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Constraining parameters for the accelerating universe in $f(R, \mathcal{L}_m)$ Gravity

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Abstract. An accelerating cosmological model is developed within the framework of $f(R, \mathcal{L}_m)$ gravity, incorporating a functional form $(R, \mathcal{L}_m) = R/2 + \alpha R^2 + \mathcal{L}_m^\beta$, inspired by the Starobinsky model and power-law matter coupling [1, 2]. The field equations for a flat FLRW Universe are derived, and the Hubble parameter is constrained using Hubble and Pantheon+ datasets via MCMC simulation. Observational data yield $q_0 \approx -0.63$, indicating a late-time accelerating Universe with a transition redshift $z \approx 0.7$. The present values of the jerk and snap parameters are $j_0 \approx 0.78$ and $s_0 \approx 0.1$, respectively, suggesting a quintessence phase. Diagnostic tests, including state-finder and $\text{Om}(z)$, affirm the model's convergence towards ΛCDM . The age of the Universe is computed as $t_0 = 13.64$ Gyr, in good agreement with Planck results [3]. The analysis supports $f(R, \mathcal{L}_m)$ gravity as a viable alternative to study dark energy dynamics.

Keywords: modified gravity, $f(R, \mathcal{L}_m)$ gravity, dark energy, cosmological diagnostics, accelerating Universe, cosmography

Introduction. This study focuses on the modified gravity theory $f(R, \mathcal{L}_m)$ [4], a generalized form of $f(R)$ gravity, where an explicit coupling between the Ricci scalar R and matter Lagrangian $\mathcal{L}_m$ is introduced. The motivation stems from the need to explain the accelerating expansion of the Universe as supported by observational data from Type Ia supernovae, CMB anisotropies, and large-scale structure. In contrast to the ΛCDM model, $f(R, \mathcal{L}_m)$ gravity may address dark energy phenomena without invoking an explicit cosmological constant.

Methods and materials; results. Field equations are derived using the variational principle in a flat FLRW spacetime in $f(R, \mathcal{L}_m)$ gravity. We consider a specific functional form: $f(R, \mathcal{L}_m) = R/2 + \alpha R^2 + \mathcal{L}_m^\beta$. The model parameters are constrained using observational Hubble and Pantheon + datasets. Markov Chain Monte Carlo (MCMC) methods are used for parameter estimation. From this, the deceleration (q), jerk (j), and snap (s) parameters are computed. We find $q_0 \approx -0.63$ and a transition redshift $z \approx 0.7$, showing compatibility with an accelerating Universe. The EoS parameter at present epoch is $\omega_0 \approx -0.72$. Diagnostic tools including state-finder and $\text{Om}(z)$ indicate a quintessence-like nature, converging toward ΛCDM at late times. The age of the Universe calculated is $t_0 \approx 13.64$ Gyr.

Conclusion. The $f(R, \mathcal{L}_m)$ gravity model considered here offers a viable cosmological framework explaining late-time acceleration. The use of observational datasets in constraining the parameters reveals consistency with known cosmological behaviour. Cosmographic parameters and diagnostics like $\text{Om}(z)$ and state-finder support its closeness to ΛCDM at late epochs. Moreover, the age of the Universe as derived aligns closely with Planck mission estimates. Thus, the model presents a compelling alternative for understanding dark energy and cosmic dynamics [5].

References

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