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$f(R)$ Dual Theories of Quintessence : Expansion-Collapse Duality

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The accelerated expansion of the universe demands presence of an exotic matter, namely the dark energy. Though the cosmological constant fits this role very well, a scalar field minimally coupled to gravity, or quintessence, can also be considered as a viable alternative for the cosmological constant. We study $f(R)$ gravity models which can lead to an effective description of dark energy implemented by quintessence fields in Einstein gravity, using the Einstein frame-Jordan frame duality. For a family of viable quintessence models, the reconstruction of the $f(R)$ function in the Jordan frame consists of two parts. We first obtain a perturbative solution of $f(R)$ in the Jordan frame, applicable near the present epoch. Second, we obtain an asymptotic solution for $f(R)$, consistent with the late time limit of the Einstein frame if the quintessence field drives the universe. We show that for certain class of viable quintessence models, the Jordan frame universe grows to a maximum finite size, after which it begins to collapse back. Thus, there is a possibility that in the late time limit where the Einstein frame universe continues to expand, the Jordan frame universe collapses. The condition for this expansion-collapse duality is then generalized to time varying equations of state models, taking into account the presence of non-relativistic matter or any other component in the Einstein frame universe. This mapping between an expanding geometry and a collapsing geometry at the field equation level may have interesting potential implications on the growth of perturbations therein at late times.

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