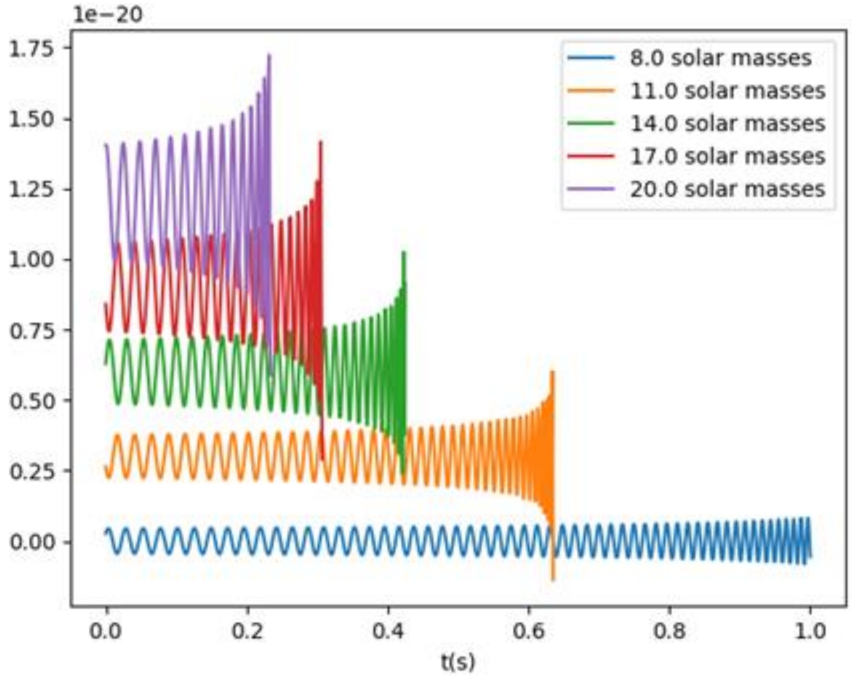
Gravitational wave detection

GW waveforms

- Chirp mass Mc
- Distance dL
- Starting frequency F0



$$h(t) = \mathcal{C}\frac{\mathcal{M}_c^{2/3}\pi^{2/3}}{d_L}\frac{(\mathcal{M}_c F_0^9)^{1/8}}{[(\mathcal{M}_c F_0)^{1/3} - 256 F_0^3 \mathcal{M}_c^2 \pi^{8/3} t/5]^{3/8}} \cos\left(\varphi_0 - 2\left(\frac{1}{256(\pi\mathcal{M}_c F_0)^{8/3}} - \frac{t}{5\mathcal{M}_c}\right)^{5/8}\right)$$

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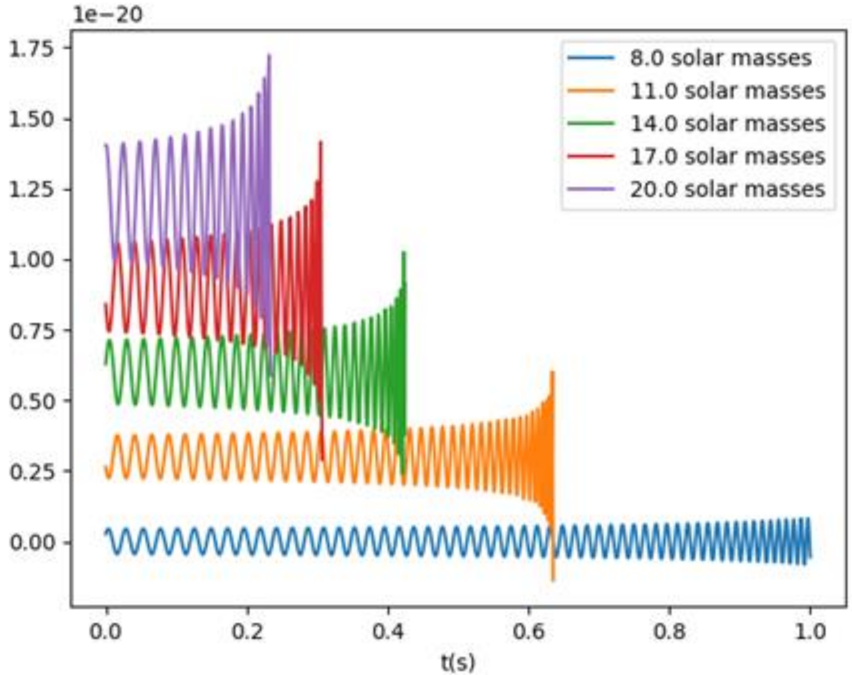

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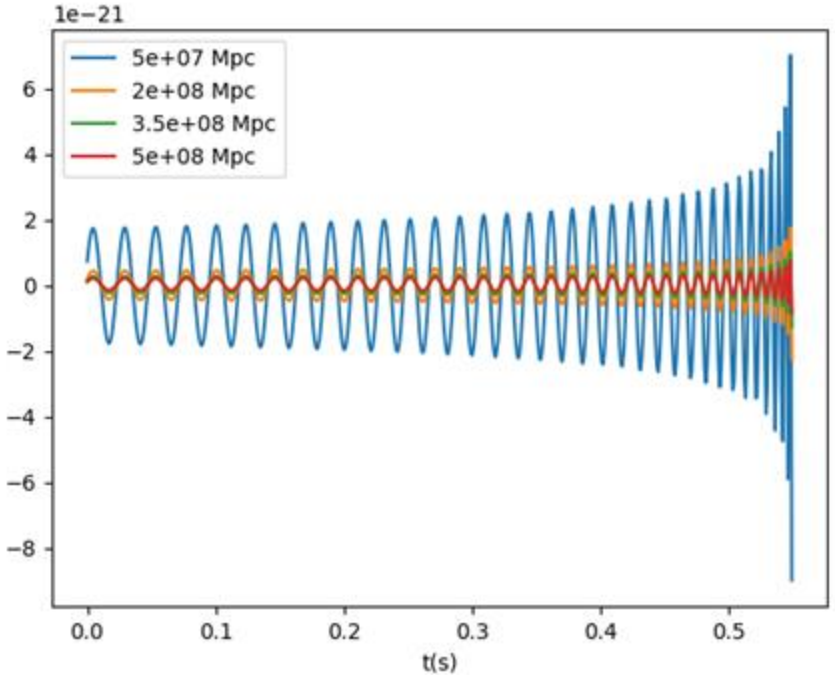

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Noisy data

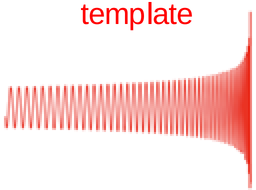
- Simulate real signal by adding gaussian noise
- How to find signal?

→ Matched filter: signal extraction from Gaussian background

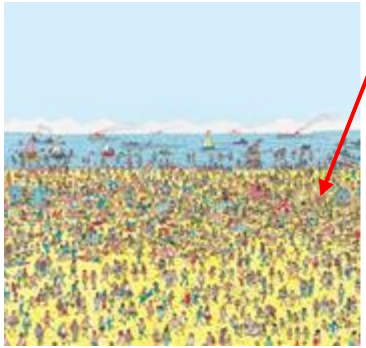
↳ Correlation between the signal template and the data sample

Wally

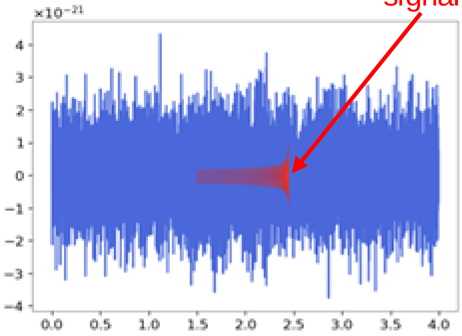
Signal template



Wally

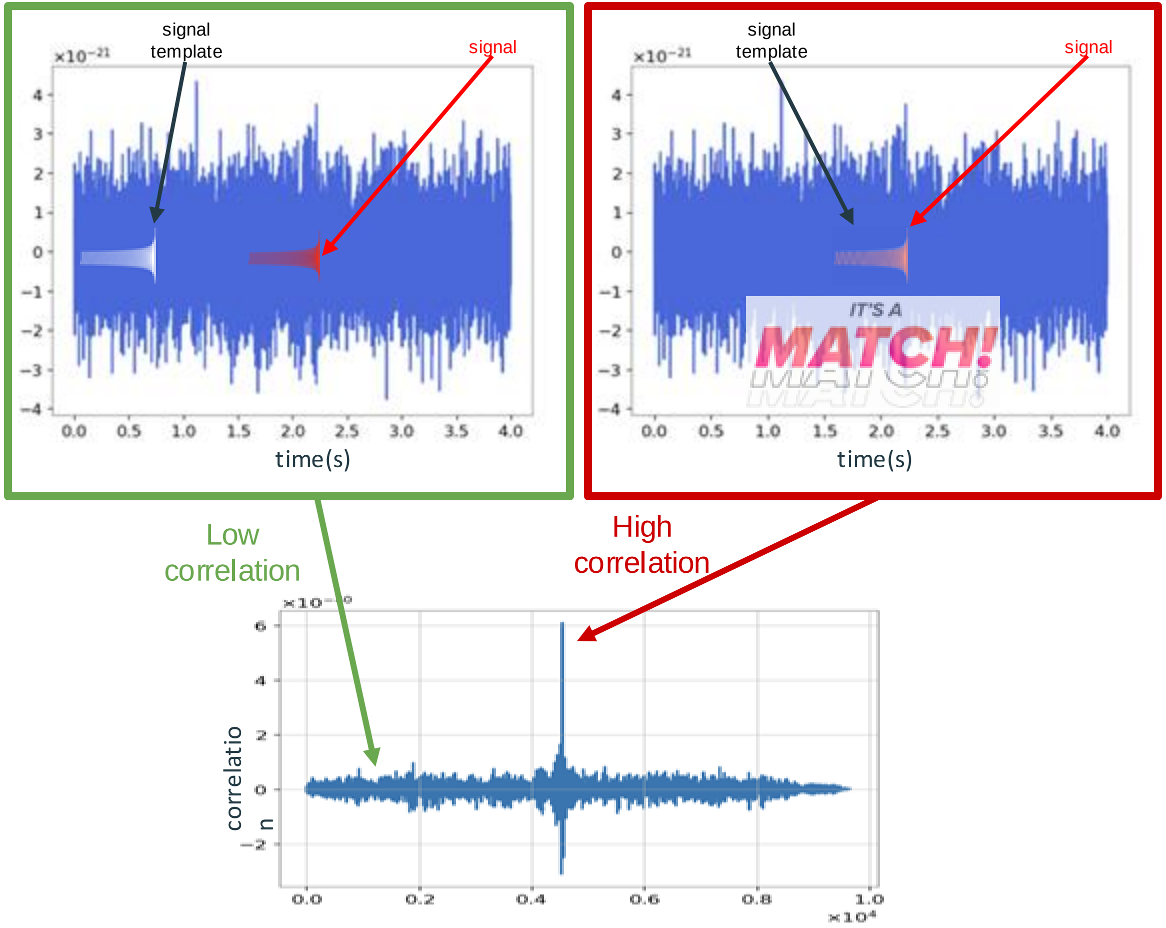


signal

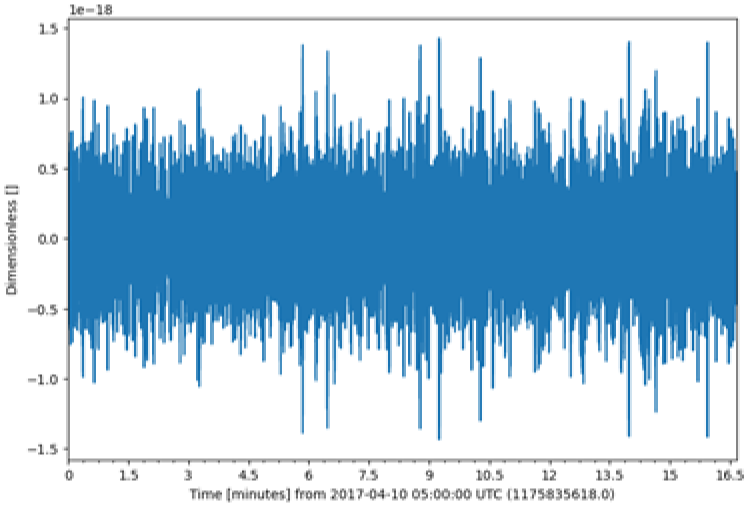


Matched filter

- Scan the data sample with our template
- For each time step compute the correlation between template and data sample

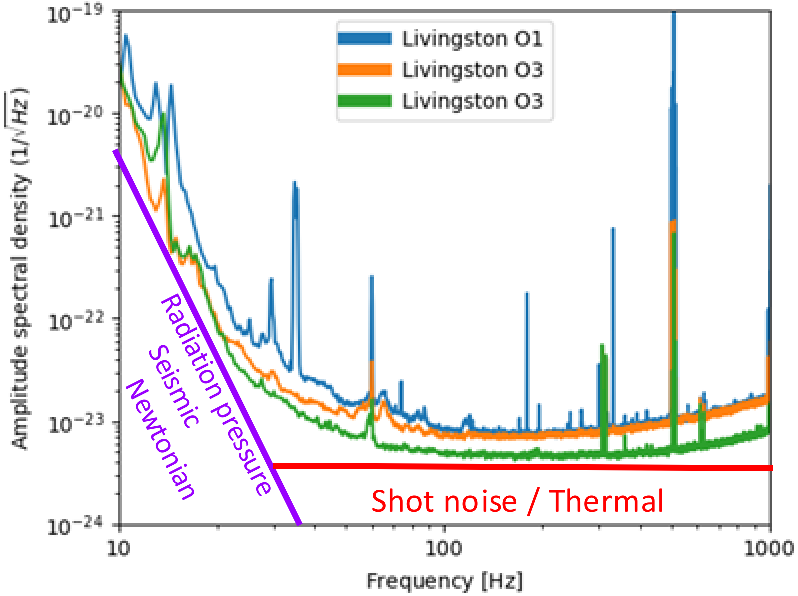


Interferometer noise spectra



Fourier

Transform

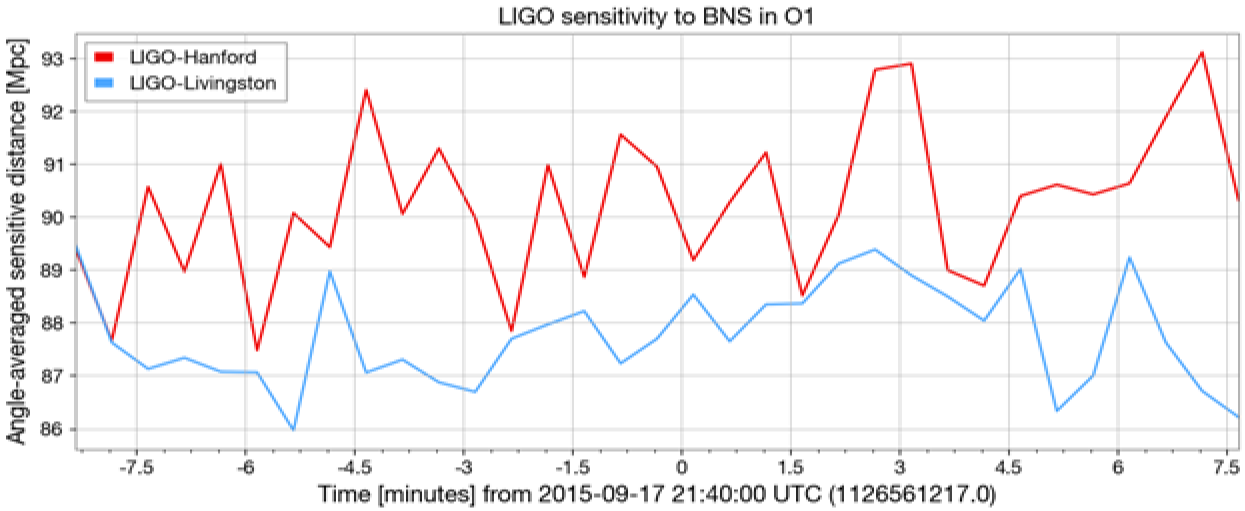


Time series of random data (without signal)

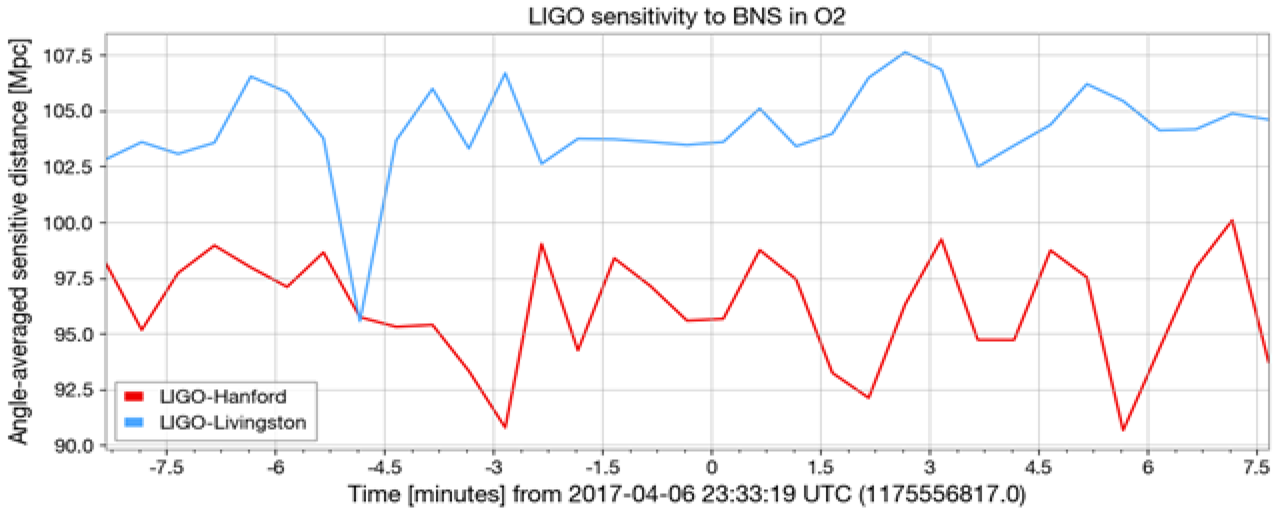
Amplitude

spectral density

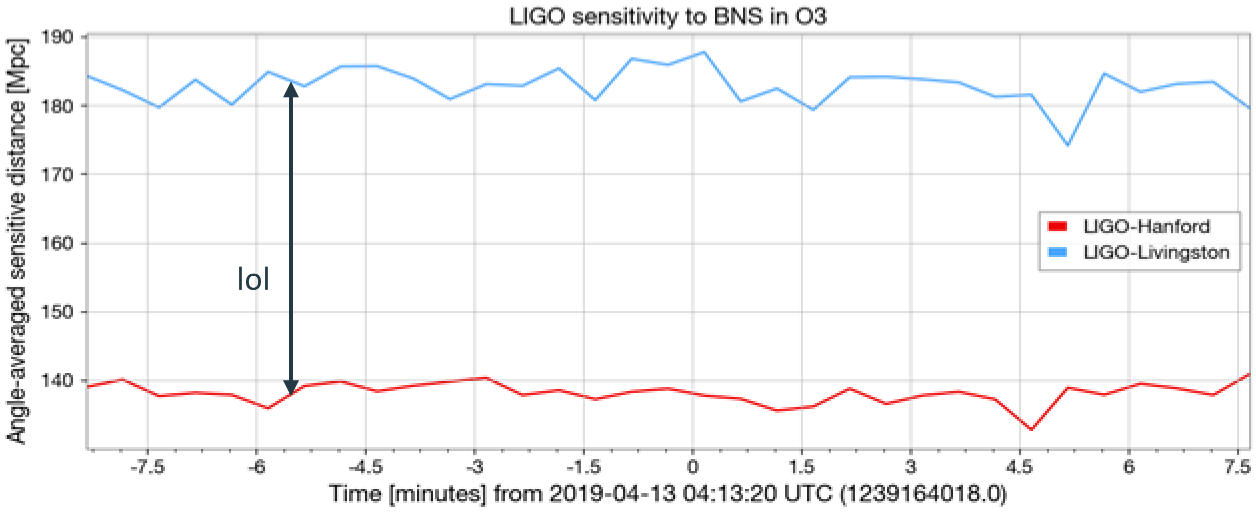
Binary neutron star range



Binary neutron star range



Binary neutron star range

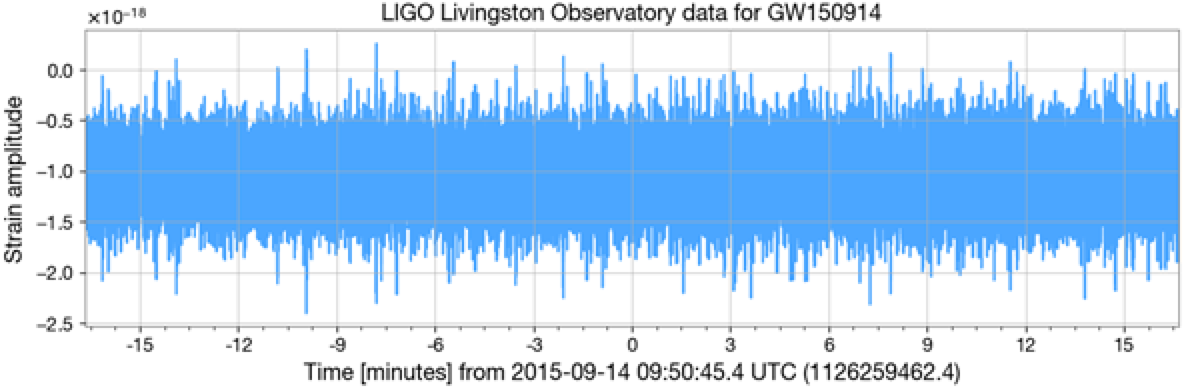


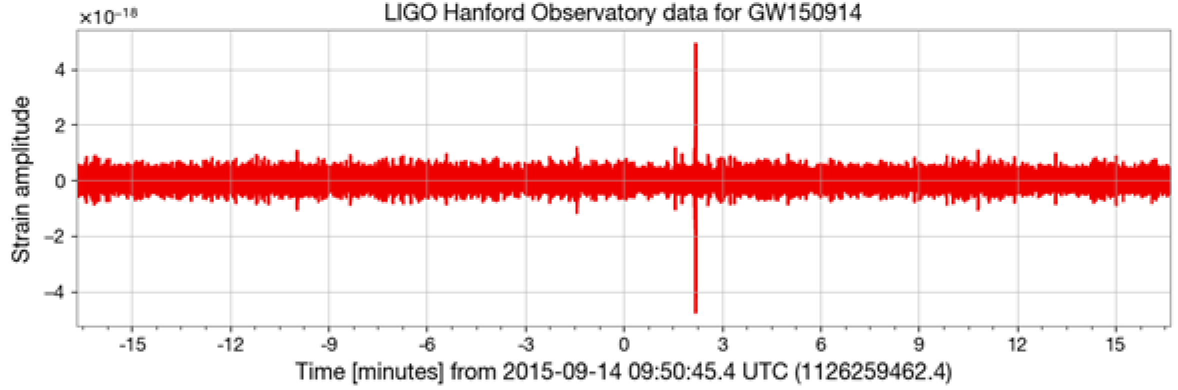
Virgo somewhere down here

Waveform correlation to real data

- 2 real detector data are studied: GW150914, GW151226
  - GW150914: merge of 2 black holes of 36 and 29 solar mass, observed at 440 Mpc
    - Expected chirp mass: 28.6 solar mass
  - GW151226: merge of 2 black holes of 14.2 and 7.5 solar mass, observed at 440 Mpc
    - Expected chirp mass: 8.9 solar mass

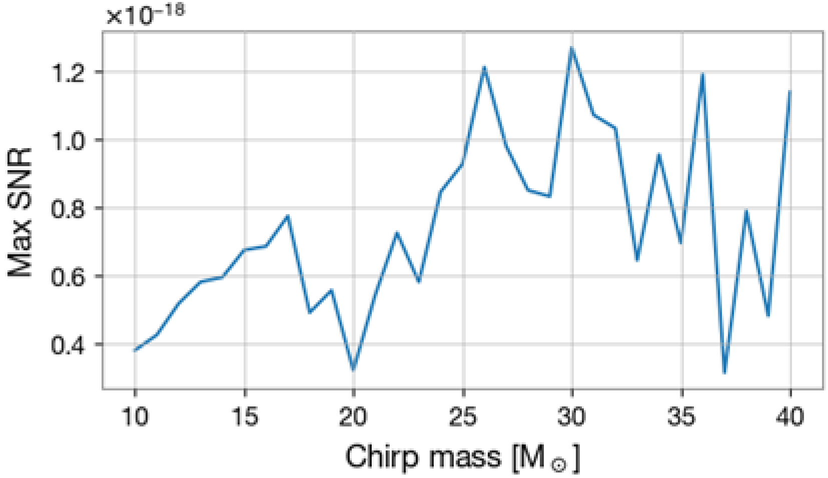
Real detector data GW150914

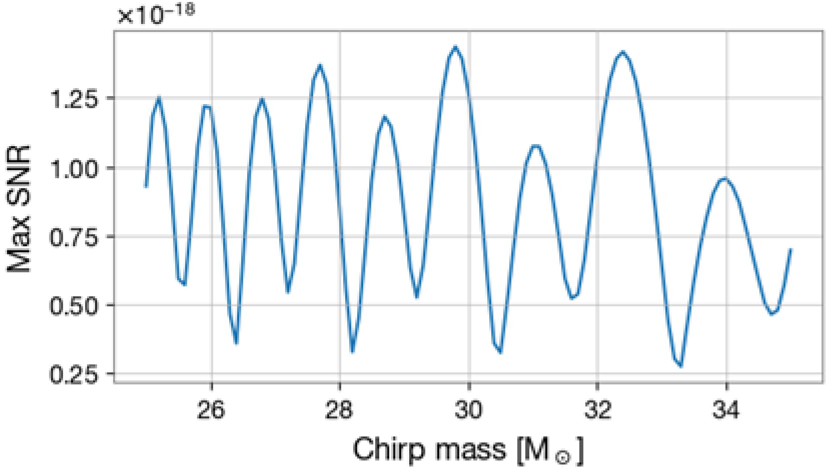




Correlation to GW150914 Livingston observation

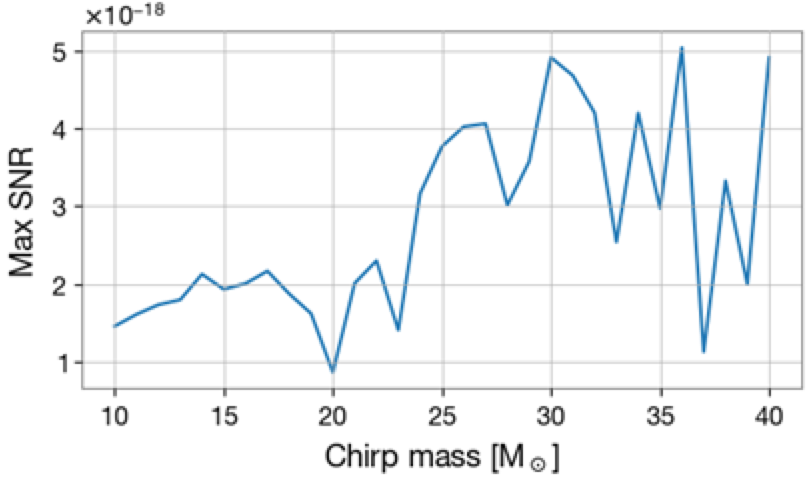
- Correlation with a scan over chirp mass from 10 to 40 solar mass with step of 1 solar mass
  - Maximum SNR is found at chirp mass = 30 solar mass
- Second scan with chirp mass from 25 to 35 solar mass with step of 0.1 solar mass
  - Maximum SNR is found at chirp mass = 29.8 solar mass

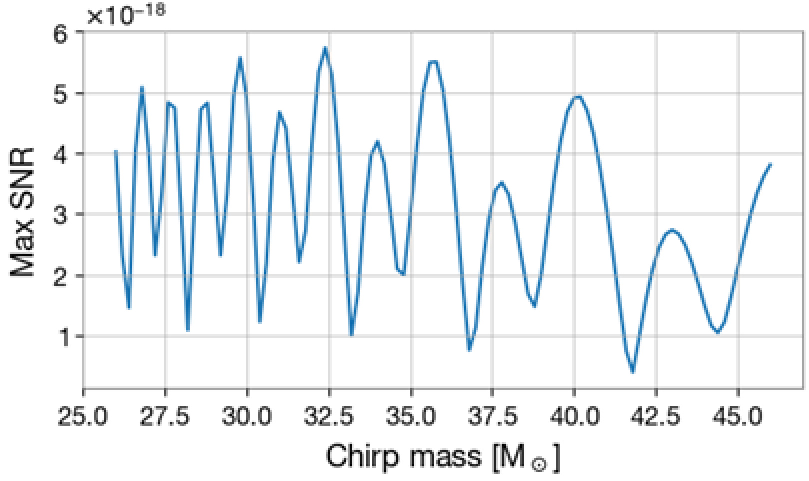




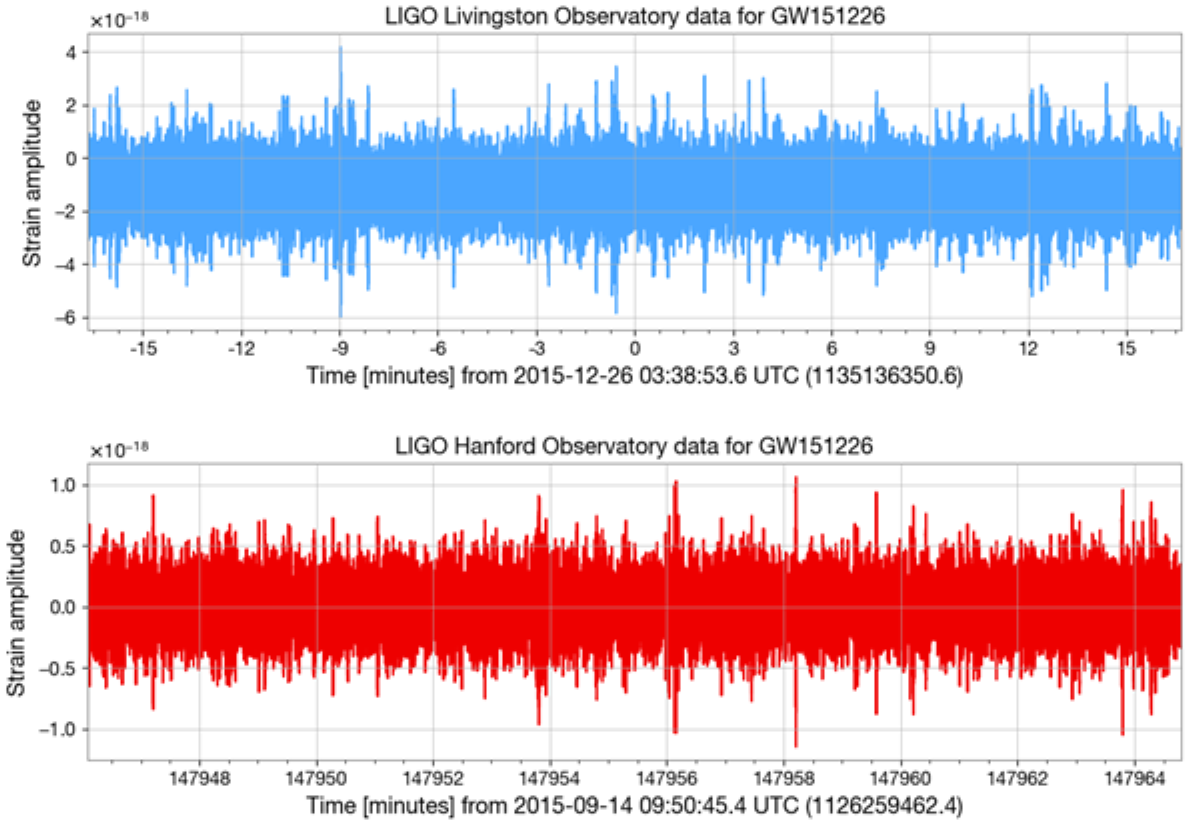
Correlation to GW150914 Hanford observation

- Correlation with a scan over chirp mass from 10 to 40 solar mass with step of 1 solar mass
    - Maximum SNR is found at chirp mass = 36 solar mass
- Second scan with chirp mass from 26 to 46 solar mass with step of 0.2 solar mass
    - Maximum SNR is found at chirp mass = 32.4 solar mass





Real detector data GW151226



Correlation to GW151226 observation

- With Livingston: scan over chirp mass from 5 to 60 solar mass with step of 1 solar mass
  - Maximum SNR is found at chirp mass = 40 solar mass
- With Hanford: problem encountered with correlation, still under investigation