1. I modelled the noise for Hanford and Livingston by taking the power spectral density of each event, and averaging the results of each detector. I used Welch's method, which produces smoother PSDs by using overlapping segments of each dataset and averaging. I also used a Blackman window, which is designed to minimize leakage of big peaks. Then I smoothed each spectrum by taking a moving average of each point with it's neighbors, and returned the interpolated result to rescale. See Figure 1.

```
from scipy.signal      import welch
from scipy.interpolate import interp1d
from scipy.ndimage     import uniform_filter

def psd(signal, dt):
    '''Takes psd with 4 overlapping segments.'''
    freq, psd = welch(signal, 1/dt, window=''blackman", nperseg= 4/dt)
    return psd, freq

def smooth(spectrum, freq, n=3):
    '''Smooths psd by averaging n points (moving)'''
    return interp1d(freq, uniform_filter(spectrum,n))
```

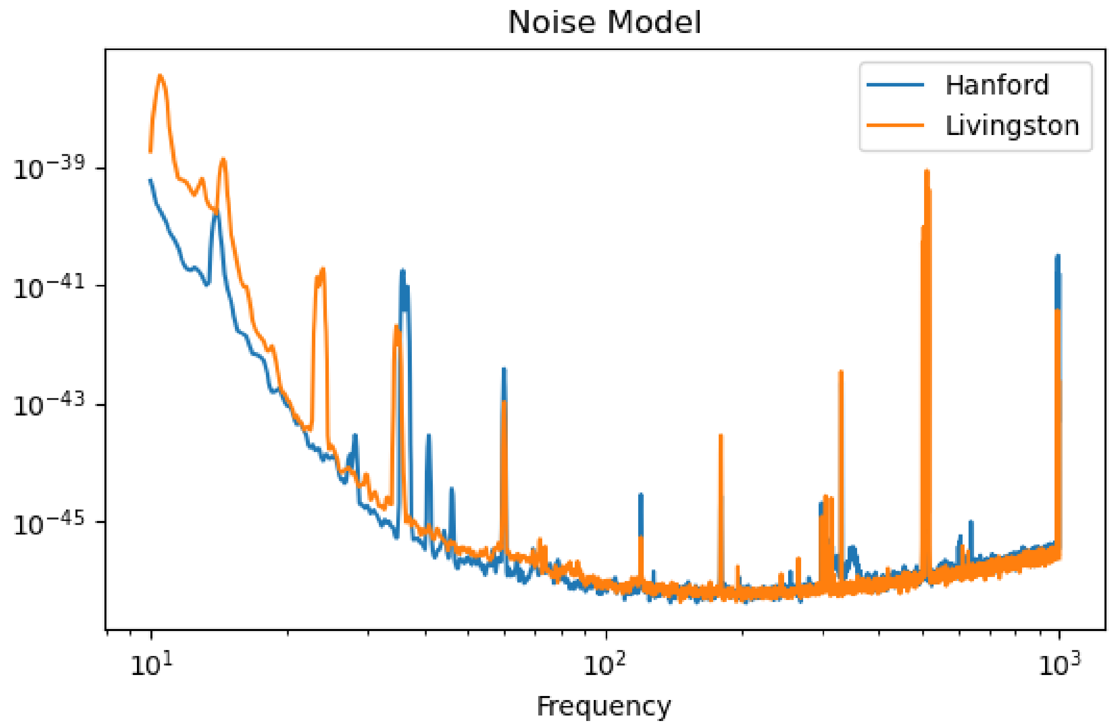

Figure 1: Noise models for Hanford and Livingston. At the relevant frequencies, it looks like the plot provided by LIGO.

I windowed the data using a 'tukey' window, which has a flat top and falls off like a cosine at the edges.

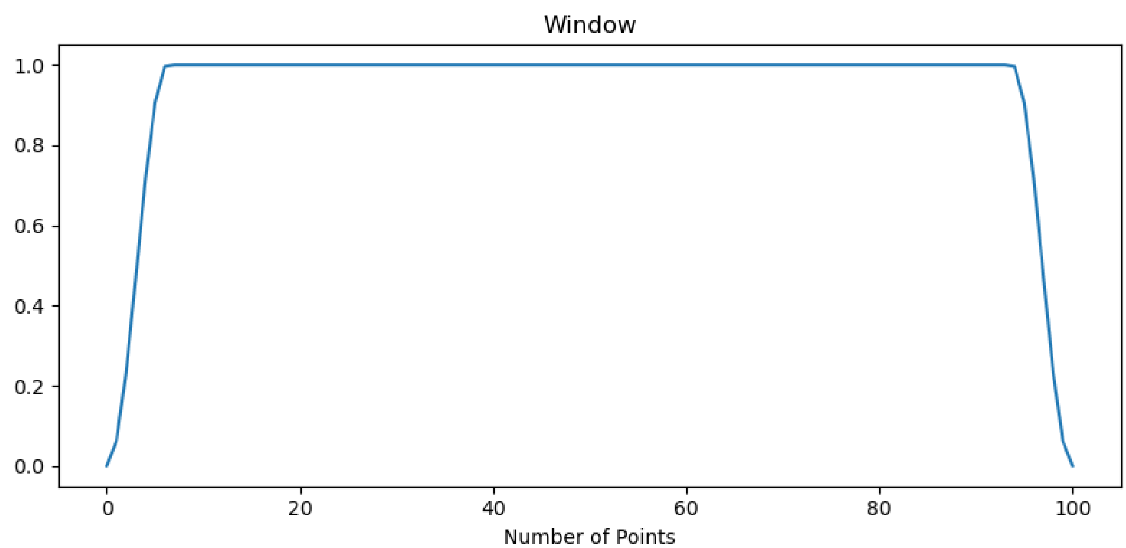

Figure 2: Window used on the data, to not suppress in the center.

2. See Figure 3.

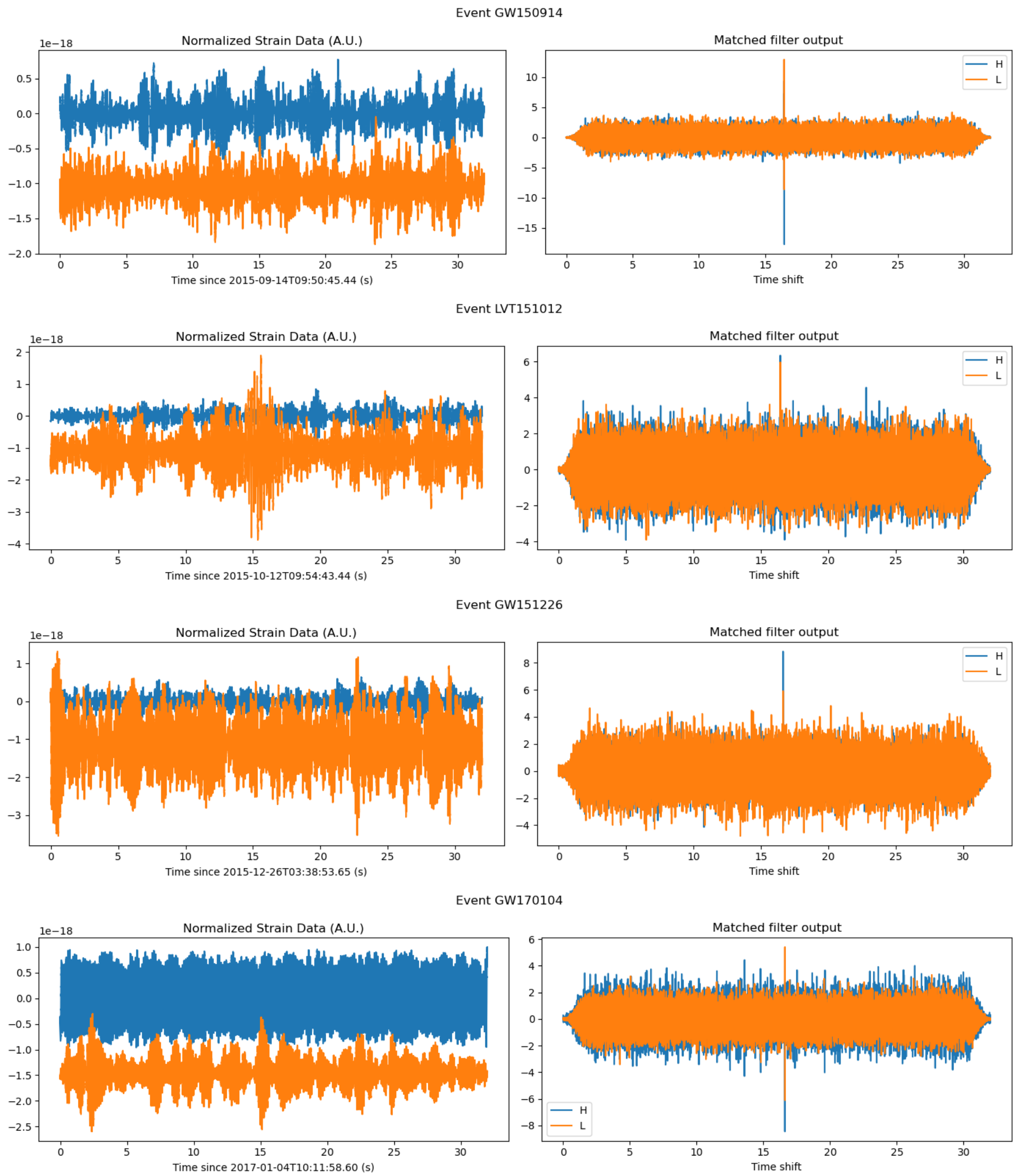

Figure 3: Strain and matched filter for each of the four events, for each detector. Hanford in blue, Livingston in orange.

3. The SNR from the data before normalization is $\frac{|max|-|mean|}{|std|}$. After normalizing, this should match the value of the peak of the matched filter, since normalization should make the standard deviation of the noise in the filter output equal to one.

Event GW150914
Hanford expected SNR 9.333
Hanford Data SNR 27.494
Livingston expected SNR 12.905
Livingston Data SNR 18.913

Event LVT151012
Hanford expected SNR 6.334
Hanford Data SNR 9.478
Livingston expected SNR 5.957
Livingston Data SNR 9.113

Event GW151226
Hanford expected SNR 8.833
Hanford Data SNR 14.771
Livingston expected SNR 5.905
Livingston Data SNR 7.219

Event GW170104
Hanford expected SNR 4.433
Hanford Data SNR 12.528
Livingston expected SNR 5.410
Livingston Data SNR 11.672

The values are mostly within a factor of 2. There might be an error in here somewhere, but I also expect a slight discrepancy due to the windowing of the data, which causes an underestimation of the standard deviation.

4. The frequency where half the weight is before and after is found by integrating in the Fourier domain.

```
# Integrate to find halfway point
intg = integral(np.abs(mf_ft), dx=df, initial=0)
mid_idx = np.argmin(np.abs(intg - max(intg)/2))
```

$$
\begin{array}{llllll}
Event & GW150914 & Hanford: & 124.406Hz & Livingston: & 134.562Hz \\
Event & LVT151012 & Hanford: & 124.188Hz & Livingston: & 135.094Hz \\
Event & GW151226 & Hanford: & 151.594Hz & Livingston: & 147.625Hz \\
Event & GW170104 & Hanford: & 120.781Hz & Livingston: & 152.000Hz
\end{array}
$$

5. Zooming in on the SNR peaks shows a rough uncertainty of 1ms, from half the width of the peak, in which a wave traveling at the speed of light goes 300km. This is a tenth of the distance between the detectors, leading to a positional uncertainty of 10%.