WHAT ARE GRAVITATIONAL WAVES?

Trampolines are fun and educational.

If you understand how a trampoline works, you'll be able to understand gravitational waves.

On Monday (October 16, 2017), LIGO and Virgo announced the first detection of gravitational waves produced by colliding neutron stars. But what are gravitational waves? Here is an explanation by **Gren Ireson**, Nottingham Trent University:

To best understand the phenomenon, let's go back in time a few hundred years. In 1687 when **Isaac Newton** published his *Philosophiæ Naturalis Principia Mathematica*, he thought of the gravitational force as an attractive force between two masses – be it the Earth and the Moon or an apple falling from a tree. However the nature of how this force was transmitted was less well understood at the time. Indeed the law of gravitation itself was not tested until British scientist **Henry Cavendish** did so in 1798, while measuring the density of the Earth.

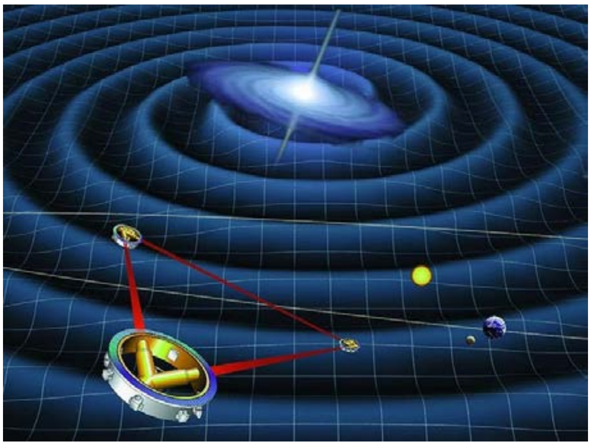
Fast forward to 1916, when **Albert Einstein** presented physicists with a new way of thinking about space, time and gravity. Building on work published in 1905, the theory of general relativity tied together that what we up to then considered to be separate entities – space and time – into what is now called "space-time".

Space-time can be considered to be the fabric of the universe. That means everything that moves through it distorts this fabric. The larger the mass, the larger the distortion. And every object in space is somehow affected by the distortions caused by objects with big mass.

One way of thinking about this is to consider a child standing on a trampoline. If we treat the surface of the trampoline as the fabric of space-time then the child standing on it distorts it and a ball placed anywhere on the trampoline it will roll towards the feet of the child. If we accept this simple analogy, then we have the basics of gravity.

Moving on to gravitational waves is a small, but very important, step. **The distortions a moving object causes in space-time fabric causes waves or ripples in that fabric, travelling away at the speed of light.** Unfortunately, detecting these ripples is not easy and only the most violent events produce distortions big enough to be detected on Earth. To put this into perspective, two colliding black holes each with a mass of ten times that of our Sun a million light years away, would result in a wave that here on Earth would cause a distortion of less than the diameter of an atom.

Earth-based LIGO (Laser Interferometer Gravitational Observatory) have managed to catch gravitational waves using laser interferometry. This technique works by splitting a laser beam in two perpendicular directions and sending each down a 1km long vacuum tunnel. The two paths are then reflected back by mirrors to the point they started at, where a detector is placed. If the waves are disturbed by gravitational waves on their way, the recombined beams would be different from the original.



LISA, a planned space-based laser interferometer, could study astrophysical sources of gravitational waves

But Earth-based systems have limited sensitivity because they have to deal with lots of interference. However, a space-based interferometers (LISA) planned for the next decade will use laser arms spanning up to a million kilometres in a (we hope) noise-free environment.

What can gravitational waves be used for? One major reason is that it would allow gravitational-wave astronomy. By studying gravitational waves from the processes that emitted them, like merging black holes (or Neutron Stars) we could see intimate details of the event not visible any other way.

Now that we know that they exist, the hope is that gravitational waves could open up the door to answering some of the biggest mysteries in science. **Do we really need Dark Matter and Dark Energy for the Universe to make sense?**

AK, with EarthSky Notes