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Dynamical Cosmological Constant

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In this work, we studied a model that dynamically realizes the equation of state $p + \rho = 0$. The perturbations of such a system, which mimics a Dynamical Cosmological Constant (DCC), exhibit pathological behavior within the perfect fluid approximation. We show that going beyond the perfect fluid paradigm is essential for achieving a stable evolution and that the presence of an anisotropic stress term is necessary. The linear stability of the system in isolation requires the Hamiltonian to be non-positive definite, analogous to the case of the Pais–Uhlenbeck oscillator.

We analyze in detail the dynamics of linear cosmological perturbations in a DCC-dominated universe and demonstrate that when DCC is minimally coupled to gravity, no severe instabilities arise. Our results indicate that the non-relativistic matter density contrast is no longer constant — as it is in the standard cosmological constant case — but displays an oscillatory behavior at small scales and a mild growth at large scales. We also examine the gravitational wave sector, finding that at small scales the amplitude is still suppressed as an inverse power of the scale factor, while at large scales it grows logarithmically. Additionally, we find propagating modes in the vector sector, though no growing instabilities are present.

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