Parameter Estimation of Barrow Agegraphic and New Barrow Agegraphic Dark Energy Models in Fractal Universe: Correspondence with Scalar field Models

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In this work, we explore the Barrow Agegraphic Dark Energy (BADE) and New Barrow Agegraphic Dark Energy (NBADE) models within the framework of a fractal universe, incorporating Barrow entropy and the holographic principle with a time scale as the infrared (IR) cut-off. By analyzing both conformal time and the universe's age as IR cutoffs, we investigate the cosmological implications of these dark energy models and examine the evolution of a universe filled with the proposed dark energy components alongside pressureless matter. Using BAO and $Pantheon^{+}$ datasets, we constrain the model parameters and plot the Hubble parameter and distance modulus for both datasets. The results align well with current observations and demonstrate excellent agreement with the $\ Lambda$CDM model. Additionally, we extract various cosmological parameters and assess the stability of the BADE and NBADE models through squared sound speed analysis. We study the $\omega_d-\omega'_d$ analysis of the BADE and NBADE models and the statefinder diagnostic for both models in the $q-\textbf{S} $ and $q-r$ planes. Also, we studied the energy conditions, evaluated our models through the framework of thermodynamics, and analyzed their thermal stability. Furthermore, in a dedicated section, we investigate the impact of introducing an interaction term between dark energy and dark matter on the classical and thermal stability of the models, as well as its role in alleviating the Hubble tension. Then, we correspond each model with quintessence, tachyon, DBI-essence, and k-essence scalar field models of DE in FRW space-time to reconstruct potentials and the dynamics for these scalar fields. Finally, we test the swampland conjecture for each reconstructed model, providing insights into their theoretical consistency within string theory. We also examine the inflationary behavior of the models by analyzing the evolution of the slow-roll parameters ϵ and η.