Late-time Acceleration and Inflationary Dynamic in $f(Q, L_m)$ Gravity with RGUP Corrections

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Introduction & Objective

The Universe has experienced two periods of accelerated expansion: an early inflationary epoch and the current dark-energy-dominated era. These phases are usually explained through separate mechanisms which raises the question of whether a unified geometric description of cosmic evolution is possible.
In this work, we aimed to investigate the recently proposed $f(Q, L_m)$ gravity framework, where gravity is governed by non-metricity and directly coupled to matter. The late-time dynamics are reconstructed using Holographic Ricci Dark Energy (HRDE), while the high-curvature regime naturally generates a Starobinsky-like inflationary phase. We further examine the impact of Relativistic Generalized Uncertainty Principle (RGUP) corrections on inflationary observables.

Central Objective: To determine whether a single $f(Q, L_m)$ gravity model can accomodate both **early inflation** and **late-time acceleration** through different curvature regimes, while remaining consistent with current observations and quantum-gravity corrections.

Methodology

Framework:

$$f(Q, L_m) = -Q + \alpha Q^2 + 2L_m + \beta Q L_m$$

with

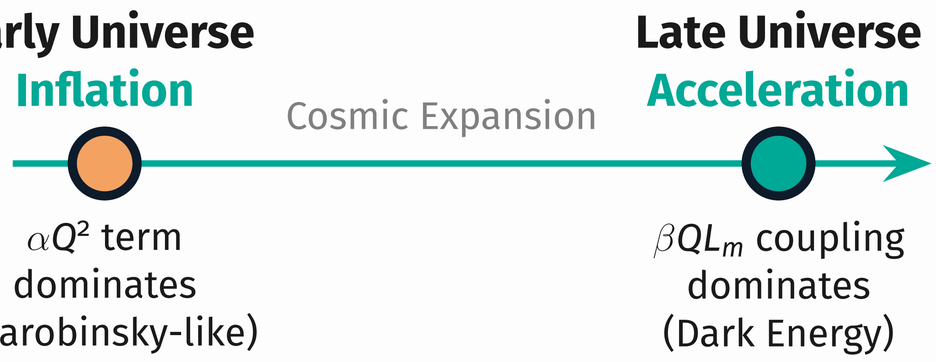
$$Q = 6H^2.$$

The late-time dynamics are reconstructed using Holographic Ricci Dark Energy (HRDE),

$$\rho_{\mathrm{HRDE}} = 3c^2(2H^2 + \dot{H}).$$

Analysis Procedure

1. Derived the modified Friedmann equations in $f(Q, L_m)$ gravity and reconstructed the cosmological evolution using HRDE.
2. Constrained the matter–geometry coupling parameter β using Pantheon, Cosmic Chronometer and DESI BAO datasets.
3. Studied inflationary dynamics.
4. Introduced Relativistic Generalized Uncertainty Principle(RGUP)-induced metric deformations and examined their impact on inflationary observables.



Late-Time Cosmology

ω_{eff} evolves from a quintessence regime ($\omega > -1$) to a transient phantom phase crossing the phantom divide smoothly and at late times, $\omega_{\mathrm{eff}} \to -1$, indicating an asymptotic de Sitter phase. The reconstructed $f(Q, L_m)$–HRDE model exhibits a viable late-time accelerated expansion history driven by the interplay between non-metricity corrections and matter–geometry coupling.

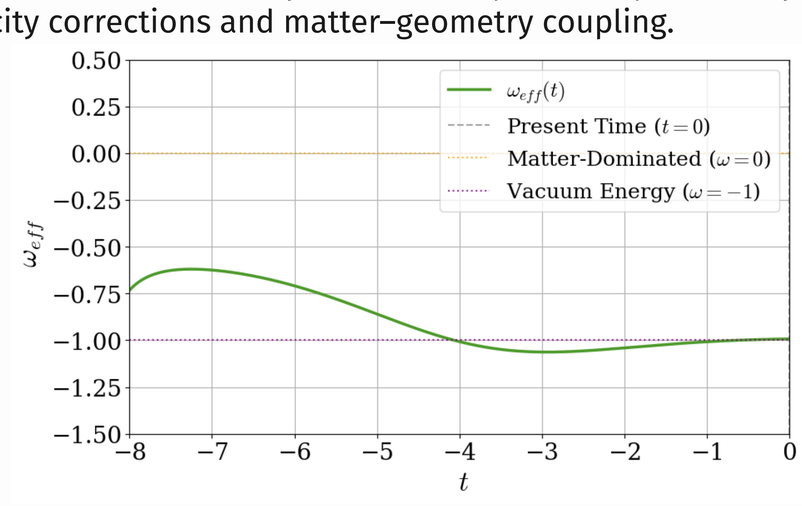


Figure 1: Evolution of the effective equation of state parameter against t in Gyrs.

Observational Constraints

Pantheon + CC + DESI BAO

- β remains weakly constrained.
- Posterior is consistent with ΛCDM (β = 0).
- Stronger constraints require future surveys.

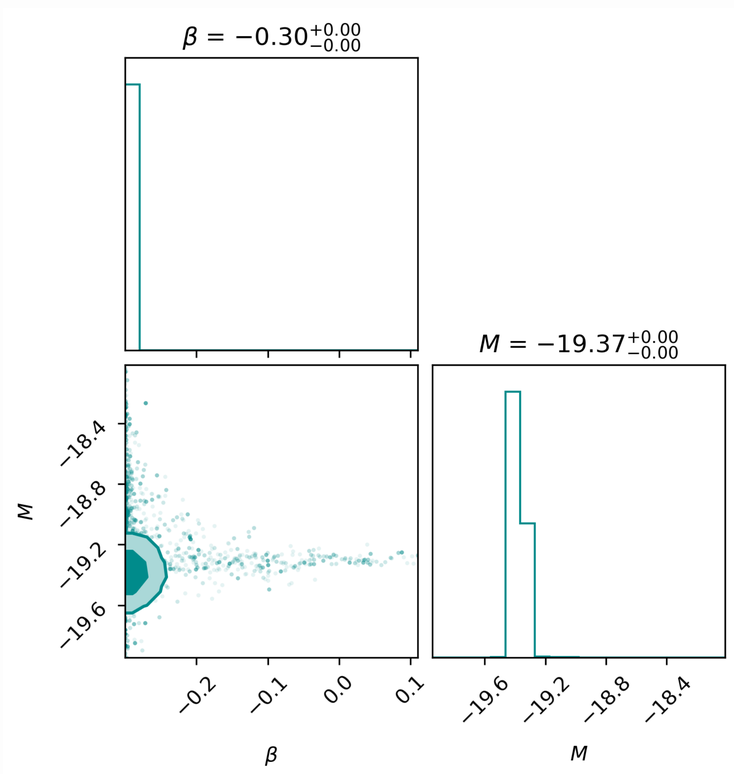


Figure 2: Corner plot for the parameters (β, M). The posterior shows strong degeneracy in β. This behaviour indicates that current late-time data do not meaningfully constrain the matter–geometry coupling.

Inflationary Dynamics & RGUP Effects

High-curvature domination (αQ^2) yields a Starobinsky-like inflationary phase. The predicted (n_s, r) values for $N = 50 - 60$ lie within the Planck 2018 allowed region.

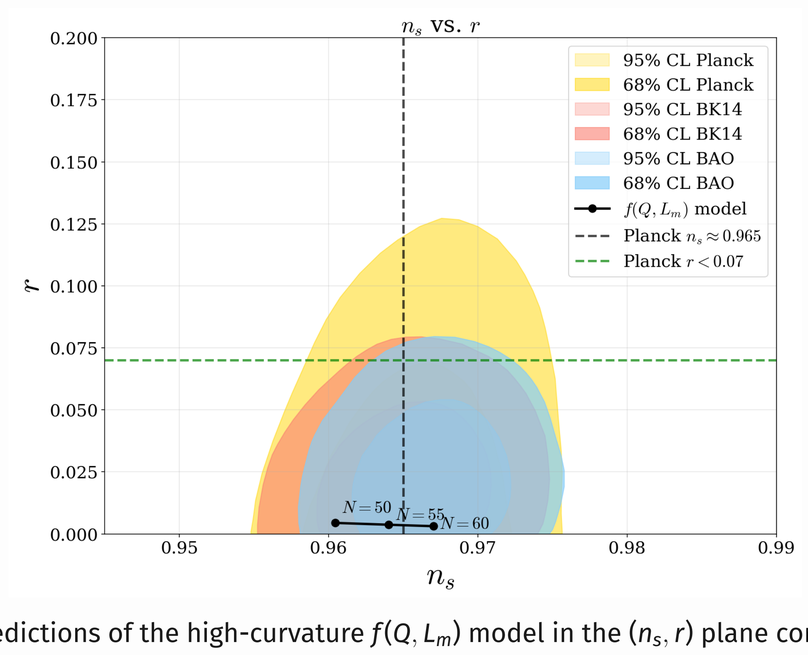


Figure 3: Predictions of the high-curvature $f(Q, L_m)$ model in the (n_s, r) plane compared with Planck 2018 constraints.

RGUP Effects: The geometric inflationary background remains unchanged, while quantum-gravity corrections induce a small shift in the running of the spectral index:

$$\alpha_s \simeq -0.00054.$$

Conclusions

- A single $f(Q, L_m)$ gravity framework successfully accommodates both inflation and late-time cosmic acceleration through different curvature regimes.
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- The high-curvature αQ^2 sector naturally generates Starobinsky-like inflation, while the matter–geometry coupling term $\beta Q L_m$ governs late-time dynamics.
- The model remains compatible with Planck 2018 observations.
- RGUP corrections preserve the geometric inflationary background while inducing small quantum-gravity signatures in higher-order observables. “‘