Physical black holes in modified theories of gravity

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The existence of black holes is a central prediction of general relativity and thus serves as a basic consistency test for modified theories of gravity. In spherical symmetry, only two classes of dynamic solutions to the semiclassical Einstein equations are compatible with the formation of an apparent horizon in finite time of a distant observer. Moreover, the formation of black holes follows a unique scenario involving both types of solutions. To be compatible with their existence, any self-consistent theory of modified gravity must satisfy several constraints. We find that modified gravity theories involving up to fourth-order derivatives in the metric generically satisfy all constraints and thus naturally accommodate both classes of solutions, which can be regarded as zeroth-order terms in perturbative solutions of these models. In addition, we explicitly identify a class of non-perturbative solutions. Consequently, the observation of an apparent horizon by itself may not suffice to distinguish between the predictions of general relativity and fourth-order gravity theories.

[1] S. Murk and D. R. Terno, *Phys. Rev. D* **104**, 064048 (2021) [arXiv:2012.11209].

[2] S. Murk, *Phys. Rev. D* **105**, 044051 (2022) [arXiv:2110.14973].

[3] S. Murk, arXiv:2111.00776.