Testing the Kerr hypothesis: the examples of synchronisation and scalarization

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The Kerr hypothesis states that astrophysical black hole candidates are well described by the Kerr metric. Theoretically, this hypothesis is based on the uniqueness theorems for electro-vacuum, which led to the mantra that "Black Holes have no hair", meaning there are no macroscopic degrees of freedom other than the ones associated to Gauss laws. Yet, there are many known hairy BH solutions. Then, the real question is, can a hairy black hole form dynamically and be sufficiently stable? I will describe two different models wherein asymptotically flat black holes with scalar hair form dynamically from instabilities of electro-vacuum black holes. In the first model, Kerr black holes are unstable, via superradiance, against the formation of hair when in the presence of a sufficiently light, massive scalar field. If the scalar field is, moreover, complex, then an entropically favoured stationary hairy black hole solution exists, which has been shown to form dynamically, via fully non-linear numerical simulations. This is not the end point of the process but can be very long lived. In the second model, Kerr black holes are unstable, via a tachyonic instability, against the formation of hair when in the presence of a real massless scalar field non-minimally coupled to the Gauss-Bonnet combination. These are also entropically favoured hairy black holes. In a toy model they can be shown to form dynamically, via fully nonlinear numerical simulations and appear to be the endpoint of the instability. I will comment on the phenomenology and implications of these (apparently) dynamically viable hairy black holes.