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motivation

By studying black hole mergers via gravitational waves, we can figure out the distance from Earth. Comparing this to the redshift of the light from these events allows us to better understand the universe's expansion.

methods

assumptions + calculations

$$\text{Chirp Mass} = \frac{c^3}{G}\left(\frac{5}{96}\pi^{8/3} f_{peak}^{-11/3} f_{deriv}\right)^{3/5}$$

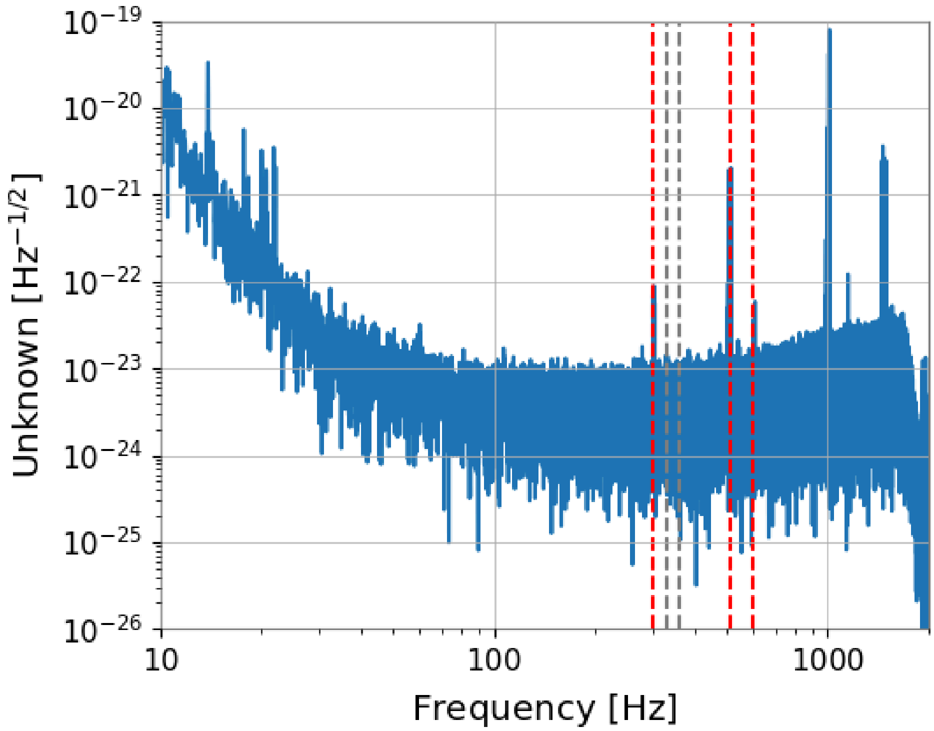
$$\text{Chirp Mass} = \frac{(m_1 m_2)^{3/5}}{(m_1+m_2)^{1/5}}$$

we assume $m_1 = m_2 = m$

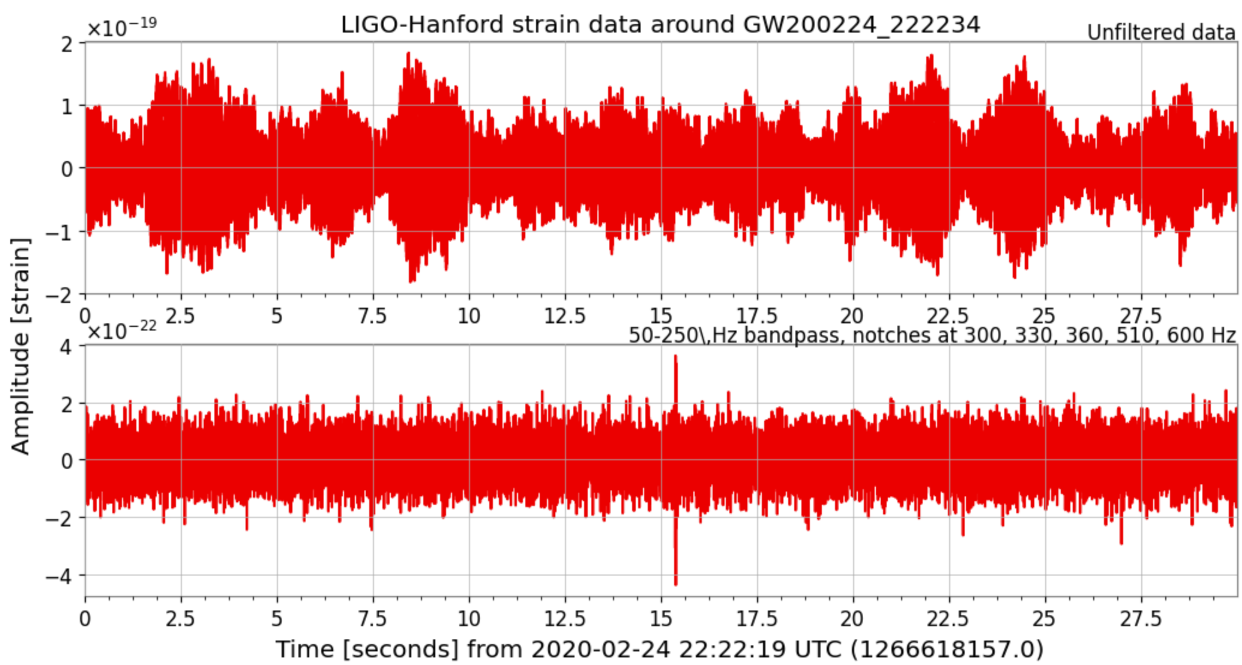
By using gravitational wave data collected from LIGO we should be able to calculate the masses of the two black holes that merged in order to cause the wave. Using data from the two different locations, we assume the Earth is round in order to account for their distance difference in order to line up the data.

results

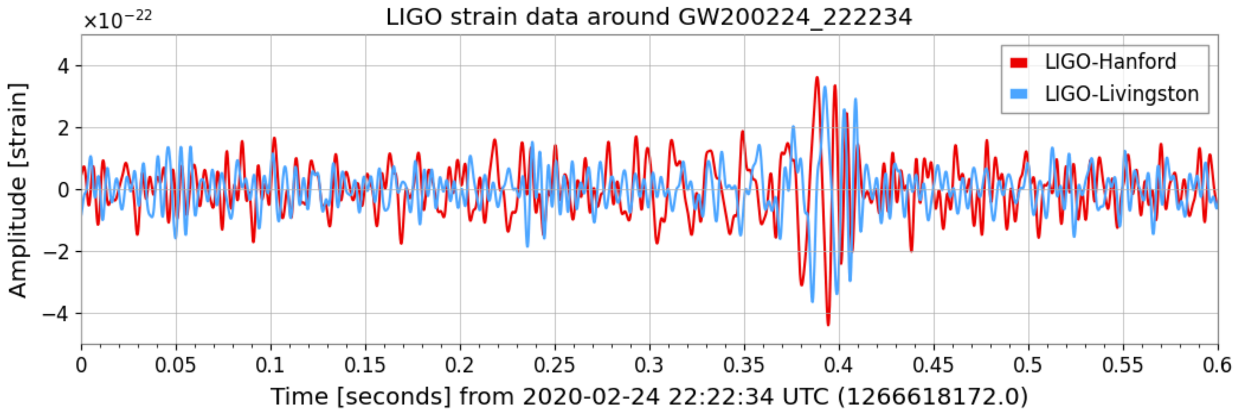
By applying a fast fourier transform on the data we get this graph which represents which frequencies are dominant in the wave.



We can also process the data to reduce noise, which gives us a better picture of the gravitational wave. Here is the before and after.



After that, we can use the data from Livingston as well as Hanford, and after shifting the data to account for a round Earth's location differences, we can overlay them to see the differences and similarities. Measuring strain is like measuring the tiny bit of change in distance that the gravitational wave causes. LIGO measures this by splitting a laser in half that bounce between mirrors in each arm of the observatory. The gravitational wave changes the distance between these two mirrors, which is how the wave is measured.



Using our assumptions and code we find that the chirp mass is 1.1 * 10^15 kg, or about 5 * 10^-16 solar masses, which is wrong, and using that we find each mass of the black hole is around 1.3 * 10^15 kg, or about 6.4 * 10^-16 solar masses, which is definitely wrong.

Using the chirp mass and peak frequency, we find that the distance is 37903 Mpc, which is pretty high, and using the max strain and chirp mass, we find the energy lost was 6.2*10^-13 J, which is pretty low. Likely because they are both also wrong.

conclusions

Had I been able to use the gravitational wave to estimate the correct masses of the two black holes that caused it I would have also been able to estimate the correct distance from Earth. That, combined with light data from the same event, using redshift, would have helped to better understand the universe's expansion.

AI acknowledgement

I used AI to generate the peak frequency, frequency derivative, and max strain.