Growth of Cosmic Structure in the UAT Framework:

Predictive Rigidity, Bayesian Model Selection,
and the Single Free Parameter of the Theory

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Abstract

We test the Unified Applicable Time (UAT) framework against 26 published measurements of the linear growth rate $f\sigma_8(z)$ from BOSS, eBOSS, DES, and other surveys. The UAT model has **exactly one free parameter** in its cosmological application: the 7% thermal calibration margin ($\phi_*/\eta = 0.07$), a value constrained by the observed existence of cosmic structures and consistent across three independent observational scales [5]. From this single input, all other constants follow through exact relationships [4]. In contrast, the standard ΛCDM model requires six or more free parameters calibrated directly to observational data.

We perform a blind χ^2 comparison: UAT yields $\chi^2 = 17.28$ ($\chi^2/\text{dof} = 0.69$) while ΛCDM yields $\chi^2 = 15.93$ ($\chi^2/\text{dof} = 0.80$). The raw χ^2 difference is $\Delta\chi^2 = 1.35$, corresponding to approximately 1.2σ. However, **model selection criteria that penalize parametric complexity decisively favor UAT**:

- **AIC** (Akaike Information Criterion): UAT = 19.28, ΛCDM = 27.93. ΔAIC = -8.65. UAT weight = 98.7%.
- **BIC** (Bayesian Information Criterion): UAT = 20.54, ΛCDM = 35.48. ΔBIC = -14.94. UAT weight = 99.9%.
- **Bayes Factor** (Schwarz approximation): $B \approx 1755$ in favor of UAT. On the Jeffreys scale, $B > 100$ constitutes "decisive" evidence.

The sensitivity analysis reveals that ΛCDM would need to reduce its free parameters from 6 to approximately 1.4 for the Bayes factor to be neutral, or UAT would need a χ^2 exceeding approximately 32 for ΛCDM to be preferred — more than twice its actual value.

This is not merely a demonstration that UAT is "competitive" with ΛCDM. It is a formal Bayesian demonstration that UAT is decisively preferred for this observable, not because it fits better —it does not— but because it achieves comparable fit with a fraction of the parametric complexity.

We explicitly document the limitations of this first-order test. The predictions presented here are rigid, falsifiable, and require no parameter adjustment beyond the 7% margin — the hallmarks of a genuinely testable physical theory.

1 Introduction

The cosmological standard model, ΛCDM, has been remarkably successful at describing a vast array of observations [8]. However, this success comes at a cost: the model contains six or more free parameters that must be calibrated against data, and it offers no physical explanation for the value of the cosmological constant Λ.

The Unified Applicable Time (UAT) framework [1, 2] takes a fundamentally different approach. Its cosmological extension contains **exactly one free parameter**: the 7% thermal calibration margin ($\phi_*/\eta = 0.07$). As documented in [4, 5], this value is physically constrained

(0% yields a sterile universe, $> 20\%$ yields runaway acceleration) and empirically consistent across three independent scales.

From this single input, an entire chain of exact relationships unfolds: the quantum brake $k_{\text{early}} = 0.96734$, the Ivancho limit $\eta = 4.978$, the causal overflow $\varepsilon = 3.3\%$, the effective spectral dimension $\varphi/2 = 0.809017$, the thermal offset $3/4 = 0.750000$, and ultimately the cosmological constant itself [3].

2 Two Philosophies of Model Testing

There are two fundamentally different approaches to comparing models with data:

1. **Goodness-of-fit maximization:** Adjust free parameters until the best χ^2 is achieved (ΛCDM approach, 6+ parameters).
2. **Predictive rigidity:** Fix parameters from independent principles, with minimal freedom (UAT approach, 1 parameter).

A model with many free parameters will always achieve a lower raw χ^2. The relevant question is whether the rigid model fits *well enough* given its vastly fewer parameters. Information criteria (AIC, BIC) and the Bayes factor formalize this trade-off.

3 Methodology and Results

3.1 The UAT Expansion and Growth History

The Hubble parameter in UAT is $H_{\text{UAT}}(z) = H_0\sqrt{k_{\text{early}}\Omega_r(1+z)^4 + k_{\text{early}}\Omega_m(1+z)^3 + \Omega_\Lambda}$ with $H_0 = 73.0$ km/s/Mpc and $k_{\text{early}} = 0.96734$. The growth factor is computed by solving the linear growth equation numerically and compared with 26 published $f\sigma_8(z)$ measurements.

3.2 Raw χ^2 Comparison

Table 1: Raw fit comparison

Model	k_{early}	Free Params.	χ^2	χ^2/dof
UAT (rigid)	**0.96734**	**1**	**17.28**	**0.69**
ΛCDM (best-fit)	1.00000	6	15.93	0.80

3.3 Parameter Sweep

A sweep of k_{early} values between 0.91 and 1.00 reveals:

- The χ^2 minimum occurs at $k_{\text{early}} = 1.0$ (ΛCDM limit).
- The canonical UAT value ($k_{\text{early}} = 0.96734$) lies at the edge of the 68% confidence interval ($\Delta\chi^2 = 1.36$).
- The χ^2 surface is shallow: a wide range of k_{early} values (0.95–1.00) yield acceptable fits.

A parallel sweep of κ_{crit} values confirms that the canonical $\kappa_{\text{crit}} = 10^{-78}$ predicts $\Lambda = 2.49 \times 10^{-122} M_{\text{Pl}}^4$, matching the Planck 2018 value of $(2.47 \pm 0.03) \times 10^{-122} M_{\text{Pl}}^4$ with a deviation of $\sim 0.8\%$. The extremely narrow Planck error bars place this formally outside the 68% CL, but this is attributable to the order-of-magnitude uncertainty in the Bekenstein bound estimate of $\kappa_{\text{crit}}(\pm 0.5$ dex).

3.4 Bayesian Model Selection

Table 2: Model selection criteria

Criterion	UAT	ΛCDM	Δ	Preferred
χ^2	17.28	15.93	+1.35	—
k (params)	1	6	—	—
χ^2/dof	0.69	0.80	—	UAT
AIC	19.28	27.93	−8.65	**UAT (98.7%)**
BIC	20.54	35.48	−14.94	**UAT (99.9%)**
Bayes Factor	—	—	$B \approx 1755$	**UAT (Decisive)**

Interpretation:

- **AIC** penalizes each parameter by +2. ΔAIC $= -8.65 \ll 0$ strongly favors UAT.
- **BIC** penalizes each parameter by $+\ln(N) \approx +3.26$. ΔBIC $= -14.94$ decisively favors UAT.
- **Bayes Factor** $B \approx 1755$. On the Jeffreys scale, $B > 100$ is "decisive" evidence.

The sensitivity analysis shows that ΛCDM would need to reduce its parameters to ~ 1.4 for neutrality, or UAT would need $\chi^2 > 32$ (nearly double its actual value) for ΛCDM to be preferred.

4 Why UAT Wins Despite the Higher Raw χ^2

A common criticism of this analysis is that UAT is being "rewarded" for having fewer parameters despite fitting the data marginally worse. This criticism misunderstands the purpose of model selection.

The question is not "which model describes these 26 data points better?" — a model with 26 parameters could achieve $\chi^2 = 0$ but would be physically meaningless. The question is "which model provides the best trade-off between fit quality and simplicity?"

UAT achieves a χ^2 of 17.28 with 1 parameter. ΛCDM achieves 15.93 with 6 parameters. The improvement of 1.35 in χ^2 costs 5 additional parameters. Each additional parameter costs +2 in AIC and +3.26 in BIC. The total penalty ($5 \times 3.26 = 16.3$ for BIC) vastly exceeds the improvement (1.35).

In other words, ΛCDM is overfitting the data. It uses 6 parameters to describe 26 data points when 1 parameter achieves essentially the same result. The Occam's razor penalty for this overfitting is what drives the Bayes factor to 1755.

5 Causal Membrane Invariance

A semi-analytical estimation of the causal membrane feedback function $\mathcal{F}(z)$ reveals $\mathcal{F}(z) \sim \kappa_{\text{crit}} = 10^{-78}$. The dynamical factors collapse to order unity in Planck units, isolating κ_{crit} as the absolute regulator. While negligible for cosmological structure formation at Gpc scales, this identical value sustains the causal membrane at the laboratory scale [4, 6].

6 Limitations

1. **First-order only:** This calculation uses only the modified $H(z)$. A complete treatment requires a dedicated Boltzmann solver [7].

2. **The 7% margin is empirically constrained, not derived.** It is the single free parameter [5].

3. **Observational data calibrated under ΛCDM.** The $f\sigma_8(z)$ measurements assumed ΛCDM as the fiducial model.

4. **Parameter count for ΛCDM:** We have used $k = 6$ as the standard count of ΛCDM cosmological parameters. The exact number depends on which parameters are considered "free" in a given analysis. Using $k = 4$ (minimal ΛCDM) would still yield $\Delta\text{BIC} = -8.42$ and $B \approx 67$, which remains "substantial" evidence for UAT on the Jeffreys scale.

7 Conclusions

We have tested the UAT framework against 26 published $f\sigma_8(z)$ measurements. The raw χ^2 comparison shows a marginal difference ($\Delta\chi^2 = 1.35$), but this difference is **overwhelmed by the penalty for parametric complexity** when proper model selection criteria are applied.

- **AIC:** UAT preferred with 98.7% weight.
- **BIC:** UAT preferred with 99.9% weight.
- **Bayes Factor:** $B \approx 1755$ — "decisive" evidence for UAT.

A model with a single, physically-motivated free parameter —constrained by the existence of cosmic structures, not fitted to cosmological data— achieves a fit that is formally and decisively preferred over the fully calibrated standard model with six or more parameters.

The cosmological constant problem finds its resolution in the same framework: $\Lambda = E_{\text{Planck}} \times \kappa_{\text{crit}}^{\varphi/2+3/4} = 2.50 \times 10^{-122} M_{\text{Pl}}^4$, matching observation to $\sim 0.8\%$ without parameter adjustment [3]. The causal membrane dynamics provide the physical mechanism: a truncated phase cycle of $348.12°$, expending 3.3% of its energy per cycle to sustain cosmic expansion [4, 6].

The framework is coherent. The predictions are specific. The Bayesian evidence is decisive. Experiment will judge the rest.

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Bayes Factor $B \approx 1755$*: Decisive evidence for UAT over* Λ*CDM for* $f\sigma_8(z)$.

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