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Universum Probabile Altera

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Abstract

We propose that spacetime admits *discrete time-density states* $\hat{t}_i$ separated by absolute, codimension-one discontinuities we term *quantum mirrors* Σ. A state-dependent field, the *fertility* $\mathcal{F}$, quantifies the spontaneous emergence of mass-energy per unit four-volume and is controlled by the prevailing time density. This framework—Universum Probabile Altera (UPA)—reinterprets black-hole horizons as time-state mirrors ($\hat{t}_1 \to \hat{t}_2$), replaces the Hawking process with a fertility-driven flux across Σ, and recasts cosmogenesis as a transient transition to a hyper-fertile state $\hat{t}_3$. We present over/under comparisons of standard forms and their UPA analogues for continuity, field equations, and horizon thermodynamics, and delineate observational consequences for gravitational waves, black-hole spectra, and early-universe imprints.

Keywords

Time, Density, Quantum, Mirror, Cosmogenesis, Black Hole, Gravity, Wave, Universe

1. Introduction—A Probable Universe Framework

General relativity (GR) and quantum field theory (QFT) provide an extraordinarily successful description of nature, yet their coexistence remains uneasy near spacetime extremes. Singularities, horizon thermodynamics, and the black-hole information problem indicate that the current ontology of spacetime may be incomplete [1] [2]. We pursue a minimal modification: *time density* is a physical property of spacetime that assumes only discrete values, and transitions between these values occur across *quantum mirrors* where the derivative of $\hat{t}$ is ill-defined (no gradient, only a jump).

Core postulates (UPA)

1) **Quantized time density.** Spacetime carries a local, frame-invariant *time*

density $\hat{t}$ that takes values in a discrete set $\{\hat{t}_1, \hat{t}_2, \hat{t}_3, \cdots\}$. Empirically known today are: $\hat{t}_1$ (cosmic domain), $\hat{t}_2$ (black-hole domain), and a transient $\hat{t}_3$ (genesis domain).

2) **Quantum mirrors.** Transitions of $\hat{t}$ occur at hypersurfaces Σ with no interpolating regime: $\partial\hat{t}/\partial n|_\Sigma \to \infty$, where n is the unit normal to Σ.

3) **Fertility field.** A scalar field $\mathcal{F}$ measures spontaneous mass-energy emergence per unit four-volume, monotonically increasing with $\hat{t}$: $\mathcal{F}(\hat{t}_1) < \mathcal{F}(\hat{t}_2) < \mathcal{F}(\hat{t}_3)$.

4) **DAGE coupling.** A dimensionful coupling $\tilde{K}$ converts fertility into a matter-energy source in the continuity equation, ensuring covariant bookkeeping.

Formal introductions of new quantities

a) *Time density* $\hat{t}$. Conceptually, $\hat{t}$ counts temporal quanta per unit four-volume. Operationally, it controls causal update rates and wave support. We do not assume a continuous equation of motion for $\hat{t}$ across Σ; instead, $\hat{t}$ is *piecewise constant* with matching (junction) conditions at Σ.

b) *Fertility* $\mathcal{F}$. Define

$$\mathcal{F} \equiv \frac{1}{\sqrt{-g}} \frac{\mathrm{d}E}{\mathrm{d}^4 x} = \frac{\mathrm{d}E}{\mathrm{d}V \mathrm{d}t}, \tag{1}$$

so that $[\mathcal{F}] = \mathrm{J} \cdot \mathrm{m}^{-3} \cdot \mathrm{s}^{-1}$. The mapping $\hat{t} \mapsto \mathcal{F}(\hat{t})$ is statewise (discrete), with $\lim_{\hat{t} \to \hat{t}_3} \mathcal{F} \to \infty$ during a short genesis interval.

c) *DAGE* $\tilde{K}$. Introduce a coupling $\tilde{K}$ (dimensions of specific energy) that converts fertility into a covariant source pointing along the local 4-velocity u^μ:

$$\nabla_\mu T^{\mu\nu}_{\mathrm{mat}} = \frac{\tilde{K}}{c^2} \mathcal{F} u^\nu. \tag{2}$$

This term preserves global diffeomorphism invariance while allowing net creation controlled by state $\hat{t}$.

Horizon reinterpretation and information

In UPA, an event horizon is identified with a quantum mirror Σ where $\hat{t}_1 \to \hat{t}_2$. Wave support is suppressed inside $\hat{t}_2$, producing a particle-ordered domain; information is not destroyed but re-encoded across Σ via a bijective transformation on the accessible Hilbert space compatible with the new state. Observationally, the outward flux customarily attributed to Hawking pair creation is replaced by a *fertility differential* across Σ (Section 3).

Over/under (standard vs. UPA) at a glance

Standard: Continuity (perfect fluid, FLRW):

$$\dot{\rho} + 3H\left(\rho + \frac{p}{c^2}\right) = 0. \tag{3}$$

UPA: Continuity with fertility source ($Q \equiv \tilde{K}\mathcal{F}/c^2$):

$$\dot{\rho} + 3H\left(\rho + \frac{p}{c^2}\right) = Q. \tag{4}$$

Standard: Einstein field equations:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \tag{5}$$

UPA: Effective vacuum depends on $\mathcal{F}(\hat{t})$:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}\left(T_{\mu\nu}^{\text{mat}} + T_{\mu\nu}^{\text{vac}}\left[\mathcal{F}(\hat{t})\right]\right). \tag{6}$$

Overview of sections

Section 2 formalizes $\hat{t}$, mirrors, and junction conditions. Section 3 defines $\mathcal{F}$ and develops Equations. (4)-(6) with observational handles. Subsequent sections (to follow) treat cosmogenesis as a transition to $\hat{t}_3$, wave suppression in $\hat{t}_2$, and falsifiable predictions in gravitational waves, black-hole spectra, and the CMB.

2. Time Density as a Quantized Property of Spacetime

We treat $\hat{t}$ as a piecewise constant scalar on spacetime with values restricted to a discrete set. Let Σ be a smooth hypersurface (possibly dynamical) that separates two domains with distinct time densities, $\hat{t}_{\text{out}}$ and $\hat{t}_{\text{in}}$. The defining property of a quantum mirror is the absence of a gradient domain:

$$\lim_{\epsilon\to 0}\left[\hat{t}(x+\epsilon n) - \hat{t}(x-\epsilon n)\right] \neq 0, \quad \left.\frac{\partial \hat{t}}{\partial n}\right|_{\Sigma} \to \infty. \tag{7}$$

2.1. Kinematics at the Mirror

Let n^{μ} be the unit normal to Σ and $h_{\mu\nu} = g_{\mu\nu} - n_{\mu}n_{\nu}$ the induced metric. We impose standard continuity of the induced geometry while allowing a state jump in $\hat{t}$ and an associated stress jump balanced by fertility:

$$\left[T_{\mu\nu} n^{\mu} n^{\nu}\right]_{\Sigma} = \frac{\tilde{K}}{c^2}\left[\mathcal{F}\right]_{\Sigma}. \tag{8}$$

Equation (8) plays the role of a junction condition tying the discontinuity of normal stresses to the fertility differential.

2.2. Horizon as Mirror: Over/Under

Standard: Schwarzschild radius from escape speed $= c$:

$$r_s = \frac{2GM}{c^2}. \tag{9}$$

UPA: Mirror radius as a phase boundary:

$$\hat{t}\left(r_{\Sigma}^{+}\right) \neq \hat{t}\left(r_{\Sigma}^{-}\right), \quad \left.\frac{\partial \hat{t}}{\partial r}\right|_{r_{\Sigma}} \to \infty. \tag{10}$$

In practice, r_{Σ} coincides with r_s for stationary solutions, but the interpretation differs: r_{Σ} is fixed by state matching rather than escape kinematics.

2.3. State Table (Phenomenological)

- $\hat{t}_1$ (cosmic): wave-permissive; $\mathcal{F}$ finite and small; information evolves locally.

- $\hat{t}_2$ (black-hole): wave support suppressed; particle-ordered interior; elevated $\mathcal{F}$.
- $\hat{t}_3$ (genesis, transient): hyper-fertile; boundary propagation dominates; entropy and causality reinitialized.

3. Fertility and Continuous Mass-Energy Emergence

We model the generative capacity of spacetime by $\mathcal{F}(\hat{t})$ with dimensions of power density. The simplest covariant insertion is a source term aligned to u^{μ}, Equation (2). For homogeneous and isotropic cosmology (FLRW), Equation (2) yields the modified continuity Equation (4) with source $Q = \tilde{K}\mathcal{F}(\hat{t}_1)/c^2$ in the background universe.

3.1. Horizon Flux as Fertility Differential

Rather than virtual-pair emission, the outward flux is governed by the jump of $\mathcal{F}$ across Σ:

$$\Phi_{\mathcal{F}}(\Sigma) = \int_{\Sigma} (\mathcal{F}_{\text{in}} - \mathcal{F}_{\text{out}})\, \mathrm{d}A. \tag{11}$$

This preserves information by re-encoding degrees of freedom into the $\hat{t}_2$ domain while allowing observable emission consistent with horizon thermodynamics.

3.2. Over/Under: Cosmological Background

Standard: Friedmann I (spatially flat for clarity):

$$H^2 = \frac{8\pi G}{3}\rho_{\text{tot}} + \frac{\Lambda c^2}{3}. \tag{12}$$

UPA: UPA: identical geometry, but ρ_{tot} includes $T^{\text{vac}}\left[\mathcal{F}(\hat{t}_1)\right]$ and explicit source Q:

$$H^2 = \frac{8\pi G}{3}\left(\rho_{\text{mat}} + \rho_{\text{vac}}\left[\mathcal{F}(\hat{t}_1)\right]\right) + \frac{\Lambda c^2}{3}, \quad \dot{\rho}_{\text{mat}} + 3H\left(\rho_{\text{mat}} + \frac{p}{c^2}\right) = Q. \tag{13}$$

3.3. Interpretive Notes

Equation (4) defines a measurable creation rate Q. Equations (6) and (13) encode a state-dependent effective vacuum that can mimic dark energy while predicting departures from a pure cosmological constant near strong gravity or evolving topology.

4. Cosmogenesis as a Phase Transition

We reinterpret the Big Bang as a short-lived transition $\hat{t}_2 \to \hat{t}_3$ occurring on a codimension-one hypersurface $\chi(x) = 0$ (a quantum mirror) with no intermediate gradient. During a finite interval Δt_{gen}, the fertility field $\mathcal{F}$ attains extremely large but finite values, driving a rapidly advancing boundary that appears as superluminal expansion from the perspective of the pre-transition domain.

4.1. Boundary Kinematics and Smoothing

Let Θ_ϵ denote a narrow smoothing of the Heaviside function with width $\epsilon \ll \Delta t_{\text{gen}}$. Model the fertility profile across the genesis front by

$$\mathcal{F}(x) = \mathcal{F}(\hat{t}_2) + \Delta\mathcal{F}_{23}\Theta_\epsilon(\chi(x)), \quad \Delta\mathcal{F}_{23} \gg \mathcal{F}(\hat{t}_2), \tag{14}$$

and define the front velocity v_χ implicitly via $\dot{\chi} + v_\chi n^\mu \nabla_\mu \chi = 0$ with n^μ the unit normal. Local causality is respected in the newly born $\hat{t}_3$ domain even if the front is superluminal relative to the old domain.

4.2. Over/Under: Inflation vs. Boundary Propagation

Standard: Inflationary acceleration from a scalar field ϕ with potential $V(\phi)$:

$$\frac{\ddot{a}}{a} = \frac{8\pi G}{3}\left(V(\phi) - \frac{1}{2}\dot{\phi}^2\right). \tag{15}$$

UPA: UPA: early acceleration driven by the fertility density in $\hat{t}_3$:

$$\frac{\ddot{a}}{a} = \frac{8\pi G}{3c^2}\mathcal{F}(\hat{t}_3), \quad \mathcal{F}(\hat{t}_3) \text{ large but finite on } \left[t_{\text{gen}}, t_{\text{gen}} + \Delta t_{\text{gen}}\right]. \tag{16}$$

Equation (16) predicts a *finite* but intense epoch of acceleration whose duration and spectral imprints are governed by Δt_{gen} and the shape of Θ_ϵ.

4.3. Entropy and Causal Reset

The transition to $\hat{t}_3$ reinitializes the entropy accounting and causal structure. Let $S[\hat{t}]$ denote state-dependent entropy; then

$$\lim_{\hat{t}\to\hat{t}_3^-} S[\hat{t}] \neq \lim_{\hat{t}\to\hat{t}_3^+} S[\hat{t}], \quad \Delta S_{\text{gen}} \sim k_B \ln\Omega\left(\mathcal{F}(\hat{t}_3)\right). \tag{17}$$

Correlations seeded during the finite genesis window replace the stochasticity of quantum fluctuations in standard inflationary scenarios.

4.4. Genesis Completion and Return to $\hat{t}_1$

After Δt_{gen}, the boundary leaves behind a $\hat{t}_1$ domain with low, nearly homogeneous fertility $\mathcal{F}(\hat{t}_1)$, which acts as a small source $Q = \tilde{K}\mathcal{F}(\hat{t}_1)/c^2$ in the background continuity equation (cf. Equation (4)). Small inhomogeneities in Q trace large-scale structure formation.

5. Wave Suppression and the Particle-Ordered Interior

In a $\hat{t}_2$ domain (black-hole interior), wave support is suppressed while particle ordering is enhanced. This modifies field propagation and vacuum structure.

5.1. Klein-Gordon Dynamics with State Damping

Standard: Klein-Gordon equation in curved spacetime:

$$\left(\Box + m^2\right)\psi = 0. \tag{18}$$

UPA: UPA: add a state damping term that grows with $\hat{t}$:

$$\left(\Box + m^2 + \gamma\left[\hat{t}\right]\right)\psi = 0,\quad \gamma\left[\hat{t}_2\right] \gg 0,\ \gamma\left[\hat{t}_1\right] \approx 0, \tag{19}$$

implying $\psi \to 0$ inside $\hat{t}_2$ and the suppression of coherent wave phenomena.

5.2. Vacuum Redefinition and Particle Density

Standard: Vacuum fluctuations for a free scalar:

$$\langle 0|\phi^2|0\rangle \propto \frac{1}{2\omega_k}. \tag{20}$$

UPA: UPA: particle-ordered ground state shaped by fertility:

$$\langle 0'|\phi^2|0'\rangle \to \frac{n\left(\hat{t}_2\right)}{\omega_{\text{eff}}\left(\hat{t}_2\right)},\quad n\left(\hat{t}_2\right) \propto \mathcal{F}\left(\hat{t}_2\right), \tag{21}$$

where $n\left(\hat{t}_2\right)$ is an interior particle density determined by the fertility level. The degeneracy favors aligned, ordered configurations ("condensed" interior).

5.3. Gentle Mergers and Information Re-Encoding

Wave suppression explains why black-hole mergers appear dynamically "gentle": the turbulent wave sector is diminished inside $\hat{t}_2$, and mass amalgamation proceeds coherently. Information is preserved via re-encoding across the mirrors, avoiding paradoxes.

6. Observational Signatures and Near-Term Tests

A credible framework must differ observably from standard theory. UPA yields several near-term tests that complement existing experiments.

6.1. Horizon Spectra: Non-Thermal Correlations

Standard: Hawking emission is (nearly) thermal:

$$\frac{\mathrm{d}N}{\mathrm{d}\omega} \propto \frac{1}{\mathrm{e}^{\hbar\omega/k_B T_H} - 1}. \tag{22}$$

UPA: UPA: fertility-driven emission induces small, frequency-dependent correlations:

$$\frac{\mathrm{d}N}{\mathrm{d}\omega} \propto \frac{1 + \epsilon\left(\omega, [\mathcal{F}]_\Sigma\right)}{\mathrm{e}^{\hbar\omega/k_B T_{\mathcal{F}}} - 1},\quad C\left(\omega_i, \omega_j\right) \neq 0, \tag{23}$$

where C measures cross-frequency correlations. Laboratory analogues (e.g. BEC horizons) can search for such structure.

6.2. Gravitational-Wave Chirp Softening

Standard: Waveforms depend on masses and spins within GR. *UPA*: UPA: as two mirrors merge and $\hat{t}$ reconfigures, transient "softening" or phase lags appear in sub-dominant modes. Targeted searches in LIGO-Virgo-KAGRA data [3] for phase anomalies correlated with horizon approach could test this.

6.3. Large-Scale Structure and Fertility Gradients

Spatial gradients in $\mathcal{F}(\hat{t}_1)$ can mimic a mild, evolving dark energy component [4] [5] and may correlate with gravitational topology. Future surveys (e.g. *Euclid*, *Roman*) can constrain such variations via cross-correlation analyses.

6.4. Inter-Domain Visitors

UPA anticipates rare cross-domain matter events. Candidate observables include anomalous isotopic ratios, unexpected decay constants, or spectral features inconsistent with local nucleosynthesis in interstellar objects.

6.5. CMB Imprints from a Finite Genesis Window

A finite Δt_{gen} should leave non-inflationary, super-horizon correlations or small anisotropies distinguishable in high-precision CMB data (e.g. CMB-S4, *LiteBIRD*).

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix

Purpose and Organization

This appendix compiles the principal relations of *Universum Probabile Altera* (UPA) in a compact, comparative format. Each subsection presents the conventional ("Standard") formulation followed by the corresponding UPA expression in an over/under layout. Equation numbering restarts here as (A1a), (A1b), etc. The UPA constructs are: the quantized *time-density state* $\hat{t}$, the *fertility* function $\mathcal{F}(\hat{t})$ (left symbolic and abstract), and the *DAGE* coefficient $\tilde{K}$ that couples fertility to matter-energy source. Mirror horizons Σ are codimension-one hypersurfaces across which $\hat{t}$ jumps without gradient.

Appendix A: Field Equations

A1. Einstein equations (geometry vs. sources)

Standard: Einstein field equations with cosmological constant

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \tag{A1a}$$

UPA: UPA: matter plus an effective vacuum functional of $\mathcal{F}(\hat{t})$

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}\left(T_{\mu\nu}^{\text{mat}} + T_{\mu\nu}^{\text{vac}}\left[\mathcal{F}(\hat{t})\right]\right). \tag{A1b}$$

Explanation. Equation (A1b) retains geometric structure while allowing a state-dependent effective vacuum through $\mathcal{F}(\hat{t})$; departures from a rigid cosmological constant arise when $\hat{t}$ varies across domains or mirrors.

A2. Stress-energy continuity

Standard: Covariant conservation

$$\nabla_\mu T_{\text{mat}}^{\mu\nu} = 0. \tag{A2a}$$

UPA: UPA: DAGE-coupled source aligned with u^ν

$$\nabla_\mu T_{\text{mat}}^{\mu\nu} = \frac{\tilde{K}}{c^2}\mathcal{F}(\hat{t})u^\nu. \tag{A2b}$$

Explanation. The source term in (A2b) encodes a controlled, state-dependent emergence of mass-energy while maintaining covariance; $\tilde{K}$ sets the conversion scale.

Appendix B: Cosmological Background

A3. Continuity in FLRW

Standard: Perfect-fluid continuity

$$\dot{\rho} + 3H\left(\rho + \frac{p}{c^2}\right) = 0. \tag{A3a}$$

UPA: UPA: continuity with fertility source Q

$$\dot{\rho} + 3H\left(\rho + \frac{p}{c^2}\right) = Q, \quad Q \equiv \frac{\tilde{K}}{c^2}\mathcal{F}(\hat{t}). \tag{A3b}$$

Explanation. A nonzero Q implies mild departure from adiabatic evolution and provides a direct observational handle via background expansion and structure growth.

A4. Friedmann I (spatially flat for clarity)

Standard: Standard Friedmann equation

$$H^2 = \frac{8\pi G}{3}\rho_{\text{tot}} + \frac{\Lambda c^2}{3}. \tag{A4a}$$

UPA: UPA: explicit split of matter and fertility-dependent vacuum

$$H^2 = \frac{8\pi G}{3}\left(\rho_{\text{mat}} + \rho_{\text{vac}}\left[\mathcal{F}\left(\hat{t}\right)\right]\right) + \frac{\Lambda c^2}{3}. \tag{A4b}$$

Explanation. The effective vacuum contribution becomes a functional of $\mathcal{F}\left(\hat{t}\right)$, allowing scale- or state-dependent departures from a strict constant.

A5. Early acceleration driver

Standard: Inflationary acceleration (scalar field)

$$\frac{\ddot{a}}{a} = \frac{8\pi G}{3}\left(V\left(\phi\right) - \frac{1}{2}\dot{\phi}^2\right). \tag{A5a}$$

UPA: UPA: finite genesis window with high fertility

$$\frac{\ddot{a}}{a} = \frac{8\pi G}{3c^2}\mathcal{F}\left(\hat{t}_3\right), \quad t \in \left[t_{\text{gen}}, t_{\text{gen}} + \Delta t_{\text{gen}}\right]. \tag{A5b}$$

Explanation. A brief, finite epoch of elevated $\mathcal{F}$ in the $\hat{t}_3$ state drives early acceleration without introducing a separate inflaton sector.

Appendix C: Action and Variational Structure

A6. Einstein-Hilbert action with matter

Standard: Standard action

$$S = \frac{c^3}{16\pi G}\int \mathrm{d}^4x\sqrt{-g}\left(R - 2\Lambda\right) + S_{\text{mat}}\left[g, \Psi\right]. \tag{A6a}$$

UPA: UPA: matter action includes fertility-driven creation

$$S = \frac{c^3}{16\pi G}\int \mathrm{d}^4x\sqrt{-g}\left(R - 2\Lambda\right) + S_{\text{mat}}\left[g, \Psi; \tilde{K}, \mathcal{F}\left(\hat{t}\right)\right]. \tag{A6b}$$

Explanation. The UPA extension is concentrated in S_{mat}, where $\mathcal{F}\left(\hat{t}\right)$ and $\tilde{K}$ enter as state-dependent sources consistent with covariance.

A7. Noether current and creation rate

Standard: Conservation from diffeomorphism invariance

$$\nabla_\mu T^{\mu\nu}_{\text{mat}} = 0. \tag{A7a}$$

UPA: UPA: modified current with aligned source

$$\nabla_\mu T^{\mu\nu}_{\text{mat}} = \frac{\tilde{K}}{c^2}\mathcal{F}\left(\hat{t}\right)u^\nu. \tag{A7b}$$

Explanation. The aligned source in (A7b) acts as a controlled symmetry-breaking term in the matter sector while preserving general covariance.

Appendix D: Mirror Horizons and Junction Conditions

A8. State jump at the mirror

Standard: No classical analogue for $\hat{t}$

$$\text{(No standard equation.)} \tag{A8a}$$

UPA: UPA: discontinuous time-density state across Σ

$$\lim_{\epsilon\to 0}\left[\hat{t}\left(x+\epsilon n\right)-\hat{t}\left(x-\epsilon n\right)\right]\neq 0,\quad \left.\frac{\partial \hat{t}}{\partial n}\right|_{\Sigma}\to\infty. \tag{A8b}$$

Explanation. The mirror horizon is defined by an abrupt state change; no gradient regime is permitted.

A9. Normal-stress balance with fertility differential

Standard: Israel junction (schematic, matter-only shell)

$$\left[K_{ab}\right]-h_{ab}\left[K\right]=-\frac{8\pi G}{c^4}S_{ab}. \tag{A9a}$$

UPA: UPA: normal stress jump tied to fertility jump

$$\left[T_{\mu\nu}n^{\mu}n^{\nu}\right]_{\Sigma}=\frac{\tilde{K}}{c^2}\left[\mathcal{F}\left(\hat{t}\right)\right]_{\Sigma}. \tag{A9b}$$

Explanation. Equation (A9b) plays the role of an effective junction condition relating stress discontinuities to the state-dependent creation field.

Appendix E: Wave Dynamics and Interior Ordering

A10. Klein-Gordon sector

Standard: Free scalar field

$$\left(\Box+m^2\right)\psi=0. \tag{A10a}$$

UPA: UPA: state damping enhances particle ordering

$$\left(\Box+m^2+\gamma\left[\hat{t}\right]\right)\psi=0,\quad \gamma\left[\hat{t}_2\right]\gg 0,\quad \gamma\left[\hat{t}_1\right]\approx 0. \tag{A10b}$$

Explanation. The function $\gamma\left[\hat{t}\right]$ suppresses coherent waves in $\hat{t}_2$, consistent with a particle-ordered interior domain.

A11. Vacuum structure

Standard: Vacuum fluctuations

$$\langle 0|\phi^2|0\rangle\propto\frac{1}{2\omega_k}. \tag{A11a}$$

UPA: UPA: fertility-shaped effective ground state

$$\langle 0'|\phi^2|0'\rangle\to\frac{n\left(\hat{t}\right)}{\omega_{\text{eff}}\left(\hat{t}\right)},\quad n\left(\hat{t}\right)\propto\mathcal{F}\left(\hat{t}\right). \tag{A11b}$$

Explanation. Interior particle density scales with fertility, modifying the spectral content of vacuum fluctuations.

Appendix F: Fluxes, Spectra, and Observables

A12. Fertility flux across a mirror

Standard: Hawking flux (thermal form, schematic)

$$\frac{\mathrm{d}N}{\mathrm{d}\omega} \propto \frac{1}{e^{\hbar\omega/k_B T_H} - 1}. \tag{A12a}$$

UPA: UPA: flux governed by fertility differential

$$\Phi_{\mathcal{F}}(\Sigma) = \int_{\Sigma} (\mathcal{F}_{\text{in}} - \mathcal{F}_{\text{out}})\,\mathrm{d}A. \tag{A12b}$$

Explanation. Horizon emission is controlled by the jump in fertility across Σ, allowing small non-thermal correlations while preserving information via re-encoding.

A13. Background creation rate

Standard: No source in ΛCDM continuity

$$Q_{\Lambda\text{CDM}} = 0. \tag{A13a}$$

UPA: UPA: small, finite creation in $\hat{t}_1$

$$Q_{\text{UPA}} = \frac{\tilde{K}}{c^2}\mathcal{F}(\hat{t}_1). \tag{A13b}$$

Explanation. A nonzero background Q offers a testable deviation in late-time expansion and structure growth.

A14. Entropy and causal reset at genesis

Standard: Inflationary seeding (qualitative)

(Model-dependent; no single canonical equation.) (A14a)

UPA: UPA: finite entropy jump during $\hat{t}_3$

$$\Delta S_{\text{gen}} \sim k_B \ln \Omega\left(\mathcal{F}(\hat{t}_3)\right), \quad t \in \left[t_{\text{gen}}, t_{\text{gen}} + \Delta t_{\text{gen}}\right]. \tag{A14b}$$

Explanation. A finite genesis interval imprints specific correlation patterns distinguishable from standard scenarios.

Appendix G: Testable Predictions

This section contrasts the observational expectations of the standard cosmological model with those emerging from the Universum Probabile Altera (UPA) framework. Each prediction is presented in paired form: the *standard expectation* followed by the *UPA prediction*.

1) Horizon-Level Phenomena

Standard: Black hole horizons emit Hawking radiation with a thermal spectrum determined solely by surface gravity, leading to featureless, information-free flux.

UPA: Horizon emission is governed by the fertility differential across the mirror surface Σ, producing a flux $\Phi_{\mathcal{F}}$ that deviates from perfect thermality. Small non-thermal correlations are expected, consistent with information preservation.

2) Cosmological Background Evolution

Standard: In ΛCDM, energy conservation requires $\dot{\rho} + 3H\left(\rho + p/c^2\right) = 0$ with no net creation. Dark energy is modeled as a constant vacuum term.

UPA: The continuity equation includes a source $Q = \tilde{K}\mathcal{F}(\hat{t})/c^2$, allowing small but finite mass-energy creation even in the late universe. This would manifest as deviations from standard Hubble-rate predictions and altered growth of cosmic structures.

3) Compact-Object Mergers

Standard: Black hole and neutron star mergers are described by general relativity waveforms with smooth inspiral, merger, and ringdown phases. No discontinuous state change is anticipated.

UPA: As compact objects cross into $\hat{t}_2$ regions, wave-like degrees of freedom are suppressed, producing subtle damping or phase shifts in gravitational-wave signals. Observed differences in ringdown consistency may provide signatures of a time-density state transition.

4) Genesis Epoch

Standard: Early-universe inflation is attributed to a scalar inflaton field, with entropy production and reheating mechanisms dependent on the field's potential.

UPA: A finite-duration genesis state ($\hat{t}_3$) drives accelerated expansion through elevated fertility $\mathcal{F}\left(\hat{t}_3\right)$. This results in a discrete entropy jump ΔS_{gen} and a causal reset distinct from inflaton-based reheating. Observable imprints may include specific non-Gaussianities in the CMB and distinct correlation structures.