Probing gravity at cosmic scales

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SUMMARY

The theoretical explanation of cosmic acceleration is nowadays one of the biggest puzzles in cosmology. Within the standard cosmological model (ΛCDM) the expansion is sourced by the vacuum energy associated to the Cosmological Constant Λ. Despite its simplicity, the Cosmological Constant presents various unresolved problems from both the theoretical and the observational side. The theoretical inconsistency resides in the 60 orders of magnitudes difference between the observed value of Λ and its expected value within the Standard Model. As for the observations, a few unresolved tensions between high and low redshift datasets seem to support the thesis that we need a new theoretical explanation of gravity at cosmological scales.

However, even if we dismiss these puzzles, the study of theoretical alternatives to ΛCDM is still of primary importance. In fact, the wealth and quality of cosmological data that we are expecting for the next decade will allow us to test gravity on cosmological scales with unprecedented accuracy. This will give us the chance to investigate many of our theoretical ideas and to assess the strength of the standard model of cosmology on the largest scales.

In this thesis we present different approaches that we can adopt to study modifications of gravity by means of cosmology. In Chapter 2, we consider the example of a simple quintessence fluid which modifies the cosmological expansion through a parametrization of the Dark Energy equation of state w_{DE}. The simplicity of the approach allows us to illustrate the importance of taking into account the theory when dealing with phenomenological parametrization. This is done by means of specific criteria of theoretical stability which have a direct impact on the parameter space of the models.

This idea is further developed in Chapter 3, where we used stability conditions in order to build large numerical samples of viable Horndeski models. Such samples allow us to study the typical phenomenology of scalar-tensor theories through the analysis of the phenomenological functions Σ and μ, which describe the deviations in the lensing and Poisson equation respectively. We are then able to build correlation matrices that can be used as correlation priors in order to reconstruct Σ and μ from data in a model-independent, but yet theoretically informed, way.

Finally, in Chapter 4, we present the full analysis of a Dark Energy model in the context of Gleyzes-Langlois-Piazza-Vernizzi theories. We analyse the observational signatures and then perform a Monte Carlo Markov Chains analysis in order to constrain its parameter space with data, including cosmic microwave background, baryonic acoustic oscillations, redshift space distortions and supernovae measurements. Finally, we are able to conclude that the Horndeski limit of this model, known as Galileon Ghost Condensate, is favoured by the data over ΛCDM.