

# About the nature of gravitational and gravity waves

## Abstract

Though the word gravity waves may sound somewhat similar to gravitational waves, there is a lot of difference between the two. First of all it is their nature. This article attempts to give a better understanding of those differences.

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## Introduction

The terms of gravity waves and gravitational waves are two commonly confused terms in physics. Gravity waves are generated in fluid mediums or on interfaces between two fluid mediums. On the other hand, gravitational waves are produced by cosmological phenomena in the universe. This is the main difference between gravity waves and gravitational waves. The detection of gravity waves is not hard task in Earth environment. On the other hand, scientists had to wait for more than hundred years to detect gravitational waves.<sup>1</sup> Fluid dynamics is a good tool for studying gravity waves. The theory of General Relativity is a starting point for studying gravitational waves. It isn't hard to conclude that these two terms have totally different physical nature. This paper is a kind of review on the main characteristics of gravity and gravitational waves.

## Gravitational waves

Gravitational waves, which Albert Einstein predicted in 1916,<sup>2</sup> were a riddle until 14 September 2015. Gravitational waves are small deformations of the four dimensional space-time geometry. They propagate with the speed of light and they are generated by catastrophic events in the Universe, in which strong gravitational fields and sudden acceleration (or deceleration) of asymmetric distribution of large masses are involved. In the other words, according to the theory of relativity, any accelerating or decelerating massive object that isn't spherically or cylindrically symmetrical generates detectable gravitational waves. That object could be for example neutron star or black hole binary system. Gravitational waves are also produced by cosmological explosions such as supernova. Gravity is the weakest of the four fundamental forces, it is known for a very long time, but still there is no a good unique gravity force (field) theory.

## Gravitational waves detection

A few different experiments are currently searching for gravitational waves. LIGO (Laser Interferometer Gravitational-Wave Observatory) looks for gravitational waves by tracking how they affect spacetime: As a wave passes by, it stretches space in one direction and shrinks it in a perpendicular direction. LIGO aims to detect these changes using an interferometer (Figure 1). In fact, the project uses two detectors, one located in Washington State and the other in Louisiana, to sense the distortions in space that occur when a gravitational wave passes through Earth. Both detectors are like a giant L, with legs four kilometers long. The laser beam is used in this experiment. It splits at the intersection of the two legs and measure their relative lengths. Half of the laser light is transmitted into one

leg while the other half is reflected into the second leg. Mirrors are suspended as pendula at the end of each leg and near the beam splitter. Laser light bounces back and forth through the legs, reflecting off mirrors, and finally returns to the intersection, where it interferes with light from the other leg. Amazingly precise atomic clocks measure how long it takes to make the journey. As the legs are exactly the same length light takes the same time to cross them. When a gravitational wave is passing through, it changes space in a way that legs will be infinitesimally expand in one and contract in other direction. As a result, perpendicular legs will no longer be the same size. One of the lasers will arrive a fraction of a second later than the other, the two light beams would no longer completely subtract each other, yielding light patterns at the detector output. Encoded in these light patterns is the information about the relative length change between two legs, which in turn tells us about what produced the gravitational waves (Figure 2).

One of the greatest challenges about LIGO was a request for its very high sensitivity. It is smaller than one ten-thousandth the diameter of a proton. Therefore, scientists and engineers had to minimize the impact of earthquakes and even nearby traffic. To help minimize local effects on the detector, LIGO has made many enhancements<sup>3,4</sup> to the basic interferometer design (Advanced LIGO). There are two LIGO detectors located on the opposite sides of the USA separated nearly 2,000 miles. If a gravitational wave is real, its signature will be observed at both locations. If it is false positive (due to noise), only one station will detect it. According to the researchers at LIGO, the gravitational waves they have detected were generated when two black holes merged to create a single giant black hole.

The theory of general relativity predicts that a system of two black holes that are orbiting around each other releases their energy as gravitational waves. So, the system loses its energy causing them to come closer. After billions of years binary black holes system, in a fraction of a second, formed one giant black hole. This tremendous occurrence caused the transformation of mass into energy ( $E = mc^2$ ) and gravitational wave was created.

The LIGO is not the only laser observatory for gravitational waves. There is European Space Agency's (ESA) Laser Interferometer Space Antenna, or LISA.<sup>5</sup> LISA will act like a giant LIGO in space. The lasers aren't the only way to detect changes in spacetime. The North American Nanohertz Observatory for Gravitational Waves (NANOGrav),<sup>6-8</sup> looks for gravitational waves by looking at the burst of radio waves emitted by the neutron stars called pulsars. These radio wave pulses are normally strictly timed, so if they arrive early

or late, it could be because a gravitational wave interfered with their journey to Earth. Programs like Background Imaging of Cosmic Extragalactic Polarization (BICEP),<sup>9</sup> Harvard's series of experiments

at the south pole, observe the leftover radiation in an attempt to find the polarization patterns.

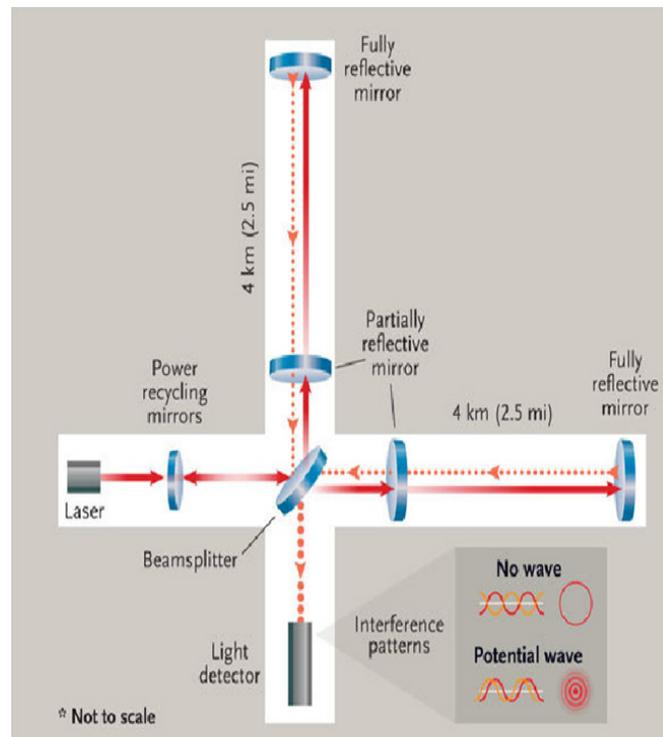


Figure 1 The scheme of LIGO interferometer taken from the website www.skyandtelescope.com.

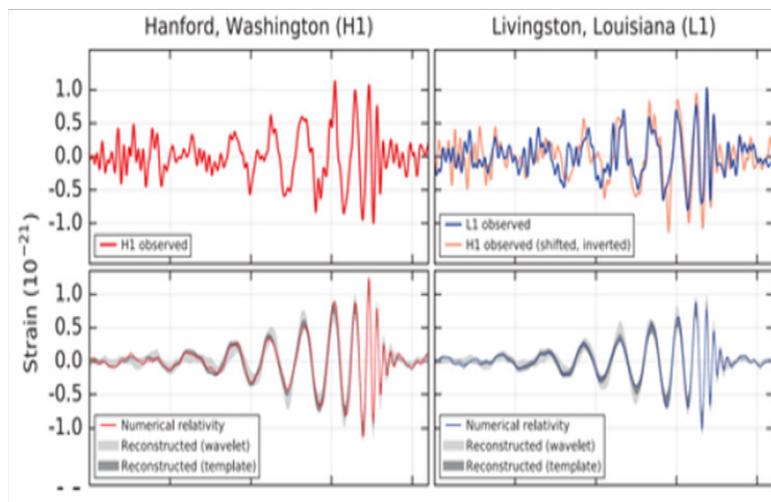


Figure 2 The gravitational-wave event GW150914 observed by the LIGO Hanford (H1, left column panels) and Livingston (L1, right column panels) detectors.<sup>1</sup> Times are shown relative to September 14, 2015 at 09:50:45 UTC.

**The importance of gravitational waves**

Most of the astronomy done in the past has relied on different forms of electromagnetic radiation (visible light, radio waves, x-rays, etc.), but electromagnetic waves are easily reflected and absorbed by any matter that may be between their source and us. Even when light from the universe is obtained, it is often transformed during its journey through the universe.

Gravitational waves will change astronomy because the universe is

nearly transparent to them: intervening matter and gravitational fields neither absorb nor reflect the gravitational waves to any significant degree. Scientists will get a mighty tool for observing astrophysical objects that would have otherwise been obscured. The era of new way of thinking and reading astrophysical data is starting. The detection and explanation of the gravitational waves signature will help to understand the mechanisms of the universe and of our world as a part of it. This is a beginning of the new era of gravitational astronomy.

## Gravity waves

In a fluid dynamics, gravity waves are waves generated in a fluid medium or at the interface between two fluid media when the force of gravity (or buoyancy) tries to restore equilibrium. Namely, gravity waves result when a fluid particle or a cluster of particles moves on an interface of two fluids (between a body of water and air for example). Gravity waves can be formed within a fluid with a different density layers. In this case gravity is restoring force for the fluid particles. It generates particles oscillations around the equilibrium state, known as gravity waves or buoyancy waves. The gravity waves that are generated at interfaces between two different media are called surface gravity waves whereas the gravity waves that are generated within the fluid bodies (such between parts of different densities) are called internal gravity waves. To exist, the fluid must be stratified: the density must change with depth/height due to changes, for example, in temperature. Gravity waves need a medium for propagation as they are mechanical waves. Stratification of the medium imposes a cutoff frequency.<sup>10</sup> For gravity waves it is Brunt–Vaisala frequency above which gravity waves cannot propagate.<sup>11</sup> Understanding how they behave is useful for explaining and predicting weather and climate phenomena. These waves, as a part of the gravito–acoustic waves spectra, are interesting because they are ubiquitous in the terrestrial and solar atmospheres, and certainly must exist in stellar atmosphere as well. Gravity waves transfer energy through matter<sup>12,13</sup> and they can be attenuated significantly by physical barriers.

## Conclusion

We can conclude that gravitational waves and gravity waves have different nature. Gravitational waves are, in their most basic sense, ripples in spacetime. They will help scientists to explore some of the great questions in physics: How do black holes form? Is General Relativity the correct description of gravity? How does matter act under the extremes of temperature and pressure in neutron stars and supernovae? Gravity waves are physical perturbations in the planetary environment. These waves are specific to planetary atmospheres and bodies of fluids.

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## Conflict of interest

Author declares there is no conflict of interest.

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