Homework #2: Outline and Data Analysis Plan

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Abstract

In this work, we explore a system of analysing LIGO Gravitational Wave data to predict properties of the event that produced the detected disturbance. Based on multi-parameter best-fit estimations, and currently known procedures on processing gravitational waves, we show how to derive similar results as LIGO derived. We show the process of using cleaning, filtering, and fitting raw data to extract a series of parameters that best represent each signal. From these parameters, and addtional known information we also show key properties about the event that generated the waveform.

1 [1 pt] Organization

A revised lab report outline from homework #1. We try out a persuasive argument used to drive the narrative of out lab report.

- **Introduction**:
  We introduce any relevant information to the reader - past work regarding gravitational waves, current work, our work, as well as the significance of what we do. We address *why* the audience should care about our research. We detail the interferometer apparatus as well as any background information from LIGO. We explain properties of decaying orbits in blackhole and neutron star orbits by using features of gravitational waves. By examining the characteristics of these waves, we accurately identify them, and how the related to the properties of decaying orbits.

- **Methodology**:
  We use data collected from LIGO Facilities to isolate gravitational wave measurements, and understand their properties. With techniques in digital signal processing, we analyze the gravitational wave data. We introduce sources of error and discuss precautions that we have used to account for them.

- **Results**:
  We present our initial interpretations of the data has be have processed it. Plots and

Figure that demonstrate features of isolated gravitational waves, and how they pertain to properties of merger events such as merger type, energy and masses. We compare this raw data to our fits and and how they related to any uncertainties in the project.

- **Conclusion**:
  What is the significance of these results? Instead of showing data, we explain why our results are important, how it relates to previous work, and how it can influence future work.

Outline the sections and their descriptions (or summary of contents) here:

2 [2 pts] Data and Analysis

Using the *Gravitational Waves Lab Manual*, outline the data analysis tasks required and their expected outcome. (The data analysis workshops should have been helpful for this.)

1. List the complete set of raw data you expect to have:
   (a) We have data from both LIGO Livingston and LIGO Hanford, particularly the events: $GW170814$ and $GW15914$ raw data.
2. List the steps you need to complete to remove background noise from your data:
   (a) Done using Tutorial 2.2: Remove about 2 seconds of the signal from either end of the file. The nature of the signal collection will cause deficiencies in the data at these slices.
   (b) We compute the Power-Spectral-Density (PSD) and pass the frequency domain through a high-pass filter to eliminate lower oscillating terms.
   (c) We use a template to compare data to known solutions from GR. The result of this is an approximation of the signal-to-noise ratio (SNR). The time with the highest SNR gives the supposed time of merger event.
3. List the steps you need to complete to find the chirp mass and the masses of the merging objects (Make sure to include which data and models are used in each step):
   (a) We plot the strain fit result and compute the frequency and change in frequency over the source of the merger event.
   (b) we compute the frequency by dividing one wavelength by the spacing between two adjacent peaks. Thus:
   $$f_0 = \frac{\lambda}{t_{i+1} - t_i} \tag{1}$$
   (c) This iteration is repeated until we reach the merger event

(d) We then compute the average frequency $\bar{f}$ and the change in frequency with respect to time

$$\frac{df}{dt} = \frac{f_{i+1} - f_i}{t_{i+1} - t_i} \tag{2}$$

(e) We can then compute the average derivative $\bar{\dot{f}}$

(f) We can use the presented data to compute the total mass of the system.

4. List the steps you need to determine the objects' relative velocity and some physical quantity from the ring-down (Make sure to include which data sets and models are used in each step):

   (a) Using the Bilby module, we can use appropriate guesses to compute the most likely range of masses as a Gaussian distribution. This best guess in masses can be used to compute the velocity.

   (b) We need the frequency as obtrained from the strain plot, and use this as well to compute the velocity.

   (c) We use the equation, with our computed masses and frequency to solve for the resulting velocity.

$$v = (GM\pi f)^{1/3} \tag{3}$$

3 [1 pt] Error and Uncertainties

List your sources of error/uncertainty. Are they statistical or systematic? Describe how each will quantitatively affect your results. (Which results will they affect?)

Sources of error on our end come from the raw data. Any physical measuring device brings with it experimental error either from instrumentation or digitization. Additionally, given the precision of floating-point numbers it's possible that when dealing with non-naturalized units that a loss of significance may arise between calculations.