We present an investigation of the viability of using gravitational wave events as a form of cosmic distance measurement through comparison to established methods, specifically Type Ia supernovae [3]. This was done through the comparison of H values calculated with gravitational wave data from LIGO with H values calculated from Type Ia supernovae using data from the Open Supernova Catalogue [6][7]. We find that the confidence intervals of the H values derived from gravitational wave events and Type Ia supernova overlap, suggesting that gravitational waves may be an effective means of cosmic distance measurement. This overlap also demonstrates the viability of the method of gravitational wave inclination angle calculation using a fitting function that uses the luminosity distance provided by LIGO.

GW's can be thought of as a longitudinal ripple in space that travels at the speed of light. These ripples occur when two massive objects collide and coalesce into a singular, more massive object, causing the distance between two points in space to change periodically according to the frequency of the signal. The amount of separation between two points is referred to as the strain of the gravitational wave, which is also the amplitude of the GW. In order to calculate distance, we need the chirp mass, strain, and inclination angle, while also accounting for the build of instrumental errors when calculating the frequency of the GW. Due to time constraints, we used observed values throughout our work, such as the combined mass rather than the exact mass. The normalized and maximum strain in order to minimize the amount of noise in the data and determine a rough estimate for the distance to each GW source and its respective H value.

We use a regression function to find a best fit line relating the recessional velocity and distance of 2677 Type Ia supernovae that were within the same redshift range as the gravitational wave sample. The slope of the best fit line was then taken as the Hubble constant. The redshift values and apparent magnitude were derived using the upper, middle, and lower bounds of the average absolute magnitude of Type Ia supernova, giving us three Hubble constants [8]. (We did not use the more accurate method of template fitting to derive absolute magnitude due to time and technical constraints.) Confidence intervals for each Hubble constant were then constructed using a bootstrap of 1000.

We found an expression to determine the distance to GW events, which relates distance to the strain, combined mass, inclination angle, and the buildup of errors as the wave propagates. We created a model based on this expression and found out that it only worked for 2/10 GW signals. To improve our model, we defined the dimensionless constant n where n = d_u / d_m, which is a measure of how far off our distance measurement is from LIGO's luminosity distance measurements. We derived an inclination angle equation which allowed us to use n as an amplifier on the strain [4]. This allowed us to get gravitational wave distance and inclination angle results for 6/10 signals. We used the redshift values reported by LIGO and our calculated distance values to determine the expansion rate of the universe.

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We found that gravitational waves can be a viable alternative to traditional methods of Hubble constant calculation and provide a new way of observing the universe.

Discussion and Future Work

The GW Distance calculator successfully determined the distance, inclination angle, and Hubble parameter for 6/10 of the gravitational waves detected by LIGO. With the error bounds of the gravitational wave H values estimates overlapping with the SNe results, they are shown to be a viable form of calculating H. However, the current uncertainties on the GW H results are too large to provide any insight into the source of the cosmological crisis, where the CMB estimates and the cosmic distance ladder estimate diverge. Determining the distance and inclination angle of the four signals where our calculator failed would require higher resolution strain data. Higher quality data would also allow us to explore the cause of the inclination angle degeneracy problem in greater detail.

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