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Detection and parameter estimation of ringdown signals using a pulsar timing array

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Gravitational wave (GW) searches using a pulsar timing array (PTA) are typically limited to the GW frequency $\leq 4\times10^{-7}$ Hz, due to the average observational cadence of 2 weeks for a single pulsar. By taking advantage of asynchronous observations of multiple pulsars, PTA has the potential to detect GW signals with frequencies higher than the Nyquist frequency of a single pulsar. An example of such a signal is the GWs from the ringdown phase of merging supermassive binary black holes (SMBHBs). In this work, we propose a likelihood-based method for detecting ringdown signals using a PTA. We consider only a single mode, i.e., the $(2,2)$ mode, to demonstrate our method. The ringdown waveform is modeled as an exponentially decaying sinusoidal signal, and its parameters are divided into extrinsic parameters and intrinsic parameters. The former ones are determined analytically, and the latter ones are determined numerically using particle swarm optimization (PSO). We show that for the optimal signal-to-noise ratio (SNR) $\rho = 10$ scenario, which corresponds, for example, to a SMBHB with chirp mass $M_c = 10^{10}M_\odot$ at a distance $D = 300$ Mpc, it has a detection probability of 99% if the threshold is set to be the highest detection statistic value obtained with the $\rho = 0$. For the same SNR, the parameter estimation errors are: $\sigma_\alpha \approx 4.8607^\circ$, $\sigma_\delta \approx 4.2476^\circ$ for sky localization, $\sigma_\omega \approx 7.3198$ rad/yr for angular frequency, $\sigma_\tau \approx 0.009838$ yr for ringdown timescale, and $\sigma_{t_0} \approx 9.54$ hr for the signal start time.

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