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Analytical computation of quasi-normal modes of slowly-rotating black-holes in dCS gravity

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Following the direct detection of gravitational waves, modification to General Relativity (GR) at strong gravity regimes is one of the most important aspects of gravity research. Chern Simons (CS) gravity is one of the most frequently studied parity-violating models of strong gravity. CS gravity is indistinguishable from GR for all conformally flat space-times and for space-times that possess a maximally symmetric 2-dimensional subspace. Also, it is known that the Kerr black-hole is not a solution for CS gravity. At the same time, the only rotating solution available in the literature for dynamical CS (dCS) gravity is the slow-rotating case. In this work, for the slow-rotating case, we derive the linear perturbation equations governing the metric and the dCS field accurate to linear order in spin and quadratic order in the CS coupling parameter (α) and obtain the quasi-normal mode (QNM) frequencies. After confirming the recent results of Wagle et al. [arXiv 2103.09913], we find an additional contribution to the eigenfrequency correction at the leading perturbative order of α^2. Unlike Wagle et al., we also find corrections to frequencies in the polar sector. We compute these extra corrections by evaluating the expectation values of the perturbative potential on unperturbed QNM wavefunctions along a contour deformed into the complex-r plane. For $\alpha = 0.1M^2$, we find the ratio of the imaginary parts of the dCS correction to the purely GR correction in the first QNM frequency (in the polar sector) to be 0.263 implying a significant change. Also, for the $(l, m) = (2, 2)$ mode, the dCS corrections make imaginary part of the first QNM of the fundamental mode less negative, thereby decreasing the decay rate. Our results, along with future gravitational wave observations, can be used as a test for dCS gravity and to further constrain the CS coupling parameter values.

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