Problem Set 7 for Matched Filtering of LIGO Data. Due Tuesday November 12 at 11:59 PM

Matched Filter of LIGO data
You are going to find gravitational waves yourselves! Key will be getting LIGO data from github:
`https://github.com/losc-tutorial/LOSC_Event_tutorial`

While they include code to do much of this, please don't use it (although you may look at it for inspiration) and instead write your own. You can look at/use simple_read_ligo.py that I have posted for concise code to read the hdf5 files. Feel free to have your code loop over the events and print the answer to each part for that event. In order to make our life easy, in case we have to re-run your code (which we should not have to do), please also have a variable at the top of your code that sets the directory where you have downloaded the data. LIGO has two detectors (in Livingston, Louisiana, and Hanford, Washington) and GW events need to be seen by both detectors to be considered real. Note that my read_template functon returns the templates for both the plus and cross polarizations, but for simplicity you can just pick one of them to work with.

1) Come up with a noise model for the Livingston and Hanford detectors separately. Describe in comments how you go about doing this. Please mention something about how you smooth the power spectrum and how you deal with lines (if at all). Please also explain how you window the data (you may want to use a window that has an extended flat period near the center to avoid tapering the data/template where the signal is not small).

2) Use that noise model to search the four sets of events using a matched filter. The mapping between data and templates can be found in the file BBH_events_v3.json, included in the github repository.

3) Estimate a noise for each event, and from the output of the matched filter, give a signal-to-noise ratio for each event, both from the individual detectors, and from the combined Livingston + Hanford events.

4) Compare the signal-to-noise you get from the scatter in the matched filter to the analytic signal-to-noise you expect from your noise model. How close are they? If they disagree, can you explain why?

5) From the template and noise model, find the frequency from each event where half the weight comes from above that frequency and half below (thinking about pre-whitening may be helpful here).

6) How well can you localize the time of arrival (the horizontal shift of your matched filter). The positions of gravitational wave events are inferred

by comparing their arrival times at different detectors. What is the typical positional uncertainy you might expect given that the detectors area a few thousand km apart?

7) Include both polarizations in your fits. A good learning exercise would be to write a two-component matched filter (along the lines of the one I posted), but you may also just do least-squares fits using the best-fit shift from the one-template matched filter. If you didn't write a multi-component matched filter, please repeat the fit for ± 10 pixel shifts in either direction around the matched-filter shift to get the actual best-fitting offset. What is your new improvement in χ^2?