# Analysis of Gravitational Wave Event GW150914

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202301621

PHYS 450

December 2025

# 1. Libraries

The code relies on `gwpy` for data handling, `scipy` for signal analysis, `numpy` for numerical calculations, and `matplotlib` for plotting.

```
import numpy as np
from numpy . fft import rfft , rfftfreq
import matplotlib.pyplot as plt
from scipy.signal import butter, filtfilt
from gwosc.datasets import event_gps
from gwpy.timeseries import TimeSeries
from gwpy.plot import Plot
from astropy.time import Time
```

# 2. Data Fetching

We first find the GPS time associated with the event.

```
gps = event_gps("GW150914")
```

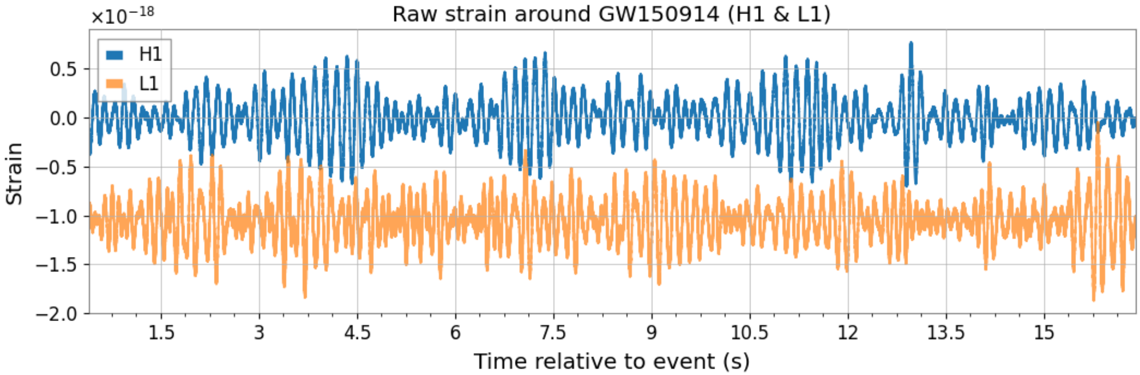
And set up the duration around it

```
duration = 16
start = gps - duration//2
end   = gps + duration//2
```

We fetch open strain data from the Hanford (H1) and Livingston (L1) detectors.

```
h1 = TimeSeries.fetch_open_data('H1', start, end, cache=True)
l1 = TimeSeries.fetch_open_data('L1', start, end, cache=True)
```

# 3. Raw Signal




**Observation:** The signal is invisible. The amplitude is dominated by low-frequency seismic drift and instrumental noise.

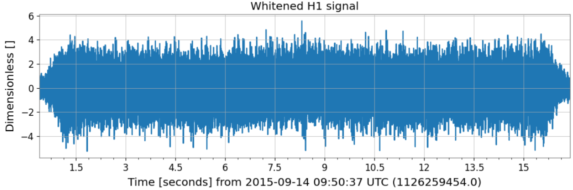
# 4. Spectral Whitening

To normalize the noise floor, we "whiten" the data.

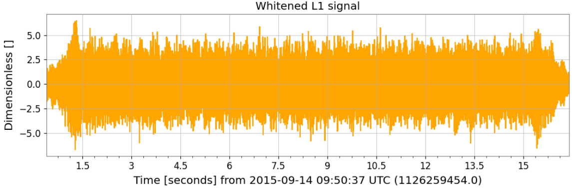
```
# Whiten the data using a 4-second FFT window with a 2 second overlap to
    estimate noise
h1_white = h1.whiten(fftlength=4, overlap=2)
l1_white = l1.whiten(fftlength=4, overlap=2)
```

# 5. Spectral Whitening (Output)

**Whitened H1 (Hanford)**




**Whitened L1 (Livingston)**



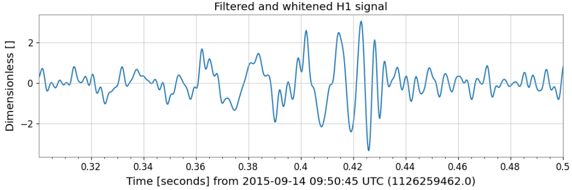
# 6. Bandpass Filtering

We design a 4th-order Butterworth filter to isolate the 35-350 Hz band.

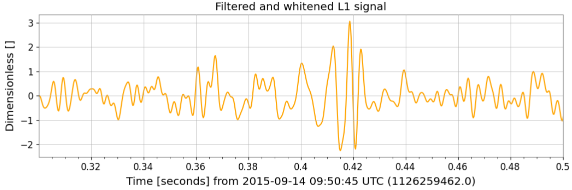
```
def bandpass(data, f_s, f_l, f_h, order=4):
    f_nyq = 0.5 * f_s # Nyquist Frequency
    # Design filter (normalized by Nyquist)
    b, a = butter(order, [f_l/f_nyq, f_h/f_nyq], btype='band')
    return filtfilt(b, a, data)

# Apply to whitened data
h1_bp=bandpass(h1_white , f_s_h , 35 , 350 , 4)
l1_bp=bandpass(l1_white , f_s_l , 35 , 350 , 4)
```

**Why `filtfilt`?** It processes the data forward and backward, canceling out phase delays. This ensures the peak time corresponds exactly to the physical event.

# 7. Bandpass Filtering (Output)




H1 Filtered Signal



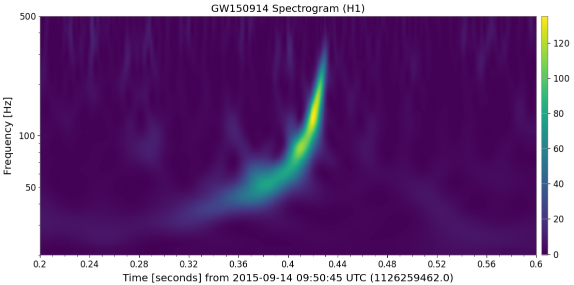

L1 Filtered Signal

The characteristic "ringdown" of the black hole merger is now clearly visible in both detectors.

# 8. Time-Frequency Analysis of H

We use the Q-transform to visualize frequency evolution over time.

```
dt_zoom = 0.2
outseg = (gps - dt_zoom, gps + dt_zoom)

hq = h1_final.q_transform(outseg=outseg, qrange=(4, 8), frange=(20, 500))
```

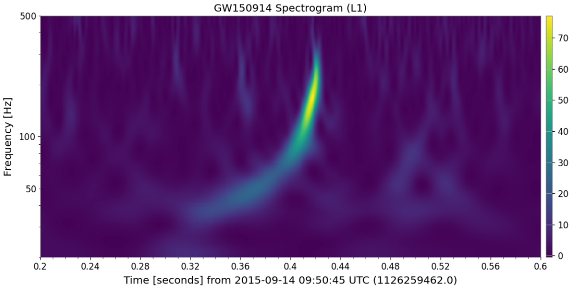



H1 Spectrogram

**Physics:** The "swoosh" shape (frequency rising with time) confirms compact binary collision.

# 9. Time-Frequency Analysis of L

```
lq = l1_final.q_transform(outseg=outseg, qrange=(4, 8), frange=(20, 500))
```




L1 Spectrogram

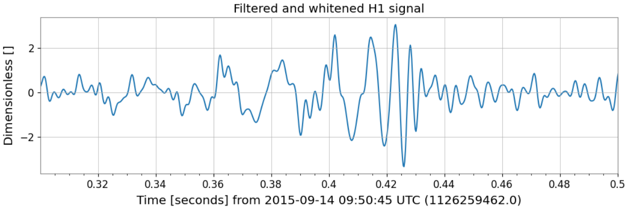
**Physics:** The "swoosh" shape (frequency rising with time) confirms compact binary collision.

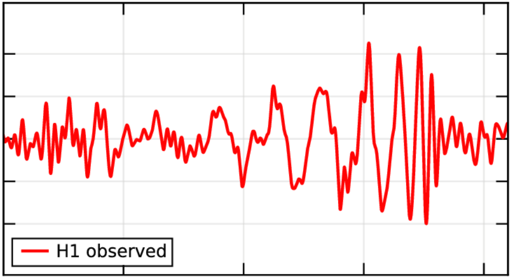
# 10. Validation vs Published Results

We compare our filtered H1 signal (left) with the official discovery figure (right).

**LIGO published figure**
Hanford, Washington (H1)

**Our Computation figure**




## Conclusion

The analysis successfully extracts a waveform that matches the frequency, duration, and amplitude envelope of the official GW150914 discovery.