A Phenomenological Relation for the Effective Matter Density

within the UAT/UCP Framework and the Hubble Tension as a Metric Scaling Artifact

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Abstract

We present a phenomenological relation —not a first-principles derivation— linking the bare baryon density of the universe to the observed effective matter density. The relation emerges from the product of three independently calibrated parameters of the Unified Applicable Time (UAT) and Unified Causal Principle (UCP) frameworks: the Ivancho limit ($\kappa_{\text{crit}} = 4.978$), the golden ratio ($\varphi \approx 1.618$), and the thermal efficiency factor ($1 - 0.07 = 0.93$). When multiplied by the baryon density inferred from Big Bang Nucleosynthesis and the local Hubble constant, the product reproduces the Planck 2018 value of Ω_m with a deviation of 0.55%. The corresponding dark energy density, obtained from geometric closure under the UAT prediction of exact spatial flatness, matches the Planck value within 0.24%. We explicitly acknowledge that the relation $\Omega_m^{(\text{eff})} = \Omega_b \times \kappa_{\text{crit}} \times \varphi \times (1 - \phi_*/\eta)$ is a phenomenological ansatz, not a rigorous consequence of the UAT Lagrangian. Its concordance with observation may indicate a genuine connection between causal geometry and cosmological parameters, or it may be a numerical coincidence. Independent experimental tests —notably the proposed three-depth experiment— will be required to distinguish between these possibilities. The accompanying Python script reproduces all calculations using no ΛCDM-derived parameters as input.

1 Introduction

Modern cosmology faces a persistent challenge: the $\sim 5\sigma$ discrepancy between the Hubble constant measured from the early universe (Cosmic Microwave Background, $H_0 \approx 67.4$ km/s/Mpc) and the late universe (Cepheid-calibrated supernovae, $H_0 \approx 73.0$ km/s/Mpc) [1, 2]. This "Hubble Tension" has resisted resolution within the standard ΛCDM framework.

The Unified Applicable Time (UAT) and Unified Causal Principle (UCP) frameworks [3, 4] propose that the tension arises not from unknown physics, but from the application of a linear cosmological model to a fundamentally non-linear causal structure. The frameworks contain a set of interlocking constants —the Ivancho limit ($\kappa_{\text{crit}} = 4.978$), the quantum braking factor ($k_{\text{early}} = 0.967$), the golden ratio (φ), and the thermal calibration margin ($\phi_*/\eta = 0.07$)— that were independently calibrated from cosmology, laboratory experiments, and geometric considerations [3, 4, 7, 6, 5].

In this document, we explore a phenomenological relation that combines these constants with the baryon density from Big Bang Nucleosynthesis (BBN) and the locally measured Hubble constant. We make no claim of a rigorous derivation; we present a numerical observation and discuss its possible physical significance.

2 Theoretical Background

2.1 The UAT/UCP Constants

The constants relevant to the present analysis are summarised in Table 1. Each was determined independently of the cosmological density parameters Ω_m and Ω_Λ, and none was adjusted to reproduce the results presented here.

Table 1: UAT/UCP constants used in the phenomenological relation.

Constant	**Symbol & Value**	**Origin**
Ivancho Limit	$\kappa_{\text{crit}} = 4.978$	Metric buffer saturation [5]
Golden Ratio	$\varphi = (1+\sqrt{5})/2 \approx 1.618$	8-phase coherence matrix [3]
Thermal Margin	$\phi_*/\eta = 0.07$ (7%)	Empirical calibration [7]
Quantum Brake	$k_{\text{early}} = 0.967$	Derived from thermal margin [5]
Causal Overflow	$\varepsilon = 1 - k_{\text{early}} = 3.3\%$	Energy fraction per cycle

2.2 The Hubble Tension as a Metric Scaling Artifact

The critical density of the universe is defined as:

$$\rho_{\text{crit}} = \frac{3H_0^2}{8\pi G} \tag{1}$$

where G is the gravitational constant. The dimensionless density parameter for any component X is $\Omega_X = \rho_X/(\rho_{\text{crit}}c^2)$.

The Planck collaboration [1] reports $\Omega_b^{(\text{Planck})} \approx 0.0493$ assuming $H_0 \approx 67.36$ km/s/Mpc. Direct local measurements (SH0ES) [2] yield $H_0 = 73.04$ km/s/Mpc. Since $\rho_{\text{crit}} \propto H_0^2$, any parameter expressed in density units is sensitive to the choice of H_0. Recalibrating the Planck baryon density to the local metric yields:

$$\Omega_b^{(\text{recalibrated})} = \Omega_b^{(\text{Planck})} \times \left(\frac{H_0^{(\text{Planck})}}{H_0^{(\text{SH0ES})}}\right)^2 = 0.0493 \times 0.8505 \approx 0.0419 \tag{2}$$

This recalibrated value is consistent with the first-principles BBN calculation presented below, indicating that the apparent discrepancy in Ω_b between early-universe and late-universe measurements is a scaling artifact, not a physical tension.

3 Calculation of Cosmological Densities

3.1 Baryon Density from BBN

The baryon-to-photon ratio η_B is measured independently of any cosmological model through primordial light-element abundances [10]:

$$\eta_B = (6.10 \pm 0.04) \times 10^{-10} \tag{3}$$

The present-day CMB photon number density is given by the blackbody distribution:

$$n_{\gamma,0} = \frac{2\zeta(3)}{\pi^2}\left(\frac{k_B T_{\text{CMB}}}{\hbar c}\right)^3 \tag{4}$$

with $T_{\text{CMB}} = 2.7255$ K [9], k_B the Boltzmann constant, $\hbar$ the reduced Planck constant, and $\zeta(3) \approx 1.20206$.

The baryon number density is $n_B = \eta_B \cdot n_{\gamma,0}$, and the baryon mass density in energy units is $\rho_b = n_B m_p c^2$, where m_p is the proton mass. The dimensionless baryon density is:

$$\Omega_b = \frac{\rho_b}{\rho_{\text{crit}} c^2} \tag{5}$$

Using $H_0 = 73.04$ km/s/Mpc (SH0ES), this yields $\Omega_b = 0.04182$.

3.2 Radiation Density from CMB Temperature

The photon energy density follows from the Stefan-Boltzmann law:

$$\rho_\gamma = \frac{\pi^2 k_B^4}{15\hbar^3 c^3} T_{\text{CMB}}^4 \tag{6}$$

With three neutrino species at $T_\nu = (4/11)^{1/3} T_{\text{CMB}}$, the total radiation density is:

$$\Omega_r = \Omega_\gamma \left[1 + 3 \times \frac{7}{8} \times \left(\frac{4}{11}\right)^{4/3}\right] = 7.79 \times 10^{-5} \tag{7}$$

4 A Phenomenological Relation for the Effective Matter Density

4.1 Statement of the Relation

We propose the following phenomenological relation linking the bare baryon density to the observed effective matter density:

$$\boxed{\Omega_m^{(\text{eff})} = \Omega_b \times \kappa_{\text{crit}} \times \varphi \times (1 - \phi_*/\eta)} \tag{8}$$

We emphasise that Eq. (8) is **not** derived from the UAT Lagrangian or from any fundamental equation of motion. It is a phenomenological ansatz —an educated guess— motivated by the physical interpretation of each factor within the UAT/UCP framework:

1. Ω_b: The bare baryon density —the mass that would be measured if no additional gravitational effects were present.

2. $\boldsymbol{\kappa_{\text{crit}}} = 4.978$: The Ivancho Limit. Within UAT/UCP, this constant governs the saturation threshold of the causal metric buffer. In the context of Eq. (8), it is interpreted as the maximum amplification factor that the causal network can exert on baryonic matter before coherence is lost.

3. $\varphi \approx 1.618$: The Golden Ratio. This constant emerges from the 8-phase coherence matrix and encodes the geometric structure of constructive phase interference. Its role in Eq. (8) is to provide the spatial modulation of the amplification.

4. $(1 - \phi_*/\eta) = 0.93$: The thermal efficiency factor. The UAT/UCP framework identifies a 7% irreducible thermal dissipation margin. Only the remaining 93% of the causal amplification contributes to the effective gravitational mass.

4.2 Numerical Evaluation

Substituting the independently determined values:

$$\Omega_m^{(\text{eff})} = 0.04182 \times 4.978 \times 1.618034 \times 0.93 = 0.3133 \tag{9}$$

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

4.3 Dark Energy Density from Geometric Closure

The UAT/UCP framework predicts exact spatial flatness ($\Omega_k = 0$) as a consequence of the entropic equilibrium condition $\dot{S}_{\text{net}} = 0$ at the causal horizon [4]. Under this condition, the dark energy density is the remaining fraction of the total energy budget:

$$\boxed{\Omega_\Lambda^{(\text{UAT})} = 1 - \left(\Omega_m^{(\text{eff})} + \Omega_r\right)} \tag{10}$$

Substituting:

$$\Omega_\Lambda^{(\text{UAT})} = 1 - (0.3133 + 0.000078) = 0.6867 \tag{11}$$

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

5 Results and Observational Comparison

Table 2: Comparison of UAT/UCP phenomenological predictions with Planck 2018 observations.

Parameter	**UAT/UCP**	**Planck 2018**	**Difference**
Ω_b (baryons)	0.04182	0.0493 ± 0.0005	15.2%*
Ω_m (effective)	**0.3133**	0.315 ± 0.007	**0.55%**
Ω_Λ (dark energy)	**0.6867**	0.685 ± 0.007	**0.24%**
Ω_r (radiation)	7.79×10^{-5}	9.24×10^{-5}	15.7%*
Ω_k (curvature)	**0** (predicted)	0.0007 ± 0.0019	consistent

*The apparent discrepancy in Ω_b and Ω_r is a direct consequence of the H_0 scaling effect described in Section 2.2. When the Planck values are recalibrated to the local $H_0 = 73.04$ km/s/Mpc, the disagreement vanishes.

6 Discussion

6.1 Interpretation of the Phenomenological Relation

Equation (8) reproduces the observed matter density with high precision. However, the following caveats must be explicitly acknowledged:

1. **The relation is phenomenological, not fundamental.** It was not derived from the UAT Lagrangian. It is a numerical observation: the product of three independently calibrated UAT constants, when multiplied by the BBN baryon density, yields a value coincident with the Planck measurement.

2. **The concordance may be coincidental.** The factors κ_{crit}, φ, and $(1 - 0.07)$ were not adjusted to produce this result. However, with three constants one can always find a combination that approximates a given target. Whether this particular combination has physical significance beyond numerics remains an open question.

3. **Independent tests are required.** The proposed three-depth experiment [8] would measure the causal friction coefficient $\kappa = 0.2791$ ns/mm in a dense medium. If this independent measurement confirms the UAT prediction, the phenomenological relation presented here would gain credibility. If it refutes it, the relation would be discarded.

6.2 Historical Precedent

Phenomenological relations have played an important role in the history of physics. Kepler's laws of planetary motion were empirical fits to Tycho Brahe's data before Newton derived them from the law of gravitation. Planck's radiation law was an empirical fit before the development of quantum mechanics. The Balmer formula for hydrogen spectral lines preceded the Bohr model. In each case, the phenomenological success motivated —and was eventually explained by— a deeper theory.

Equation (8) may occupy a similar status within the UAT/UCP framework: a numerical observation that, if confirmed by independent experiment, would motivate a rigorous derivation from the UAT Lagrangian.

6.3 What This Result Does and Does Not Show

What it shows: The UAT/UCP constants κ_{crit}, φ, and ϕ_*/η, when combined as in Eq. (8), transform the independently measured baryon density into the observed total matter density with a deviation of less than 1%.

What it does not show: That dark matter is definitively explained as causal friction. That κ_{crit} necessarily amplifies gravitational mass. That the relation is unique or inevitable. That the UAT/UCP framework is validated.

7 Conclusion

We have presented a phenomenological relation, $\Omega_m^{(\text{eff})} = \Omega_b \times \kappa_{\text{crit}} \times \varphi \times (1 - \phi_*/\eta)$, that reproduces the Planck 2018 matter density with a deviation of 0.55% and the corresponding dark energy density with a deviation of 0.24%. The relation uses no ΛCDM parameters as input and relies exclusively on independently calibrated UAT/UCP constants, standard physics, and observational data independent of the standard cosmological model.

We explicitly acknowledge the phenomenological nature of this relation and the possibility that its concordance with observation is coincidental. Independent experimental tests —foremost among them the proposed three-depth experiment— will be required to determine whether Eq. (8) reflects a genuine physical connection or a numerical curiosity.

$$\boxed{\text{The relation is observed. Its meaning is open.}}$$

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

Data and Code Availability

The Python script `uat_phenomenological_matter.py` that reproduces all calculations in this document is provided as supplementary material. It uses only standard Python libraries (NumPy, SciPy) and requires no external data files.

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Technical Note — July 12, 2026
This document presents a phenomenological relation, not a first-principles derivation.
Its physical significance remains to be determined by independent experiment.

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