Five Observational Tests of the UAT/UCP Framework

Miguel Ángel Percudani
`miguel_percudani@yahoo.com.ar`
Puan, Buenos Aires, Argentina

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Overview

This repository presents five independent but complementary observational analyses of the Unified Applicable Time (UAT) and Unified Causal Principle (UCP) frameworks. The primary aim is to test whether the UAT/UCP paradigm, originally developed to resolve the Hubble tension, can simultaneously address a broad range of cosmological and astrophysical tensions without introducing additional free parameters beyond those already fixed by the UAT axioms.

Each analysis is self-contained in a separate ZIP file and includes:

- the corresponding Python script,
- all generated figures,
- a LaTeX document detailing the methodology, results, and limitations of the test.

All analyses use the canonical UAT parameters: the quantum brake $k_{\text{early}} = 0.967$, the local Hubble constant $H_0 = 73.04$ km/s/Mpc, and the density parameters re-scaled from their Planck values to preserve the physical matter density at high redshift. No further free parameters are introduced. The results are presented with complete transparency regarding their limitations, and the author encourages independent verification and open collaboration.

The Five Observational Tests

Test 1: Big Bang Nucleosynthesis (BBN) – Helium-4 Abundance

The expansion rate during the first minutes of the universe determines the neutron-to-proton ratio at freeze-out and hence the primordial helium-4 mass fraction Y_p. Because a full BBN code requires modification of the source code to incorporate the UAT expansion history, this test employs a well-established linear perturbation formalism. The quantum brake is mapped onto an effective variation of the relativistic degrees of freedom ΔN_{eff}, and the helium abundance is adjusted using published sensitivity coefficients. The result, $Y_p^{\text{UAT}} = 0.2443$, lies within 0.15σ of the observed value $Y_p^{\text{obs}} = 0.2449 \pm 0.0040$, improving upon the standard ΛCDM baseline.

Test 2: Primordial Gravitational Waves – Tensor Transfer Function

The evolution of primordial tensor modes after horizon re-entry is sensitive to the expansion history. We solve the tensor mode equation for a representative comoving wavenumber $k = 0.1\,\mathrm{Mpc}^{-1}$ using the UAT and ΛCDM backgrounds, and extract the proper envelope amplitude to avoid oscillatory phase artefacts. The tensor amplitude in UAT is found to be 0.3% larger than in ΛCDM, corresponding to a 0.6% increase in the tensor-to-scalar ratio r. The effect is far below current observational sensitivity ($r < 0.036$) but could serve as a target for next-generation CMB experiments.

Test 3: Strong Gravitational Lensing – Angular Diameter Distances and Time Delays

Strong lensing time delays provide a geometric probe of the expansion history that is independent of the cosmic distance ladder. We compute the angular diameter distance $D_A(z)$ for UAT and ΛCDM. Owing to the higher local H_0, UAT predicts distances that are 3–6% shorter at redshifts $0.5 \leq z \leq 2.0$. This reduction is consistent with the shorter time delays measured by the H0LiCOW collaboration, which prefer a high local H_0. The difference between the two models decreases at higher redshifts, reflecting the compensating effect of the quantum brake.

Test 4: Dwarf Galaxy Dark Matter Density Profiles – Solitonic Core vs. NFW Cusp

The UAT scalar field ϕ has a mass $m_\phi \approx 1.5 \times 10^{-27}\,\mathrm{eV}$ and a Compton wavelength $\lambda_c \approx 4.2\,\mathrm{kpc}$. On scales smaller than λ_c, quantum pressure counteracts gravitational collapse, producing a flat, constant-density core. This natural solitonic profile is in qualitative agreement with kinematic observations of dwarf spheroidal galaxies (e.g., Fornax, Sculptor), which favour cores over the cuspy NFW profile predicted by standard cold dark matter.

Test 5: Variation of the Fine-Structure Constant – Sensitivity to a Scalar–Photon Coupling

If the UAT scalar field couples to the electromagnetic sector via a dimensionless Yukawa coupling ζ, it would induce a cosmological variation of the fine-structure constant α. We perform a sensitivity analysis and find that for $\zeta \lesssim 10^{-9}$ the predicted variation is comfortably below the current observational upper limit $|\Delta\alpha/\alpha| < 2 \times 10^{-5}$. The UAT framework is therefore fully consistent with the non-detection of α variation. Future high-resolution spectroscopy could either detect a non-zero ζ or further tighten the constraint.

Related DOIs

The UAT/UCP research programme is documented in a series of public Zenodo repositories:

- **UAT Framework**: `https://doi.org/10.5281/zenodo.17729221`

- **UPC Framework**: `https://doi.org/10.5281/zenodo.17718670`
- **UAT Lagrangian**: `https://doi.org/10.5281/zenodo.20500722`
- **UAT Tensions (Hubble, S_8, Age)**: `https://doi.org/10.5281/zenodo.20534633`
- **Technical Limitations Note**: `https://doi.org/10.5281/zenodo.20534771`
- **This repository (Five Observational Tests)**: `https://doi.org/10.5281/zenodo.20549616`

Author: Miguel Ángel Percudani (Puan, Buenos Aires, Argentina)