Article from William Katzman to Catawba Science Center:

Imagine you could hear the universe speak. Of course that's absurd – sound doesn't travel through the vacuum of outer-space. But who says the universe speaks through sound? It shows us its secrets through light – as stars shine brightly in different hues. Stars and other celestial objects shine in visible light as well as radio, infrared, x-ray and more types of light that we can't see with our eyes, but we can detect with various telescopes. Yet there is information that not even telescopes can see…information in the very fabric of space and time – that information comes through gravitational waves. Now for the first time we can hear those waves: https://www.ligo.caltech.edu/video/ligo20160211v2 .

One hundred years ago Albert Einstein gave us the General Theory of Relativity that says that gravity is due to the curvature of space-time (the 3 dimensions we know and the 4th dimension of time). If you think of the universe as a trampoline, then every mass bends that trampoline – dense, heavy masses indent the trampoline sharply while other objects barely cause an indentation. Just as adults cause bigger dents than children do on a trampoline. If I sat on the trampoline and you tried to roll a ball by me, the indentation I made would cause the ball to deflect – going around me in a curve instead of the intended straight line – orbiting as a comet orbits the sun. But what if I was moving around – or what if two of us were running around the trampoline- then the curvature would constantly change. Gravitational waves are the changes in the stretching of the trampoline of space-time that propagate out from the two object which are in orbit around each other.

Black holes are strange. By definition you can't see them because they don't emit visible light. While the escape velocity of planet Earth (the speed needed by a rocket to not fall back down to earth) is about 25,000 mph, the escape velocity of a black hole is greater than the speed of light (670 million mph). We don't know of anything that goes faster than the speed of light, so nothing gets out![1] This means we can't see them directly.[2] Yet rapidly moving black holes can ripple the fabric of space-time giving us information in the form of gravitational waves.

When black holes get closer to each other they move faster and faster just as a coin moving around Catawba Science Center's gravity well circles faster and faster. The black holes circle in towards each other at incredible speeds until they merge into one black hole. As they do this they ripple space-time like crazy, giving off more and more energy. That's what happened about 1.3 billion years ago when two black holes collided with each other at half of the speed of light. They formed a black hole that is the size of Iceland, with the mass of 62 of our Suns.

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[1] There is a possibility of something called Hawking radiation getting out due to quantum mechanics, but generally we say nothing gets out.

[2] We can see light from objects falling into the black holes, and we can see ripples in the star field from gravitational lensing around the black holes – but we don't see the black holes themselves.

The largest man-made explosion was a 50-60 Megaton bomb called the Tsar Bomba. This bomb was equivalent to turning a 5 lb bag of sugar, (or flour or anything) into pure energy. The collision of the two black holes turned the equivalent of 3 of our Suns, or a million Earths into pure energy. So much energy was released so quickly that, in that brief moment, it was more than the power of all of the stars in the universe combined! Only without LIGO we couldn't see that power because it was in Gravitational Waves, and it happened so far away (1.3 billion light years). Waves lose power over distance – this is why your friend's voice fades the farther away they are. The gravitational wave also becomes weaker. LIGO uses a laser shot split down two 4km tubes, in order to see if that 4 km length varies by as much as a thousandth the diameter of a proton. When the two identical detectors located in Louisiana and Washington state pick up the same motions, then we might have seen a gravitational wave. This is what happened on Sept. 14, 2015. Then the collaboration started evaluating the results to see if it really **was** gravitational wave signals. The verdict: it was a signal – from two colliding black holes!

My job at LIGO in Livingston, LA is to relay this information and to get people excited to discover science! This is the same goal I had when I was the Exhibits Director for Catawba Science Center from 1997 – 2009. What we must all realize is that science is very much alive and thriving. Science isn't just about the facts of a discovery – it's about the methods of exploring the universe, inquiring about how things work. The major discoveries haven't all been made! Surprises await us – there's still room for major discoveries and progress. It takes a lot of people who are curious about the universe to work on these problems. Over 1000 scientists, engineers and specialists work on LIGO – and many more worked on it years ago, paving the way to this detection. Yet now the work begins anew – How can we use gravitational waves to make sense of the universe and understand its mysteries? The universe will speak to us, but we have to have the right type of detectors to hear it, and the patience to understand it.

-William Katzman

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