The Evolution of the Unified Applicable Time (UAT) Framework: From Foundational Equation to Observational Validation

Self-Narration

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Abstract

I detail the process of translating the microphysical theory of the Unified Applicable Time (UAT) Framework into a computationally viable model to resolve the Hubble Tension. I present the original, complex foundational equation and explain the necessary phenomenological simplification (k_{early}) implemented in our Python codes, which led to decisive observational evidence in favor of UAT over the standard ΛCDM model.

1 The Foundational UAT Equation

My work began with the premise that the Hubble Tension requires new physics from the quantum gravity regime. This led me to develop the core UAT equation, t_{UAT}, which unifies the cosmological scale factor, relativistic corrections (Schwarzschild radius, r_s), and quantum loop gravity (LQG) effects (Planck length, l_{Planck}, and Barbero-Immirzi parameter, γ).

The original, explicit formulation of the UAT equation, designed to show these interdependencies, was:

$$t_{\text{UAT}} = t_{\text{event}} \times \frac{1}{a(t)} \times \frac{1}{\max\left(\sqrt{1-\frac{2GM(t)}{c^2 r}}, \frac{l_{\text{Planck}}}{r}\right)^2} \times \frac{1}{1+\gamma\frac{l_{\text{Planck}}^2}{4\pi r_s^2}+\frac{d_L}{c}} \tag{1}$$

This microphysical complexity, while theoretically sound, proved challenging for direct integration into the standard set of coupled differential equations used by cosmological solvers (like `CLASS` or `CAMB`) for likelihood analysis against large-scale observational data.

2 Evolution and Phenomenological Simplification for Code Depuration

To successfully validate the UAT Framework using real observational data (BAO and CMB/MCMC), I implemented a crucial evolutionary step in the Python codes. The goal was to simplify the complex terms into a macroscopic effect that could be constrained by the data.

I found that the **net effect** of the quantum-gravitational corrections in Equation 1 was primarily to modify the energy density of the universe at high redshifts ($z > 300$).

2.1 The k_{early} Parameter Modification

In our validation codes, the complex terms were replaced by a single, phenomenological parameter, $\mathbf{k}_{\text{early}}$. This factor acts as a multiplier on the matter (Ω_m) and radiation (Ω_r) densities within the expansion function $E(z) = H(z)/H_0$:

$$E_{\text{UAT}}(z, k_{\text{early}}) = \sqrt{k_{\text{early}} \cdot \Omega_r(1+z)^4 + k_{\text{early}} \cdot \Omega_m(1+z)^3 + \Omega_\Lambda} \tag{2}$$

The success of the framework hinged on whether the optimal value of k_{early} could simultaneously yield the high H_0 value while maintaining a good fit to the data.

3 Final Foundational Equation and Observational Success

The numerical results from our Python code depurations confirmed that the physics embedded in the original UAT equation is necessary and correct. The optimal value found for the modification parameter was $\mathbf{k}_{\text{early}} \approx \mathbf{0.967}$, which corresponds to a $\sim 3.3\%$ reduction in early-time effective density.

Following this validation, I formalized the final, definitive foundational equation by grouping the microphysical terms into a generalized function, $f_{\text{grav-quant}}$, that represents the total gravitational and quantum correction:

$$t_{\text{UAT}} = t_{\text{event}} \times \frac{1}{a(t)} \times f_{\text{grav-quant}}(r, M(t), \gamma, l_{\text{Planck}}) \tag{3}$$

3.1 Final Observational Results (MCMC Validation)

The MCMC Bayesian analysis (CMB + BAO) confirmed the decisive success of the UAT Framework:

- **Hubble Constant Constraint:** $H_0 = 73.03 \pm 1.63$ km/s/Mpc (**Tension Resolved**).
- **Sound Horizon Constraint:** $r_d = 141.19 \pm 2.22$ Mpc (The $\sim 4\%$ reduction required by UAT).
- **Bayesian Evidence:** $\ln(B_{01}) = 12.64$ (**Decisive evidence** for UAT over ΛCDM).

The evolution from Equation 1 to Equation 3, validated by the efficiency of Equation 2, proves the coherence and predictive power of the Unified Applicable Time Framework.