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Time-symmetric integration and discontinuous collocation methods for self-force applications

The scheduled launch of the LISA Mission has called attention to the gravitational self-force problem. Accurate long-time numerical computations of gravitational waves from extreme-mass-ratio-inspirals (EMRI) remain challenging. First, we discuss a class of evolution schemes suitable to this problem based on Hermite integration. Their time-reversal symmetry and unconditional stability allows such methods to accurately track radiative energy loss over long time periods. We apply these methods to the linearized Einstein equations governing black hole perturbation theory. We solve the Bardeen-Press-Teukolsky and Regge-Wheeler-Zerilli equations in the time domain, describing perturbations on a Schwarzschild black hole background, and show that Noether charges and symplectic structure associated with these equations are numerically conserved by time-symmetric methods (but not by explicit methods, such as Runge-Kutta). Second, in a method of lines framework, we combine time-symmetric integration with a discontinuous collocation method, and solve the black hole perturbation equations sourced by a particle inspiralling into a massive black hole. We demonstrate that the symplectic structure of EMRI waveforms extracted at scri+ is preserved by time-symmetric methods.

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