Quasinormal modes of Proca field perturbations in higher-dimensional Schwarzschild-AdS spacetimes

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Abstract

A Proca field is a massive spin 1 field and can thus be viewed as the generalization of the Maxwell field. The former contains an additional degree of freedom, resulting in a dynamics more involved to address. In d-dimensional spherically symmetric black hole spacetimes, the Proca field equations can be separated into two distinct sectors, according to the tensorial behavior of the field components on the (d-2)-sphere. One sector is vector type, with all the d-3 components governed by the same wave-like equation that describes the d-3 vector-type degrees of freedom of the field. The other sector is scalar type, governed by two coupled wave-like equations and describing the remaining two degrees of freedom of the field. In order to better understand this scalar sector, we show that the two degrees of freedom can be distinguished in the massless limit, i.e., in the Maxwell field case, where there is a pure gauge degree of freedom that obeys a Klein-Gordon equation and there is a Maxwell physical degree of freedom that obeys the scalar-type Maxwell field equation. Once this distinction is made, one can uncover, by back propagation inference, which of the two coupled Proca field modes is the one that gives the spurious gauge mode and which is the one that is going to yield the physical mode in the Maxwell limit. The stability of the d-dimensional Schwarzschild-anti de Sitter (Schwarzschild-AdS) spacetime against vector-type and monopole perturbations of the Proca field is then analyzed, and it is proved using a technique, called the S-deformation technique, that makes use of a suitably defined effective potential, that the spacetime is stable to these perturbations. Imposing Dirichlet boundary conditions at spatial infinity, we obtain numerically, the quasinormal mode spectrum of Proca field perturbations in 4,5,6,7-dimensional Schwarzschild-AdS spacetime, with two dfferent methods. One method uses the Horowitz-Hubeny prescription, the other method resorts to integrating the equations of motion. The dependencies of the spectrum with the black hole radius, and with the mass, the overtone number, and the angular momentum number of the field are studied. Additionally, an analytical quasinormal mode analysis for small Schwarzschild-AdS black holes is performed by matching asymptotic expansions of the solutions in an overlapping region.

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