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Model-agnostic inspiral tests of the multipolar structure and tidal properties of a Kerr Black Hole

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The groundbreaking discovery of Gravitational Wave (GW) astronomy in the past decade has significantly advanced our understanding of the gravitational interaction in extreme gravity environments. One of the key scientific goals of future ground-based GW detectors like the Einstein Telescope (ET) is to test Einstein' s theory of General Relativity (GR) and explore the nature of GW sources, such as compact objects; holding extraordinary potential for breakthroughs in astrophysics, cosmology, and fundamental physics.
This work mainly focuses on a test of gravity in the extreme regime, more precisely on a forecast for parametrized deviations to the inspiral phase of the GW signal emitted by compact binary coalescing systems as predicted by GR. Several Parameter Estimation (PE) codes tuned toward future detectors, such as gwfish, are based on the Fisher Information Matrix formalism and designed to investigate and compare the PE capabilities of different detector networks. The main goal of this project is to evaluate statistical constraints expected from ET on possible modifications to GR, exploiting and generalizing gwfish. Beginning with state-of-the-art GR templates, such as TaylorF2, we explore model-agnostic deviations from the multipolar structure and tidal properties of a Kerr black hole predicted by GR.
By leveraging gwfish flexibility in terms of detector network simulations, we explore how the predicted constraints from ET can improve by roughly an order of magnitude compared to even anticipated future interferometers, such as Advanced LIGO in its fifth observing run, and the results with the 15 km-2L configuration are better than those with a 10 km-triangular configuration by a factor of a few. Additionally, to ensure confidence in our results, we compare them to a parallel full Bayesian analysis performed with bilby, and we investigate the ET capability of breaking correlations among parameters, or parametrized GR deviations, entering the GW phase.

Author: AGAPITO, Alessandro

Co-authors: Prof. MASELLI, Andrea (Gran Sasso Science Institute); Dr CRESCIMBENI, Francesco (Sapienza University of Rome); Prof. PANI, Paolo (Sapienza University of Rome)

Presenter: AGAPITO, Alessandro

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