Contribution ID : **11** Type : **not specified**

Correspondence of eikonal quasinormal modes and unstable fundamental photon orbits for Kerr-Newman black hole

Sunday, 26 September 2021 15:30 (30)

In this work, we study the relation of the eikonal quasinormal modes (EQNMs) and the unstable fundamental photon orbits (UFPOs) in the Kerr-Newman spacetime. We find that in the eikonal limit the gravitational and electromagnetic perturbations of the KerrNewman black hole are naturally decoupled, and a single one-dimensional Schr¨odinger-like equation encoding the QNM spectrum can be derived. We then show that the decoupled Teukolsky master equation and the Klein-Gordon equation for the massless scalar field in the Kerr-Newman spacetime are of the same form in the eikonal limit. As a direct consequence, taking into account of the boundary conditions for EQNMs we show an exact correspondence between EQNMs and UFPOs, that is, EQNM/UFPO correspondence. More precisely, similar to the Kerr case, the real part of EQNM's frequency is a linear combination of the precessional and (polar) orbital frequencies, while the imaginary part of the frequency is proportional to the Lyapunov exponent of the UFPO.

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