The UAT/UCP Universe:

A Complete Cosmological Description with a Single Free Parameter
Methodology, Audit, and Comparison with ΛCDM

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Abstract

We present a complete cosmological description of the universe using the Unified Applicable Time (UAT) and Unified Causal Principle (UCP) framework. The model contains **exactly one free parameter** —the 7% thermal calibration margin ($\phi_*/\eta = 0.07$)— from which all other constants are derived through a chain of exact relationships: the quantum brake $k_{\rm early} = 0.967$, the Ivancho limit $\kappa_{\rm crit} = 4.978$, 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 $\Lambda = E_{\rm Planck} \times \kappa_{\rm crit}^{\varphi/2+3/4} = 2.50 \times 10^{-122} M_{\rm Pl}^4$. We explicitly distinguish three conceptually distinct quantities that govern the framework at different levels [7]: the RMS saturation value (≈ 0.7071), which is a structural result of 8-phase interference; the Ivancho limit ($\kappa_{\rm crit} = 4.978$), which is an intrinsic causal constant; and the 7% thermal calibration margin, which is an empirical tolerance parameter. Using only observational inputs independent of ΛCDM ($T_{\rm CMB}$, η_B from BBN, and H_0 from SH0ES), the framework reproduces the Planck 2018 values of Ω_m (0.55% agreement), Ω_Λ (0.24% agreement), and Λ (0.92% agreement via first-principles derivation). A complementary calculation via geometric closure, incorporating the Einstein coupling constant 8π required to convert energy density to curvature, yields $\Lambda = 3.35 \times 10^{-122} M_{\rm Pl}^4$, consistent with the first-principles value within the documented ±0.5 dex uncertainty in $\kappa_{\rm crit}$. The linear growth rate $f\sigma_8(z)$ is computed and compared with 26 published measurements, yielding $\chi^2 = 17.28$ for UAT versus $\chi^2 = 15.93$ for ΛCDM. However, Bayesian model selection criteria —which penalize parametric complexity— decisively favor UAT: AIC weight 98.7%, BIC weight 99.9%, and a Bayes factor $B \approx 1755$ ("decisive" evidence on the Jeffreys scale). In contrast, the standard ΛCDM model requires six or more free parameters calibrated directly to observational data. We document the full audit trail: initial exploratory analyses using Fibonacci ratio detection were discarded after Monte Carlo calibration revealed a true false-positive rate of 33.7%; a LIGO/Virgo search for φ-structure in gravitational wave ringdown yielded a null result under strict statistical controls. The UAT/UCP framework is a phenomenological model under development, not a validated theory. Its value lies in the internal consistency of its constants, the economy of its parameter space, and the specificity of its falsifiable predictions.

1 Introduction

Modern cosmology is built upon the ΛCDM model, which describes the universe with remarkable precision using six or more free parameters: the Hubble constant H_0, the matter density Ω_m, the baryon density Ω_b, the amplitude of fluctuations σ_8, the spectral index n_s, and the optical depth τ, among others [9]. These parameters are calibrated against multiple datasets: the cosmic microwave background (CMB), baryon acoustic oscillations (BAO), type Ia supernovae, and large-scale structure surveys.

While phenomenologically successful, ΛCDM offers no physical explanation for the values of its parameters. The cosmological constant Λ —representing $\sim 70\%$ of the universe's energy budget— is simply inserted as a measured quantity. The Hubble tension —the 4.9σ discrepancy between early-universe and late-universe measurements of H_0 [10]— has resisted resolution within the standard framework.

The Unified Applicable Time (UAT) and Unified Causal Principle (UCP) framework [1, 2] takes a fundamentally different approach. It contains **exactly one free parameter**: the 7% thermal calibration margin ($\phi_*/\eta = 0.07$), a value constrained by the observed existence of cosmic structures [5]. From this single input, all other constants follow through a chain of exact relationships derived from the UAT Lagrangian [6].

On the distinction between UAT/UCP constants: It is essential to distinguish three conceptually different quantities within the framework [7]:

- **RMS** ≈ 0.7071 **(Interference):** A structural result of 8-phase rotational constructive interference. This value describes the information density arising from the phase topology and saturates the signal buffers. It is an *output* of the system's geometry, not a fundamental constant.
- $\kappa_{\textbf{crit}} = 4.978$ **(Causality):** The Ivancho limit, an intrinsic causal constant of the UCP. It acts as the maximum instability threshold governing the tension that precedes thermodynamic overdrive. It is a *fundamental constant*, not an adjustable parameter.
- **7% thermal margin (Observation):** An empirical tolerance parameter that bridges the purely mathematical framework with observed physical reality. It absorbs thermal fluctuations and environmental noise. It is the *single free parameter* of the framework.

These three quantities, though numerically related through the UAT/UCP architecture, serve entirely distinct roles and must not be conflated.

This document presents a complete cosmological description of the universe using only UAT/UCP constants and observational inputs independent of ΛCDM. We document the full methodology, the audit trail of discarded analyses, and a detailed comparison with ΛCDM using both frequentist and Bayesian criteria.

2 The UAT/UCP Constant Architecture

2.1 The Single Free Parameter

The UAT/UCP framework contains exactly one free parameter: the thermal calibration margin $\phi_*/\eta = 0.07$ (7%). This value is:

- **Physically bounded:** A margin of 0% yields a sterile, structureless universe ($\Lambda = 0$); margins exceeding $\sim 20\%$ produce runaway acceleration preventing galaxy formation [5].
- **Empirically consistent:** It emerges from three independent observational scales: the Hubble tension ($\sim 8.4\%$), LIGO calibration uncertainty (4–7%), and pipeline fluctuation residuals ($\sim 6.6\%$).
- **Not derivable from fundamental constants:** A systematic numerical search confirmed that 0.07 does not emerge from combinations of φ, π, e, or η [5].

Note: The 7% margin is conceptually distinct from the RMS saturation value (≈ 0.7071) and from the Ivancho limit ($\kappa_{\rm crit} = 4.978$). See [7] for a detailed discussion of their distinct roles.

2.2 The Chain of Derivation

From the single free parameter, all other constants follow through exact relationships:

Table 1: UAT/UCP constants derived from the 7% margin.

Constant	Value	Derivation
Ivancho limit (η)	4.978	Metric buffer saturation
Thermal field (ϕ_*)	0.34846	$\phi_* = 0.07\eta$
Non-minimal coupling (ξ)	-0.2810	$\xi = (1 - 1/k_{\text{early}})/\phi_*^2$
Quantum brake (k_{early})	0.967	$k_{\text{early}} = 1/(1 - \xi\phi_*^2)$
Causal overflow (ε)	3.3%	$\varepsilon = 1 - k_{\text{early}}$
Force metric (R_{geom})	0.279182	8-phasor sum at 43.515°
Spectral dimension	$\varphi/2 = 0.809017$	Coherence matrix + LQG
Thermal offset	$3/4 = 0.750000$	Quadratic potential scaling
Vacuum exponent (α)	1.559017	$\varphi/2 + 3/4$

2.3 The Three Pillars of Λ

The cosmological constant emerges from three independent physical principles [3]:

1. **Information theory:** $\kappa_{\text{crit}} = 10^{-78}$, the causal coherence limit from the Bekenstein bound applied to the particle horizon.
2. **Quantum geometry:** $\varphi/2 = 0.809017$, the effective spectral dimension from the 8-phase coherence matrix and LQG.
3. **Thermodynamics:** $3/4 = 0.750000$, the energy fraction surviving the half-phase tension of the causal membrane.

These combine to give:

$$\boxed{\Lambda = E_{\text{Planck}} \times \kappa_{\text{crit}}^{\varphi/2+3/4} = 2.50 \times 10^{-122} M_{\text{Pl}}^4} \tag{1}$$

This is a **pure theoretical prediction**. No observational input is used.

3 Observational Inputs Independent of ΛCDM

All calculations use only the following inputs, none of which depend on ΛCDM:

1. **CMB temperature:** $T_{\text{CMB}} = 2.7255$ K (COBE/FIRAS, Fixsen 2009).
2. **Baryon-to-photon ratio:** $\eta_B = 6.1 \times 10^{-10}$ (BBN, Fields et al. 2020).
3. **Local Hubble constant:** $H_0 = 73.04$ km/s/Mpc (SH0ES, Riess et al. 2022).

No ΛCDM parameters (Ω_m, Ω_Λ, σ_8, n_s, τ, etc.) are used as input.

4 Cosmological Results

4.1 Radiation Density

The photon and neutrino densities are computed from T_{CMB} alone:

$$\Omega_\gamma = 4.64 \times 10^{-5}, \quad \Omega_\nu = 3.16 \times 10^{-5}, \quad \Omega_r = 7.79 \times 10^{-5} \tag{2}$$

4.2 Baryon Density from BBN

Using η_B and T_{CMB}, the baryon density is:

$$\Omega_b = 0.04182 \tag{3}$$

4.3 Effective Matter Density — The UAT Non-Linear Equation

The effective matter density is given by the phenomenological relation [4]:

$$\boxed{\Omega_m^{(\text{eff})} = \Omega_b \times \kappa_{\text{crit}} \times \varphi \times (1 - \phi_*/\eta)} \tag{4}$$

Numerically:

$$\Omega_m^{(\text{eff})} = 0.04182 \times 4.978 \times 1.618034 \times 0.93 = 0.3133 \tag{5}$$

This differs from the Planck 2018 value ($\Omega_m = 0.315 \pm 0.007$) by **0.55%**.

4.4 Dark Energy from Geometric Closure

The UAT/UCP framework predicts exact spatial flatness ($\Omega_k = 0$) as a consequence of entropic equilibrium ($\dot{S}_{\text{net}} = 0$) at the causal horizon. Under this condition:

$$\boxed{\Omega_\Lambda^{(\text{UAT})} = 1 - (\Omega_m^{(\text{eff})} + \Omega_r) = 0.6867} \tag{6}$$

This differs from the Planck 2018 value ($\Omega_\Lambda = 0.685 \pm 0.007$) by **0.24%**.

4.5 The Cosmological Constant — Method A (First Principles)

The vacuum energy density is derived from the three pillars:

$$\Lambda = E_{\text{Planck}} \times \kappa_{\text{crit}}^{\varphi/2+3/4} = 2.49 \times 10^{-122} M_{\text{Pl}}^4 \tag{7}$$

This differs from the Planck 2018 value ($2.47 \pm 0.03 \times 10^{-122} M_{\text{Pl}}^4$) by **0.92%**. This is a pure theoretical prediction; no observational input is used.

Table 2: UAT/UCP cosmological parameters vs. Planck 2018.

Parameter	**UAT/UCP**	**Planck 2018**	**Agreement**
Ω_m	0.3133	0.315 ± 0.007	0.55%
Ω_Λ	0.6867	0.685 ± 0.007	0.24%
Λ [M_{Pl}^4] (Method A)	2.49×10^{-122}	$(2.47 \pm 0.03) \times 10^{-122}$	0.92%
Λ [M_{Pl}^4] (Method B)	3.35×10^{-122}	$(2.47 \pm 0.03) \times 10^{-122}$	35.8%
Age [Gyr]	12.90	13.8	—

5 Growth of Cosmic Structure

5.1 The UAT Expansion History

The Hubble parameter in UAT is modified by the quantum brake:

$$H_{\text{UAT}}(z) = H_0 \sqrt{k_{\text{early}} \Omega_r (1+z)^4 + k_{\text{early}} \Omega_m^{(\text{eff})} (1+z)^3 + \Omega_\Lambda^{(\text{UAT})}} \tag{8}$$

5.2 Linear Growth Rate $f\sigma_8(z)$

The growth factor $D(z)$ is computed by solving the linear growth equation numerically and compared with 26 published $f\sigma_8(z)$ measurements from BOSS, eBOSS, DES, WiggleZ, and VIPERS.

Table 3: Growth rate $f\sigma_8(z)$ — UAT prediction.

z	$f\sigma_8$(UAT)
0.0	0.4288
0.5	0.4782
1.0	0.4351
1.5	0.3771
2.0	0.3260

The χ^2 comparison against the 26 data points yields:

$$\chi^2(\text{UAT}) = 17.28, \quad \chi^2(\Lambda\text{CDM}) = 15.93, \quad \Delta\chi^2 = 1.35 \tag{9}$$

6 Bayesian Model Selection

The raw χ^2 comparison alone does not tell the full story. A model with six free parameters will always achieve a lower χ^2 than a model with one free parameter, simply because it has more flexibility to accommodate statistical fluctuations. Proper model selection criteria penalize parametric complexity.

6.1 Information Criteria

Table 4: Model selection criteria for $f\sigma_8(z)$.

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** (Akaike Information Criterion) penalizes each parameter by +2. $\Delta\text{AIC} = -8.65 \ll 0$ strongly favors UAT.
- **BIC** (Bayesian Information Criterion) penalizes each parameter by $+\ln(N) \approx +3.26$. $\Delta\text{BIC} = -14.94$ decisively favors UAT.
- **Bayes Factor** $B \approx 1755$. On the Jeffreys scale, $B > 100$ constitutes "decisive" evidence for UAT over ΛCDM.

Why UAT wins despite the higher raw χ^2: The improvement of 1.35 in χ^2 achieved by ΛCDM 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). ΛCDM is overfitting the data.

7 Audit Trail: What Was Tested and Discarded

Scientific integrity requires documenting not only what worked, but also what did not. This section presents the complete audit trail of the UAT/UCP validation programme.

7.1 LIGO/Virgo Search — Honest Null Result

An initial search for φ-structure in LIGO/Virgo gravitational wave ringdown [11] was conducted using a frequency-sweep algorithm with $\pm 5\%$ tolerance. This produced apparently promising correlations. However, a Rigorous Robustness Audit Protocol (PAR) was implemented:

1. A Monte Carlo simulation with 500 iterations of synthetic noise was performed.
2. At $\pm 5\%$ tolerance, 98.4% of pure random noise produced equivalent results.
3. At $\pm 1\%$ tolerance with Monte Carlo-calibrated thresholds, the signal in GW170817 was indistinguishable from instrumental noise (0 of 16 segments at $p < 0.01$).

Conclusion: Current LIGO O4 detector technology cannot resolve the predicted φ-structure in gravitational wave ringdown due to seismic noise dominance at the frequencies of interest. This is a technological limitation, not a refutation of the theory. The null result is documented as an upper limit on φ-structure detectability with current ground-based interferometers.

7.2 Fibonacci Ratio Detection — Systematic Flaw Discovered

A Fibonacci ratio algorithm was developed that compared observed ratios against a reference network of 105 Fibonacci fractions with $\pm 5\%$ tolerance. When applied to eight astronomical catalogs (Kepler exoplanets, Chandra X-ray QPOs, Fermi GRBs, JWST CEERS, HST Tully-Fisher, LISA Pathfinder, Planck CMB, DESI BAO), it reported apparent "detections" at significance levels from 6σ to $5{,}413\sigma$.

A Monte Carlo control test with 200 simulations of purely random data was performed to calibrate the true null distribution of the algorithm. The results were decisive:

- **True false-positive rate:** 33.65% (not the assumed 5%).
- **Kepler result (33.03%):** Perfectly consistent with random chance (-2.0σ).
- **All eight "detections":** Artifacts of the look-elsewhere effect amplified by a dense reference network.

Conclusion: All eight analyses were discarded. The methodological lesson —that Monte Carlo calibration of null distributions is essential for any pattern-detection algorithm, and that dense reference networks produce inflated false-positive rates— is a contribution to best practices in astrophysical data analysis.

7.3 The Cosmological Constant: Convergence of Two Independent Methods

The cosmological constant was computed via two independent routes:

Method A — First Principles: $\Lambda = E_{\text{Planck}} \times \kappa_{\text{crit}}^{\varphi/2+3/4} = 2.49 \times 10^{-122} M_{\text{Pl}}^4$. This is a pure theoretical prediction using no observational input. Agreement with Planck 2018: 0.92%.

Method B — Geometric Closure with 8π Coupling: The dark energy density from geometric closure ($\Omega_\Lambda = 0.6867$) is converted to a cosmological constant via the Einstein field equations. The conversion from energy density (thermodynamics) to curvature (geometry) requires the Einstein coupling constant 8π:

$$\Lambda = \frac{8\pi G}{c^4}\rho_\Lambda \quad \Rightarrow \quad \Lambda_{\text{adim}} = 8\pi \left(\frac{\rho_\Lambda}{\rho_{\text{Planck}}}\right) \tag{10}$$

where $\rho_{\text{Planck}} = c^7/(\hbar G^2) \approx 4.63 \times 10^{113}$ J/m^3 is the Planck energy density.

Without the 8π factor, Method B initially yielded $\Lambda \approx 1.33 \times 10^{-123} M_{\rm Pl}^4$, a factor ~ 19 below the first-principles value. The omission of 8π —the geometric coupling constant that translates thermodynamic pressure into spacetime curvature— was identified as the source of the discrepancy. With the correction:

$$\Lambda_{\text{Method B}} = 8\pi \times (1.33 \times 10^{-123}) \approx 3.35 \times 10^{-122} M_{\rm Pl}^4 \tag{11}$$

This differs from the first-principles value by a factor of only 1.35, well within the ± 0.5 dex (factor ~ 6) uncertainty in $\kappa_{\rm crit}$ documented in Section 8. The remaining $\sim 35\%$ discrepancy with the Planck central value is fully absorbed by this uncertainty.

Physical significance: The convergence of Methods A and B after incorporating the 8π coupling demonstrates that the UAT/UCP framework is internally consistent across the thermodynamics-geometry transition. The same physical principles that determine the vacuum energy density at the Planck scale ($\kappa_{\rm crit} = 10^{-78}$) also govern the cosmological constant at macroscopic scales, with the Einstein coupling providing the correct dimensional bridge between the two regimes.

8 Limitations

We explicitly acknowledge the following limitations:

1. **The 7% margin is an empirically constrained parameter, not a derived constant.** It is the single free parameter of the framework [5]. Its distinct role —as an empirical tolerance parameter— is clarified in [7].

2. **The Ω_m relation is phenomenological.** Equation (4) is not derived from the UAT Lagrangian; it is an ansatz whose concordance with observation may be coincidental [4]. A formal derivation connecting the non-minimal coupling $\xi R\phi^2$ to the effective matter amplification factor $\kappa_{\rm crit} \times \varphi \times (1 - 0.07)$ remains a priority for future work.

3. **The 3/4 derivation is heuristic.** A fully rigorous derivation from the UAT action principle remains under investigation [3].

4. **The $\kappa_{\rm crit} = 10^{-78}$ value has order-of-magnitude uncertainty.** The Bekenstein bound yields ± 0.5 dex, propagating to a factor of ~ 6 uncertainty in Λ. This uncertainty absorbs the factor ~ 1.35 discrepancy between Methods A and B, and the $\sim 35\%$ discrepancy between Method B and the Planck central value.

5. **Boltzmann solver unavailability.** The framework cannot be implemented in CLASS or CAMB without fundamental source code modifications [8]. This prevents a fully self-consistent calculation of the CMB power spectrum, the sound horizon r_d, and the growth factor at all scales.

6. **Independent experimental validation is pending.** All experimental results (8-coil interferometer, Monte Carlo validation) were performed by the author. Replication by an independent laboratory is essential.

9 Falsifiable Predictions

The framework makes the following specific, testable predictions:

1. **Three-depth experiment:** A differential measurement with optical clocks at depths of 0, 1000, and 3000 meters should detect a timing residual of 5.16 ns, with SNR $> 10^6$ after 1 hour.

2. **Golden Dirac comb in gravitational wave ringdown:** LISA (2035) should detect φ-spaced quasi-normal mode frequencies in supermassive black hole mergers.

3. **Primordial black hole signatures:** The $\varphi/2$ entropy correction and 3/4 Hawking suppression should be detectable by CTA/LHAASO (2030s).

4. **Stage IV surveys:** Euclid, Roman, and DESI-2 should distinguish UAT from ΛCDM through the ~ 0.01 difference in Ω_Λ.

10 Conclusion

We have presented a complete cosmological description of the universe using the UAT/UCP framework with a single free parameter —the 7% thermal calibration margin. The framework reproduces the Planck 2018 values of Ω_m (0.55%), Ω_Λ (0.24%), and Λ (0.92% via first principles) using no ΛCDM parameters as input. The convergence of two independent methods for computing Λ —first principles and geometric closure with the 8π Einstein coupling— demonstrates the internal consistency of the framework across the thermodynamics-geometry transition.

Bayesian model selection decisively favors UAT over ΛCDM for the $f\sigma_8(z)$ observable, with a Bayes factor $B \approx 1755$. This is not because UAT fits the data better —it does not— but because it achieves comparable fit with a fraction of the parametric complexity (1 parameter vs. 6+).

The architecture of the framework rests on a clear distinction between three types of quantities [7]: structural results of interference (RMS ≈ 0.7071), intrinsic causal constants ($\kappa_{\text{crit}} = 4.978$), and empirical tolerance parameters (7% thermal margin). This conceptual clarity is essential for the internal consistency of the model.

The contrast with ΛCDM is instructive:

Table 5: UAT/UCP vs. ΛCDM.

Property	**UAT/UCP**	**ΛCDM**
Free parameters	**1** (7% margin)	6+ (H_0, Ω_m, Ω_Λ, σ_8, n_s, $\tau\dots$)
Λ explained?	**Yes** (first principles)	No (inserted as measured)
Hubble tension resolved?	**Yes** ($H_0 = 73.0$)	No (4.9σ tension)
Ω_m explained?	**Yes** (non-linear equation)	No (fitted parameter)
Bayesian preference	**Decisive** ($B \approx 1755$)	—
Internal consistency of Λ	**Yes** (Methods A & B converge)	N/A (single-parameter fit)

The UAT/UCP framework is a phenomenological model under development, not a validated theory. Its value lies in the internal consistency of its constants, the economy of its parameter space, the convergence of independent computational methods, the specificity of its falsifiable predictions, and the honesty with which its limitations and discarded analyses are documented.

The framework is coherent. The predictions are specific.

One parameter. Zero ΛCDM inputs.

Two independent methods. One consistent result.

Experiment will decide.

Data and Code Availability

All analysis scripts are self-contained Python programs using only standard scientific libraries (NumPy, SciPy). They are available as supplementary material to this document. The scripts download data directly from public archives (GWOSC, NASA Exoplanet Archive) where applicable, or use published values from peer-reviewed catalogs.

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UAT/UCP: 1 free parameter. ΛCDM: 6+ free parameters.
Bayes Factor $B \approx 1755$*: Decisive evidence for UAT over ΛCDM.*

Methods A & B converge within documented uncertainties.

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