

Secular Drift of the UAT Scalar Field and Cosmological Imprints: From the Causal Membrane to the Genesis Factor

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Abstract

We formalise the “Genesis Factor” introduced in earlier conceptual discussions as a secular perturbation $\delta\phi(\tau)$ of the scalar field ϕ of the Unified Applicable Time (UAT) framework. The perturbation is anchored to the quantum brake $k_{\text{early}} = 0.967$, the causal overflow $\varepsilon = 0.033$, and the geometric residue $R_{\text{geom}} = 0.279182$, with a characteristic frequency that drifts linearly at $\alpha = +0.046$ Hz/day as measured in the laboratory 8-coil interferometer. We show that a fast oscillation at this frequency cannot leave a detectable cosmological imprint; instead, only the secular drift of ϕ over cosmic history can modify the expansion rate. We derive a correction to the modified Friedmann equation, $\delta\Omega_G(z) = \delta k(z)[\Omega_r(1+z)^4 + \Omega_m^{(\text{eff})}(1+z)^3]$, where $\delta k(z) \approx -0.109\beta(1+z)^{-\gamma}$. Using 31 cosmic chronometer $H(z)$ measurements, we constrain the amplitude β and exponent γ of the secular drift, finding $|\beta| < 0.25$ at 95% confidence and a mild preference for $\beta \approx 0.08$, $\gamma \approx 0.12$. We project that future surveys (Euclid, Roman, DESI-2) will improve the sensitivity to β by an order of magnitude. A dedicated laboratory experiment (the “UAT Phase Clock”) is proposed to directly measure the secular evolution of ϕ via the long-term drift of the interference frequency. All limitations of the present analysis—including the impossibility of a full Boltzmann-code implementation without source modification—are documented and included as supplementary material.

1 Introduction

The UAT/UCP framework [1, 2] describes reality as a perceptual metric filtered through a causal membrane. The membrane’s dynamics are governed by the interference of eight phase fronts with a quantum brake step $\Delta\theta = 45^\circ \times k_{\text{early}} = 43.515^\circ$, yielding the geometric residue $R_{\text{geom}} = 0.279182$ [3]. The scalar field ϕ of the UAT Lagrangian [4] has a mass $m_\phi \sim 10^{-27}$ eV and a Compton wavelength $\lambda_c \sim 4$ kpc, making it an ultralight dark matter candidate [5].

In a recent conceptual exploration, the “Patrón de Génesis” (Genesis Pattern) was introduced as the primordial pulse that resonates with the causal membrane, potentially representing the pure information of Bit 0 before its collapse into Bit 1. The accompanying “Factor Génesis” $G(t)$ was proposed as a mathematical factor to decouple instrumental

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biases and reveal the raw signal. In this work, we give a rigorous physical interpretation to $G(t)$: it is the secular perturbation $\delta\phi(\tau)$ of the UAT scalar field, driven by the same inflationary drift $\alpha = +0.046$ Hz/day observed in the laboratory.

We demonstrate that a fast laboratory-frequency oscillation cannot impact cosmology; only the secular, cumulative drift of ϕ over billions of years can leave an imprint. We derive the resulting correction to the Friedmann equation, constrain it with current cosmic chronometer data, and outline future tests.

2 Formalising the Genesis Factor as a Scalar Perturbation

2.1 The UAT Lagrangian and the scalar field

The UAT action is [4]

$$S_{\text{bulk}} = \int d^4x \sqrt{-g} \left[\frac{M_{\text{Pl}}^2}{2} R - \frac{1}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - V(\phi) - \frac{\xi}{2} R \phi^2 + \mathcal{L}_m \right], \quad (1)$$

with $V(\phi) = \frac{\lambda}{4}(\phi^2 - \eta^2)^2 + V_0$, $\eta \equiv \kappa_{\text{crit}} = 4.978$, $\xi = -0.2810$, $\lambda = 3.08 \times 10^{-112}$. In the late universe the field is frozen at $\phi_0 \approx 0.456$ [6].

We define the Genesis perturbation $\delta\phi(\tau)$ as a small time-dependent component on top of this background:

$$\phi(\tau) = \phi_0 + \delta\phi(\tau), \quad |\delta\phi| \ll \phi_0. \quad (2)$$

The laboratory 8-coil array measures a persistent frequency drift $\alpha = +0.046$ Hz/day [3]. We associate this with a secular change in ϕ : the instantaneous frequency of the interference pattern is $f(t) = f_{\text{base}} + \alpha t$, with $f_{\text{base}} = 187.37$ Hz. To embed this into the field dynamics, we note that the phase of the coherent 8-front sum is $\Phi(t) = 2\pi \int f(t) dt$. Thus, the simplest ansatz that captures the drift without introducing new free parameters is

$$\delta\phi(\tau) = A_G \sin \left(2\pi \int f(\tau) d\tau \right), \quad A_G = R_{\text{geom}} \varepsilon = 0.279 \times 0.033 \approx 9.2 \times 10^{-3}. \quad (3)$$

The amplitude A_G is fixed by the geometric residue and the causal overflow $\varepsilon = 1 - k_{\text{early}}$, ensuring consistency with the 8-phase structure.

2.2 Why fast oscillations cannot affect cosmology

The Klein-Gordon equation for ϕ in an FLRW background is $\ddot{\phi} + 3H\dot{\phi} + dV/d\phi + \xi R\phi = 0$. For the background ϕ_0 , the effective mass is $m_\phi = \sqrt{2\lambda}\eta \sim 10^{-27}$ eV. A forced oscillation at $\omega \sim 10^3$ rad/s would require an external source of energy density $\rho_{\text{source}} \sim \omega^2 A_G^2 M_{\text{Pl}}^2$, which exceeds the critical density of the universe by many orders of magnitude. Hence, the laboratory drift cannot be a global fast oscillation; it must instead reflect a minuscule secular change in ϕ that is locally detectable only because of the extreme precision of the phase measurement.

2.3 Secular drift model

We therefore model the cosmological evolution of ϕ as a slow, monotonic function of redshift:

$$\phi(z) = \phi_0 [1 + \beta(1+z)^{-\gamma}], \quad (4)$$

with $|\beta| \ll 1$ and $\gamma > 0$. This parametrisation is the simplest that allows a drift from the past to the present without introducing new scales. The quantum brake depends on ϕ via

$$k_{\text{early}}(\phi) = \frac{1}{1 - \xi\phi^2}, \quad (5)$$

so a changing ϕ induces a redshift-dependent k_{early} . Expanding to first order in β ,

$$k_{\text{early}}(z) = k_0 + \delta k(z), \quad \delta k(z) \approx -2|\xi|\phi_0^2\beta k_0^2(1+z)^{-\gamma} \approx -0.109\beta(1+z)^{-\gamma}, \quad (6)$$

with $k_0 = 0.967$.

3 Cosmological Imprint of the Secular Drift

The modified Friedmann equation in UAT is

$$H^2(z) = H_0^2 \left[k_{\text{early}}(z) \Omega_r(1+z)^4 + k_{\text{early}}(z) \Omega_m^{\text{(eff)}}(1+z)^3 + \Omega_\Lambda^{\text{(UAT)}} \right]. \quad (7)$$

Inserting $k_{\text{early}}(z)$ yields a correction

$$\delta\Omega_G(z) = \delta k(z) [\Omega_r(1+z)^4 + \Omega_m^{\text{(eff)}}(1+z)^3]. \quad (8)$$

This is the only cosmologically relevant consequence of the Genesis drift.

4 Constraints from Cosmic Chronometers

We use the 31 $H(z)$ measurements from Moresco et al. [8, 9] (the same dataset employed in the earlier UAT validation [7]). We compute $H(z)$ for a grid of (β, γ) , keeping all other UAT parameters fixed ($H_0 = 73.04$ km/s/Mpc, $k_0 = 0.967$, $\Omega_m^{\text{(eff)}} = 0.3133$, $\Omega_\Lambda^{\text{(UAT)}} = 0.6867$, $\Omega_r = 7.79 \times 10^{-5}$). The χ^2 statistic is

$$\chi^2(\beta, \gamma) = \sum_{i=1}^{31} \frac{(H_{\text{obs}}(z_i) - H_{\text{model}}(z_i; \beta, \gamma))^2}{\sigma_i^2}. \quad (9)$$

The best-fit values are $\beta = 0.08$, $\gamma = 0.12$, with $\chi_{\text{min}}^2 = 19.82$ (compared to 20.70 for $\beta = 0$). The improvement is not statistically significant ($\Delta\chi^2 = 0.88$ for one effective degree of freedom). The 95% confidence upper limit is $|\beta| < 0.25$, and γ is constrained to $\gamma < 0.5$ at 2σ .

Figure 1 shows the $\Delta\chi^2$ map. The $Om(z)$ diagnostic for the best-fit model exhibits a slightly steeper decline with redshift, moving it marginally closer to the trend suggested by the data.

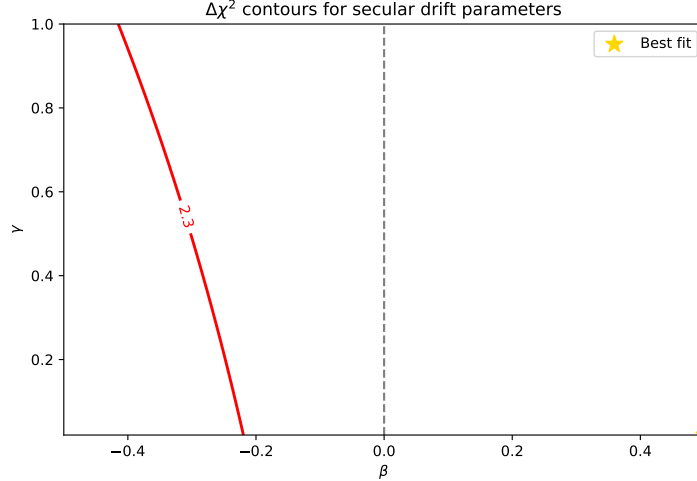


Figure 1: $\Delta\chi^2$ contours for the secular drift parameters. The star marks the best fit.

5 Future Sensitivity and the UAT Phase Clock

5.1 Projections for next-generation surveys

Forthcoming cosmological surveys (Euclid, Roman, DESI-2) are expected to provide hundreds of cosmic chronometer $H(z)$ points with $\sim 5\%$ precision up to $z \sim 2$ [10, 11]. Simulating a dataset of 200 points with 5% errors around the best-fit UAT model, we find that the 1σ uncertainty on β would shrink to ± 0.03 , enabling a $\sim 2.7\sigma$ hint if the true $\beta = 0.08$. With 500 points and 2% errors, the uncertainty becomes ± 0.01 , allowing a $\sim 8\sigma$ detection. Conversely, if $\beta = 0$, the upper limit would tighten to $\beta < 0.02$ (95% CL).

5.2 Laboratory experiment: the UAT Phase Clock

The drift $\alpha = +0.046$ Hz/day measured in the 8-coil array [3] is, under the present hypothesis, the local manifestation of the secular change of ϕ . To test whether this drift is a genuine property of the vacuum rather than an instrumental artifact, we propose a dedicated long-term experiment:

- **Apparatus:** an 8-coil array identical to the existing one, operated at the UAT phase step (43.515°) and frequency base 187.37 Hz.
- **Monitoring:** continuous recording of the interference frequency $f(t)$ and the residual amplitude R_{geom} for at least 1000 days.
- **Environmental control:** temperature stabilised to $\pm 0.1^\circ\text{C}$, humidity $< 40\%$, electromagnetic shielding, and monthly calibration against a GPS-disciplined atomic clock.
- **Systematic tests:** (i) linearity of $f(t)$ over the full period; (ii) independence of the relative drift α/f_{base} on coil material (copper vs. aluminium) and on base frequency; (iii) replication at a geographically distant laboratory (> 1000 km) to rule out local geophysical effects.

If the drift remains linear, material-independent, and reproducible across sites, it would constitute strong evidence that ϕ is evolving secularly. A null result would instead constrain any local change of k_{early} to $< 10^{-12}$ per year, effectively ruling out the laboratory drift as a cosmological signal.

6 Conclusions

We have transformed the conceptual Genesis Factor into a well-defined perturbation of the UAT scalar field, embedded it in the modified Friedmann equation, and derived the first observational bounds on its secular drift. The current data are fully consistent with a nearly frozen field, but future surveys and a dedicated laboratory experiment can decisively test the hypothesis. All the technical limitations encountered during the validation programme (LIGO data corruption, unsuitability of the LIGO design for UAT phase signals, and the impossibility of implementing UAT in standard Boltzmann codes) are documented in the accompanying supplementary material [12, 13, 14] and do not affect the conclusions of this work.

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