NEW look at the universe

Is it a light wave? Is it a radio wave? No! It's a gravitational wave! Now, what's that, you wonder. Let's take a peek into our universe.

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IN LOUISIANA: Aerial view of the Laser Interferometer Gravitational-wave Observatory (LIGO). *Photo: Reuters*

Space is BIG — unimaginably, indescribably, impossibly big. And filled with strange and massive objects that we don't fully understand. We also have limited means to experiment in space to deepen our understanding. But we do know a bit of physics to construct ideas about what might exist and how the universe might work.

Einstein's General Theory of Relativity is one such idea. All of its predictions that can be put to test have been proved, but there are some that have eluded testing because we have lacked the required technology. The theory isn't completely proved, but has some neat mathematics and physics that can explain much of the phenomena we observe in the universe. Among other things, the theory implies that space (and also time) is like a stretched rubber sheet. Something like a trampoline.

Balls, pins and needles

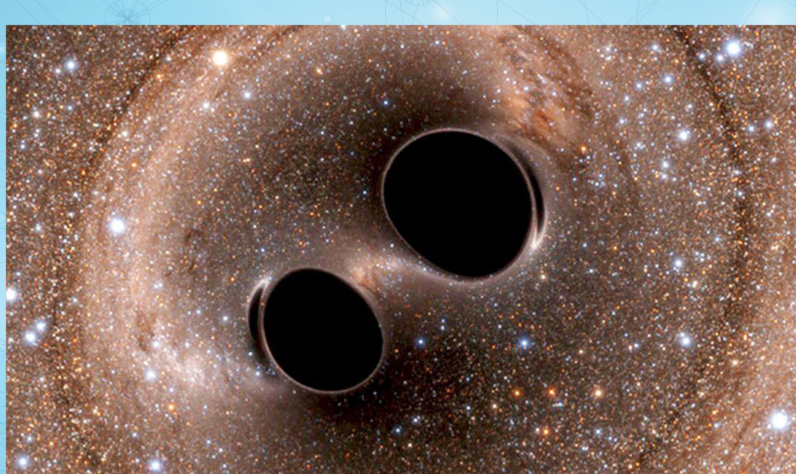
What happens when you drop an iron ball on a trampoline? It curves. Smaller objects around this ball are drawn towards it, and that in a nutshell, is gravity. If you were to walk straight along a curved surface (such as the rim of a bowl) you would actually be tracing a circle or ellipse, and that, in a nutshell, is an orbit.

What happens when another ball is dropped on a different part of the trampoline? It causes ripples to go all around.

What happens when a pin is dropped on that trampoline? That would also cause ripples, but so small that no one would notice.

No one drops balls and pins in space, but Einstein theorised that massive stars and black holes in space behave like the iron balls on a trampoline. Planets and asteroids are like pins. When the massive objects explode or collide with each other, they cause ripples. Small collisions such as asteroids hitting a planet would also cause ripples, but they would be really small.

Einstein was particularly interested in black holes and neutron stars because from what we know today, they are the most massive objects in the universe. Neutron stars are supernovae that burn out all their energy and collapse within themselves, retaining their density in a hugely reduced size. They are unimaginably dense. So dense that if you could scoop out one teaspoon from a neutron star, it would weigh about 10 million tons! Collisions of objects this massive would cause ripples that would reach the farthest corners of the galaxy. And we would have a good chance of detecting these ripples — or gravitational waves.



COLLISION COURSE: Computer generated image of two black holes marked for collision. *Photo: Reuters*

Detecting waves

Keeping this in mind, scientists designed an apparatus that would catch a ripple from such collisions in space. The tricky part of building this was in making it sensitive enough to catch a ripple from billions of light years away, while at the same time making it deaf to ordinary everyday rumbles of traffic. Just to be doubly sure, they built two of these detectors — one in Louisiana and the other in Washington State — and analysed only those graphs that both machines recorded identically.

The apparatus, called LIGO (Laser Interferometer Gravitational-Wave Observatory), looks like a giant L, with each of its arms 2.6 miles long. A laser beam is split and shot through each arm. At the end of each arm is a mirror, so the beams bounce off the mirrors and recombine at the starting point where a detector analyses the beams to detect any gravitation waves.

Imagine an L shape on a bedsheet on which you created a ripple. One arm of the L would get stretched by the wave, and the perpendicular arm would get squeezed. The lasers are designed to detect exactly that kind of wave, except it would be originating from the depths of space, and that the squeezing and stretching would be of dimensions less than an atom.

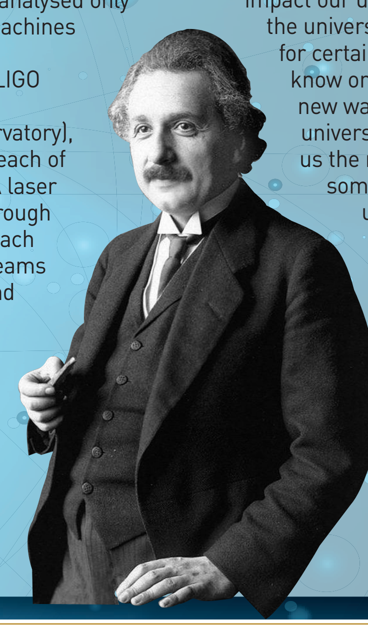
Over in the LIGO, when the two laser beams recombine, the detector checks if their waves are in sync. On ordinary days, they would be. But when a gravitational wave occurs, because one arm of the L is stretched and the other squeezed, the two beams would be out of sync.

And that was exactly what happened on February 12, 2016, when the LIGO recorded a "chirp".

But how did scientists know what exactly the chirp represented? How did they know that the gravitational wave that gave the chirp was a result of two colliding black holes and not something else, such as a supernova exploding?

They used Einstein's mathematics. In order to come up with a viable theory, you need to back it up with some solid mathematics. Scientists built up simulation models using this math to predict the type of graph that the LIGO detector would produce for the different events that are theorised to happen in space. As it turned out, the chirp corresponded to the event of massive objects circling each other and finally colliding to release massive energy causing a ripple. In fact, we also know the amount of energy released by the event, thanks to the famous equation $E=mc^2$.

When Galileo first pointed his telescope towards the sky, he had nothing but visible light waves to help him understand the mysteries of the cosmos. With time, scientists were able to use other kinds of waves as well — radio waves, x-rays, gamma rays, infrared, ultraviolet (all electromagnetic waves), and now gravitational waves. How does this impact our understanding of the universe? We don't know for certain yet, but we do know one thing — it is a new way of looking at the universe, which will give us the means to discover something new! Our understanding of the universe is about to change.



GENIUS: Einstein's theories have helped unravel the mysteries of the universe. *Photo: Wikimedia Commons*