Gravitational Waves

What are Gravitational Waves?

Einstein's Theory of Relativity

Space is not flat!

Warped by GRAVITY

Larger Objects

Bigger effect on Space Time

As two large celestial objects orbit and accelerate

Ripples that distort Space Time are created

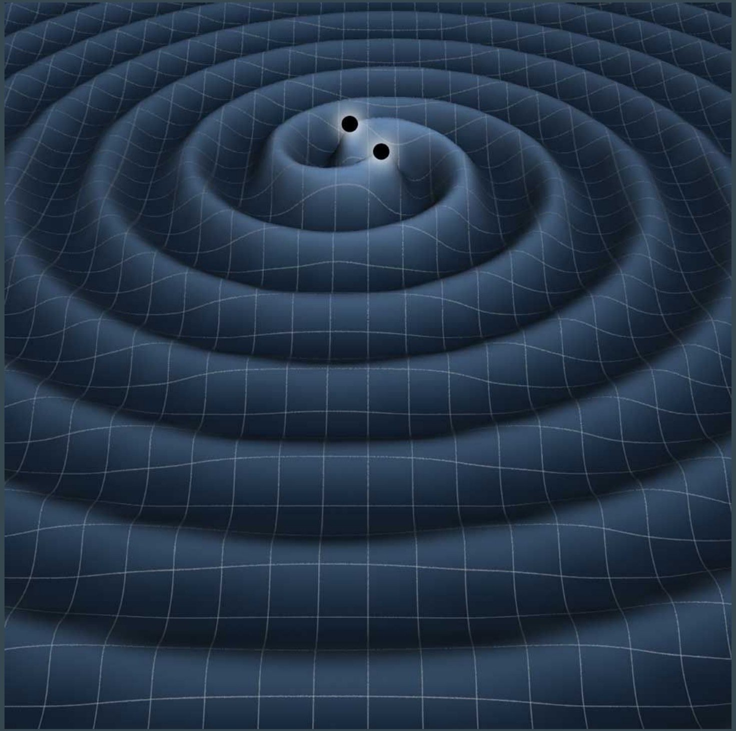
These ripples are known as **Gravitational Waves**

What Produces Gravitational Waves ?

Gravitational Waves originate from the merging events of two celestial objects

Black Holes and White Dwarfs (neutron stars) are common objects which emit gravitational waves

As the two orbiting objects get closer the frequencies of the waves increase and eventually hit a maximum before rippling out into space



How Can we Find Gravitational Waves ?

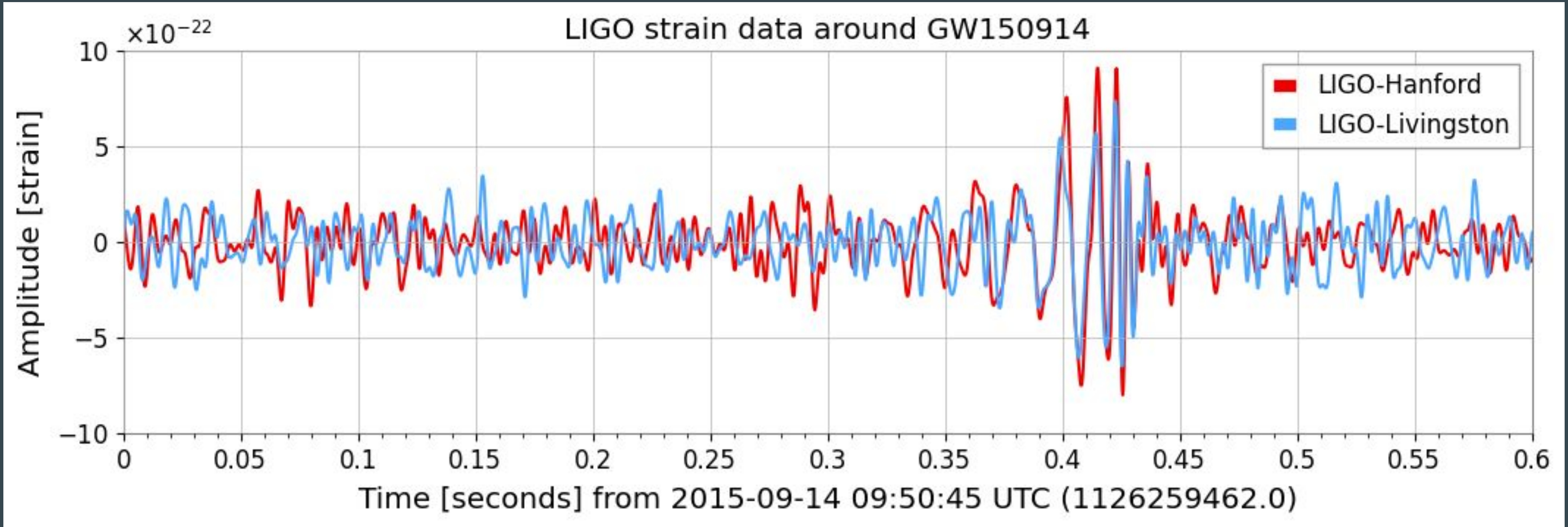
- LIGO is a laser detector built to detect the low frequencies of gravitational waves emitted by merger events
- The lasers are each 4 km long
- There are two LIGO detectors, one in Hanford, Washington and the other in Livingston Louisiana
- The location of the detectors helps researchers gather accurate data and eliminate inaccurate frequencies

GW150914

Using data from the LIGO data base we plotted the frequencies of the gravitational wave event due to a merge of two black holes

Steps Taken:

- Imported the data with the Time Series function
- Filtered the powerline frequency from the data
- Plotted the Hanford data with the Livingston Data
- Visually transformed the data to analyze the signal
- Converted the data into an audio file

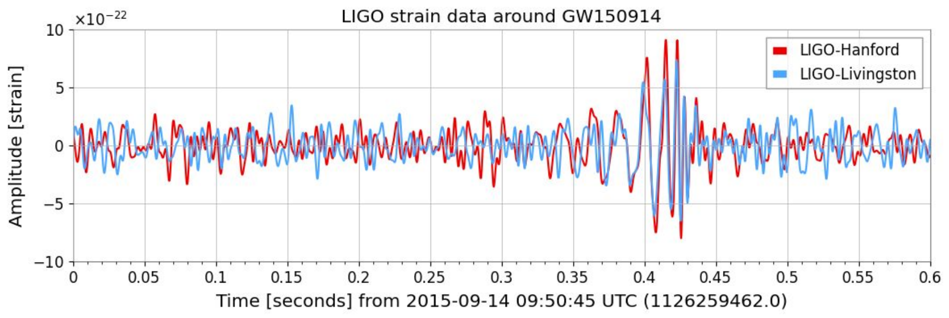

LIGO strain data around GW150914
×10^−22
Amplitude [strain]
Time [seconds] from 2015-09-14 09:50:45 UTC (1126259462.0)
LIGO-Hanford
LIGO-Livingston
10
5
0
−5
−10
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6

Estimation of black holes masses

Orbital Period: Δt = 0.01

Orbital velocity: v= sqrt(GM/a),

Schwarzschild radius: Rsch = 2GM/c^2



$$\delta t = 2\pi a/v = 2\pi \frac{4GM}{c^2}/(c/2) = 16\pi GM/c^3.$$

M_black holes=Δt · c^3/16πG

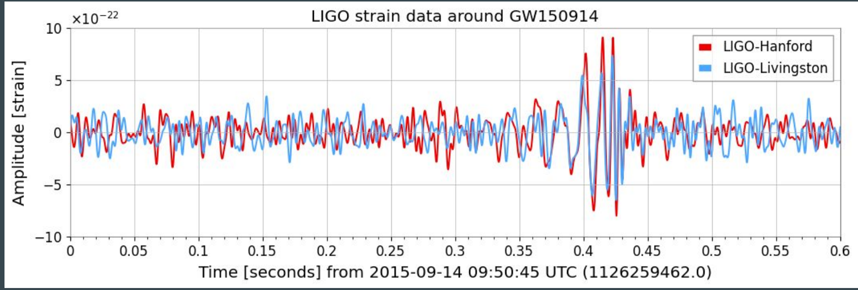
40.3906 Solarmass

Estimation of black holes distance

Schwarzschild radius: Rsch = 2G M_blackholes / c^2

M_black holes=40.3906 Solarmass

Rsch ≈ 59.64km



Gravitational wave strain Amplitude: h ≈ 10^-21

D=Rsch/h ≈ 1932.86 mpc (6.3 billion light-years)

Estimation of Released Energy

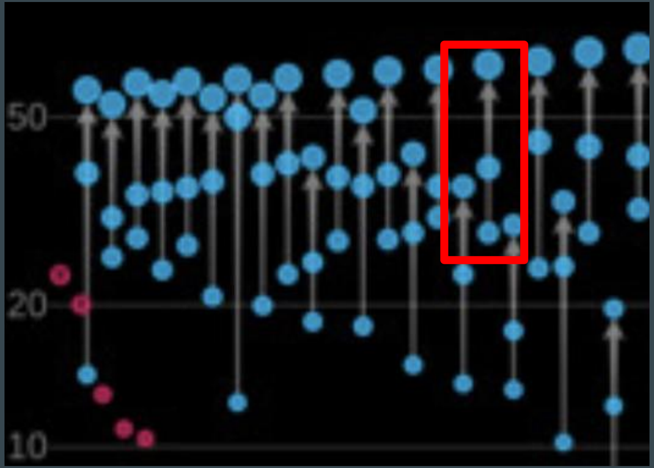
Einstein's mass-energy equivalence: $E = \Delta M \cdot c^2$

Let $\Delta M = 0.1 \cdot M_{blackholes}$

$E = 4.039$ solar mass $\cdot\ c^2 = 7.23 \cdot 10^{47}$ Joules

Results

- The estimated mass of the two black holes came to be 40.39 solar masses
- The estimated distance of the merger events was 1932.86 mpc
- The estimated energy released is 7.23 · 10^47 Joules



LIGO-Virgo / Aaron Geller / Northwestern University.