

# A wee bit on gravitational waves

# You live in amazing times!

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667

## Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.*\*

(LIGO Scientific Collaboration and Virgo Collaboration)  
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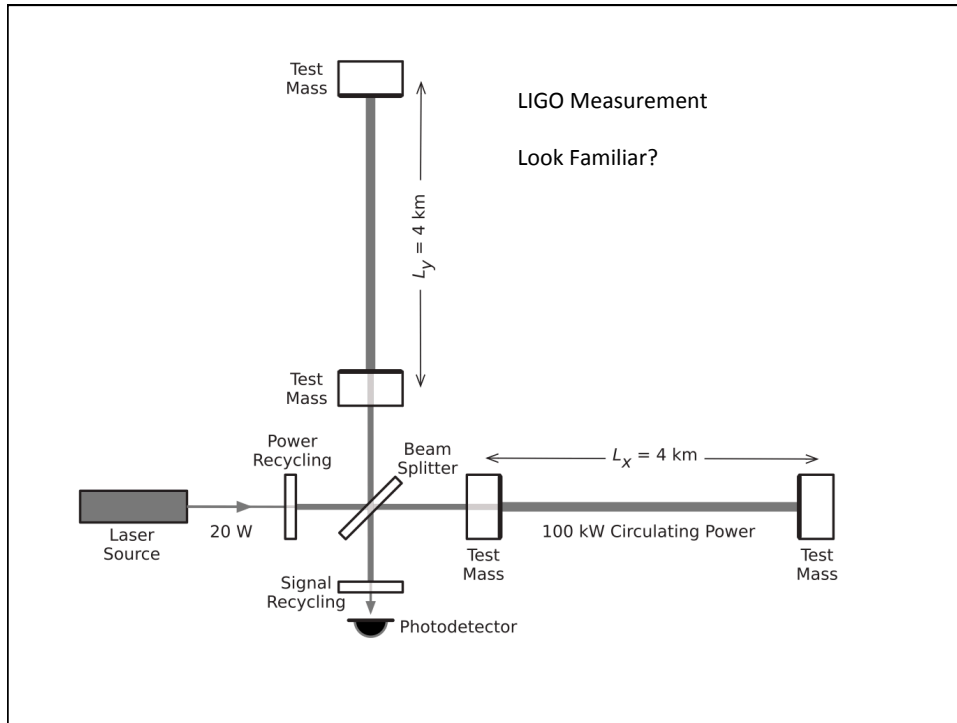
On September 14, 2015 at 09:50:45 UTC the two detectors of the Laser Interferometer Gravitational-Wave Observatory simultaneously observed a transient gravitational-wave signal. The signal sweeps upwards in frequency from 35 to 250 Hz with a peak gravitational-wave strain of  $1.0 \times 10^{-21}$ . It matches the waveform predicted by general relativity for the inspiral and merger of a pair of black holes and the ringdown of the resulting single black hole. The signal was observed with a matched-filter signal-to-noise ratio of 24 and a false alarm rate estimated to be less than 1 event per 203 000 years, equivalent to a significance greater than  $5.1\sigma$ . The source lies at a luminosity distance of  $410^{+160}_{-180}$  Mpc corresponding to a redshift  $z = 0.09^{+0.03}_{-0.04}$ . In the source frame, the initial black hole masses are  $36^{+4}_{-4} M_{\odot}$  and  $29^{+4}_{-4} M_{\odot}$ , and the final black hole mass is  $62^{+4}_{-4} M_{\odot}$ , with  $3.0^{+0.5}_{-0.5} M_{\odot} c^2$  radiated in gravitational waves. All uncertainties define 90% credible intervals. These observations demonstrate the existence of binary stellar-mass black hole systems. This is the first direct detection of gravitational waves and the first observation of a binary black hole merger.

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### INTRODUCTION

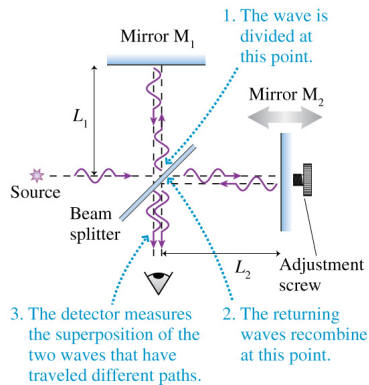
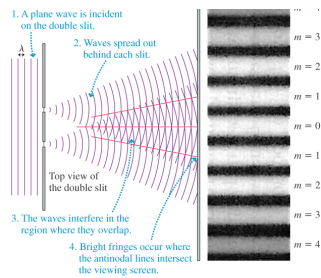
In 1916, the year after the final formulation of the field equations of general relativity, Albert Einstein predicted the existence of gravitational waves. He found that the linearized weak-field equations had wave solutions: transverse waves of spatial strain that travel at the speed of

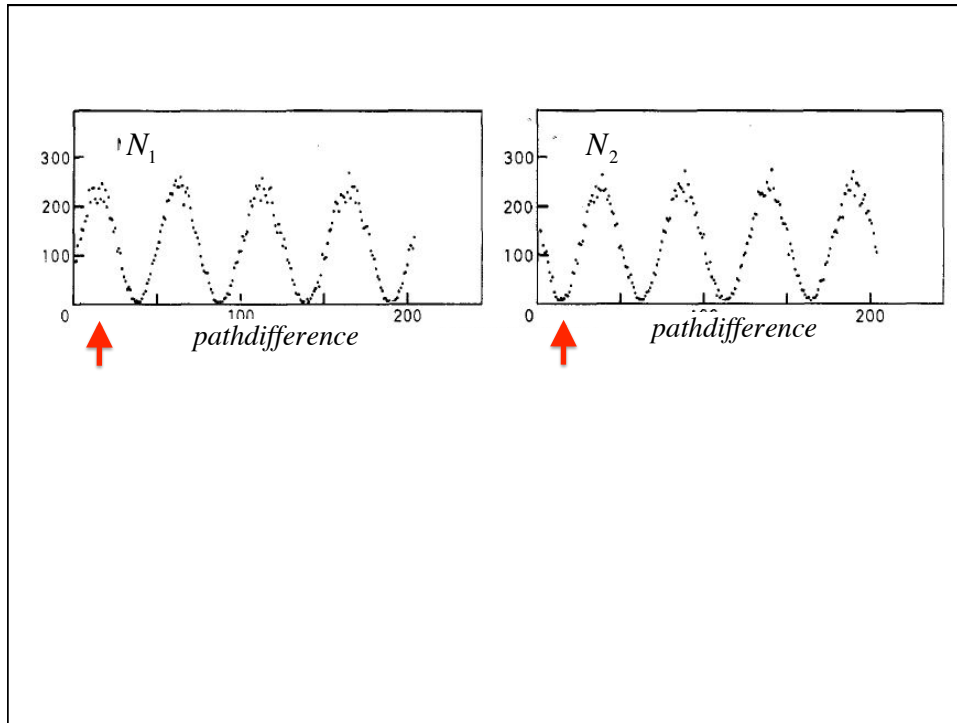
The discovery of the binary pulsar system PSR B1913+16 by Hulse and Taylor [20] and subsequent observations of its energy loss by Taylor and Weisberg [21] demonstrated the existence of gravitational waves. This discovery, along with emerging astrophysical understanding [22], led to the recognition that direct observations of the



## Same idea for interferometer

Tool for measuring frequencies, speed, index of refraction...

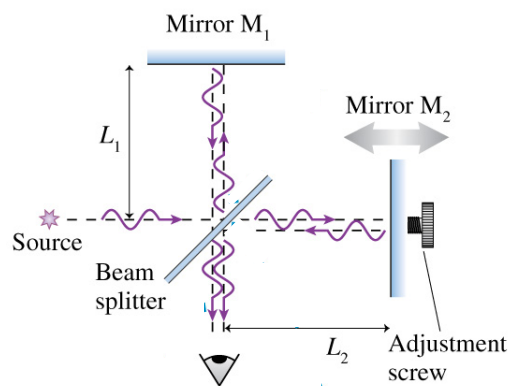


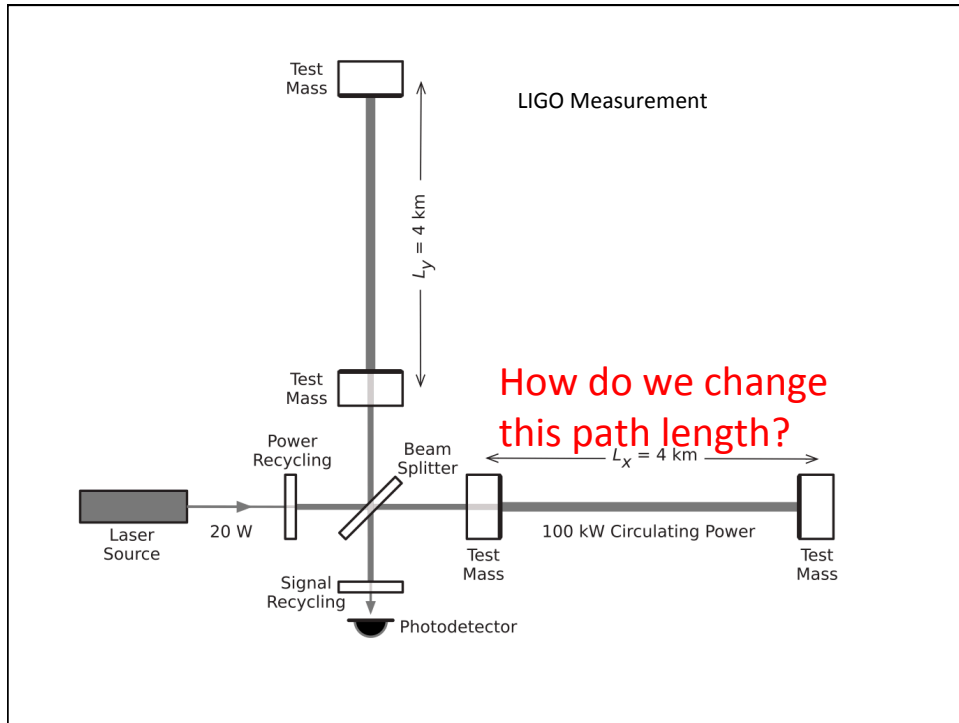


## Michelson interferometer

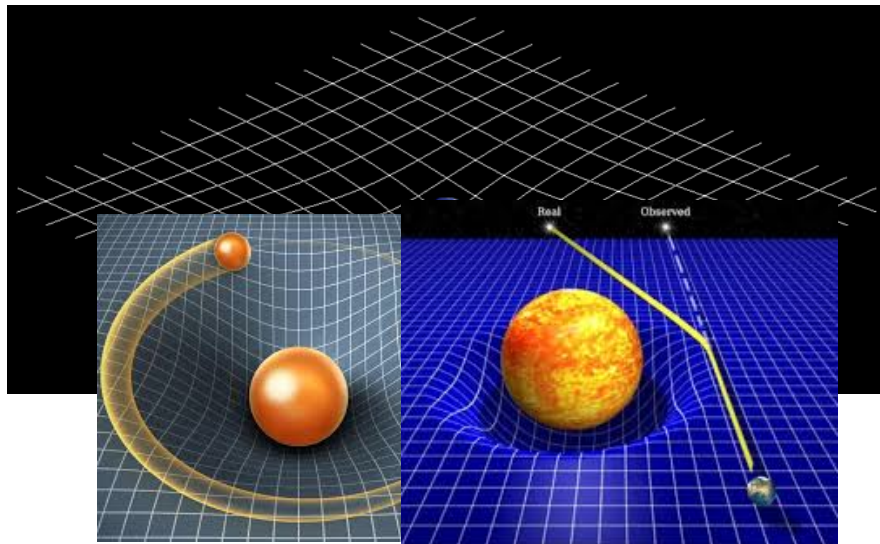
What's the path difference?

- a)  $L_2 - L_1$
- b)  $2L_2 - 2L_1$
- c)  $2L_2 - L_1$
- d) 0





# GRAVITY!



## Gravity changes space

- <https://www.youtube.com/watch?v=MTY1Kje0yLg>

## From Brian Green or Cartoon Physics

- [https://www.youtube.com/watch?v=s06\\_jRK939I](https://www.youtube.com/watch?v=s06_jRK939I)
- <https://www.youtube.com/watch?v=4GbWfNHtHRg>

