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Energy Condition Bounds in $f(R)$ Theories for Observational Confrontation: An Application to the Hu-Sawicki Model

Observational data suggest a recent accelerated expansion of the universe. Within the framework of the Standard Model of Cosmology, such expansion is regarded as a consequence of dark energy. An alternative approach, however, involves geometric modifications to General Relativity, leading to modified theories of gravity. The energy conditions are a set of physical assumptions that impose constraints on the Ricci and energy-momentum tensors, which translate into inequalities when applied to some gravity theory. These constraints can be written in terms of cosmographic functions, such as the Hubble $H(z)$, the deceleration $q(z)$, the jerk $j(z)$ and the snap $s(z)$ functions, which can be reconstructed from observational data. In this work, we derive the equations of motion for a general $f(R)$ gravity model and evaluate the energy conditions within the Hu-Sawicki $f(R)$ theory, obtaining bounds for its parameters in terms of these cosmographic functions. We also find expressions for $j(z)$ and $s(z)$ in terms of $H(z)$, $q(z)$, and its derivatives. This provides a foundation for future comparisons with observational data through the reconstruction of such functions and, in this way, enables the imposition of observational constraints on the Hu-Sawicki $f(R)$ model parameters.

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