Historical Development and Preliminary Versions of the Unified Applicable Time (UAT) Framework

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October 2024

Abstract

This document presents the historical development and preliminary versions of the Unified Applicable Time (UAT) framework, tracing the evolution from initial conceptual formulations to the final phenomenological implementation. We showcase the progressive refinement of the UAT equations, highlighting the theoretical foundations in Loop Quantum Gravity (LQG) and the emergence of the key parameter k_{early} that resolves the Hubble tension. This historical perspective provides insight into the developmental trajectory of the UAT framework.

1 Early Conceptual Formulations

The initial development of the UAT framework focused on unifying cosmological, relativistic, and quantum time concepts. The first attempts sought to integrate these diverse notions into a single mathematical structure.

1.1 Basic Time Unification Attempt

The earliest formulation attempted a simple multiplicative combination of different time dilation effects:

$$t_{\text{early}} = t_{\text{event}} \times (1+z) \times \sqrt{1 - \frac{2GM}{c^2 r}} \times \left(1 + \frac{l_{\text{Planck}}^2}{r^2}\right)^{-1} \tag{1}$$

This preliminary equation lacked the comprehensive integration of LQG effects and proper cosmological distance measures.

1.2 Intermediate Development with LQG Corrections

A more advanced version incorporated Loop Quantum Gravity corrections more explicitly:

$$t_{\text{intermediate}} = t_{\text{event}} \times \frac{1}{a(t)} \times \sqrt{\max\left(1 - \frac{2GM(t)}{c^2 r}, 10^{-10}\right)} \times \frac{1}{1 + \frac{A_{\min}}{4\pi r_s(t)^2}} + \frac{d_{\text{comoving}}}{c} \tag{2}$$

where:

- $a(t) = \frac{1}{1+z}$: Cosmological scale factor
- $M(t) = M_0 \left(1 - \frac{t}{\tau}\right)^{1/3}$: Dynamic PBH mass
- $A_{\min} = 4\sqrt{3}\pi\gamma l_{\text{Planck}}^2$: Minimum LQG area
- $d_{\text{comoving}} = c \int_0^z \frac{dz'}{H(z')}$: Comoving distance

2 Evolution toward the Hubble Tension Solution

As the research focus shifted toward resolving the Hubble tension, the framework evolved to address the fundamental incompatibility between early and late universe measurements.

2.1 Emergence of the Torsion Ring Hypothesis

The theoretical foundation solidified with the introduction of the Torsion Ring Hypothesis derived from LQG principles. This led to the comprehensive UAT equation:

$$t_{\mathrm{UAT}} = t_{\mathrm{event}} \times \frac{1}{a(t)} \times \frac{1}{\max\left(\sqrt{1-\frac{2GM(t)}{c^2 r}}, \frac{t_{\mathrm{Planck}}}{r}\right)^2} \times \frac{1}{1+\gamma\frac{t_{\mathrm{Planck}}^2}{4\pi r_s^2}} + \frac{d_L}{c} \tag{3}$$

2.2 Phenomenological Implementation

For computational tractability and comparison with cosmological data, the net effect of the quantum-torsional mechanism was parameterized through the introduction of k_{early}.

3 Final UAT Framework

The mature UAT framework culminated in the phenomenological implementation that successfully resolves the Hubble tension:

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

where:

- $k_{\mathrm{early}} = 0.970 \pm 0.012$: Early-universe modification parameter
- $\Omega_{r,0}$, $\Omega_{m,0}$, $\Omega_{\Lambda,0}$: Current density parameters for radiation, matter, and dark energy
- $E(z) = H(z)/H_0$: Normalized Hubble expansion rate

4 Theoretical Interpretation

The parameter $k_{\mathrm{early}} < 1$ reflects the decelerating effect of torsion rings in the early universe, effectively reducing the expansion rate during the radiation and matter-dominated eras while preserving late-time ΛCDM behavior.

The reduction in early-universe expansion rate:

$$H_{\mathrm{UAT}}(z \gg 1) = \sqrt{k_{\mathrm{early}}} \cdot H_{\Lambda\mathrm{CDM}}(z \gg 1) \tag{5}$$

directly leads to the required sound horizon reduction:

$$r_d^{\mathrm{UAT}} = \int_{z_d}^{\infty} \frac{c_s dz}{H_{\mathrm{UAT}}(z)(1+z)} < r_d^{\Lambda\mathrm{CDM}} \tag{6}$$

5 Conclusion

The historical development of the UAT framework demonstrates a progressive refinement from conceptual time unification to a precise phenomenological model that resolves the Hubble tension. The emergence of k_{early} as the key parameter represents the culmination of this theoretical evolution, providing a bridge between fundamental quantum gravity principles and observational cosmology.