GW Coding Report

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**Motivation**

Observing a merger between black holes is a task that requires sufficient data and huge interferometers. This allows us to observe gravitational waves from deep in our universe, but if it is that sensitive, then how do we know the difference between a merger and someone slamming their door? There are calculations and data that helps us “filter” out all the noise that could interfere with our observations. Weiss, Barish, and Thorne figured out the problems and helped solve them and make LIGO a reality. We observed the merger called GW200129\_0654581 with a set GPS time (1264316116.4)1. We used LIGO’s data base1 to look at the data labeled “confident” and with a high SNR. The data once it has been filtered and found, we can make a soundbite commonly known as a “chirp.” This chirp audibly lets us observe the speed at which the 2 black holes orbit each other until they merge, and then there is silence meaning no more gravitational waves are being sent out.

**Methodology**

Figuring out what to filter is a difficult process but it means finding sources of noise that we do not want because they are not the gravitational waves. The waves can be hard to see but they have similar “shapes” when we observe them. Taking out frequencies like 60Hz, 120Hz and 180Hz. 60Hz is the main source of noise while the rest are its harmonics. They are not part of the gravitational wave but rather electronics and other signal sources from Earth.

**Results**

A graph with numbers and lines

Description automatically generated

**Figure 1: Graph of data from 16s before and after GPS time**

**of the merger event. As you can see, we are going to ignore the**

**frequencies that are just background noise.**

This data did not require much calculation. However, the observed mass of the two black holes were respectively, 34.5 +9.9-3.2 Solar Masses and 28.9 +3.4-9.3 Solar Masses with a total mass of 63.4 +4.3-3.6 Solar Masses. This tells us that during the merger, some of the mass is turned into energy that is shot out and away from the merger event. Once filtered we can then take our data and put it through another process that will get us even closer to what we are looking for. We can do a filtering process in the code and compare the unfiltered to the filtered to see if we notice a spike separate from the noise.

A graph of a waveform

Description automatically generated with medium confidence

**Figure 2: Unfiltered and Filtered data with a noticeable spike after being filtered.**

This graph now shows us the merger event we observed except the data is clear and has an obvious spike. We can then stretch this graph to get more precise data. We take the GPS time and focus on a point 0.3 seconds before and after.

A graph of a wave

Description automatically generated

**Figure 3: Stretched data from fig. 2.**

Now we can take this data that is stretched and do the same process we have done for Hanford, except now for Livingston. We can observe that they are quite similar and have a spike in roughly the same spot. However, to get it to be similar when need to account for the speed of a gravitational wave. Which is found to be almost the speed of light.

**c = λf**

So, we find that there is a 6.9millisecond difference between the two LIGO stations. We can shift one graph over 6.9ms so that we can see the spike.

A graph of a waveform

Description automatically generated

**Figure 4: Stretched data from LIGO-Hanford and Livingston.**

A purple and green background

Description automatically generated with medium confidence

**Figure 5: The q-transfer of the data.**

You can clearly see the chirp mentioned before. You can see the gradual increase in frequency and its drop off when the merger event has ended.

**Conclusion**

After finishing all the code and looking at all the graphs, my conclusion is that this proves the existence of gravitational waves as well as Einstein’s theory of E=Mc2. This means we can detect when black holes merge as well as neutron stars. This could lead to new theories or answers to how our universe operates and what is happening in distant systems. I am looking forward to what’s to come of LIGO’s detectors. This data can be used to show people what is really happening in our universe and what is truly possible in the ever-expanding universe.

**References**

https://gwosc.org/eventapi/html/allevents/