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Economy of Reusability of Future Cosmonautics and Issues of Efficiency

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Abstract. In this work, we have investigated the phase space analysis in modified Galileon cosmology, where the Galileon term is considered a coupled scalar field, $F(\phi)$. We focus on the exponential type function of $F(\phi)$ and the three well-motivated potential functions $V(\phi)$. We obtain the critical points of the autonomous system, along with their stability conditions and cosmological properties. The critical points of the autonomous system describe different phases of the Universe. The scaling solution for critical points was found in our analysis to determine the matter-dark energy and radiation-dark energy-dominated eras of the Universe. In these scaling solutions, dark energy is typically introduced alongside another component, such as radiation or matter, and helps explain the transition between cosmological eras. The dark energy dominated critical points show stable behavior and indicate the late-time cosmic acceleration phase of the Universe. Further, the results are examined with the Hubble rate $H(z)$ and the Supernovae Ia cosmological data sets.

Keywords: dynamical system analysis, late-time cosmic acceleration, stability, dynamical parameters, cosmological observation

Introduction. In recent years, several cosmological models have been proposed in modified gravity theories to address the issue of late-time cosmic phenomenon [1, 2] and in particular the resolution to Hubble tension issue [3]. Though several cosmological problems have been resolved in General Relativity (GR), some key issues still need to be addressed. Therefore, modification/extension in GR is inevitable. Someone can either modify the matter part or the underlying geometry. As part of the first approach, additional fields are introduced into the Universe, including canonical and phantom fields, vector and chiral fields, k-essence, etc. [4]. In the second approach, the geometry part is modified to produce modified/extended gravitational theories. The formalism of the modified gravity theory that produces second-order equations in four-dimensional space-time can originate from TEGR. A more interesting case could arise by introducing non-minimal coupling terms and higher derivative quantum gravity modifications in the action. A modification of this might take the form of

a field self-interaction of the Galileon type [5] in the form $G(\phi, X)$ where ϕ is an arbitrary function of ϕ and kinetic energy X . Based on the Dvali-Gabadadze-Porrati (DGP) model [6] decoupling limit and its cosmological implications, the Galileon theory was developed. In this article, we have studied late-time cosmic acceleration in modified Galileon theory through the dynamical system analysis.

Methods and materials; results. The dynamical system approach [7] is a potent technique that helps to explain the overall development and global dynamics of the Universe. A specific cosmological model may be expressed as an independent system of certain differential equations by carefully selecting the dynamical variables. This also provides a prompt response to whether the model can replicate the observed expansion of the Universe. First, we need to define the autonomous systems: $X' = f(X)$, where X is the column vector and prime (') denotes the derivative for $N = \log(a)$. For that, we propose the dimensionless variables to generate the relevant autonomous system associated with the set of cosmological equations. Through the behavior of the critical points of the autonomous system, we have obtained the different phases of the Universe, such as radiation-dominated, matter-dominated, stiff matter, and dark energy-dominated phases of the Universe.

Conclusion. We performed the phase space analysis for the exponential form of $F(\phi)$ with three well-motivated functions of potential $V(\phi)$. The cosmological parameters, such as EoS parameters, density parameters, and deceleration parameters, are obtained through the dynamical variables to analyze the cosmological features of the models. In all three cases, we have obtained the stable critical points that can describe the late-time cosmic accelerated phase of the Universe. We have also obtained scaling solutions for critical points. The points show that non-standard matter and radiation dominated eras of the Universe. We observe that the results obtained are similar to the standard quintessence model. We can conclude that the Galileon term has no contribution to the dark energy sector of the Universe. But there is the contribution of the Galileon term to the inflationary behavior of the Universe.

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