What is a Black Hole?

A black Hole is a region in space where gravity is so strong that not even light can escape from it. Black holes in our galaxy are thought to be formed when stars more than ten times as massive as our Sun end their lives in a supernova explosion. There is also evidence indicating that super massive black holes (more massive than ten billion Suns) exist in the centres of some galaxies.

How Big Is A Black Hole?

There are two different ways to describe how big somethi ng is. We can say how much mass it has, or we can say how much space it takes up …

There is no limit to how much or how little mass a black hole can have. Any amount of mass at all can in principle be made to form a black hole if you compress it to a high e nough density.

It is suspected that most of the black holes that are actually out there were produced in the deaths of massive stars, and so we expect those black holes to weigh about as much as a massive star. Astronomers also suspect that other galaxies may harbour extremely massive black holes at their centres. These are thought to weigh about a million times as much as the Sun, or $1x10^{36}$ kilograms.

The more massive a black hole is the more space it takes up. In fact, the if one black hole weighs ten t imes as much as another, its radius is ten times as large. A black hole with a mass equal to that of the Sun would have a radius of 3 kilometres. So a typical 10-solar-mass black hole would have a radius of 30 kilometres, and a million-solar-mass black hole at the centre of a galaxy would have a radius of 3 million kilometres. Three million kilometres may sound like a lot, but it's actually not so big by astronomical standards. The Sun, for example, has a radius of about 700,000 kilometres, and so that supe r massive black hole has a radius only about four times bigger than the Sun.
If The Earth were a black hole then it would be only about 9m radius roughly the size of my bedroom ☺

If a black hole existed, would it eventually suck up all the matter in the Universe?

Hell, no. A black hole has a "horizon," which means a region from which you can't escape. If you cross the horizon, you're doomed to eventually hit the singularity (middle). But as long as you stay outside of the horizon, you can avoid getting sucked in. In fact, to someone well outside of the horizon, the gravitational field surrounding a black hole is no different from the field surrounding any other object of the same mass. In other words, a one -solar-mass black hole is no better than any oth er one-solar-mass object (such as, for example, the Sun) at "sucking in" distant objects .

What happens if Luke falls into a black hole?

Let's suppose that Luke gets into his spaceship and points it straight towards the million-solar-mass black hole in the centre of our galaxy. (Actually, there's some debate about whether our galaxy actually contains this central black hole, but let's assume it does for the moment.) Starting from a long way away from the black hole, he just turns off his rockets and coasts in. What happens?

At first, he doesn't feel any gravitational forces at all. Since he is in free fall, every part of his body and his spaceship is being pulled in the same way, and so he feels weightless. (This is exactly the same thing that happens to astronauts in Earth orbit: even though both astronauts and space shuttle are being pulled by the Earth's gravity, they don't feel any gravitational force because everything is being pulled in exactly the same way.) As he gets closer and closer to the centre of the hole, though, he starts to feel "tidal" gravitational forces. Imagine that his feet are closer to the centre than your head. The gravitational pull gets stronger as he get closer to the centre of the hole, so his feet feel a stronger pull than his head does. As a result he feels "stretched." (This force is called a tidal force because it is exactly like the forces that cause tides on earth.) These tidal forces get more and more intense as he gets closer to the centre, and eventually they will rip him apart.

For a very large black into, the tidal forces are not really noticeable until you get within about 600,000 kilometres of the centre. If you were falling into a smaller black hole, say one that weighed as much as the Sun, tidal forces would start to make you quite uncomfortable when you were about 6000 kilometres away from the centre, and you would have been torn apart by them long before you crossed the horizon of the black hole (That's why I decided to let you jump into a big bla ck hole instead of a small one: I wanted you to survive at least until you got inside.)

What do you see as you are falling in? Surprisingly, you don't necessarily see anything particularly interesting. Images of faraway objects may be distorted in strange ways, since the black hole's gravity bends light, but that's about it. In particular, nothing special happens at the moment when you cross the horizon. Even after you've crossed the horizon, you can still see things on the outside: after all, the light from the things on th e outside can still reach you. No one on the outside can see you, of course, since the light from you can't escape past the horizon.

How long does the whole process take? Well, of course, it depends on how far away you start from. Let's say you start at rest from a point whose distance from the singularity is ten times the black hole's radius. Then for a million -solar-mass black hole, it takes you about 8 minutes to reach the horizon. Once you've gotten that far, it takes you only another seven seconds to hit the middle, so if you'd jumped into a smaller black hole, your time of death would be that much sooner.

Once you've crossed the horizon, in your remaining seven seconds, you might panic and start to fire up your engines in a desperate attempt to avoid the centre, unfortunately, it's hopeless, it's best just to sit back and enjoy the ride.

Kate was watching Luke, What did she see?

Kate sees things quite differently from you. As you get closer and closer to the horizon, she sees you move more and more slowly. In fact, no matter how long she waits, she will never quite see you reach the horizon.

Kate sees you get smaller and smaller, approaching but never quite reaching its horizon. This is why black holes were originally called frozen stars: because they seem to 'freeze' at a size just slightly bigger than the horizon (Schwarzschild radius)

Why does she see things this way? The best way to think about it is that it's really just an optical illusion. It doesn't really take an infinite amount of time for Luke to cross the horizon. (If you don't believe me, just try jumping in! You'll be across the horizon in eight minutes, and crushed to death mere seconds later.) As you get closer and closer to the horizon, the light that you're emitting takes longer and longer to climb back out to reach Kate. In fact, the radiations you emit right as you cross the horizon will hover right there at the horizon forever and never reach her. You've long since passed through the horizon, but the light signal telling her that won't reach her for an infinitely long time.

There is another way to look at it; in a sense, time really does pass more slowly near the horizon than it does far away. Suppose you take your spaceship and ride down to a point just outside the horizon, and then just hover there for a while (burning enormous amounts of fuel to keep yourself from falling in). Then you fly back out and rejoin Kate. You will find that she has aged much more than you during the whole process; time passed more slowly for you than it did for her.

In practice, you will actually become invisible to Kate before too much time has passed. For one thing, light is red shifted to longer wavelengths as it rises away from the black hole, so if you are emitting visible light at some particular wavelength, Kate will see light at a longer wavelength. The wavelengths get longer and longer as you get closer and closer to the horizon. Eventually, it won't be visible light at all: it will be infrared radiation, then radio waves. At some point the wavelengths will be so long that she'll be unable to observe them. Furthermore, remember that light is emitted in individual packets called photons. Suppose you are emitting photons as you fall past the horizon. At some point, you will emit your last photon before you cross the horizon. That photon will reach Kate at some time -- typically less than an hour for that million-solar-mass black hole -- and after that she'll never be able to see you again. (After all, none of the photons you emit *after* you cross the horizon will ever get to her.)

What if the Sun became a black hole?

Well the Sun has no intention of doing any such thing. Only stars that weigh considerably more than the Sun end their lives as black holes. The Sun is going to stay roughly the wa y it is for another five billion years or so. Then it will go through a brief phase as a red giant star, during which time it will expand to engulf the planets Mercury and Venus, and make life quite uncomfortable on Earth (oceans boiling, atmosphere escapi ng, that sort of thing). After that, the Sun will end its life by becoming a boring white dwarf star.

But what if for some random reason the Sun *did* become a black hole

The main effect is that it would get very dark and very cold around here. The Earth and the other planets would not get sucked into the black hole; they would keep on orbiting in exactly the same paths they follow right now. Why? Because the horizon of this black hole would be very small -- only about 3 kilometres -- and as you found out earlier so as long as you stay well outside the horizon, a black hole's gravity is no stronger than that of any other object of the same mass.

Can you have a white hole?

If you are lame enough to still take maths then using some equations of general relativity you can get a very interesting result; there is always an anti-thing, so you get “white holes”.
Since a black hole is a region of space from which nothing can escape, the anti-black hole (white hole) is a region of space into which nothing can fa ll. In fact, just as a black hole can only suck things in, a white hole can only spit things out.

White holes are a perfectly valid mathematical solution to the equations of general relativity, but that doesn't mean that they actually exist in nature. In fact, they almost certainly do not exist, since there's no way to produce one. (Producing a white hole is just as impossible as destroying a black hole, since the two processes are time-reversals of each other.)

I suggest we spend the remainder of this le sson trying to make a white hole and sell all of the things that spit out on eBay, and we would be rich.

Another option is to create a white hole and blast it at a black hole; see who would win. My money is on black hole to win.