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Circular equatorial orbits of extended bodies with spin-induced quadrupole around a Kerr black hole

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The worldline of an extended body in curved spacetime can be described by the Mathisson-Papapetrou-Dixon equations when its centroid, i.e., its center of mass, is fixed by a spin supplementary condition (SSC). Different SSC choices result in distinct worldlines. To examine the properties of these choices, we investigate the frequency of circular equatorial orbits of extended bodies within the pole-dipole-(spin-induced) quadrupole approximation moving around a Kerr black hole for the Tulzcyjew-Dixon (TD) and the Mathisson-Pirani (MP) SSCs. First, we examine similarities and discrepancies in the prograde and retrograde orbital frequencies by expanding these frequencies in power series of the spin without taking into account the fact that both the position of the centroid and the spin measure change under the transition from one SSC to another. Then, by taking into account the centroid transition laws, we examine the orbital frequencies convergence between the non-helical MP frame and the TD frame. In particular, we demonstrate that, in analogy to the pole-dipole approximation, the transition from one circular orbit to another within the pole-dipole-(spin-induced)quadrupole approximation under a change in the SSC, results in convergence between the SSCs only up to certain terms in the spin expansion and does not extend to the entire power series. Finally, we discuss the innermost stable circular orbits (ISCOs) in the pole-dipole-(spin-induced)quadrupole approximation under TD and MP SSCs.

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