Open Schools Journal for Open Science

Τόμ. 7, Αρ. 2 (2024)

Open Schools Journal for Open Science - Special Issue -IDEA Conference Proceedings

Gravitational Waves

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doi: [10.12681/osj.39505](https://doi.org/10.12681/osj.39505)

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Abstract:

This is a presentation on gravitational waves. Specifically, how they are created, how they "behave", how we detect and study them and why we study them. Gravitational waves are ripples in spacetime caused by some of the most violent and energetic processes in the universe. Predicted by Albert Einstein in 1916 as part of his general theory of relativity. They were detected for the first time in 2015 by LIGO (Laser Interferometer Gravitational-Wave Observatory).

1. Introduction/ Creation of Gravitational Waves

They are technically created by any accelerating object but only objects with a lot of mass can create noticeable gravitational waves, events such as merging black holes , neutron star collisions or supernovae. These events cause ripples in the fabric of spacetime, these ripples are what we call gravitational waves. These waves travel outward from the source at the speed of light.

2.Behaviour of gravitational waves

Gravitational waves are transverse, they distort spacetime perpendicular to their direction of propagation. They have very long wavelengths and low frequencies compared to electromagnetic waves. Their main difference from electromagnetic waves is that they are created and travel inside the sheet of spacetime itself. The intensity of the waves decreases with distance from the source but are not affected by any celestial bodies. Gravitational waves periodically stretch and squeeze time and space.

3.Detection of gravitational waves

To detect gravitational waves we use interferometers. Interferometers function as follows: first, we have a source of light, a laser pass through a beam splitter, this way two identical waves of light are created, perpendicular to each other, these two waves pass through identical tunnels and meet mirrors at the end.

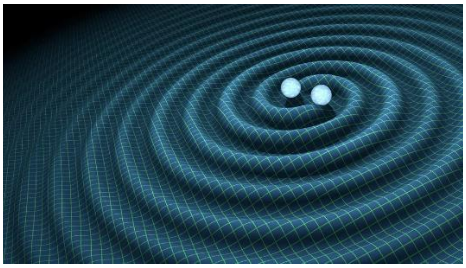
Afterwards, they travel back through the tunnels and meet back at the beam splitter, where they merge back together. The result of the merge is sent to a light detector. Since the interferometer is completely isolated from any electromagnetic wave we would expect the waves to merge together with destructive interference and therefore to be no light at the light detector. But that does not happen. As the waves pass through the tunnels, gravitational waves pass through the earth and the tunnels start to stretch and squeeze, therefore the tunnels are no longer identical and the waves merge with constructive interference. Furthermore, by measuring the intensity of light at the light detector we can measure the intensity of the gravitational wave that passed through the earth.

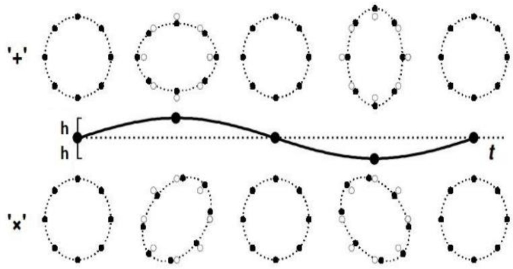
4. Purpose of studying gravitational waves

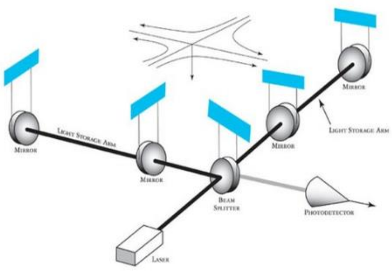
Gravitational waves allow us to study bodies of high mass and how they interact with each other. Should there be any mistakes in Einstein's general theory of relativity we would notice it in the interaction between bodies of high mass, therefore studying gravitational waves allows us to test the limits of Einstein's theory. Furthermore, gravitational waves help us understand the rate of expansion of the universe and the behaviour of dark matter and dark energy.

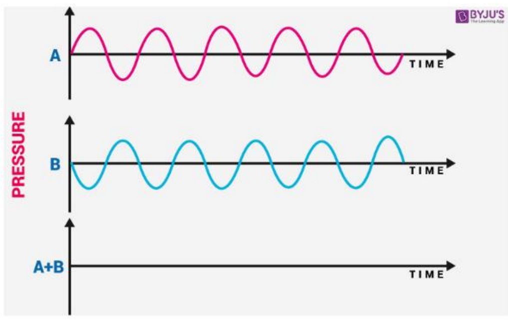
Overall, it provides a new way to observe the cosmos with fewer limitations than electromagnetic observations, by studying them we probe the nature of extreme gravitational environments. For example, before discovering gravitational waves we systems with two black holes were purely theoretical since we could not observe or study them with electromagnetic observations. Since 2015 we have not only proven their existence, but we have a large catalogue of observations and a very large understanding of them.

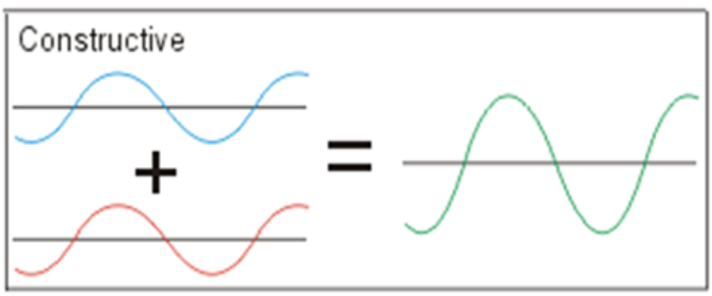
5. Images

i. 

ii. 

iii. 

iv. 

v. 

6. Bibliography:

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B.P. Abbot , et al. “Observation of gravitational waves from a binary black hole merger” Physical Review Letters , vol. 116 , no.6

LIGO Scientific collaboration “What are gravitational waves?”

NASA “Gravitational Waves: Ripples in the fabric of space-time“

National Science Foundation “LIGO Detects Gravitational Waves”