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Cosmological Dynamics in Covariant $f(Q)$ Gravity with Dynamical Coupling Functions

We investigate the cosmological dynamics of the Universe within the framework of covariant $f(Q)$ gravity by considering a dynamically evolving coupling function proportional to the Hubble parameter. Two representative models, namely power-law and logarithmic forms, are examined to explore their viability in describing the large-scale evolution of the Universe. The cosmological field equations are reformulated into an autonomous dynamical system, allowing a systematic analysis of the corresponding critical points and their stability properties. The dynamical analysis reveals that both models successfully reproduce the standard sequence of cosmic evolution, encompassing radiation, matter, and dark energy-dominated epochs, together with smooth transitions between these phases. The cosmological behavior at each equilibrium point is characterized through the total equation-of-state parameter, density parameters, and the deceleration parameter, providing a comprehensive understanding of the underlying dynamics. For non-hyperbolic critical points, the stability is further investigated using center manifold theory, enabling a rigorous assessment of their asymptotic behavior. Phase-space trajectories are presented to illustrate the global evolution of the system, while numerical evolution of the radiation, matter, and dark energy density parameters, together with the effective equation-of-state parameter, demonstrates consistency with the observed expansion history of the Universe. The results indicate that the considered covariant $f(Q)$ gravity models naturally accommodate the observed transition from decelerated to accelerated expansion without introducing additional exotic components. These findings highlight the potential of covariant $f(Q)$ gravity as a viable modified gravity framework for explaining the late-time acceleration of the Universe and provide new insights into the dynamical behavior of non-metricity-based cosmological models.

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