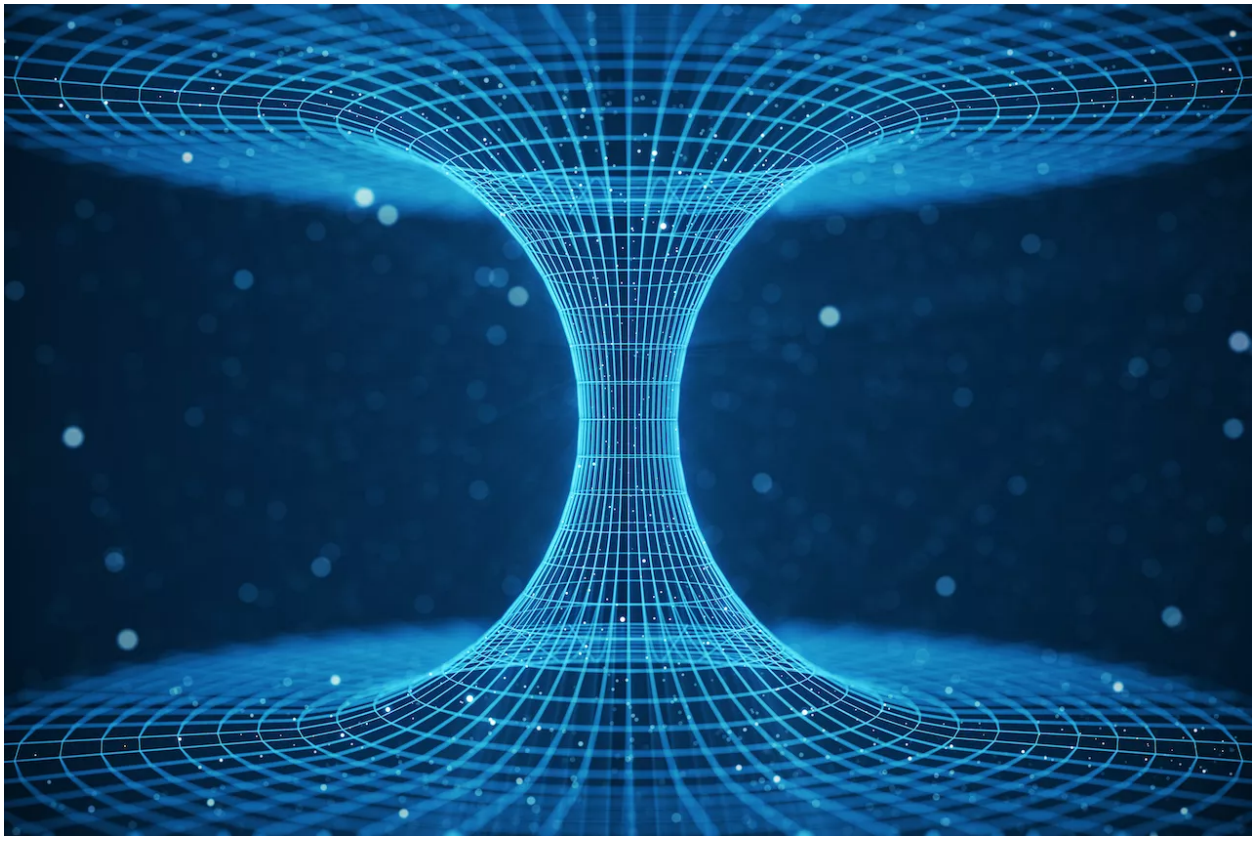
The singularity is at the very center of a black hole. NASA states in "The Anatomy of a Black Hole,"

> The singularity may be either a physical structure or a purely mathematical one, but right now astronomers don't know which is true. The prediction of a singularity may signal the limits of relativity, where quantum effects not included in the theory become important in a more complete description of gravity.

At this point, matter is being crushed. As a result, it becomes extremely dense. It is the final place for anything that falls into the black hole.

Can A Black Hole Be Used As A Wormhole?

A wormhole is a puncture in the fabric of space-time that is like a bridge that links two places together. This, in turn, helps to decrease the travel time needed to go somewhere.



Credit: What is wormhole theory? *Space.com*

Wormholes were first theorized to exist in 1935 by Albert Einstein and Nathan Rosen, thanks to their theory of general relativity. General relativity is the theory of gravity that warps the fabric of space-time. Today, scientists do not know if we could use black holes as a wormhole. Instead, it is probably more likely that we could make an artificial one. If we could use black holes as wormholes or even artificial wormholes, there would, unfortunately, be three problems.

The first problem is that wormholes are very fragile. Any matter that passes through the wormhole would end up pulling it shut due to its gravitational pull. To keep the wormhole open, you would need something to stabilize it; scientists call this "exotic" matter.

In 2017 two physicists figured out a way to prop open a wormhole using quantum entanglement. Oxford Language Dictionary defines Quantum Entanglement as "the phenomenon whereby a pair of particles are generated in such a way that the individual quantum states of each

are indefinite until measured, and the act of measuring one determines the result of measuring the other, even when at a distance from each other" (Oxford Languages Dictionary) Using Quantum Entanglement provides the wormhole with the necessary "exotic" matter that is needed to stabilize the wormhole. Unfortunately, using this method would only end up creating microscopic wormholes instead of big ones which is the second problem. There are currently no ships strong or capable enough to get to the black hole, or even to go through it.

The third problem is the black hole's gravity and how a spacecraft would have to travel faster than the speed of light to be able to escape the grasp of the black hole when leaving it. That is if the spacecraft were able to exit it. There are also currently no ships strong or capable enough to get to the black hole or even to go through it.

Theoretically, using a black hole as a wormhole for space travel is possible. The problem is that scientists are not sure if the type of black hole we would need to use exists. Now let's assume that a black hole is found and accessible; scientists would need to figure out a way to enter the singularity. This may be done by finding a black hole with a wormhole with a big enough opening to pass through; or by stabilizing it with "exotic" matter. It would be necessary to explore ways to safely enter the event horizon in order to get to the Singularity without getting ripped to shreds.

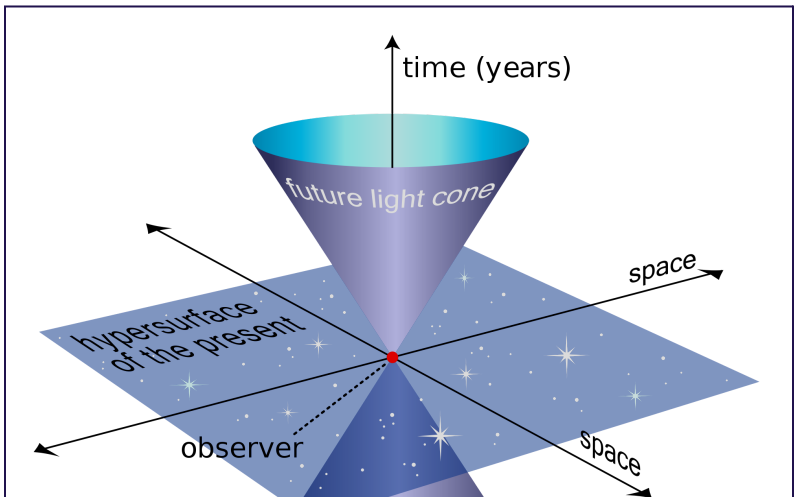
Gravitational Slingshot

Even though black holes can not be used as a wormhole due to the fact that the type of black hole needed has not been discovered at this moment, that does not mean that they do not exist. Scientists just have not found them yet. In terms of space travel, it is believed that they very much can be used for that. Gravitational slingshots are being used today by using the

gravitational pull of planets to help satellites reach their destination faster. If a black hole were to be used as a gravitational slingshot, then it would definitely work for getting through space faster. The way gravitational assist works, is by using the gravitational pull of a planet, or in this case, a black hole, to make an object move faster and further than it is able to go by itself. To do this, a person or object would need to go around the black hole, which should increase the velocity of the person or object by stealing momentum from the black hole.

How black holes can be used as a time machine?

If you were to take two clocks and put them at different heights, the one that is higher up would move faster than the one that was lower. This is because gravity is stronger the closer you are to the Earth. Another example would be if you were to put a clock next to a black hole you would probably notice that your clock is moving a lot slower than it would on Earth this is because the black hole is warping the fabric of space-time. This is called time dilation. For example, "In 10 years, two clocks that are 1,000 meters apart from each other in height will be off by just 31 millionths of a second. That would only be a nanosecond of a difference in time." - Scientists take an atomic clock on the road and use it to measure the height of a mountain. If you were to spend one year near a black hole, that could mean eighty years could have passed on Earth. Due to space-time being warped, we could use black holes for time travel to the future.



Credit - Wikipedia

Space consists of 4 dimensions, three are space and one is time. If something in the dimension were not moving at all, it would be considered a vertical line because it is not moving in any of the other dimensions of space but is still moving forward on the time axis. This is called the world line. Something moving diagonally on the space-time axis would be called a diagonal line; it would be moving in one of the space coordinates. Something that is accelerated on the space-time axis would end up creating a curved line.

If a person were to flash a bright light, this light would create what scientists call a light cone. We will call this event A. Now let's just say that another person was just standing there watching the flashing light and did not move. Eventually, the light and the person would intersect each other resulting in event B. The light represents all the future events that the light reaches in space-time from the initial point where it started. In the diagram above, there is also an upside-down cone. That cone represents all the past events of event A in spacetime.

If the cone were close to the black hole, it would start to tilt. Once it starts to fall into the event horizon, it will start to tilt the space-time axes at a forty-five-degree angle. As it keeps on falling to the center of the black hole, it will start to point toward it completely. Once it does this, it is theoretically possible to use the singularity to travel back in time by going around the singularity and coming out where the person or object started. Unfortunately, once a person or object enters the event horizon, there is no coming back out due to its extreme gravity. Luckily there are two ways to get out of the black hole. The first way to get out is to be faster than the speed of light. Currently, this is impossible. If technology were created in the future to move faster than the speed of light, it would be possible to exit the black hole. The second way to escape the black hole would be for the black hole to be spinning extremely fast. If the black hole spins fast enough the event horizon will disappear completely, resulting in a naked singularity. This would

allow for an escape from the black hole. From what scientists have observed, this is not possible because a black hole is not able to move fast enough for the event horizon to disappear. The black hole would have had to also exist during the time that the person or object wants to travel back to. Right now traveling forward and backward in time is plausible. However, the technology currently will not work, but maybe in the future, the technology could end up being created.

Black Holes have a powerful gravitational pull that warps the fabric of space-time, therefore, making it possible to use them as a means of Space and Time travel. Black holes are an area in space where gravity is so dense that nothing can escape from its grasp. They form when a star collapses in on itself when it dies. Black holes cannot currently be used as a wormhole for space travel but theoretically could be used as a gravitational slingshot as a primary method of time travel. Lastly, black holes could potentially be used as time machines, but it will be easier to move forward in time as opposed to traveling backwards in time.

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