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LISA's Potential to Test the Kerr Hypothesis: Symmetry-Breaking Effects in Extreme-Mass-Ratio Inspirals

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Extreme-Mass-Ratio Inspirals (EMRIs) are one of the main sources of gravitational waves in the low-frequency band, where space-based detectors like LISA will operate. These systems consist of a stellar-mass compact object (sCO), known as the secondary object—typically a neutron star or a stellar-mass black hole—orbiting a massive black hole (MBH), the primary, in an evolutionary phase dominated by gravitational-wave emission. Due to their high precision as gravitational-wave sources, EMRIs provide a powerful framework in which to perform fundamental physics studies, such as probing the nature of the primary object and checking whether it corresponds to a Kerr black hole or a more exotic compact object.

In this work, we take advantage of the rich multipolar structure of self-gravitating bodies beyond the constraints imposed by General Relativity for black holes. We analyze the impact of gravitational radiation on generic orbits around a primary object modified by an arbitrary mass quadrupole and its non-axisymmetric component, as well as a mass octupole and its non-axisymmetric component, at leading post-Newtonian order and linear order in the mass ratio.

For this study, we use the Analytic Kludge waveform model and perform parameter estimation via Fisher analysis for our extended parameter space. We evaluate how accurately LISA will constrain the non-axisymmetric mass quadrupole and octupole moments, providing insights into the detector's ability to detect symmetry-breaking effects. This analysis will shed light on LISA's potential to probe deviations from the Kerr hypothesis.

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