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

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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 (e.g., CLASS/CAMB).

2 The Phenomenological Simplification (k_{early})

To make the UAT physics testable against high-precision data (CMB, BAO), a phenomenological simplification was necessary. I defined the parameter k_{early} to capture the net quantum-gravitational correction effect of the Torsion Ring Hypothesis in the early universe, where $z \gg 300$.

The modified Friedmann equation implements this correction by reducing the effective density of the radiation and matter components:

$$E_{\text{UAT}}(z, k_{\text{early}})^2 = k_{\text{early}} \cdot \Omega_{r,0}(1+z)^4 + k_{\text{early}} \cdot \Omega_{m,0}(1+z)^3 + \Omega_{\Lambda,0} \tag{2}$$

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 $k_{\text{early}} \approx \mathbf{0.970}$, which corresponds to a $\sim 3.0\%$ 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 + SNe Ia) confirmed the decisive success of the UAT Framework:

- Hubble Constant Constraint: $H_0 = \mathbf{73.02 \pm 0.82}$ km/s/Mpc (Tension Resolved).
- Sound Horizon Constraint: $r_d = \mathbf{141.75 \pm 1.1}$ Mpc (The $\sim 3.6\%$ reduction required by UAT).
- Statistical Improvement: $\Delta\chi^2 = +\mathbf{40.389}$ (vs ΛCDM optimal).
- Bayesian Evidence: $\ln(B_{01}) = \mathbf{12.64}$ (Decisive evidence for UAT over ΛCDM).

The evolution from Equation 1 to Equation 3, validated by the robust observational constraints, demonstrates the fundamental power of the UAT framework in resolving the Hubble Tension through quantum gravitational effects.