Analysis and Sonification of GW200311_115853

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I. Abstract

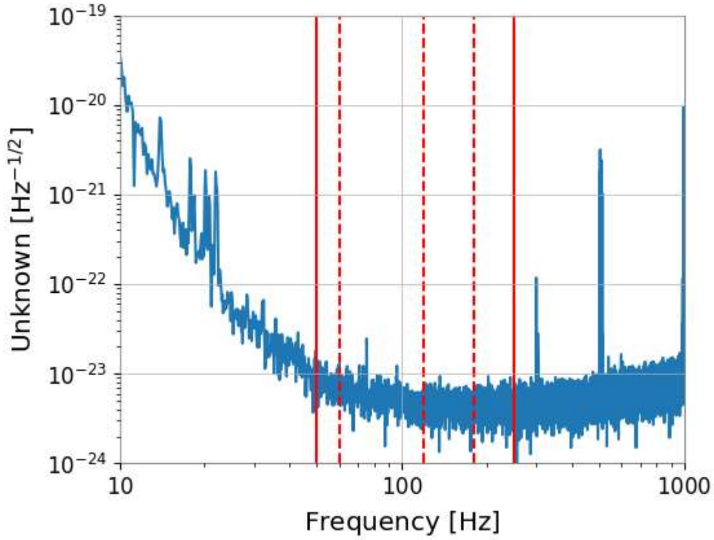
Using data attained by the LIGO Hanford and LIGO Livingston, the data from the black hole-black hole collision gravitational wave event GW200311_115853 was plotted and sonified. This was achieved by filtering out noise and writing a sound file using this filtered data. The distance of the black hole merger and deformation on Earth due to the event was also calculated, as well as the final mass of the merged black holes.

II. Motivation

The main goal was to better understand gravitational wave events, as well as the process that goes into analyzing them using the data from LIGO Hanford and LIGO Livingston. It also posed an interesting way in observing the universe in more than one way, by listening to it. I also wanted to understand the magnitude of this event, the distance, the final mass, and its effects on the Earth.

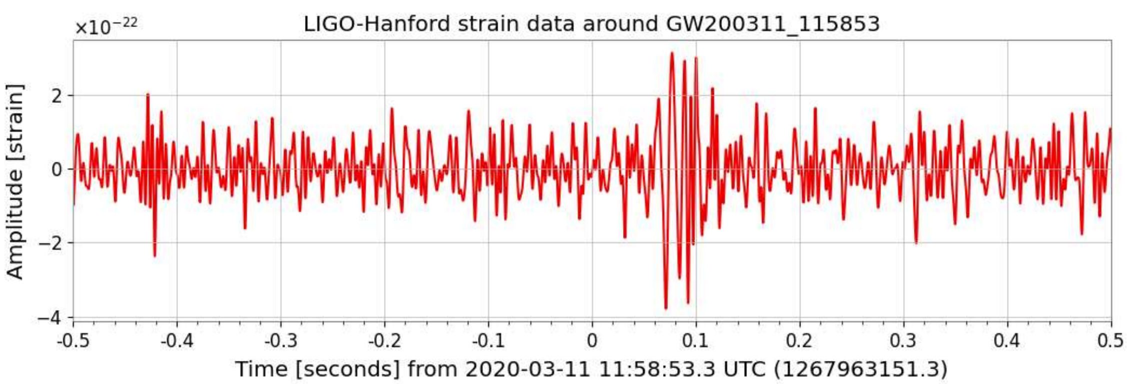
III. Methods

In order to begin analysis using coding, the Python package for gravitational wave astrophysics (GWpy) was installed. From there, I set the variable t0 to the GPS time the gravitational wave event GW200311_115853 occurred, and grabbed the time series centered on t0 and 32 days away from t0. I then used frequency analysis to get frequency and power of frequency and plotted it, as seen in Figure 1



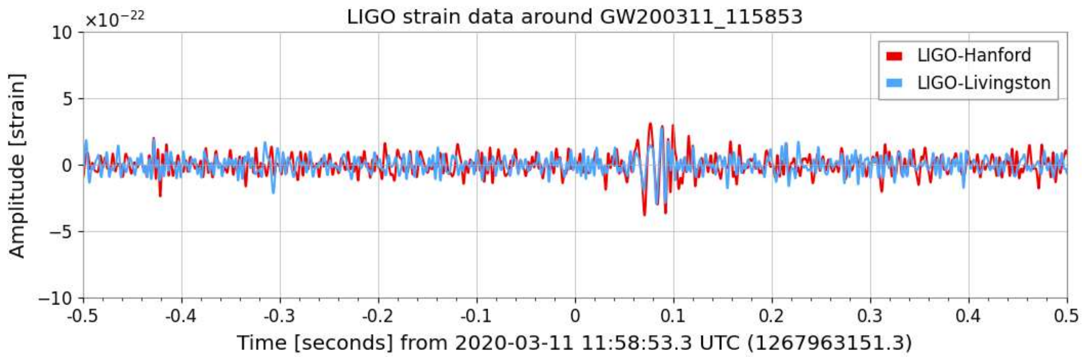
[Figure 1]

Noticing the spikes at 60, 120, and 180 Hertz, likely due to A/C frequencies interfering with the detectors and these frequencies, I used a filter to crop those frequencies and unwanted data out. Noticing a spike in the unfiltered data from LIGO Hanford, the filter was applied, producing a gravitational wave graph centered around t0 half a second before and after the event, as seen in figure 2.



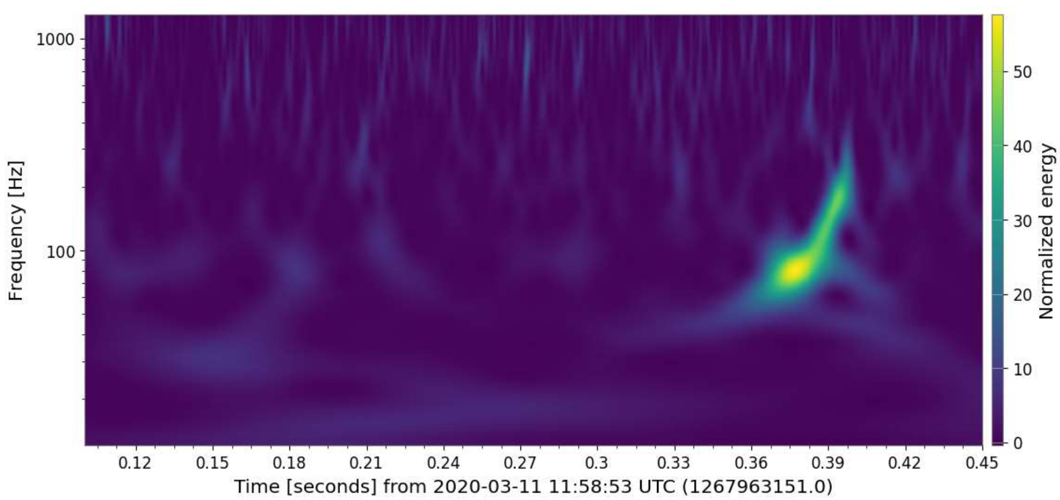
[Figure 2]

By repeating the steps with the data from LIGO Livingston, adjusting it by 6.9 milliseconds to account for their positions on Earth and different configurations, and overlaying them, the gravitational wave event becomes clear, as seen in figure 3.



[Figure 3]

I then generated a q-transform of the data, producing a frequency-time graph with a color scale. This produced a graph where the increase in frequency as the black holes approach each other in the merger event becomes clear, producing a chirp as seen in figure 4.



[Figure 4]

From here I imported SciPy, the module to create sound files, and used the data from LIGO Hanford to generate a sound for the gravitational wave event. I worked on beautifying this sound by upsampling and using a Fourier transform in order to make it more prominent from the surrounding noise. Following the analysis and sonification of the data, I calculated the mass of the merged black hole given the time between the two of the peaks on the amplitude-time graph from the data from LIGO Hanford. For this I used the equation $\frac{\delta t c^3}{16\pi G}$. Following this I calculated the radius of this new black hole with its mass using the equation $\frac{2Gm}{c^2}$. Then I calculated the deformation on the Earth by multiplying the radius of the Earth and the strain of the merger, and from there I calculated the distance the gravitational wave event occurred by dividing the radius of the new black hole by the strain.

IV. Results

Ultimately, we were able to produce great looking visual graphs in analyzing gravitational wave merger events. These have a characteristic shape that is distinct from the noise. The sonification process did not go as well, and the merger is still somewhat hidden within the noise. The resulting mass of the new black hole is about 60.59 solar masses, with a radius of about 178.92 kilometers. We also find the gravitational wave event to occur at a spectacularly large distance of about 5798.58 million parsecs, and despite its incredible magnitude with tremendous mass lost to energy during the process, the effects on Earth are miniscule, only deforming it by about 6.38 femtometers.

V. Conclusion

Whilst sonification is a different way to look at data and the universe, more work needs to be done to translate data into a way easily understood to our ears. Visual plotting and graphing continues to be the more orthodox way of observing data. Moving forwards, we may need to look more into the sonification process to produce better sounds with value to them. And due to the distance the gravitational wave event occurred, despite the large transformation of mass into energy, the deformation of the Earth is on a magnitude of femtometers.

References

LIGO Scientific Collaboration and Virgo Collaboration. LIGO Virgo Strain Data from GWTC-3 Catalog. Gravitational Wave Open Science Center, 2021, doi:10.7935/B024-1886.