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Understanding ghosts in scalar-tensor theories of gravity

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Pushing beyond the boundaries of general relativity has long been a major goal in both theoretical and experimental physics, especially in the pursuit of a quantum theory of gravity and the explanation of cosmological phenomena like dark energy and cosmic acceleration. Constructing modified gravity models often leads to additional degrees of freedom, but these can also introduce problematic, non-physical elements, such as "ghosts" and Ostrogradsky instabilities. Such instabilities render the theory unviable by causing unboundedness in the Hamiltonian, leading to the breakdown of predictability.
In this work, we investigate the nature and origin of ghost instabilities within scalar-tensor theories of gravity. We begin with simple toy models, which serve as a controlled environment for understanding the mechanisms by which ghost degrees of freedom emerge. These models help illustrate how adding higher-order derivative terms or modifying the kinetic structure can lead to the appearance of ghosts, even when the theory initially seems stable. The final aim is to progressively go to R+f(G) Gauss-Bonnet gravity and see why, in opposition with f(R) models, there are ghosts in these theories.

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