KINEMATICS

Units 4 & 5 Dr. John P. Cise, Professor of Physics, Austin Com. College, 1212 Rio Grande St., Austin Tx. 78701 jpcise@austincc.edu & NYTimes Feb. 14, 2016 by Lawrence M. Krauss

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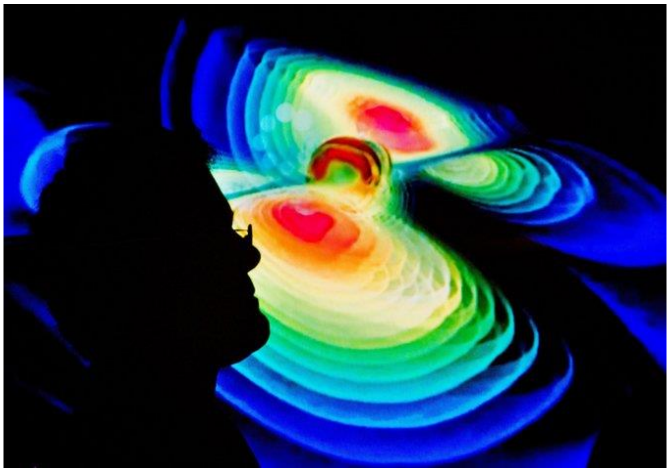
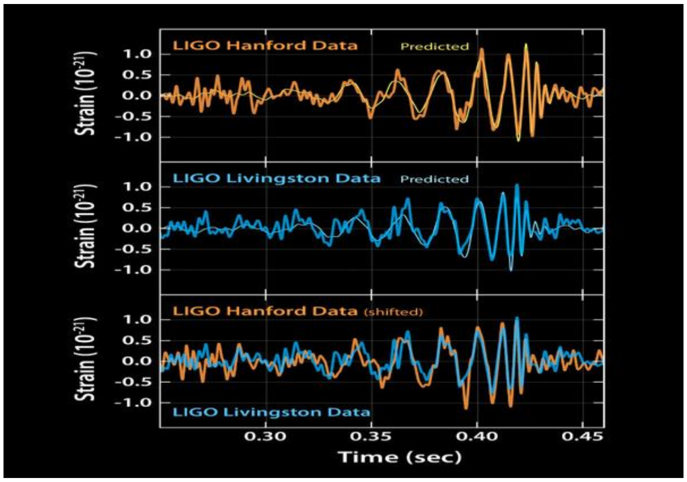
Finding Beauty in the Darkness





The silhouette of a scientist against a visualization of gravitational waves on Feb. 11, 2016. Above is seen the tunnel length change ~ 10^{-21} m.

One hundred years ago, Albert Einstein used his newly discovered general theory of relativity (which implies that space itself responds to the presence of **matter by curving, expanding or contracting**) to demonstrate that each time we wave our hands around or move any matter, disturbances in the fabric of space propagate out at the speed of light, as waves travel outward when a rock is thrown into a lake. **As these gravitational waves traverse space they will literally cause distances between objects alternately to decrease and increase in an oscillatory manner.** The oscillations in space caused by gravitational **waves are so small that those ripples in length had never been seen.** Yet on Thursday, the Laser Interferometer Gravitational-Wave Observatory, or LIGO, announced that a signal from **gravitational waves had been discovered emanating from the collision and merger of two massive black holes over a billion light-years away**. How far away is that? Well, **(((one light-year is about 5.88 trillion miles))).** To see these waves, the experimenters built two mammoth detectors, one in Washington State, the other in Louisiana, each consisting of two tunnels about 2.5 miles in length at right angles to each other. By shooting a laser beam down the length of each tunnel and timing how long it took for each to be reflected off a mirror at the far end, the **experimenters could precisely measure the tunnels' length.** **If a gravitational wave from a distant galaxy traverses the detectors at both locations roughly simultaneously, then at each location, the length of one arm would get smaller, while the length of the other arm would get longer, alternating back and forth.** To detect **the signal they observed they had to be able to measure a periodic difference in the length between the two tunnels by a distance of less than one ten-thousandth the size of a single proton.** **[** ***It is equivalent to measuring the distance between the earth and the nearest star with an accuracy of the width of a human hair.] last sentance***

INTRODUCTION: **A proton radius R is 0.8768 X 10^{-15} m. The diameter(size) would be twice R. Nearest star to earth is Alpha Centauri at 5.3 light years. A human hair is about 10^{-4} m in size (diameter). HINT: 1609 m/ mile**

QUESTIONS: **(a) Find diameter (size) of proton? (b) The ΔL of the tunnel they wanted to detect (with the passing gravitational wave) was one 10,000th proton size. Find this ΔL? (c) Find distance to nearest star in meters?**
(d) Verify the accuracy needed mentioned in last sentence at end of article above? HINT:Hair size/star distance = A

ANSWERS: **(a) ~ 1.75 X 10^{-15} m , (b) ~ 1.75 X 10^{-19} m. , (c) ~ 5 X 10^{16} m. (d) A = [10^{-4}/5 X 10^{16}] = 2 X 10^{-21}** **COMMENT: Notice in actual experimental graphic (upper right) the chirp of gravitational waves measured changed length of tunnel ~ 10^{-21} m. Amazing!**