Qualitative Analysis of the UAT Framework:

Sensitivity of the Vacuum Energy Density to Model Parameters
and Comparison with ΛCDM

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Abstract

We present a qualitative analysis of the UAT/UCP framework's prediction for the vacuum energy density Ω_Λ as a function of the matter density parameter Ω_m and the quantum braking factor k_{early}. Unlike ΛCDM, where $\Omega_\Lambda = 1-\Omega_m-\Omega_r$, the UAT framework predicts $\Omega_\Lambda = 1-k_{\text{early}}(\Omega_m+\Omega_r)$, introducing a dependence on the early-universe expansion rate. We explore the sensitivity of this prediction to variations in the input parameters and provide a summary of the fundamental constants of the UAT framework. This document makes no claim of new physics; it serves as a qualitative reference for future comparison with observational data from Euclid, Roman, and other Stage IV surveys.

1 Introduction

The UAT/UCP framework [1, 2] modifies the standard ΛCDM expansion history through the introduction of a quantum braking factor $k_{\text{early}} = 0.967$. This factor reduces the effective density of matter and radiation in the early universe, shortening the sound horizon and resolving the Hubble tension while maintaining consistency with late-universe observations.

A consequence of this modification is that the vacuum energy density is not simply $\Omega_\Lambda = 1-\Omega_m-\Omega_r$, but rather:

$$\boxed{\Omega_\Lambda^{(\text{UAT})} = 1 - k_{\text{early}}(\Omega_m+\Omega_r)} \tag{1}$$

This document explores the qualitative behavior of Eq. (1) as a function of its input parameters.

2 Sensitivity to the Matter Density Ω_m

Table 1 shows the predicted Ω_Λ for various values of Ω_m, with $k_{\text{early}} = 0.967$ and $\Omega_r = 9.24\times10^{-5}$ held fixed. For comparison, the ΛCDM value $\Omega_\Lambda = 1-\Omega_m-\Omega_r$ is also shown.

Table 1: Ω_Λ as a function of Ω_m. The difference $\Delta = \Omega_\Lambda^{(\mathrm{UAT})} - \Omega_\Lambda^{(\Lambda\mathrm{CDM})}$ is shown in the last column.

Ω_m	$\Omega_\Lambda^{(\mathrm{UAT})}$	$\Omega_\Lambda^{(\Lambda\mathrm{CDM})}$	Δ
0.250	0.7582	0.7499	+0.0083
0.280	0.7292	0.7199	+0.0093
0.300	0.7099	0.6999	+0.0100
0.315	0.6953	0.6849	+0.0104
0.330	0.6808	0.6699	+0.0109
0.350	0.6614	0.6499	+0.0115
0.380	0.6323	0.6199	+0.0124
0.400	0.6130	0.5999	+0.0131

The UAT prediction is systematically higher than ΛCDM by approximately 0.01. This is a direct consequence of $k_{\mathrm{early}} < 1$: the quantum brake reduces the effective matter density, requiring a larger Ω_Λ to maintain spatial flatness.

3 Sensitivity to the Quantum Braking Factor k_{early}

Table 2 shows the predicted Ω_Λ for various values of k_{early}, with $\Omega_m = 0.315$ and $\Omega_r = 9.24\times10^{-5}$ held fixed.

Table 2: Ω_Λ as a function of k_{early}. The difference relative to the nominal value $k_{\mathrm{early}} = 0.967$ is shown.

k_{early}	$\Omega_\Lambda^{(\mathrm{UAT})}$	Δ vs. nominal
0.950	0.7007	+0.0054
0.958	0.6982	+0.0029
0.963	0.6966	+0.0013
0.967	0.6953	0.0000
0.970	0.6944	-0.0009
0.975	0.6928	-0.0025
0.980	0.6912	-0.0041

A variation of ±0.01 in k_{early} produces a shift of approximately ∓0.003 in Ω_Λ. The prediction is therefore relatively robust to small changes in the quantum braking factor.

4 Fundamental Constants of the UAT Framework

For reference, Table 3 lists the fundamental constants of the UAT/UCP framework. All values are derived from the framework's internal consistency requirements and the 7% thermal calibration margin [3]. We emphasize that these constants are specific to the UAT/UCP framework and have not been independently measured by third-party experiments.

Table 3: Fundamental constants of the UAT/UCP framework.

Constant	**Value**	**Physical meaning**
κ_{crit}	4.978	Ivancho limit — metric buffer saturation
k_{early}	0.967	Quantum brake — early-universe modification
$\varphi/2$	0.809017	Effective spectral dimension
3/4	0.750000	Half-phase thermodynamic offset
R_{geom}	0.279182	Force metric — 8-phasor residual at 43.515°
ε	0.0330 (3.3%)	Causal overflow fraction per cycle
ϕ_*/η	0.07 (7%)	Thermal calibration margin
κ	0.2791 ns/mm	Causal friction coefficient
α_f	0.046 Hz/day	Inflationary drift rate
f_{base}	187.37 Hz	Base operational frequency

5 Discussion

The qualitative behavior of $\Omega_\Lambda^{(\text{UAT})}$ is straightforward: it increases linearly as Ω_m decreases (Table 1) and decreases linearly as k_{early} increases (Table 2). Both trends are direct consequences of Eq. (1).

The UAT prediction for Ω_Λ is systematically higher than the ΛCDM value by approximately 0.01. This difference, while small, is potentially distinguishable with Stage IV surveys (Euclid, Roman, DESI-2) given their projected precision of $\sigma(\Omega_m) \sim 0.003$.

We emphasize that this document is **qualitative**. It does not claim that the UAT prediction is correct or that ΛCDM is incorrect. It merely illustrates the internal consistency of the UAT framework and provides reference values for future comparison with observational data.

6 Conclusion

We have presented a qualitative analysis of the UAT/UCP framework's prediction for the vacuum energy density. The framework contains a single free parameter ($\phi_*/\eta = 0.07$) from which all other constants are derived. The prediction $\Omega_\Lambda = 1 - k_{\text{early}}(\Omega_m + \Omega_r)$ is a direct consequence of the quantum brake and the requirement of spatial flatness.

Future observational data from Stage IV surveys will determine whether the systematic offset of ~ 0.01 between UAT and ΛCDM is a feature of nature or an artifact of the model.

References

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