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GRAVITATIONAL WAVES

Has The Experimental Data Confirmed The Theory?

Katie Healey | A2 Physics | August 2016

On the 11th of February 2016, the LIGO project announced it had finally observed gravitational waves. But do we have enough data to confirm the theory yet?

Gravity waves are ripples in space-time that were predicted by Einstein's theory of general relativity in 1916 [2]. They are caused by 2 very large objects, that have a much larger mass than our sun, orbiting each other and eventually colliding in space such as black holes or neutron stars.

$$P = \frac{dE}{dt} = -\frac{32}{5}\frac{G^4}{c^5}\frac{(m_1 m_2)^2(m_1 + m_2)}{r^5}$$

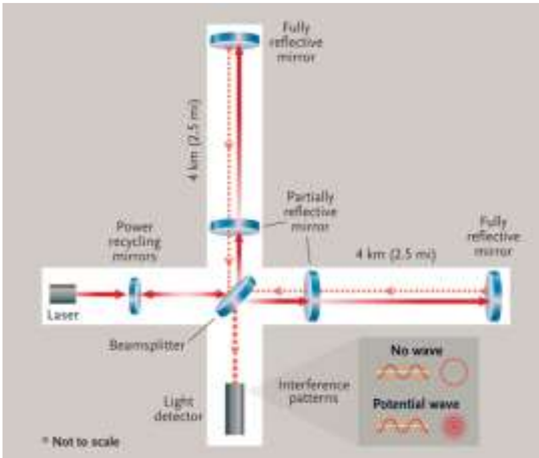
The equation for the power of the wave caused by 2 objects with masses of m_1 and m_2 orbiting each other at a distance of r. G is the gravitational constant and c is the speed of light. The equation is negative as energy will leave the system as a gravitational wave [3]

This causes the fabric of space-time to warp. When they eventually collide the warp becomes a wave that travels at the speed of light across the galaxy. This is caused by events that are billions of light years away so by the time they reach the earth they are only strong enough to 'ring' space in an atom.

There are 4 types of gravity waves: Continuous, Compact binary inspiral, Stochastic and Burst gravitational waves. Continuous waves are caused by a single object that constantly spins in space. This produces waves that always have the same amplitude and frequency. Compact binary inspiral gravity waves are can be caused by a binary neutron star, a binary black hole or a Neutron star – black hole binary. They all generate gravity waves in the same way. The more waves they emit the less orbital energy the system has hence the distance between them decreases. As the distance between them decreases they orbit around each other faster, therefore they will emit stronger gravity waves. Eventually, they coalesce which results in them releasing an extremely strong gravitational wave. These types of waves have a very small period, therefore a very high frequency. Stochastic gravitational waves are random waves that come from every direction. They are thought to of originated from the big bang. Stochastic are the smallest type of wave and are also the hardest to detect.

Burst gravitational waves are waves that might be detected in a system. Usually from systems where the physics of it is limited. [4]

This means that to detect them you will need very sensitive equipment like LIGO which is currently the only way we can detect them. The original idea for LIGO came from Rainer Weiss when he was a professor at MIT. The basic concept is that you position two mirrors in space so they are parallel to an observer. Next



you then continuously the distance between them using light, as it always travels at a constant speed in a vacuum – hence you can always work out the distance. As a gravity wave reaches the earth

the LIGO [5]

space-time will warp causing the distance between the mirrors to change. This means that if the amount of time it takes for the light to leave the observer, hit the 2 mirrors and return to earth changes then it must have travelled a different distance – so the observer must have observed a gravity wave.

[6]. The current version of LIGO is much more sensitive but the basic idea is the same. The beams must be perpendicular to each other as the wave will stretch space-time in one direction and reduce it in the perpendicular direction [7]. There are currently 2 detectors one in Louisiana and the other in Washington state. Both are extremely large.

Gravity waves were first detected on the 14th of September 2015. The wave was detected by both detectors. The wave was from binary black hole around 1.3 billion light years away [8]. There was a second detection on the 26th December 2015 and again it was detected by both detectors and caused by a binary black hole. It was estimated that the black holes are around 1.4 billion light years away. The second detection was more useful as it showed that the initial black holes where spinning which was the first time this could be confirmed [9].

Even though we have observed gravity waves does this confirm the theory? Well with two observations already and a planned upgrade to increase its sensitivity it looks very promising as it will soon be able to collect more data and observe other types of waves. Due to the fact only compact binary inspiral waves have been observed, we have no evidence to prove that the 3 other types of gravity waves exist. Also, as both of them were produced by a binary black hole there is no evidence to say that there has been a collision of 2 neutron stars or a collision of a black hole and a neutron star.

The detector itself is very reliable. Some tests on the detector have concluded that any disturbance such as radio waves would have also been detected on some of the environmental sensors. During the first observation, none of the environmental sensors recorded any disturbances at any point of the observation. It was also concluded that any environmental disturbances would be so weak would on increase/ decrease the amplitude by no more than 6% [10] therefore it is certain that gravity waves have been observed.

References

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