The UAT/UCP Framework in Cosmology:

A Synthesis of Results
Hubble Tension, Cosmological Constant, Causal Membrane Dynamics, and Falsifiable Predictions

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Abstract

We present a unified synthesis of the UAT/UCP (Unified Applicable Time / Unified Causal Principle) framework and its results in cosmology. The framework introduces a single free parameter —the 7% thermal calibration margin ($\phi_*/\eta = 0.07$)— from which all other constants are derived: the quantum braking factor ($k_{\text{early}} = 0.967$), the Ivancho limit ($\kappa_{\text{crit}} = 4.978$), the causal overflow ($\varepsilon = 3.3\%$), and the force metric ($R_{\text{geom}} = 0.2791$). We show that the framework resolves the Hubble tension by reducing the effective density of matter and radiation in the early universe, yielding $H_0 = 73.0$ km/s/Mpc and a sound horizon $r_d \approx 141$ Mpc. The vacuum energy density is derived as $\Lambda = E_{\text{Planck}} \times \kappa_{\text{crit}}^{\varphi/2+3/4} = 2.50 \times 10^{-122}\, M_{\text{Pl}}^4$, matching Planck 2018 within $\sim 1.2\%$. The dynamic extension —causal membrane dynamics— reveals that the universe operates on a truncated phase cycle of 348.12°, expending 3.3% of its energy per cycle to sustain expansion. A Monte Carlo simulation with 10,000 iterations validates the non-random nature of the force metric ($p < 0.001$). We present the full set of falsifiable predictions and explicitly acknowledge the framework's limitations. The UAT/UCP framework is a phenomenological model under development, not a validated theory. Its value lies in the internal consistency of its constants and the specificity of its testable predictions.

1 Introduction

Modern cosmology faces two profound challenges. The first is the Hubble tension: the 4.9σ discrepancy between early-universe measurements of the expansion rate ($H_0 \approx 67.4$ km/s/Mpc from Planck CMB data) and late-universe measurements ($H_0 \approx 73.0$ km/s/Mpc from SH0ES Cepheid-calibrated supernovae) [11, 12]. The second is the cosmological constant problem: the 10^{122} discrepancy between the predicted vacuum energy density from quantum field theory and the observed dark energy density.

The UAT/UCP framework [1, 2] addresses both challenges through a single mechanism: the quantum brake. The universe, in this model, does not expand at the full rate predicted by General Relativity. A small fraction of its energy —the causal overflow ($\varepsilon = 3.3\%$)— is continuously expended to sustain expansion against gravitational collapse. This expenditure modifies the early-universe expansion rate, shortening the sound horizon and reconciling the two measurements of H_0. The same mechanism, operating over cosmic history, yields the observed vacuum energy density.

This document provides a unified synthesis of the UAT/UCP framework and its results. It is intended as a reference for researchers who wish to understand the full logical chain, from the foundational postulates to the falsifiable predictions.

2 Foundations: Constants and Parameters

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 constrained by the observed existence of cosmic structures: a margin of 0% would yield a sterile, structureless universe ($\Lambda = 0$), while margins exceeding $\sim$ 20% would produce runaway acceleration preventing galaxy formation [4]. The 7% value is inferred from three independent observational scales: the Hubble tension ($\sim$ 8.4%), LIGO calibration uncertainty (4–7%), and pipeline fluctuation residuals ($\sim$ 6.6%). Its average is $\sim$ 7.3%.

A systematic numerical search has confirmed that 0.07 does not emerge from simple algebraic combinations of the fundamental constants φ, π, e, or η [4]. It is a genuine empirical input. We acknowledge that a parameter inferred from observation —however consistently— is not equivalent to one derived from first principles. The 7% margin remains the single phenomenological input of the framework.

2.2 Derived Constants

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

Table 1: Fundamental constants of the UAT/UCP framework. All are derived from $\phi_*/\eta = 0.07$ and the UAT Lagrangian.

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	$\xi = (1 - 1/k_{\text{early}})/\phi_*^2$
Self-coupling (λ)	3.08×10^{-112}	$\lambda = -\xi R_c/(2\eta^2)$
Quantum brake (k_{early})	0.967	$k_{\text{early}} = 1/(1 - \xi\phi_*^2)$
Causal overflow (ε)	0.0330 (3.3%)	$\varepsilon = 1 - k_{\text{early}}$
Force metric (R_{geom})	0.279182	$R(8, 43.515°)$
Causal coherence (κ_{crit})	10^{-78}	Bekenstein bound
Spectral dimension	$\varphi/2 = 0.809017$	8-phase coherence matrix + LQG
Thermal offset	$3/4 = 0.750000$	Quadratic potential scaling

3 Cosmological Results

3.1 Resolution of the Hubble Tension

The quantum brake modifies the effective Friedmann equation in the early universe:

$$H^2(z) = H_0^2 \left[k_{\text{early}}\,\Omega_m(1+z)^3 + k_{\text{early}}\,\Omega_r(1+z)^4 + \Omega_\Lambda\right] \tag{1}$$

With $k_{\text{early}} = 0.967$, the effective density of matter and radiation is reduced by 3.3% for $z \gg 1$. This shortens the sound horizon from the Planck value $r_d = 147.09$ Mpc to $r_d \approx 141$ Mpc, reconciling the CMB-inferred H_0 with the local measurement.

3.2 BAO Validation

The UAT model has been tested against BAO data from BOSS, eBOSS, and DESI [13]. Table 2 presents the results. We note that the value $r_d \approx 141$ Mpc used in these comparisons is an effective parameter obtained from MCMC fits, not a first-principles calculation. A self-consistent computation of r_d within the UAT framework requires modifying Boltzmann solvers, which remains a technical barrier [8].

Table 2: χ^2 comparison between ΛCDM and UAT against BAO data.

Model	H_0 (km/s/Mpc)	r_d (Mpc)	χ^2	$\Delta\chi^2$ vs. ΛCDM
ΛCDM (Planck)	67.36	147.09	87.09	—
ΛCDM (SH0ES)	73.00	147.09	72.75	−14.34
UAT	**73.00**	**141.00**	**48.68**	**+38.41**

The UAT model yields a χ^2 significantly lower than both ΛCDM variants, indicating superior fit to the BAO data while maintaining consistency with the local H_0 measurement.

3.3 The Cosmological Constant

The vacuum energy density is derived from the three pillars of the framework [3]:

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

This matches the observed value (Planck 2018: $2.47 \pm 0.03 \times 10^{-122}\, M_{\text{Pl}}^4$) to within $\sim 1.2\%$. The derivation uses no free parameters beyond the three pillars and the Bekenstein bound. We note that the uncertainty in $\kappa_{\text{crit}} = 10^{-78\pm0.5}$ propagates to an uncertainty of approximately a factor of 6 in Λ, so the precise numerical agreement should be interpreted with caution.

3.4 The Cosmic Coincidence Problem

In the standard ΛCDM model, the approximate equality $\Omega_m \sim \Omega_\Lambda$ at the present epoch is considered a puzzle: why should the matter density and the dark energy density be of the same order of magnitude just now, when they evolve so differently with redshift? This is the "cosmic coincidence problem" [10].

Within the UAT/UCP framework, this apparent coincidence is a direct consequence of the condition of causal closure. The dark energy density is not a free parameter but is determined by the quantum brake and the matter density:

$$\Omega_\Lambda^{(\text{UAT})} = 1 - k_{\text{early}}(\Omega_m + \Omega_r) \tag{3}$$

For $k_{\text{early}} = 0.967$, any value of Ω_m in the range 0.25–0.35 produces Ω_Λ in the range 0.66–0.76. The two densities are therefore forced to be of comparable magnitude by the geometry of the causal membrane, not by an accident of cosmic timing. The question "why now?" is replaced by "why this value of k_{early}?" —a question that is referred back to the 7% thermal calibration margin.

We emphasise that this explanation, while internally consistent, does not constitute a rigorous solution to the coincidence problem. It reframes the question rather than answering it definitively.

3.5 The Extended Cosmic Age

The UAT expansion history implies an older universe than ΛCDM. A calculation using the modified Friedmann equation yields a present-day age of approximately 15.8 Gyr, compared to 13.8 Gyr for ΛCDM [9]. This additional ~ 2 Gyr provides more time for structure formation at high redshift, which may alleviate the tension between the standard cosmological timeline and the observation of massive, mature galaxies by JWST at $z > 10$. We note that the precise age depends on the specific formulation of the UAT expansion history and that the value cited is illustrative rather than definitive.

4 Causal Membrane Dynamics

4.1 The Cyclic Moment Equation

The static vacuum structure is complemented by a dynamic description: the accumulation of moment in the causal membrane over an operational cycle [6]:

$$\boxed{M_p = \oint \frac{\Psi_{\text{8phase}} \cdot \kappa_{\text{crit}}}{\sqrt{1-(v/c)^2}}\, dt} \tag{4}$$

where $\Psi_{\text{8phase}} = \sum_{k=0}^{7} A_k e^{i(\omega t + \theta_k)}$ is the collective state of the 8 phase fronts, with $\theta_k = k \times 43.515°$.

4.2 The Causal Overflow

Numerical evaluation reveals that the operational cycle spans $8 \times 43.515° = 348.12°$, not the classical $360°$. The deficit:

$$\boxed{\varepsilon = 360° - 348.12° = 11.88° \quad \Rightarrow \quad \varepsilon_{\text{frac}} = 0.0330 = 3.3\% = 1 - k_{\text{early}}} \tag{5}$$

is the **causal overflow**: the fraction of phase space that cannot be coherently integrated within a single cycle. This energy is expended to sustain cosmic expansion. The temporal difference per cycle is 176,122 ns at $f_{\text{base}} = 187.37$ Hz, corresponding exactly to $1 - k_{\text{early}}$.

The M_p ratio between the UAT and classical cycles is approximately 2.54, indicating enhanced moment accumulation due to the non-Euclidean phase geometry. The relativistic correction is negligible ($\gamma \approx 1$, with $v/c \approx 2.84 \times 10^{-9}$).

4.3 Connection to the 7% Margin

The causal overflow (3.3%) is doubled by the quadratic scaling of the double-well potential $V(\phi) \propto \phi^4$ to yield the thermal calibration margin:

$$2 \times 3.3\% = 6.6\% \approx 7\% = \phi_*/\eta \tag{6}$$

5 Laboratory Validation: The 8-Coil Interferometer

5.1 The Force Metric

The force metric $R_{\text{geom}} = 0.279182$ is derived from the 8-phasor sum with step $\Delta\theta = 45° \times k_{\text{early}} = 43.515°$:

$$R_{\text{geom}} = \left| \sum_{k=0}^{7} e^{ik\Delta\theta} \right| = \frac{\sin(8 \times 43.515°/2)}{\sin(43.515°/2)} = 0.279182 \tag{7}$$

This value agrees with the experimentally measured amplitude in an 8-coil phase interferometer (0.2792 ± 0.0005) [1].

5.2 Monte Carlo Validation

A Monte Carlo simulation with 10,000 iterations tested the null hypothesis that the observed residual arises from random thermal phase jitter (Gaussian noise with $\sigma = 3°$ added to the classical 45° step). The results are presented in Table 3.

Table 3: Monte Carlo validation of the force metric.

Statistic	**Value**
Simulations	10,000
Null mean amplitude	0.0164
Null standard deviation	0.0085
Maximum null amplitude	0.0588
Observed amplitude (R_{geom})	0.2791
p-value	$< \mathbf{0.001}$
Ratio observed/maximum null	**4.7**$\times$

The null hypothesis is decisively rejected. The observed residual cannot be explained by thermal noise. We note that the Monte Carlo simulation demonstrates that the signal is non-random; it does not independently prove that the system operates at the UAT phase angle.

6 Falsifiable Predictions

The framework makes the following specific, testable predictions:

1. **Three-depth experiment:** A differential measurement with three optical clocks at depths of 0, 1000, and 3000 meters, with timing photons traversing the water column, should detect a residual of 5.16 ns between 1000 m and 3000 m, with an SNR $> 10^6$ after 1 hour of integration [5]. A null result would constrain or refute the causal friction coefficient $\kappa = 0.2791$ ns/mm.

2. **Causal overflow timing:** At the base frequency $f_{\text{base}} = 187.37$ Hz, each operational cycle should exhibit a timing discrepancy of 176,122 ns relative to the classical expectation. This is measurable with current optical clock technology.

3. **8-coil replication:** Any 8-element phase-coherent array operated at the UAT step angle of 43.515° should produce a normalized residual amplitude of 0.2791, independent of the physical substrate (copper coils, optical fibers, acoustic resonators).

4. **Euclid/Roman/DESI-2:** The UAT prediction $\Omega_\Lambda \approx 0.6953$ is systematically higher than the ΛCDM value (~ 0.685) by approximately 0.01. Stage IV surveys with projected precision $\sigma(\Omega_m) \sim 0.003$ should be able to distinguish between the two models.

5. **Exact spatial flatness:** The UAT/UCP framework predicts $\Omega_k = 0$ exactly, as a consequence of the entropic equilibrium condition $\dot{S}_{\text{net}} = 0$ at the causal horizon. This is a stronger statement than the ΛCDM assumption of flatness (which is a postulate of inflation, not a dynamical necessity). Future measurements with $\sigma(\Omega_k) \sim 0.001$ from Euclid and Roman will test this prediction.

7 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. Its value is inferred from observation, not from first principles. A systematic numerical search confirmed that 0.07 does not emerge from combinations of φ, π, e, or η [4].

2. **The UAT/UCP framework is not part of mainstream physics.** Its constants do not appear in standard references (CODATA, NIST) and it has not undergone peer review in high-impact journals.

3. **The framework does not extend to particle physics.** A systematic numerical exploration found no structural connection between UAT/UCP constants and Standard Model constants (α, $\sin^2\theta_W$, α_s) [7].

4. **The M_p equation is phenomenological.** It is motivated by the UAT Lagrangian through Noether's theorem, but a rigorous derivation remains incomplete. The connection is formal, not rigorous.

5. **The BAO comparison uses an effective r_d.** The value $r_d \approx 141$ Mpc is obtained from MCMC fits, not from a first-principles integration over the UAT expansion history. A self-consistent calculation requires a modified Boltzmann solver [8].

6. **Independent experimental validation is pending.** The 8-coil measurement and the Monte Carlo simulation were performed by the author. Replication by an independent laboratory is essential.

7. **The explanation of the cosmic coincidence problem is a reframing, not a solution.** Equation (3) shows that $\Omega_m \sim \Omega_\Lambda$ is forced by the geometry of the causal membrane, but the question of why $k_{\text{early}} = 0.967$ is referred back to the 7% margin, whose origin remains empirically constrained rather than derived.

8 Conclusion

The UAT/UCP framework is a phenomenological model that addresses the Hubble tension and the cosmological constant problem through a single mechanism: the quantum brake. With one free parameter —the 7% thermal calibration margin— it produces a self-consistent set of constants that yield $H_0 = 73.0$ km/s/Mpc, $\Lambda = 2.50 \times 10^{-122}\, M_{\text{Pl}}^4$, and a superior fit to BAO data ($\chi^2 = 48.7$ vs. $\chi^2 = 87.1$ for ΛCDM).

The dynamic extension —causal membrane dynamics— reveals that the universe operates on a truncated phase cycle, expending 3.3% of its energy per cycle on expansion. The force metric $R_{\text{geom}} = 0.2791$ has been validated in the laboratory and confirmed non-random by Monte Carlo simulation ($p < 0.001$).

The framework makes specific, falsifiable predictions. The three-depth experiment, the causal overflow timing measurement, the comparison with Stage IV survey data, and the prediction of exact spatial flatness will determine whether the UAT/UCP framework describes physical reality or is an internally consistent but ultimately incorrect model.

$\boxed{\text{The framework is coherent. The predictions are specific.}}$

$\boxed{\text{Experiment will decide.}}$

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This document unifies all UAT/UCP results in cosmology.
It is intended as a reference for researchers evaluating the framework.
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