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Spin precession across timescales

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The dynamics of precessing black-hole binaries in the post-Newtonian regime is deeply characterized by a timescale hierarchy: the orbital timescale is short compared to the spin-precession timescale which, in turn, is shorter than the radiation-reaction timescale on which the orbit is shrinking due to gravitational-wave emission. I present the development of a generic multi-timescale analysis that averages the dynamics over both the orbital and the precessional motions. Spin-precession cones can be treated "as a whole", without tracking the spin's secular motion. These solutions improve our understanding of spin precession in much the same way that the conical sections for Keplerian orbits provide additional insights beyond Newton's 1/r^2 law. Over the years, our multi-timescale approach led to an explosion of new predictions ranging from spin morphologies to new dynamical instabilities, resonances, and maximal nutations. Our multi-timescale solutions are now at the backbone of some state-of-the-art waveform templates used in gravitational-wave parameter estimation. Recent progress includes extensions to eccentric sources, and reconstructions of spin effects in both simulated and real gravitational-wave data.

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