Autoregressive Approach to Extract
Ring-down Gravitational Wave of Black-hole Merger

Outline & Summary

We apply an autoregressive (AR) model for identifying the ring-down part of gravitational wave of binary black-hole mergers. This approach enables us to extract signals without templates, and is effective for short-period data. After having experience of parameters using mock data, we apply to extract the ring-down frequency of the remnant black-hole of GW150914, GW170104, and GW170814, of which ring-down waves are expected to be included in LIGO data.

We find that AR analysis extracts ringdown part for GW150914 and GW170814 with consistent mass and spin of the remnant BH which were reported by LIGO/Virgo group. However, we failed for GW170104, which might be due to the small S/N (=13) compared to the others (S/N=23.7 & 18).

Example with mock data

Application to GW150914, GW170104, GW170814

We apply AR method for GW150914. We downsampled the data from the Ligo site\(^2\), of the 163-second data of 88 MHz sampling rate taken at both Hanford and Livingston observatories. We used the data from t = -8 to t = 22. We applied a bandpass filter for 100 Hz – 449 Hz, and made a segment of 1/1024 second (8 data points) shifting them with 1/1024 second (9 data points).

We then get the power spectrum \( \tilde{S}(f) \) from eq. (2) at each segment, and the number of its local maximum are less than 3 for the data 16.4 to 22.4. We name the frequencies \( f_N \) which give the local maximums of the spectrum. We also solve (6) at each segment (which is at most 30th order polynomial equation), and identify the solutions \( \ell_n \) which real part of frequency is mostly close to the one obtained \( f_N \). We list the solutions \( \ell_n \) of each segment which are candidates for ring-down modes, and check whether these candidates are within a close value over several segments. We found that sometimes a segment in 1/1024 second shows quite different numbers from estimative segments. We excluded such data if it shows the peak frequency is non-agenta apart from the line.

In result, we conclude that 4 segments of Hanford data (from t = 18.4258 to 16.4125), and 8 segments of Livingston data (from t = 18.4212 to 16.412) have a consistent frequency and damping rate. We obtain the ring-down frequency of the remnant BH of GW150814 as in Table 1. The results include the mean and std of the BH, which are consistent with the values reported originally\(^3\), as 0.24(11) M\(_\odot\) and a/M = 0.04(8) respectively.