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Post-adiabatic approximation for gravitational wave inspirals

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The most accurate semi-analytical models for gravitational wave models for compact binaries are based on the effective-one-body (EOB) approach and calibrated to numerical relativity (NR) simulations. These models are however too slow to be used in parameter estimation runs, when $\sim 10^7$ waveforms have to be generated. This has prompted the construction of surrogate models, based on the reduced-order modeling (ROM) technique, in order to shorten the waveform evaluation time.
The post-adiabatic approximation is used in state of the art EOB-NR models to generate initial conditions with low eccentricity. In arxiv:1805.03891, this approximation has been extended and used to determine the complete dynamics of the binary system. This avoids the numerical solution of two of the four Hamilton's equations (for non-precessing systems), which constitutes the main contribution to the waveform computation cost.
In practice, one can analytically compute the momenta of the system at any given radius, under the approximation that the gravitational wave flux is small. The time and orbital phase are then recovered by means of numerical quadratures on a very sparse grid. In the regime where this approximation is no longer valid (tipically the last few orbits), it can be used to generate the initial conditions of the ordinary dynamics as done usually.
Using this approach, it is possible to evaluate a binary neutron star waveform from 10 Hz in 50 milliseconds, with respect to the ~ 1 second that we obtain numerically solving the four ordinary differential equations (these times refer to the TEOBResumS model). Even when this time-domain waveform is interpolated (using the standard GLS interpolator) on a uniform-in-time grid, the evaluation times become 0.37 and 1.7 seconds respectively.
The use of the post-adiabatic approximation hence drastically reduces the computational cost of EOB-NR models while retaining their full flexibility. This makes it possible to directly use the best available semi-analytical models in parameter estimation runs and, above all, tests of general relativity.
This approach should be adaptable to the case of eccentric binaries and would be of certain use for extreme mass ratio inspirals that will be detected by LISA.

Summary

Presentation of the post-adiabatic approximation.
This is an analytical method used to reduce evaluation times of gravitational wave models.

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