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The impact of a stochastic gravitational-wave background on pulsar timing parameters

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Gravitational waves are predicted by Einstein's theory of general relativity as well as other theories of gravity. The rotational stability of the fastest pulsars means that timing of an array of these objects can be used to detect and investigate gravitational waves. Simultaneously, however, pulsar timing is used to estimate spin period, period derivative, astrometric, and binary parameters. Here we calculate the effects that a stochastic background of gravitational waves has on pulsar timing parameters through the use of simulations and data from the millisecond pulsars PSR J0437--4715 and PSR J1713+0747. We show that the reported timing uncertainties become underestimated with increasing background amplitude by up to a factor of ~10 for a stochastic gravitational-wave background amplitude of $A=5\times 10^{-15}$, where A is the amplitude of the characteristic strain spectrum at one-year gravitational wave periods. We find evidence for prominent low-frequency spectral leakage in simulated data sets including a stochastic gravitational-wave background. We use these simulations along with independent Very Long Baseline Interferometry (VLBI) measurements of parallax to set a 2--sigma upper limit of $A\le9.1\times 10^{-14}$. We find that different supermassive black hole assembly scenarios do not have a significant effect on the calculated upper limits. We also test the effects that ultralow--frequency (10^{-12}--10^{-9} Hz) gravitational waves have on binary pulsar parameter measurements and find that the corruption of these parameters is less than those due to 10^{-9}--10^{-7} Hz gravitational waves.

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