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Stability of monopole perturbations in Horndeski theory on a dynamical spherically symmetric background

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Constructing physically viable models within Horndeski and Beyond Horndeski theories requires strict checks to avoid ghost and gradient instabilities, yet the corresponding stability constraints for dynamical spherically symmetric backgrounds remain incomplete. Previous studies of perturbations over such backgrounds focused exclusively on the odd-parity sector, which yields stability conditions solely for the tensor (gravitational) mode. Consequently, the behavior of the scalar degree of freedom remained unconstrained.

In this work, we address this gap by investigating the even-parity sector of perturbations in both Horndeski and Beyond Horndeski gravity over a general time-dependent, spherically symmetric background. By utilizing the Regge-Wheeler formalism and focusing on monopole ($\ell = 0$) perturbations, we isolate the dynamics of the scalar degree of freedom. We successfully integrate out non-dynamical fields and derive the explicit quadratic action for the remaining physical scalar mode.

As a main result, we obtain exact no-ghost and gradient stability conditions, as well as the expression for the radial propagation speed of the scalar mode. These novel constraints strictly limit the scalar sector and complement the previously known tensor-mode conditions from the odd sector. Together, they establish a stringent theoretical framework for the parameter space of Horndeski and Beyond Horndeski theories, which is essential for building physically consistent astrophysical and cosmological models.

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