Blake Sodikoff
ASTRO 1221
October 18, 2023

Gravitational Waves: Tuning in to the Universe

Motivation For This Project

• • •

Over the course of the past few weeks, I have deciphered the perturbations in space-time that arise due to the cosmic phenomenon known as gravitational waves. This process occurs when two massive bodies, typically black holes or neutron stars, engage in a close binary orbit of one another, and this orbital velocity causes immense warping of the fabric of the universe known as space-time. This occurrence has immense significance to our understanding of modern physics and the universe altogether.

The clear reason why this further proves our understanding of physics is due to the theory of General Relativity, which was published by Einstein in 1915. This theory predicts the existence of these gravitational perturbations, or waves, in space-time as a consequence of massive objects engaging in a rotational embrace resulting in a merge or collision. The existence of gravitational waves is further evidence for this theory and enforces our confidence in its authenticity.

In summation, the motivation for this project is to decipher perturbations in space-time recorded at two interferometers in the United States and to decode these minuscule changes in our universe into a tangible audio waveform. The goal of this project is to perceive the universe in ways that we have yet to experience.

Methods

• • •

The methodology behind this project is extensive and complex and involves the evaluation of data interpreted by established interferometers in Hanford, Washington and Livingston, Louisiana. The process begins with the detection at these sites. These interferometers, called LIGO, can detect extremely small changes in space-time through constructive/destructive interference associated with the behavior of light waves. The process begins with light pulses sent down two identical perpendicular arms, where they bounce off a mirror about 4 km away from the source. In unaltered space-time, these light waves will travel down the arm, reflect, bounce back, and meet each other in perfect synchronicity at the light detector back at the start. Without any sort of disturbance, these light waves will perfectly cancel out, resulting in total destructive interference. However, in the presence of a gravitational wave, space-time is warped ever so slightly. During this occurrence, LIGO's arms bend proportionally due to the tiny changes in space-time, which causes the arm lengths of the interferometer to vary in extremely small quantities. This tiny change is undeniably detectable, however. This alteration causes the light waves to travel slightly different distances, and when met back at the detector, they are slightly out of sync, leading to a situation where there isn't total destructive interference, giving evidence for the existence of Gravitational Waves.

We can correlate this data to a value known as strain, or the amplitude at which space-time is perturbed. This strain can thus correlate with a frequency, which is measured by the wavelength between two crests in the moments leading up to the merge/collision. By mapping this wavelength to an audible frequency, we can consequently "hear" the merger. In actuality, we are simply correlating the frequency of the perturbation of space-time to an audible sound wave, but the correlation is still mesmerizing to listen to as it represents a new form of astronomical evaluation.

Results

•••

After taking data from a gravitational wave occurring in 2019, I inputted the GPS time coordinate into my code to set the initial parameters and input the data from the event. I then altered the graph of the frequency range to notch down interfering frequencies that could possibly interfere with the perception of the moment. From there, I was able to see a clear spike in strain around 100 Hz, which clearly indicated the presence of a gravitational wave. Then, by comparing the data of that instance between the two interferometers, and adjusting their values to coincide with one another, I could see the clear similarity between the two, indicating that this occurrence isn't just an anomaly. Subsequently, I was able to produce the waveform audio file, however, at around 100Hz it was very difficult to hear as that is the border of what humans can interpret. I then shifted the pitch (frequency) up, creating a much clearer and more perceivable waveform file.

After completing this process of strain frequency evaluation, I then went back to the original figures presented by LIGO to confirm my findings. LIGO's detection of the event labeled this merger with a final mass of 76.3 Solar Masses resulting from the merge between a black hole of 43.4 Solar Masses and 33.4 Solar Masses. There is a difference here of about 0.5 Solar Masses, which is further evidence of a gravitational wave and is thus further evidence for the existence of the event. Since energy cannot be destroyed, this discrepancy of 0.5 Solar Masses must have been transformed into a new energy form, in this case, gravitational waves.

Conclusion

•••

In conclusion, this process proves the existence of gravitational waves without uncertainty. Through extensive analysis, thorough reevaluation, and proofing as mentioned before, I can say without ambiguity that this event, which we perceived on May 21, 2019, was in fact a gravitational wave event and not some other anomaly. This has immense significance to our understanding of gravity and opens the door to many possibilities for new and exciting ways to evaluate our universe.