Black Holes

Overview: We're ready to deal with the topic you've all been waiting for! Join me as we find out what happens to stars that wander too close, how black holes collide, how we can detect super-massive black holes in the centers of galaxies, and wrestle with question: what's down there, inside a black hole?

What to Learn: We're going to take a sneak peek at the laws of physics that govern these and more in our adventure through black holes.

Materials

- Marble
- Metal ball (like a ball bearing) or a magnetic marble
- Strong magnet
- Small bouncy ball
- Tennis ball and/or basketball
- Two balloons
- Bowl
- 10 pennies
- Saran wrap (or cup open a plastic shopping bag so it lays flat)
- Aluminum foil (you'll need to wrap inflated balloons with the foil, so make sure you have plenty of foil)
- Scissors

Experiment

1. During the presentation, when you get to the supernova question: ""Why do supernovas explode at all if they are shrinking and collapsing?" stop the video and do the experiment:
2. Pull out the two different sizes of balls that you set aside.
3. First, hold out the larger ball at arm's length in front of you. You'll want to do this over a flat surface – something without any rugs or carpet. Drop (don't throw and don't bounce) your larger ball on the floor. Do you see how high it bounces on its own?
4. Now drop your smaller ball (this can be a bouncy ball or a tennis ball if you're using a basketball) on the ground and notice how far it bounces back up.
5. Now place the smaller ball on top of the larger ball like it shows here in the picture and let them BOTH drop at the same time so that they fall together and hit the ground with the smaller ball still on top. You've got to make sure that the smaller ball stays on top when it hits the ground. If it falls off, you've got to do it again.

When the two balls hit the floor, the smaller ball suddenly rebounds with enough energy to hit the ceiling! How high did the larger ball bounce? More or less than when you dropped it by itself? The larger ball transferred its energy to the smaller ball and didn't bounce much (if at all). This is exactly what happens in a supernova. When the core of a star collapses, it smacks together so HARD that it rebounds – it bounces back. When it rebounds and bounces back out, it collides with the rest of the gas that is still falling inward. When the rebounding core hits the in-falling gas, the core blasts everything out into space… and this makes a giant explosion! This idea is just like the experiment with the tennis ball we just did – the bigger ball is the core collapsing, and the small ball is the outer gas layers that take longer to collapse. When the core (big ball) rebounds, it hits the gases (small ball) with enough energy to blow the gas layers away from the star. That's why supernovas explode.

Reading

Stars like to live together in families. Galaxies are stars that are pulled and held together by gravity. Some galaxies are sparse while others are packed so densely you can't see through them. Galaxies also like to hang out with other galaxies (called galaxy clusters), but not all galaxies belong to clusters, and not all stars belong to a galaxy.

Active galaxies have very unusual behavior. Most galaxies have super-massive black holes in the center, many of which lie dormant. Scientists think active galaxies are the ones where the black hole is actively feeding on in-falling material. What scientists can detect are huge bursts of energy in the form of X-ray and gamma rays spewing up and out of the plane of the galaxy – a sure sign of a voracious black hole. There are several different types of active galaxies, including radio galaxies, quasars, blazars, and more. Our own galaxy, the Milky Way, has a super-massive black hole at its center, which is currently quiet and dormant.

When you look up at the night sky, it seems like the pinpoints of light are each isolated from each other. When viewed through a telescope, however, single stars can actually transform into tens of millions of stars. Globular clusters are massive groups of stars held together by gravity, usually housing between tens of thousands to millions of stars (think New York City). Open clusters are made up of stars that all have the same chemical composition, but don't usually stay together for long.

When a star uses up its fuel, the way it dies depends on how massive it was to begin with. Smaller stars simply fizzle out into white dwarfs, while larger stars can go supernova. A recent supernova explosion was SN 1987. The light from Supernova 1987A reached the Earth on February 23, 1987 and was bright enough to see with a naked eye from the Southern Hemisphere.

Neutron stars are formed from stars that explode in a tremendous supernova explosion, but aren't big enough to collapse forever and turn into a black hole. When a star explodes, it blows off its outer layers of gases and the inner core collapses down and crushes the atoms together so much that protons and electrons fuse into neutrons. The neutrons are so densely packed together that the space between them is basically gone. Pick up a strand of your hair right now – feel how heavy it is? If this was made of neutron material, it would weigh the same as the Empire State Building. As the neutron star forms, it starts to rotate and form huge magnetic fields. We already know that when you have magnetic fields, electrical fields are not far behind. Neutron stars can wind up spinning very fast, spewing jets of high-energy X-ray particles out the poles. When our telescopes detect the X-rays from a neutron star, we call it a pulsar**.**

Black holes are the leftovers of a BIG supernova. When a star explodes, it collapses down into a white dwarf or a neutron star. However, if the star is large enough, there is nothing to keep it from collapsing, so it continues to collapse forever. It becomes so small and dense that the gravitational pull is so great that light itself can't escape.

The only way you can detect a black hole is to look at what happening around it. If a star seems to be orbiting something that isn't there, you can bet it's a black hole. Stuff doesn't just fall straight into a black hole, either. When matter approaches the black hole, it stars to swirl around an accretion disk, which heats up the particles in the disk and lights up the disk so it's visible in the X-ray part of the spectrum (even though the black hole itself is not). You can also detect black holes by the way light is bent when passing by.

Question: What is a black hole? It's **BLACK** because does not emit or reflect light. Black holes are the darkest black in the universe – no matter how powerful a light you shine on it, even if it's a million-watt flashlight, no light ever bounces back, because it's truly a "hole" in space.

HOLE means nothing entering can escape. Anything that crosses the edge is swallowed forever. Scientists think of black holes as the edge of space, like a one-way exit door. What's a black hole made of? Black holes are made of nothing but space and time, and they are the strangest things in nature.

One of the biggest myths about black holes: Black holes are not vacuum cleaners with infinite-sized bags. They do not roam around the universe sucking up everything they can find. They will grow gradually as stars and matter falls into them, but they do not seek out prey like predators. A black hole just sits there with its mouth open, waiting for dinner.

It's actually more like a basketball hoop – think about a hoop: it just sits there waiting for you to put a ball through, right? I mean, you wouldn't expect a basketball hoop to chase you around the court, would you? So a black hole just sits there waiting for stuff to fall in, kind of like an invisible trap.

So what IS a black hole?

Here's an example of what a black hole is: Hold out your hand in front of you, and place in your hand an imaginary ball. Don't use a real one, or someone might be upset with what we're going to do with it. Now take that ball and toss it up in the air… does it come back down to you? Sure!

Toss it up even higher now… and it still comes back, right? Pretend you're outside and really toss it up hard – higher than the house! Does it STILL come back down?

What if you toss it up so fast that it exceeds the escape velocity of earth? (7 miles per second) Will it ever come back? No. The escape velocity depends on the gravitational pull of an object. The escape velocity of the Sun is 400 miles per second. A black hole is an object that has an escape velocity greater than the speed of light. That's exactly what a black hole is.

Let me say that again – a black hole is an object that requires objects to go faster than light to escape the gravitational pull. That's all there is to it. The rest is all on the video, including the three ways to detect black holes, what happens if you were to fall into a black hole, and the most famous black hole scientists.

Exercises

1. What are three different ways to detect a black hole?
2. How many ways can a black hole kill you? Can you name them?
3. What happens if you get close to a black hole, but not close enough to get sucked in? (Remember your magnet-marble experiment!)
4. What's the most interesting thing you learned from the video about black holes?
5. What causes a black hole to form?
6. Does a black hole search for its next victim?
7. Where is the closest super-massive black hole?
8. What is gravitational lensing and why does it work? (Remember your marble-bowl experiment!)

Answers to Exercises: Black Holes

1. What are three different ways to detect a black hole? (Look for X-rays from actively feeding black holes, gravitational lensing, and stars that appear to orbit something that's not there.)

2. How many ways can a black hole kill you? Can you name them? (You can get killed by a black hole by: falling in, spaghettification, being near when it forms, being near when it evaporates, being near when two black holes smack into each other, fried by the X-ray light coming out)

3. What happens if you get close to a black hole, but not close enough to get sucked in? (Remember your magnet-marble experiment! Your path appears to be straight (to you), but in follows the curve of space and deflects.)

4. What's the most interesting thing you learned from the video about black holes?

5. What causes a black hole to form? (When the biggest stars run out of fuel, they explode and what's left over is a black hole as the core collapses forever.)

6. Does a black hole search for its next victim? (No – it just sits there waiting.)

7. Where is the closest super-massive black hole? (At the center of our galaxy.)

8. What is gravitational lensing and why does it work? (When gravity from a black hole bends light, we can see the effects in photographs. Although we can't actually "see" a black hole, we can see the light being bent around it.)