

Eccentricity evolution consistency test to distinguish eccentric gravitational-wave signals from eccentricity mimickers

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Eccentric compact binary coalescences (CBCs) are expected to be observed in current and future gravitational-wave (GW) detector networks. Such detections are especially valuable as they can provide insights on the environments that nurture CBCs. However, it has been recently pointed out that a number of other physical and beyond-GR effects could imitate, or be mimicked by, eccentric CBCs. The standard approach to ascertain that a detected CBC is eccentric is to employ Bayesian model selection, where the eccentric CBC hypothesis is compared against other hypotheses. Such an approach is not only computationally intensive and time-consuming, but could also be misleading if none of the models under consideration represent the true model. In this work, we propose a conceptually simple but powerful method to directly confirm or reject the eccentric hypothesis, without needing to compare the hypothesis with the plethora of other possible hypotheses. The key idea is that while spurious nonzero values of eccentricity, at some reference frequency, could be acquired when a noneccentric CBC with additional physical/beyond-GR effects is recovered with an eccentric CBC waveform model, the evolution of eccentricity with frequency will in general not be mimicked. We accordingly formulate an eccentricity evolution consistency test (EECT). The method compares the eccentricity recovered at some low frequency value (e.g., 10 Hz), evolved to higher frequencies assuming GR, with eccentricities recovered at those same higher frequencies. Discrepancy between the two eccentricities at any reference frequency would violate EECT and indicate the presence of a mimicker. As a proof of concept, assuming a few eccentric CBC systems, quasicircular CBCs with additional physics mimicking eccentricity, and an O4-like three-detector-network configuration, we demonstrate that our proposed method is indeed able to reject mimickers at $\geq 68\%$ confidence, while ensuring that truly eccentric CBCs satisfy EECT.

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