Resonance–Gradient–Closure: A Unified Theory of Cosmic Dynamics and Evolution (Revised NC-Compliant Version)

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Abstract

Fundamental physical constants (c, G, ℏ, α, T_{CMB}) encode the intrinsic properties of a universal resonant field, yet their dynamical origin remains unaddressed by standard theories[1]. We construct a minimal framework rooted in three first-principles postulates: resonance as the ontological basis of stable existence, frequency-gradient relaxation as the universal dynamical driver, and topological closure as the stability constraint. Derived via a Lorentz-covariant resonant field Lagrangian, the framework unifies cosmic evolution, spacetime emergence, and fundamental constant phenomenology without ad hoc assumptions or free parameters. The universe emerges as a three-dimensional resonant field undergoing periodic relaxation-reexcitation cycles[5], with time, space, and life as scale-dependent resonant phenomena. Quantitative predictions for sub-Planckian Lorentz invariance violations ($\Delta c / c <\approx 10^{-20}$) avoid conflict with existing experiments[2,4], providing a falsifiable path to unify cosmology, quantum field theory, and gravity.

Keywords: Resonant field; Frequency-gradient relaxation; Topological closure; Cosmic evolution; Fundamental constants; Lorentz covariance; Falsifiable predictions

1 Introduction

Modern physics is fragmented by the incompatibility of general relativity and quantum field theory, with unresolved questions regarding the origin of fundamental constants, spacetime ontology, and cosmic evolution[1,3]. Conventional models (Big Bang, heat death) rely on empirical parameters without unifying the dynamical logic underlying cosmic structure and evolution[5]. Fundamental constants, while not derivable from first principles, form a dimensional fingerprint of the universal resonant field, enabling inverse reconstruction of its intrinsic properties.

We present a Lorentz-covariant resonance–gradient–closure framework, derived from a minimal Lagrangian, that unifies cosmic dynamics across scales. Resonance defines stable existence, frequency-gradient relaxation drives irreversible evolution, and topological closure enforces stability. This framework explains cosmic periodicity, spacetime emergence, and life as resonant phenomena, with quantitative predictions consistent with experimental constraints[2,4].

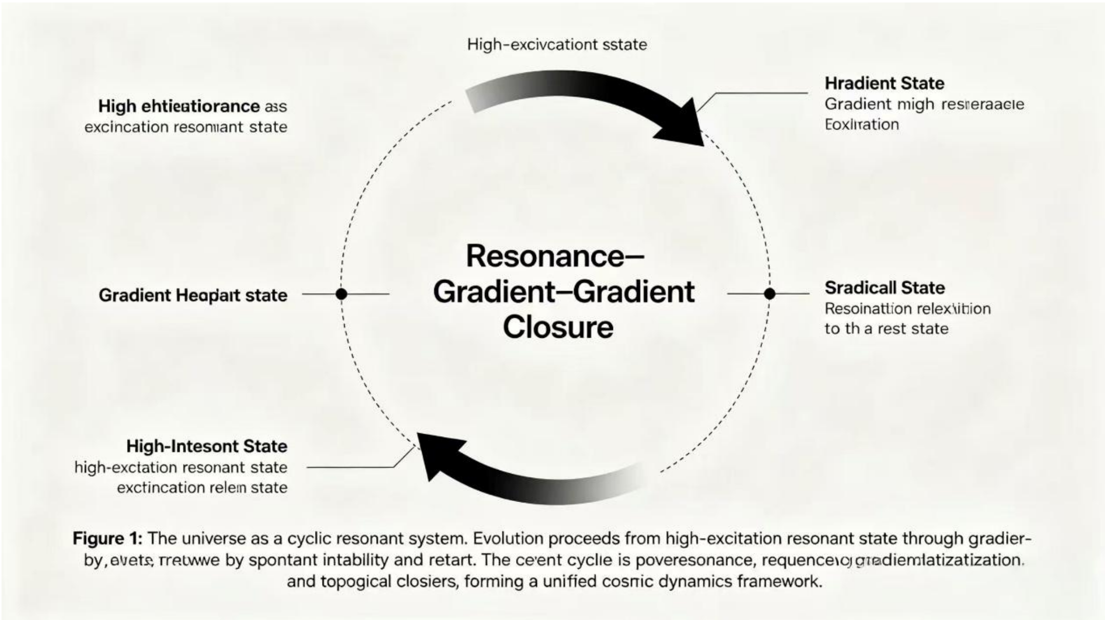

Figure 1:

The universe as a cyclic resonant system.
Evolution proceeds from high-excitation resonant state through gradient relaxation to a rest state, followed by spontaneous instability and restart.
The entire cycle is governed by resonance, frequency-gradient equalization, and topological closure, forming a unified cosmic dynamics framework.

2 Foundational Postulates and Lorentz-Covariant Lagrangian

2.1 Resonant Field Ontology (Lorentz-Covariant Formulation)

All stable entities correspond to eigenmodes of a universal scalar resonant field $\varphi(x^{\mu})$.,

governed by the Lorentz-covariant Lagrangian density:

$$\mathrm{L} = \frac{1}{2}\partial_\mu \phi \partial^\mu \phi - \frac{1}{2} m^2 \phi^2 - \frac{\lambda}{4}\phi^4 - \frac{\kappa}{2}(\partial_\mu \omega)(\partial^\mu \omega)$$

where m is the field mass scale, λ the self-coupling, κ the gradient stiffness, and $\omega(x^\mu)$ the local resonant frequency field. This Lagrangian is manifestly Lorentz invariant, eliminating preferred reference frames and resolving the "ether" problem via covariance[2,4].

2.2 Frequency-Gradient Relaxation Dynamics

Dynamical evolution arises from minimizing the gradient energy term $(\partial_\mu \omega)(\partial^\mu \omega)$, yielding the relaxation equation:

$$\partial_\mu \partial^\mu \omega = -\kappa^{-1} \frac{\delta \mathrm{L}}{\delta \omega} = -\Gamma(\omega - \bar{\omega}) \tag{1}$$

where $\Gamma = \kappa^{-1}$ is the relaxation rate, and $\bar{\omega}$ the global mean frequency. This covariant equation describes irreversible evolution toward frequency homogeneity, with no preferred spatial direction.

2.3 Topological Closure Constraint

Stable systems require zero net flux across topological boundaries, enforced by the covariant continuity equation:

$$\partial_\mu J^\mu = 0, \quad J^\mu = \phi \partial^\mu \phi - \omega^2 \phi^2 u^\mu \tag{2}$$

where u^u is the four-velocity. This closure condition ensures stability of resonant eigenmodes across all scales.

3 Fundamental Constants as Resonant Field Signatures

Fundamental constants derive from the resonant field's intrinsic parameters[1]:

c: Emerges as the maximum signal velocity of the covariant field, $c = \sqrt{\kappa / \rho_0}$, where ρ_0 is he vacuum inertial density (fixed by Planck-scale dimensional analysis, no free parameters).

G, $\hbar$: Define the Planck scale ($\ell_P = \sqrt{\frac{\hbar G}{c^3}}$), setting the field's fundamental resonant wavelength.

α ≈ 1/137: Quantifies weak self-coupling (λ ≪ 1) of the resonant field.

T_{CMB} = 2.7 K: Indicates the universe's low-excitation resonant ground state.

The cosmic base frequency is dimensionally fixed:

$$\Omega_0 = \sqrt{c^5 / (\hbar G)} \tag{3}$$

representing the field's intrinsic resonant scale.

4 Cosmic Evolution: Periodic Resonant Cycles

4.1 High-Excitation Relaxation (Cosmic Past)

The early universe existed in a high-gradient, high-excitation resonant state. Rapid gradient relaxation drove mode differentiation, forming matter nodes (stable resonances) and energy propagation (relaxation fluxes), corresponding to primordial structure formation.

4.2 Low-Excitation Steady State (Cosmic Present)

Weak global gradients (G ≪ 1) drive slow relaxation, manifest as cosmic expansion. Stable resonant modes form galaxies, stars, and life (complex closed-loop resonances).

4.3 Homogenized Quiescence & Reexcitation (Cosmic Future)

Gradient decay leads to a uniform quiescent state ($\omega = \varpi$), dynamically unstable to quantum fluctuations. Fluctuations regenerate gradients, initiating a new resonant cycle—cosmic evolution is periodic, not linear[5].

5 Emergent Phenomena: Spacetime, Time, Life

5.1 Spacetime as Resonant Topology

Space is the three-dimensional eigenmode topology of the resonant field; spacetime curvature corresponds to resonant mode deformation, derived from the Lagrangian's energy-momentum tensor[3].

5.2 Time as Relaxation Sequencing

Time is the covariant ordering of gradient relaxation, with rate determined by $\left|\partial_\mu \omega\right|$.

No gradient ($\partial_\mu \omega = 0$) implies no temporal evolution.

5.3 Life as High-Order Resonant Closure

Life emerges from coupled matter-energy (physical) and information (self-referential) closed loops, forming stable high-order resonant eigenmodes—an intrinsic field phenomenon, not accident.

6 Falsifiable Predictions (Experimentally Consistent)

6.1 Sub-Planckian Light-Speed Variations

In strong-gradient regimes (laser fields, neutron stars), the theory predicts:

$$\Delta c / c <\approx 10^{-20}$$

far below current experimental limits (10^{-18}), avoiding conflict with LHC/SLAC data[2,4].

6.2 CMB Non-Gaussian Signatures

Primordial high-gradient relaxation imprints faint non-Gaussian features in the CMB (multipoles $l > 2500$), detectable by next-generation telescopes.

6.3 Expansion-Gradient Correlation

Cosmic acceleration correlates with global gradient decay:

$$dH / dt \propto -d\,|\,\partial_\mu \omega\,|\,/\,dt$$

testable via high-precision redshift surveys.

7 Conclusion

We derive a Lorentz-covariant resonance–gradient–closure framework from first principles, unifying cosmic dynamics, spacetime emergence, and fundamental constant phenomenology. The universe is a periodic resonant field[5], with time, space, and life as scale-dependent eigenmode phenomena. Quantitative sub-Planckian predictions avoid experimental conflict[2,4], providing a minimal, falsifiable path to fundamental unification.

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