

# Nonminimal coupling for the gravitational and electromagnetic fields: Black hole solutions and solitons

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## Abstract

Using a Lagrangian formalism, a three-parameter nonminimal Einstein-Maxwell theory is established. The three parameters  $q_1$ ,  $q_2$ , and  $q_3$  characterize the cross-terms in the Lagrangian, between the Maxwell field and terms linear in the Ricci scalar, Ricci tensor, and Riemann tensor, respectively. Static spherically symmetric equations are set up, and the three parameters are interrelated and chosen so that effectively the system reduces to a one parameter only,  $q$ . Specific black hole and other type of one-parameter solutions are studied. First, as a preparation, the Reissner-Nordström solution, with  $q_1=q_2=q_3=0$ , is displayed. Then, we search for solutions in which the electric field is regular everywhere as well as asymptotically Coulombian, and the metric potentials are regular at the center as well as asymptotically flat. In this context, the one-parameter model with  $q_1\equiv-q$ ,  $q_2=2q$ ,  $q_3=-q$ , called the Gauss-Bonnet model, is analyzed in detail. The study is done through the solution of the Abel equation (the key equation), and the dynamical system associated with the model. There is extra focus on an exact solution of the model and its critical properties. Finally, an exactly integrable one-parameter model, with  $q_1\equiv-q$ ,  $q_2=q$ ,  $q_3=0$ , is considered also in detail. A special submodel, in which the Fibonacci number appears naturally, of this one-parameter model is shown, and the corresponding exact solution is presented. Interestingly enough, it is a soliton of the theory, the Fibonacci soliton, without horizons and with a mild conical singularity at the center. © 2008 The American Physical Society.

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