

GRAVITATIONAL WAVES TEACHER'S GUIDE

1. Use the two columns labeled "I Notice" where you record observations from the video and "I Wonder" where you record additional questions that you have been pondering or that the video brought up.

| I Notice | I Wonder |
|-------------------------|-------------------------|
| Observations will vary. | Observations will vary. |

2. If spacetime is being stretched and compressed around us, wouldn't we notice?

We exist in spacetime, and so we are being stretched and compressed along with what we are trying to measure. Our ruler will stretch and compress by the same amount that the object being measured will be altered by the gravitational wave.

In addition to this the stretch and compression from these gravitational waves is very small since their amplitude decreases the further that they are away from their source.

3. How can distortion in spacetime be measured when the measuring tape itself would be stretched as well.

Light travels the same speed (3×10^8 m/s) in every reference frame, and so if the time it takes light to travel back and forth changes, this means that the spacetime itself must be being stretched or compressed. An interferometer splits a beam of light into two perpendicular paths before recombining the light to see if the light has shifted phase, which can be used to measure how much spacetime has been stretched or compressed. There is additional information about how interferometers work at the end of this document.

4. If spacetime is really there, we should see gravitational waves (ripples in spacetime) when objects accelerate. Do we see gravitational waves?

The size of the ripple in spacetime from an object like a car accelerating has never been measured. It takes a huge event, like huge neutron stars or black holes orbiting one another and combining. Scientists predicted the pattern that should be created by these events, and the LIGO detector did detect its first gravitational wave on September 14, 2015. It is very important that this detection was made by a detector in Louisiana and Washington, which is evidence of a pattern created by a passing gravitational wave and not a local event like an earthquake or car driving by shaking the detector.

Additional teacher resources for video discussion, and more explanation of an interferometer:

1. Good Video to show during discussion if you want to clarify how an interferometer works since it shows how the split beam could be in or out of phase when it is recombined if the distance of one of the paths is changed. [Link](#)

The video shows the actual LIGO interferometer with a good demonstration of its components and how they work.

2. Shows how manually adjusting the length of one arm of the interferometer changes the interference pattern. [Link](#)

This video shows how changing the length of one of the two arms on an interferometer causes the interference of recombining the split laser beam to change. The length of the two paths goes from constructive interference when the difference in the lengths of the path is a whole number multiple of the wavelength of the laser light to destructive interference when the difference in the length of the path is a half integer multiple of the wavelength. The demonstration is done by turning a screw that changes the length of one of the paths by micrometers, but in the LIGO experiment the two perpendicular paths are identical length until a gravitational wave causes the compression in one dimension and stretching in the other dimension which changes the interference pattern.

3. Additional video that could be shown to students if bringing up the discussion on an additional day. [Link](#)

This video shows the signature signal recorded showing evidence of the creation of a gravitational wave created as two black holes closely orbited each other before coming together. It also emphasizes that all accelerating objects create gravitational waves, but that it takes a very, very massive event to produce waves that are big enough to be measured above the background noise of other vibrations that shake the detector.