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Effective gravitational couplings for cosmological perturbations in generalized Proca theories

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We consider the finite interactions of the generalized Proca theory including the sixth-order Lagrangian and derive the full linear perturbation equations of motion on the flat Friedmann-Lema\^{i}tre-Robertson-Walker background in the presence of a matter perfect fluid.
By construction, the propagating degrees of freedom (besides the matter perfect fluid) are two transverse vector perturbations, one longitudinal scalar, and two tensor polarizations.
The Lagrangians associated with intrinsic vector modes neither affect the background equations of motion nor the second-order action of tensor perturbations, but they do give rise to non-trivial modifications to the no-ghost condition of vector perturbations and to the propagation speeds of vector and scalar perturbations.
We derive the effective gravitational coupling $G_{\rm eff}$ with matter density perturbations under a quasi-static approximation on scales deep inside the sound horizon.
We find that the existence of intrinsic vector modes allows a possibility for reducing $G_{\rm eff}$. In fact, within the parameter space, $G_{\rm eff}$ can be even smaller than the Newton gravitational constant G at the late cosmological epoch, with a peculiar phantom dark energy equation of state (without ghosts). The modifications to the slip parameter η and the evolution of growth rate $f\sigma_8$ are discussed as well.
Thus, dark energy models in the framework of generalized Proca theories can be observationally distinguished from the ΛCDM model according to both cosmic growth and expansion history. Furthermore, we study the evolution of vector perturbations and show that outside the vector sound horizon the perturbations are nearly frozen and start to decay with oscillations after the horizon entry.

Summary

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