GRAVITATIONAL WAVES: A NEW ERA OF ASTRONOMY BEGINS

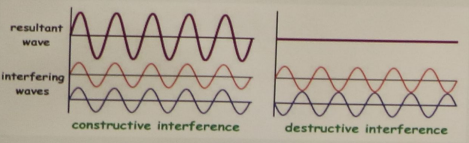
Jose D'Arruda, University of North Carolina Pembroke

WHAT ARE WAVES?

A wave can be described as a disturbance that travels through a medium from one location to another location, transporting energy from one location to another location. For example, the medium could be a rope, where the wave travels along the rope. Or the medium could be water, in which case you would have a water wave. Additionally, the medium could be air, in which case you would have a sound wave.

WAVE INTERFERENCE

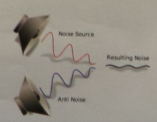
A most important property of waves is called wave interference. This occurs when two waves come together, combine, and interfere with each other. Interference can occur constructively or destructively



INTERFERENCE OF SOUND WAVES

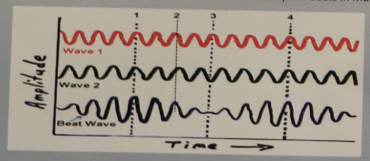
When designing an auditorium for musical performances one takes into account the fact that the wave from the stage will be interfered with from that same wave bouncing off the walls of the auditorium

Noise canceling speakers and headphones work

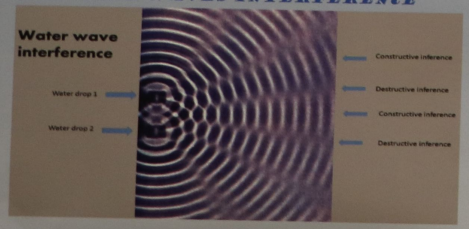


BEATS

Another example of sound wave interference is the concept of beats in music.

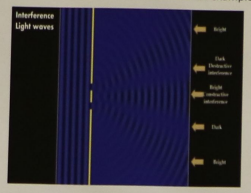


WATER WAVES INTERFERENCE

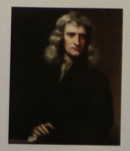


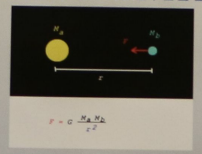
INTERFERENCE OF LIGHT WAVES

In the diagram below we show an example of the interference of light waves.

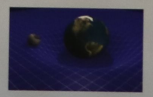


NEWTON'S CONCEPT OF GRAVITY





EINSTEIN'S CONCEPT OF GRAVITY



Einstein's Theory of General Relativity

Earth Moon system in spacetime

The Einstein field equation

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$G_{\mu\nu}$ Einstein Tensor
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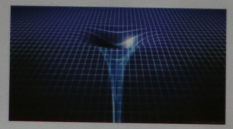
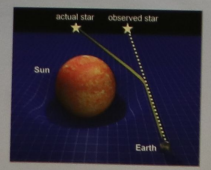
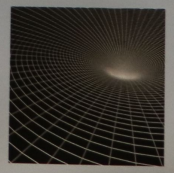


Black Hole bending spacetime





SEEING GRAVITATIONAL WAVES

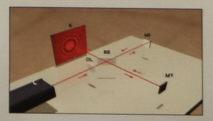
THE APPARATUS TO MEASURE WAVE INTERFERENCE

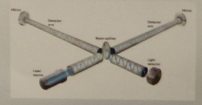
How do we measure wave interference? ---We use an Interferometer--What is an Interferometer?

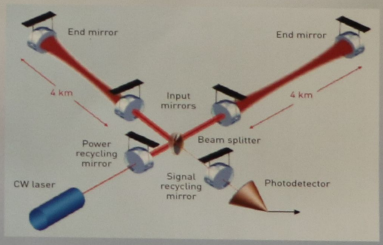
Interferometers are investigative tools used in many fields of science and engineering. They are called interferometers because they work by merging two or more sources of light to create an interference pattern, which can be measured and analyzed; hence "Interfere-ometer".

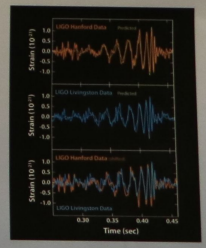
THE MICHELSON INTERFEROMETER

The interferometer is a device invented by Michelson which allows study of the effects of interference. It takes a single beam of light and splits it into two perpendicular paths of variable length. The light then recombines and the interference effects are observed. The interference pattern for a Michelson interferometer is circular-- that is, it produces concentric circles of light and dark "fringes". When one mirror on the interferometer is moved, the path difference between the two split beams of light changes, and we observe an interference pattern. The beauty of this Michaelson interferometer is that this instrument uses the wavelength of light itself as a measuring stick to measure distances as small as the wavelength of light being used. If the difference in travel lengths of the two beams are different by ½ wavelength, they will combine destructively and cancel one another and provide a dark fringe. If the paths are exactly the same, or a difference of 1, 2, 3, ..., wavelength, they will combine constructively and appear as a bright fringe.

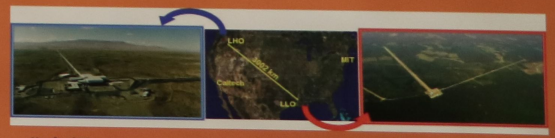








The Laser Interferometer Gravitational-Wave Observatory



Hanford Observatory

Livingston Observatory

LIGO is two Laboratory Sites separated by over 3000 km.

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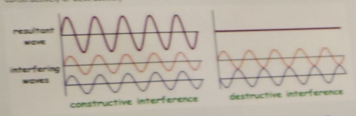

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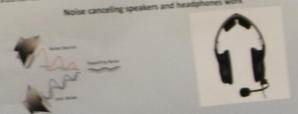

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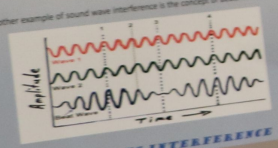

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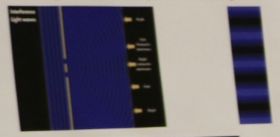

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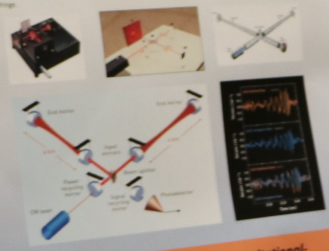

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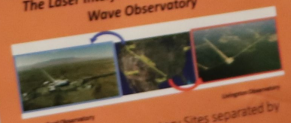

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