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Experimental mathematics meets gravitational self-force: Using a high-accuracy numerical computation to obtain analytic forms for the post-Newtonian expansion of the redshift invariant to 11.5PN and beyond

NATHAN JOHNSON-MCDANIEL, International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, ABHAY SHAH, Mathematical Sciences, University of Southampton, BERNARD WHITING, Institute for Fundamental Theory, Department of Physics, University of Florida — The redshift invariant of a point particle in a circular orbit about a black hole gives the linear-in-mass-ratio portion of the binding energy of a circular binary with arbitrary mass ratio. This binding energy, in turn, encodes the system's conservative dynamics. We demonstrate how one can obtain analytic forms for high-order post-Newtonian (PN) coefficients of the redshift invariant for a circular orbit in Schwarzschild from high-accuracy numerical self-force results (over 1000 digits). Using this method, we improve the analytic knowledge of these coefficients to at least 11.5PN from the previously known 8.5PN. At these high orders, an individual coefficient can have over 30 terms, including a wide variety of transcendental numbers, when written out in full. We are still able to obtain analytic forms for such coefficients from the numerical data through a careful study of the structure of the expansion. We also obtain numerical values for even higher-order coefficients. The additional terms in the expansion we obtain improve the accuracy of the PN series for the redshift observable, even in the very strong-field regime inside the innermost stable circular orbit. The structure we find also allows us to predict certain "leading logarithm"-type contributions to all orders.

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