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Charged Scalar Hair on Reissner-Nordström Black Holes

The Israel-Carter theorem (famously known as “no-hair theorem”) puts a restriction on the existence of parameters other than mass, electric charge, and angular momentum of a black hole. On the other hand, Bekenstein showed the possibility of existence of scalar hair by considering a massless conformal scalar field non-minimally coupled to gravity. The Einstein-Maxwell-scalar solution for a static spherically symmetric metric was found to be unbounded at the horizon. Bekenstein’s study established scalar charges, like other parameters allowed by the no-hair theorem, to be also admissible in black hole solutions. There also exists a new family of Einstein-Maxwell-scalar field models where the scalar field is non-minimally coupled with the Maxwell field.

In the present work, we consider a novel Einstein-Maxwell-scalar model where an electrically charged scalar field is gauge-coupled with the Maxwell field, generating interaction of the charge e with the electromagnetic field, described by the action

S=$\int d^4x\sqrt{-g}\left[\frac{R}{16\pi G}-(D_\mu\phi)^*\,D^\mu\phi-\mu^2\phi^*\phi-\frac{1}{4}F_{\mu\nu}F^{\mu\nu}\right] where \mathrm{D}_\mu=\partial_\mu+ieA_\mu$ is the covariant derivative, μ is the mass of the scalar field, and $F_{\mu\nu}=\partial_\mu A_\nu-\partial_\nu A_\mu$, with A_μ the vector potential.

Detailed solution of this Einstein-Maxwell-scalar model in the background of a static spherically symmetric Reissner-Nordstr\”om spacetime yields a charged hairy black hole solution. A stability analysis shows that this charged hair is stable against time-dependent perturbations.

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