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A multi-parameter expansion for Extreme Mass Ratio Inspirals in astrophysical environments

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Asymmetric binaries have attracted increasing attention as golden sources for probing the astrophysical environment in which they evolve. Black holes do not exist in isolation; they inhabit diverse environments where particles and fields, possible of unknown nature, interact with each others and with compact objects. For example, massive BHs are surrounded by accreting matter, dark matter halos, which may consist of exotic fields or beyond-standard-model candidates. Moving beyond vacuum general relativity presents significant challenges due to the lack of relativistic solutions describing BHs embedded in matter and the complexities introduced by metric-matter couplings. As a result, modeling environmental effects on extreme mass ratio inspirals often relies on post-Newtonian approaches, though fully relativistic descriptions remain key to confidently extract small deviation from vacuum predictions. I along with Prof. Andrea Maselli, develope a multi-parameter framework to describe environmental effects on BHs, where the surrounding matter is modeled as a fluid stress-energy tensor. We adopt a general anisotropic prescription, incorporating both radial and tangential pressure components. We compute axial and polar perturbations at first order in the mass ratio, induced by the secondary on the geometry of a non-rotating BH embedded in an environment. We discuss practical, ready-to-use expressions for computing gravitational and fluid perturbations, as well as the resulting GW emission, as functions of environmental parameters and the secondary's orbital motion.

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