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Effective potentials and morphological transitions for binary black-hole spin precession MICHAEL KESDEN, University of Texas at Dallas, DAVIDE GEROSA, University of Cambridge, RICHARD O'SHAUGHNESSY, Rochester Institute of Technology, EMANUELE BERTI, University of Mississippi, ULRICH SPERHAKE, University of Cambridge — We derive an effective potential $\xi_{\pm}(S)$ for binary black-hole (BBH) spin precession as a function of the magnitude of the total spin S. This allows us to solve the 2PN orbit-averaged spin-precession equations analytically for arbitrary BBH mass ratios and spins. These solutions are quasiperiodic functions of time: after a period τ the spins return to their initial relative orientations and precess about the total angular momentum by an angle α. We classify BBH spin precession into three distinct morphologies between which BBHs can transition during their inspiral. Our new solutions constitute fundamental progress in our understanding of BBH spin precession and also have important applications to astrophysical BBHs. We derive a precession-averaged evolution equation for the total angular momentum that can be integrated on the radiation-reaction time, allowing us to statistically track BBH spins from formation to merger far more efficiently than was possible with previous orbit-averaged precession equations. This will greatly help us predict the signatures of BBH formation in the GWs emitted near merger and the distributions of final spins and gravitational recoils. The solutions may also help efforts to model and interpret GWs from generic BBH mergers.

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