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Bringing Nobel Prize Physics in the Classroom

Discovering the Michelson Interferometer

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Background information for teachers

Overview of this lesson pack:

Name of the activity	Gravitational waves and sound
Topics introduced	Waves, wave interference, gravitational waves, constructive and destructive interference
Curriculum Connection	IRELAND: LC Physics students: waves, TY students: a good investigative approach to waves and gravitational waves. PORTUGAL: Gravity (7 th, 9th, 11 th and 12th grades); Waves: Sound and Light (8th, 11 th and 12 th grades) and Measurements (7th, 10 th grades) to 13 until 18 years old students; Citizenship GREECE: connection with sound 15 year old students or after shcool club for 16 -17 year old students
Reference Demonstrator	Discovering and building a Michelson Interferometer http://inspiringscience.rdea.gr/delivery/view/index.html?id=404b1c2b74af43b4960bbb75331921c9&t=p
Age of students	13 - 18
Duration	120-180 minutes

Discovering and building a Michelson interferometer:

This demonstrator introduces the concept of waves, interference, and the wave nature of light, supported by mechanical waves, like sound... Students are introduced to the history of the Michelson interferometer and the Michelson-Morley experiment, a groundbreaking experiment that led to Einstein's theory of special relativity. In an historical overview, they will learn how, more than a hundred years later, the same principle of the instrument was adapted to detect gravitational waves, thus confirming one of the main predictions of Einstein's general relativity.

Students will work with sound waves, a simple interference similar experiment. They will learn about the basic properties of light interference and the working principle of an interferometer. Real images from the sites of the LIGO and Virgo instruments will be used to explain how modern-day interferometers are used to detect gravitational waves.

Students will get involved in the Citizen Science Project Gravity spies, to reinforce the similar behavior of different kind of waves. As a pre-work students will do a worksheet about interference.

Students will present their work to the class and discuss their results.

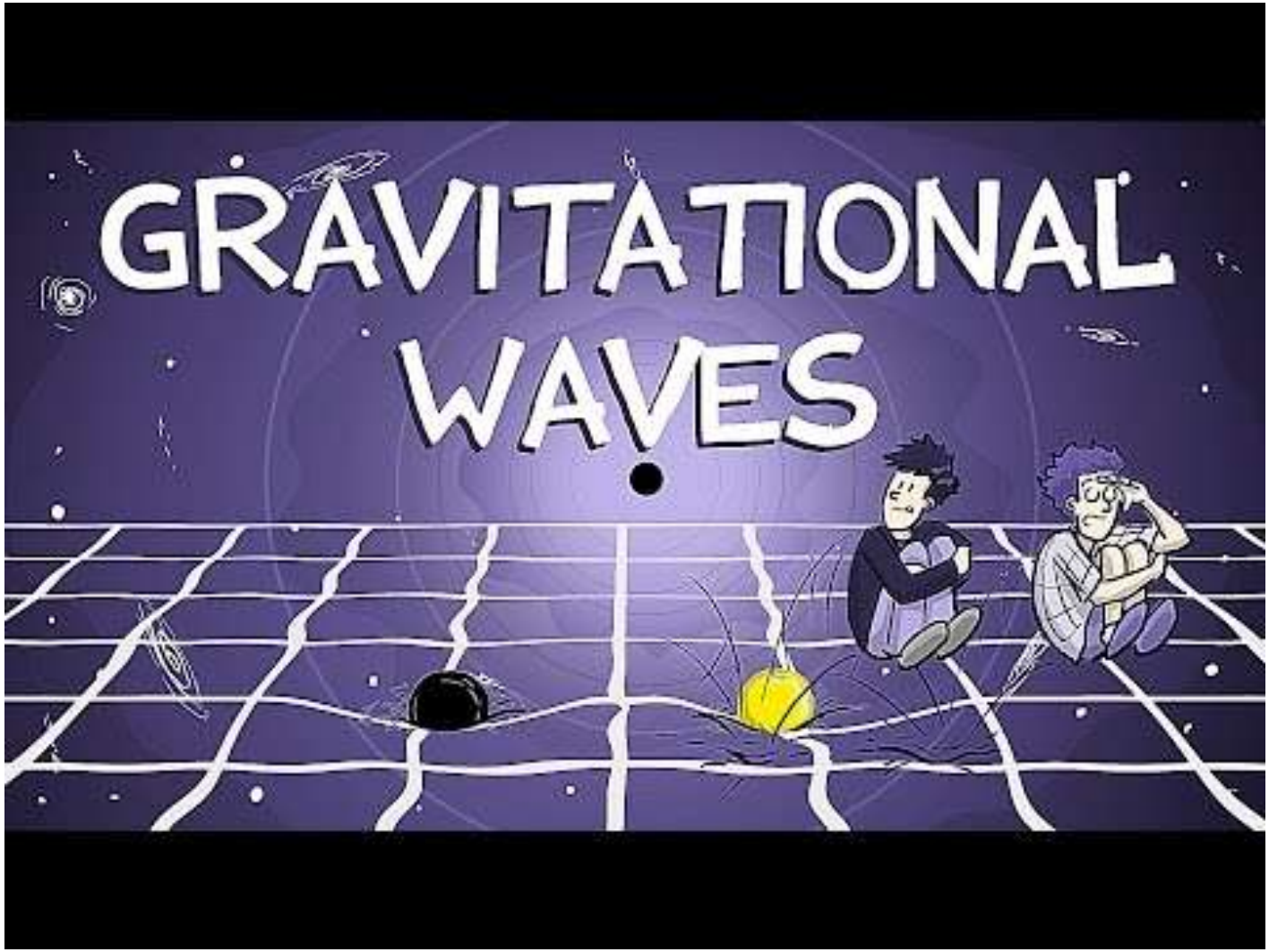
Overview of this lesson pack:

Type of activity	Experimental hands on; gamification, working group activities using computers and mobile phones
Description of activity	Activity 1: Interference card sort Activity 2: INterference of sound waves and modelling interference Activity 3: Building a Michelson Interferometer Activity 4: Citizen Science: Gravity Spy
Equipment requirements	Activity 1: Printed version of the cards to sort Activity 2: Signal generator, two speakers, space to do it in. Optional Google Science Journal app Activity 3: All materials listed in the link on the slide Activity 4: Access to Gravity Spy (either phone, tablet, laptop, etc.)
Prior knowledge for students	

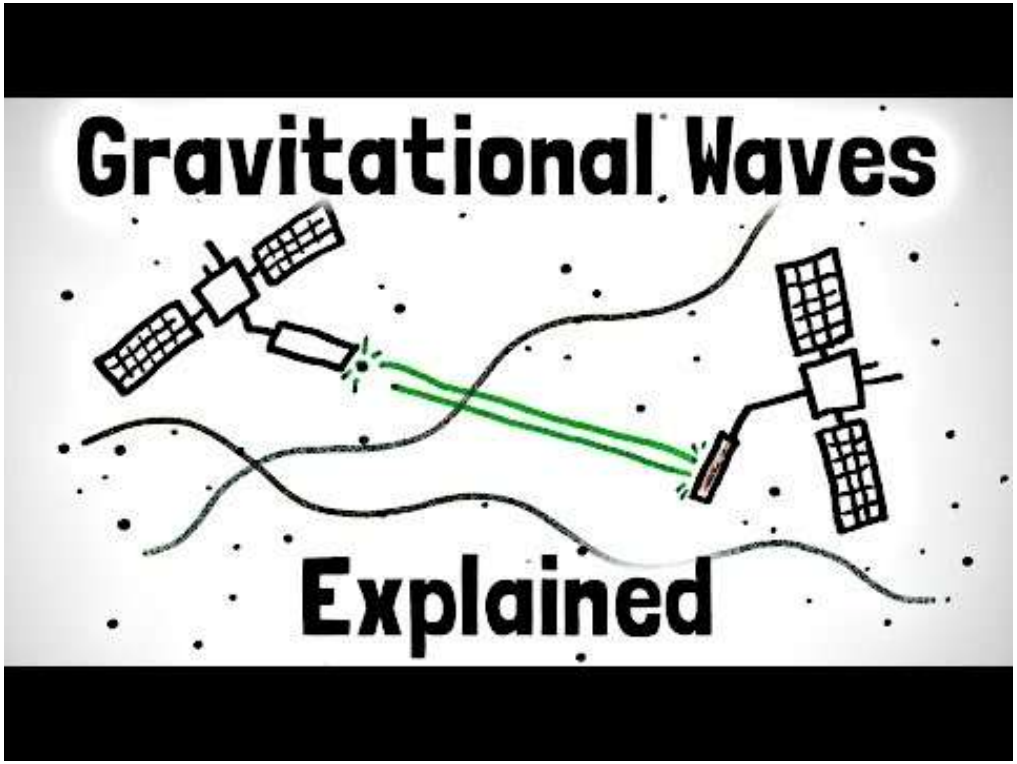
Presentation for students

Teacher guidelines can be found in the notes attached to each slide

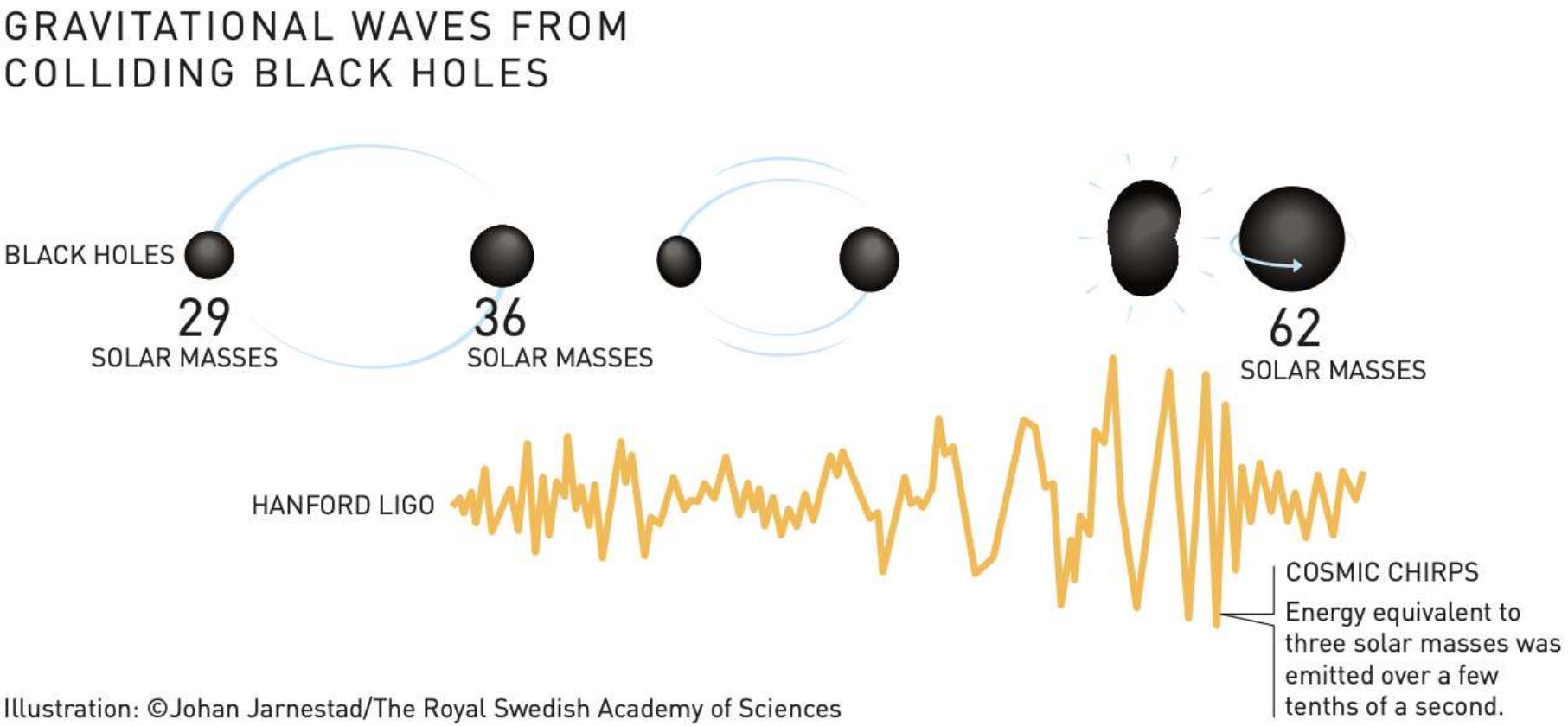
What are gravitational waves?



What are gravitational waves? Minute Physics



Detection of gravitational waves at Ligo in 2015



Albert Abraham Michelson

Photo from the Nobel Foundation archive.

The Nobel Prize in Physics 1907 was awarded to Albert Abraham Michelson "for his optical precision instruments and the spectroscopic and metrological investigations carried out with their aid."

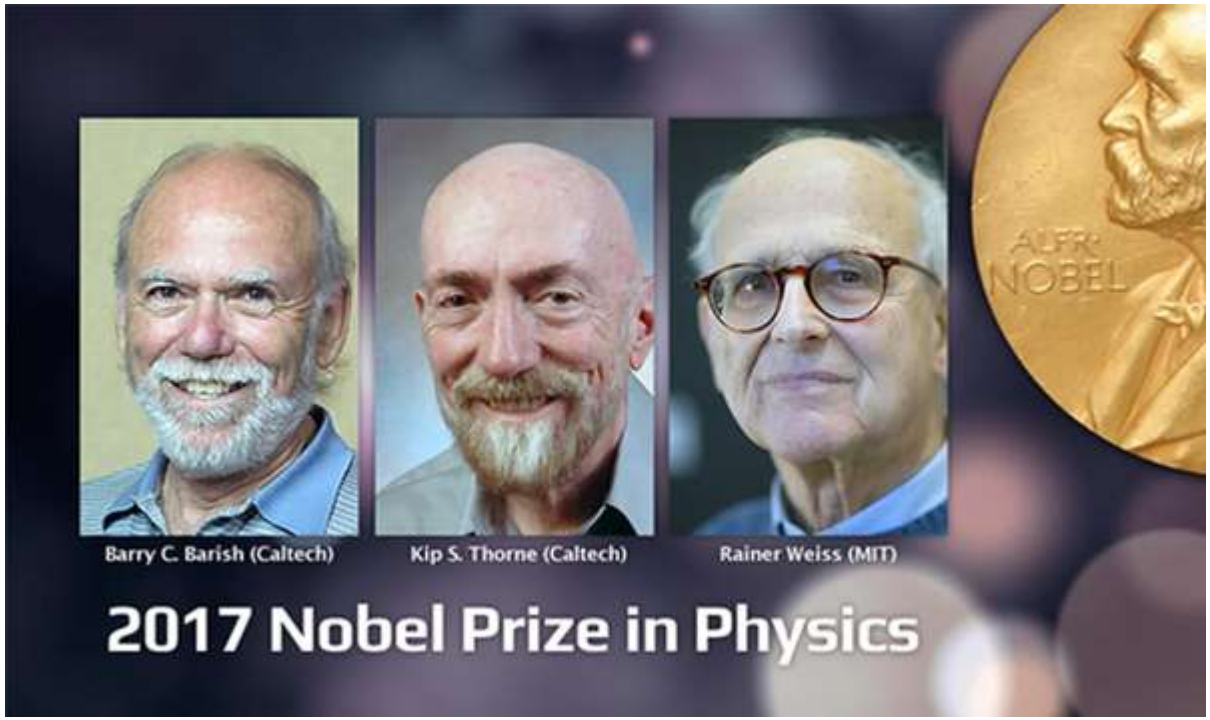
The Nobel Prize in Physics 1907. NobelPrize.org. Nobel Media AB 2020. Wed. 22 Jul 2020. <https://www.nobelprize.org/prizes/physics/1907/summary/>

Russell A. Hulse e Joseph H. Taylor Jr.

Photo from the Nobel Foundation site

The Nobel Prize in Physics 1993 was awarded to Russell Hulse and Joseph Taylor Jr. "for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation."

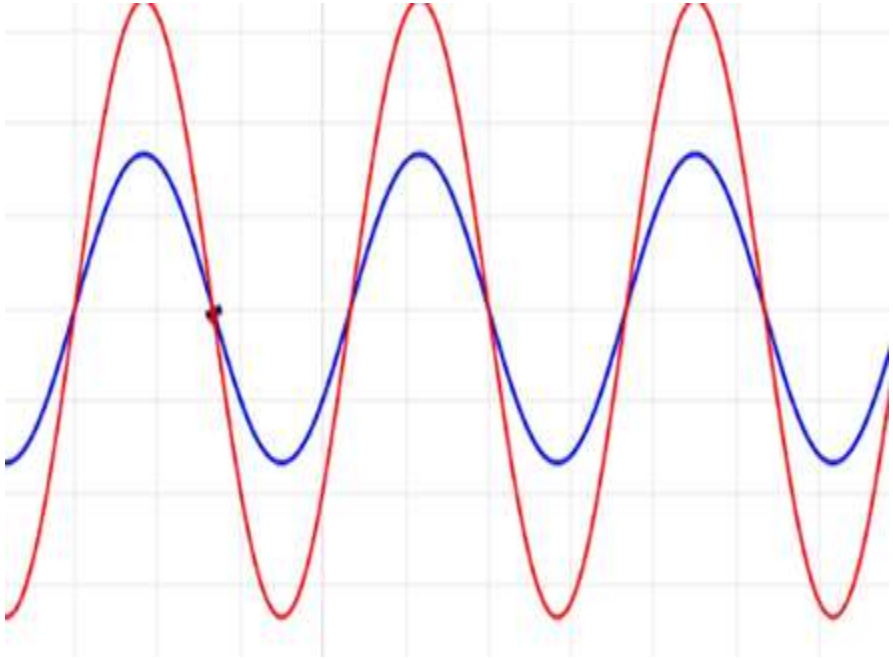
The Michelson interferometer connects 130 years of science history and two Nobel prizes.



Barish, Thorne and Weiss, Nobel prize 2017, for the detection of gravitational waves (Credit: nobelprize.org)

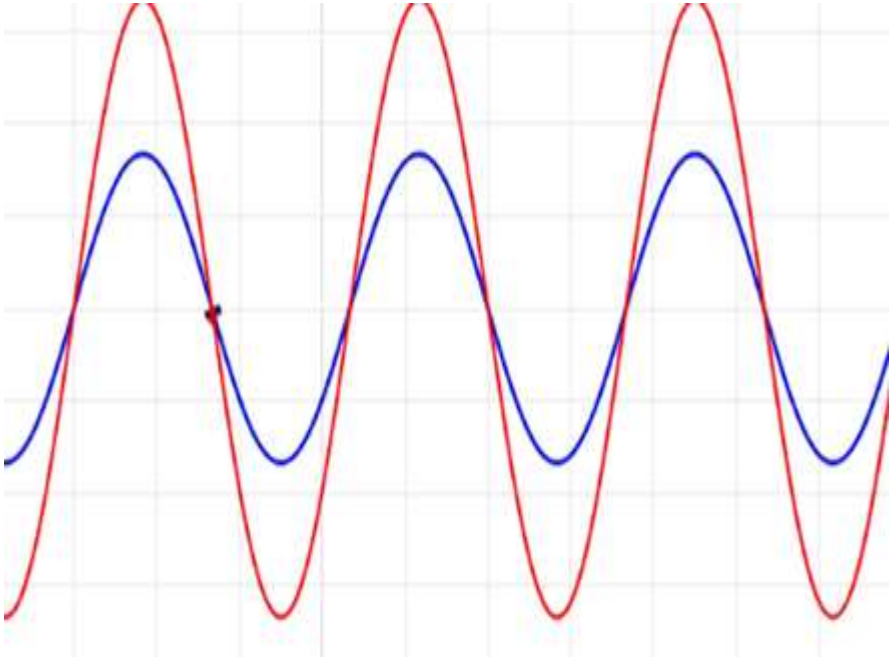
The principle of superposition of waves

When two or more waves of the **same type** exist in the **same place**, the resultant wave will be found by **adding the displacements** of each individual wave.



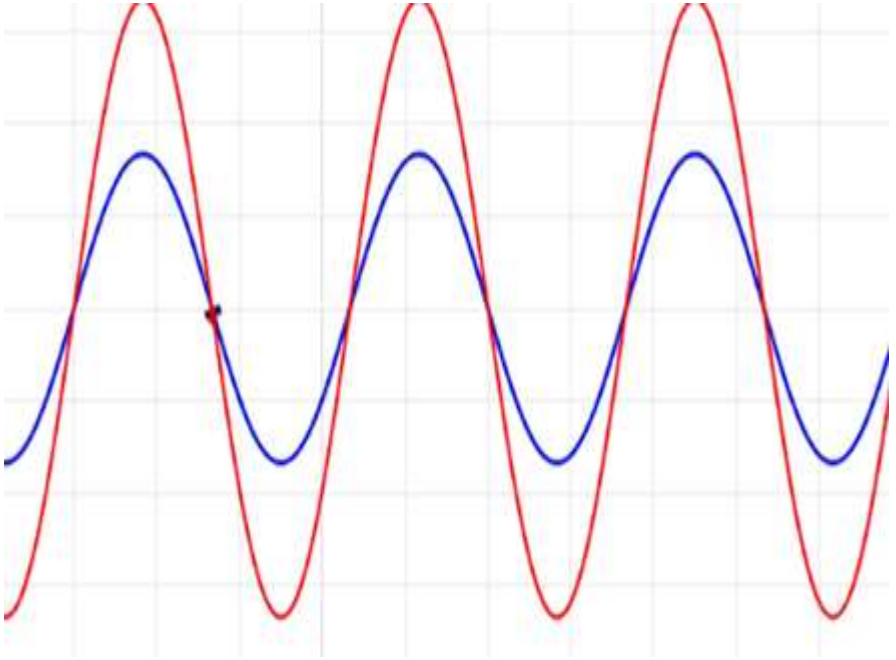
Constructive Interference

If the two waves of the same type with the same amplitude are **in phase** the amplitude of the resulting wave will be twice that of the original wave.

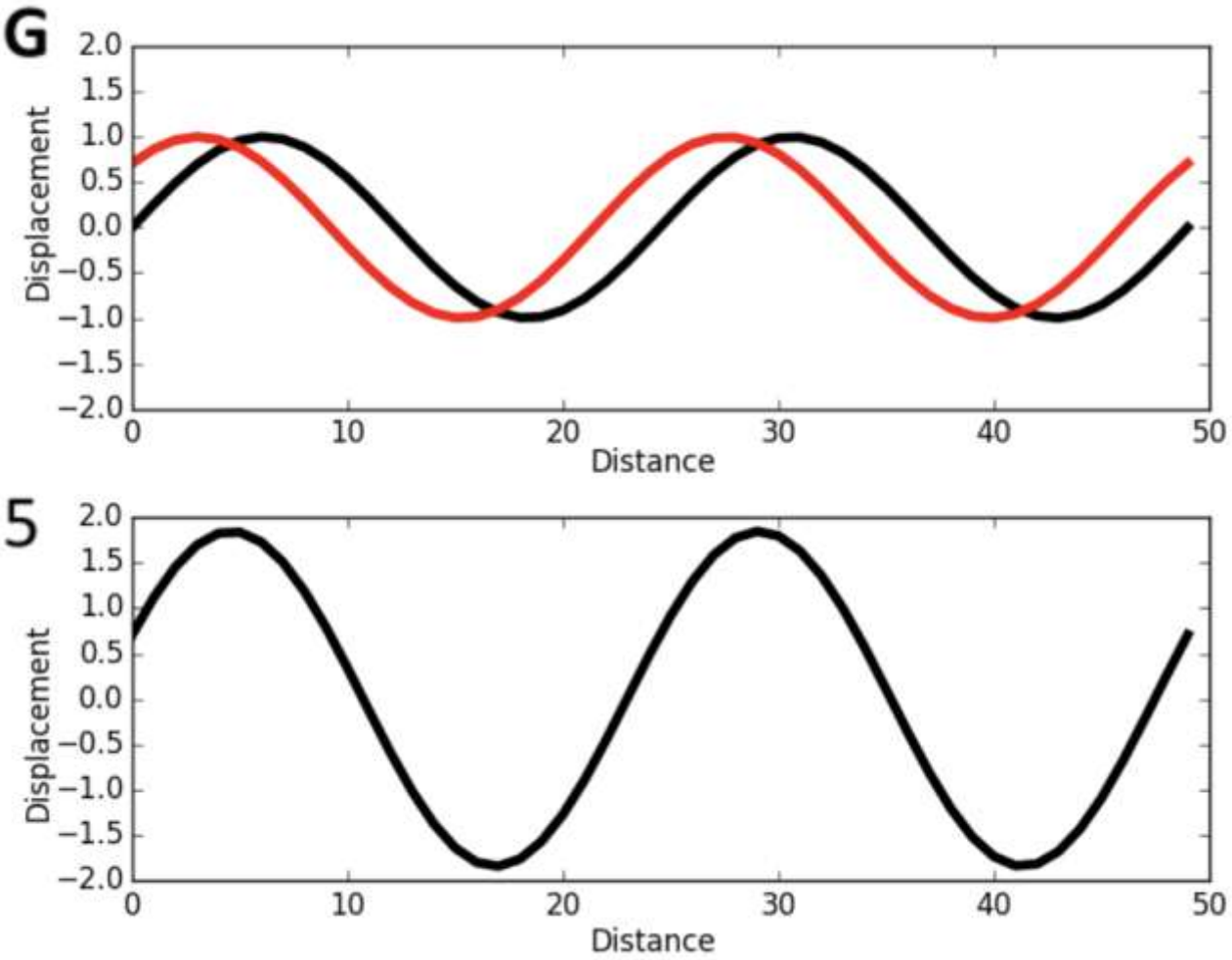


Destructive Interference

If the two waves of the same type with the same amplitude are **in antiphase** the amplitude of the resulting wave will be zero



Interference card sort



Interference with sound waves

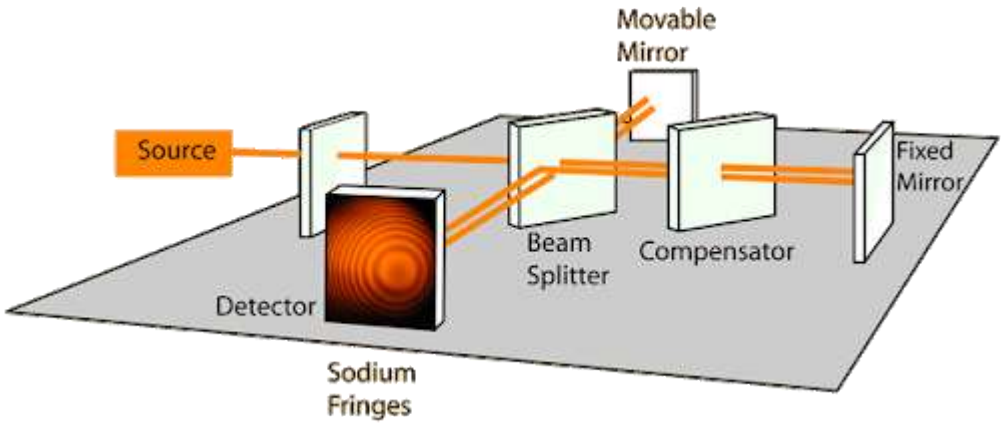
Questions:

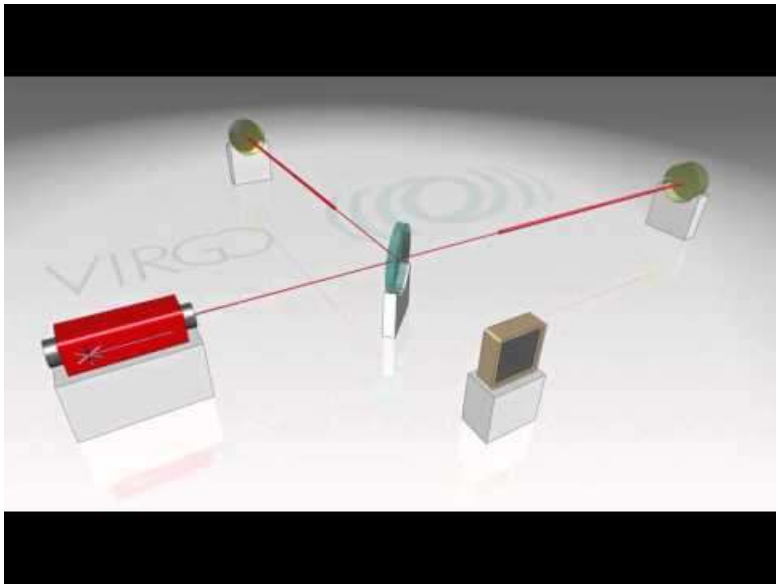
1. What do you hear as you walk in front of the speakers?

1. What is causing this?

1. How could we change what you are hearing?

What is a Michelson interferometer?

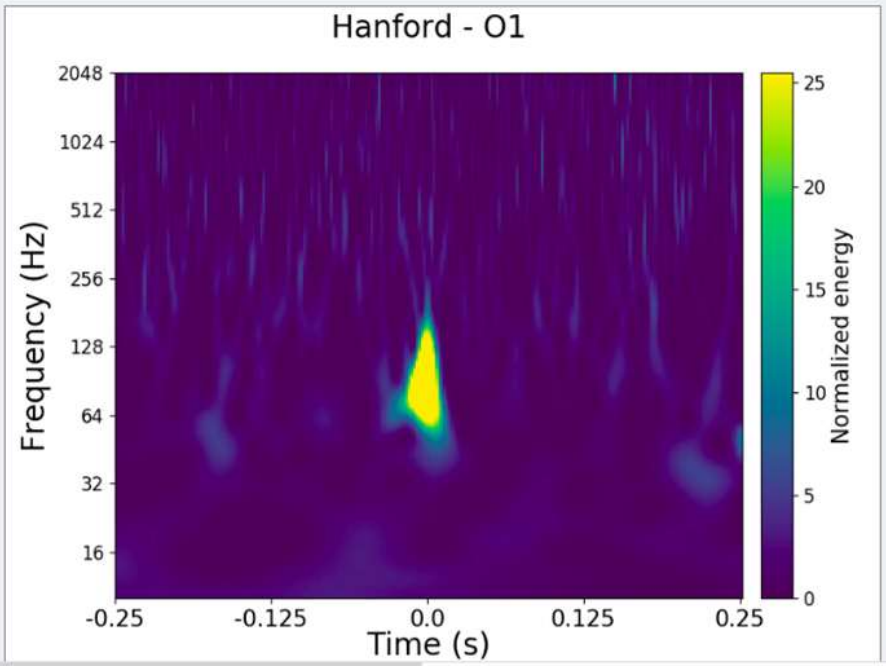


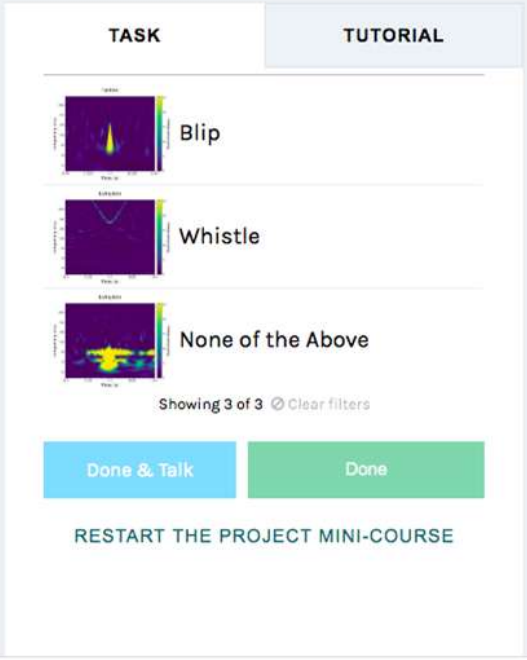


http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/michel.html

Building an interferometer

Citizen Science Project: Gravity Spy





https://www.zooniverse.org/projects/zooniverse/gravity-spy/classify

THE SOUNDS OF GRAVITATIONAL WAVES

Follow these links and it will be almost as if you're listening to the rippling fabric of spacetime itself!

- audio files for all GWTC-1 detections – Listen to audio versions of all 11 confident detections (10 binary black holes and 1 binary neutron star) from the LIGO-Virgo catalog GWTC-1 (spanning the first two observation runs). Available at gw-openscience.org.
- MIT Gravitational Wave Sounds – Listen to the gravitational radiation from binary black holes and a variety of other sources, with the frequency information from numerical simulations turned into audio files. (by Scott Hughes, MIT)
- MSU Sounds of Spacetime – This site contains a detailed exploration of gravitational-wave "sounds." (by Marc Favata and collaborators, Montclair State University)

There is now approximately one gravitational wave discovered each week!