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# A Rutherford-like formula for scattering off Kerr-Newman BHs and subleading corrections

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Analytic methods for studying gravitational processes have received review interest due to their application to gravitational wave phenomenology. In this direction, one of the challenges is to develop a systematic apparatus to obtain the dynamics of spinning objects from the classical limit of quantum scattering amplitudes. Exploring the Kerr-Schild gauge properties seems promising, and within this framework we study the scattering of a massive (charged) scalar off a Kerr-Newman black hole. In this gauge, the interactions between the probe and the target involve only tri-linear vertices, and we manage to write down the tree-level scattering amplitudes in analytic form, from which we can construct an expression for the eikonal phase which is exact in the spin of the black hole at arbitrary order in the Post-Minkowskian expansion. We compute the classical contribution to the cross-section and deflection angle at leading order for a Kerr black hole for arbitrary orientation of the spin. Finally, we test our method by reproducing the classical amplitude for a Schwarzschild black hole at second Post-Minkowskian order and outline how to extend the analysis to the Kerr-Newman case.

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