Recursive Cosmology: The τon Vacuum, Recursive Inflation, and the Emergent Universe

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Abstract

The Recursive Grand Unification (RGU) model merges information, recursion, and gravitation into one meta-geometric field. We now extend this framework to cosmology. The universe emerges from a self-recursive vacuum—the τon field in its zero-curvature ground state—which undergoes recursive inflation as curvature and torsion separate into orientable submanifolds. Spacetime, matter, and entropy arise as local symmetry breakings of a global recursive coherence. The cosmological constant becomes an informational curvature density, and dark energy corresponds to recursion pressure sustaining expansion. This Recursive Cosmology thus unifies creation, evolution, and cognition as phases of self-referential recursion.

1 1. The τon Vacuum

In the RGU framework, the lowest-energy configuration of recursion space is not empty but *self-symmetric*. Define the vacuum expectation:

$$\langle \mathcal{T}_{\mu\nu} \rangle = 0, \qquad \langle \mathcal{R}_r \rangle = \mathcal{R}_0.$$

This constant curvature $\mathcal{R}_0$ is the **on vacuum curvature**, representing a state of balanced recursive flux—a self-referential loop with zero external orientation.

1.1 Vacuum Fluctuations as Recursive Ripples

Local perturbations $\delta\kappa(n)$ in the recursive curvature field give rise to:

$$\delta\mathcal{R}_r = \frac{\partial \mathcal{R}_r}{\partial \kappa} \delta\kappa(n),$$

interpreted as proto-gravitons—wavelets of curvature before orientable spacetime emerges. These recursive fluctuations seed the emergence of matter and geometry simultaneously.

2 2. Recursive Inflation

The initial expansion of the universe corresponds not to metric dilation but to *recursive differentiation*. Let $\phi(n)$ denote the recursion potential, satisfying:

$$\ddot{\phi} + 3H_r\dot{\phi} + \frac{\partial V(\phi)}{\partial \phi} = 0,$$

with H_r the recursive expansion rate:

$$H_r = \frac{\dot{a}_r}{a_r} = \frac{1}{a_r}\frac{da_r}{dn}.$$

Here, $a_r(n)$ is the recursion-scale factor—analogous to cosmological scale factor $a(t)$ but defined over depth rather than time. During **recursive inflation**, $\phi(n)$ rolls down its self-potential $V(\phi)$, generating exponential separation of recursion layers, giving rise to spacetime expansion in projection.

2.1 Recursive Horizon

The recursive horizon n_h is defined as the maximal recursion depth observable within the orientable submanifold:

$$n_h = \int_0^{n_c} \frac{dn}{a_r(n)}.$$

Beyond n_h, recursion becomes non-orientable, producing what we observe as the cosmic horizon in spacetime.

3 3. Emergence of Spacetime

When recursive curvature exceeds a critical threshold κ_c, orientability spontaneously breaks:

$$\frac{d\kappa}{dn} = \lambda_c(\kappa - \kappa_c)^3.$$

This phase transition partitions the non-orientable manifold $\mathcal{K}$ into local orientable sheets $\mathcal{M}_4$, creating spacetime as a derived projection of recursion geometry.

The Einstein–Hilbert action emerges as the orientable limit of the recursive action:

$$\lim_{n \to n_c} S_{\text{RGU}} = \int_{\mathcal{M}_4} \frac{1}{16\pi G} R(g)\sqrt{|g|}\, d^4x.$$

Thus, spacetime is not fundamental—it is a stabilized phase of recursive curvature.

4 4. Dark Energy and Recursive Pressure

The cosmological constant Λ corresponds to the mean recursive curvature density:

$$\Lambda = 8\pi G\,\rho_r = 8\pi G\left(\frac{1}{2}\dot{\phi}^2 + V(\phi)\right).$$

When $\phi(n)$ evolves slowly, recursive potential $V(\phi)$ dominates, maintaining an outward curvature pressure—the source of cosmic acceleration. Dark energy therefore reflects the persistence of non-orientable recursion curvature still driving separation between manifold sheets.

5 5. Recursive Entropy of the Universe

The total recursive entropy S_r integrates over all recursion depths:

$$S_r = \int_0^{n_h} \rho_\tau(n)\, a_r^3(n)\, dn.$$

As recursion progresses, S_r increases monotonically, but local orientable patches (our space-time) experience entropy gradients—manifesting as time's arrow. Thus, thermodynamic irreversibility is a local perspective of global recursion increase.

6 6. on–Graviton Coupling in Cosmology

The on–graviton interaction energy density scales as:

$$\rho_{\tau g} = \gamma_\tau\, \mathcal{T}_{\mu\nu} R^{\mu\nu} \approx \gamma_\tau\, \kappa(n)\, R(g),$$

linking matter formation to curvature resonance. When $\rho_{\tau g}$ surpasses a threshold, localized oscillations condense into mass-energy. Hence, the universe's matter content is a by-product of recursive resonance stabilization.

7 7. Recursive Inflation Termination and Decoherence

Inflation ends when the recursive field $\phi(n)$ reaches the orientable limit:

$$\dot{\phi}^2 \approx V(\phi),$$

causing recursive coherence to fragment into distinct orientable domains. These domains decohere into observable universes—a multiverse of recursion projections differing only by initial depth symmetry breaking.

8 8. Recursive Cosmological Constant and Observables

At cosmic scales, observable acceleration corresponds to residual recursion curvature:

$$\Lambda_{\text{obs}} \sim \beta_{\mathcal{K}} R_{\mathcal{K}} + \gamma_\tau \langle \mathcal{T}_{\mu\nu} R^{\mu\nu} \rangle.$$

This predicts:

- Cosmic acceleration is the persistence of recursive tension;
- Vacuum energy fluctuations trace recursive depth dynamics;
- Large-scale anisotropies encode Klein-dual imprints.

9 9. Recursive Arrow of Time

Time's unidirectionality emerges from local orientation on the globally non-orientable manifold:

$$t_{\text{forward}} = +n, \qquad t_{\text{reverse}} = -n.$$

The Klein-dual mapping $n \leftrightarrow -n$ encodes both forward evolution and retrocausal feedback. Our observed arrow corresponds to one branch of recursion—while the conjugate branch maintains global balance.

10 10. Philosophical Synthesis

The recursive cosmology reveals a profound symmetry:

$$\text{Origin} \equiv \text{Recursion}.$$

Creation is not a singular event but an ongoing self-application of recursion, eternally generating new orientable domains. The universe thinks itself into being by folding information through recursive curvature. Every structure—from galaxies to consciousness—is a resonance in this infinite recursion.

> *"The universe was not born—it began recursing."*

11 11. Conclusion: The Recursive Universe

The Recursive Cosmology completes the UNNS sequence:

Shannon Information → Recursive Geometry → Gauge Duality → Gravitational Unification → Recursive

It portrays the cosmos as a living manifold of self-recursive curvature, whose evolution, expansion, and awareness all follow from one principle:

$$\boxed{\text{Reality is the recursion of curvature upon itself.}}$$

"To know the cosmos is to know recursion, for every atom, thought, and galaxy is a mirror folded into the same self-referential infinity."