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Bayesian model-emulation of stochastic gravitational-wave spectra for probes of the final-parsec problem with pulsar-timing arrays

STEPHEN TAYLOR, Jet Propulsion Laboratory, California Institute of Technology, JOSEPH SIMON, University of Wisconsin-Milwaukee, LAURA SAMPSON, CIERA, Northwestern University — The final parsec of supermassive black-hole binary evolution is subject to the complex interplay of stellar loss-cone scattering, circumbinary disk accretion, and gravitational-wave emission, with binary eccentricity affected by all of these. The strain spectrum of gravitational-waves in the pulsar-timing band thus encodes rich information about the binary population's response to these various environmental mechanisms. Current spectral models have heretofore followed basic analytic prescriptions, and attempt to investigate these final-parsec mechanisms in an indirect fashion. Here we describe a new technique to directly probe the environmental properties of supermassive black-hole binaries through "Bayesian model-emulation". We perform black-hole binary population synthesis simulations at a restricted set of environmental parameter combinations, compute the strain spectra from these, then train a Gaussian process to learn the shape of spectrum at any point in parameter space. We describe this technique, demonstrate its efficacy with a program of simulated datasets, then illustrate its power by directly constraining final-parsec physics in a Bayesian analysis of the NANOGrav 5-year dataset. The technique is fast, flexible, and robust.

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