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Phase-Space Constraints on a General Class of Eckart-like viscous Cosmologies

We study the cosmological dynamics of a general class of models where bulk viscosity is a property of dark matter using a dynamical system analysis. These viscous cosmologies are characterized by a dimensionless bulk viscous pressure given by $\Omega_\Pi = \Omega_\Pi(\Omega_m)$, where Ω_m is the matter density parameter. This phase-space analysis suggests that, in an Eckart framework, a viable early radiation era requires the complete absence of viscosity, while a proper matter-dominated epoch demands a highly sub-dominant viscous pressure. Therefore, the background cosmology must closely track the standard ΛCDM evolution and the only physically admissible late-time attractor is the cosmological constant-dominated fixed point; arguments in this paper suggest that this behaviour could be extended to a truncated Israel-Stewart theory. These constraints are validated numerically using the power-law parametrization $\Omega_\Pi = -\hat{\xi}_0 \Omega_m^s$ where $\hat{\xi}_0$ and s are real parameters. For $s \geq 1$ and $\hat{\xi}_0 \ll 1$, the background reproduces ΛCDM while, for $s < 1$, the system encounters a past-time integration boundary where the dark matter density transitions into negative values and its viscous pressure evaluates to nonphysical complex numbers, disrupting the standard expansion history. Because the background expansion essentially duplicates ΛCDM, the model is unlikely to resolve the H_0 tension; however, linear sub-horizon perturbations evaluated under the quasi-static approximation reveal that the bulk viscosity causes a scale-dependent dissipative drag. This increases the Hubble friction, offering a possible channel to suppress structure growth and alleviate the σ_8 (or S_8) tension; however, a detailed scale-by-scale analysis is needed to know its imprint on the matter power spectrum.

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