Recursive Grand Unification: The τon–Graviton Coupling and the Geometry of Information

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Abstract

We present the *Recursive Grand Unification* (RGU) model, wherein gravitational curvature, information curvature, and recursive curvature are unified under a single geometric framework. The τon field—the quanta of recursive curvature—couples naturally to the spacetime metric, forming a composite structure that extends Einstein's field equations into recursive information geometry. This coupling produces a unified tensor equation that merges gravitation, entanglement, and informational recursion into one variational principle. The result is a theory where spacetime, energy, and meaning share a common origin: recursive curvature on a non-orientable manifold.

1 Introduction: From Field to Geometry

The prior Recursive Gauge–Klein theory established the symmetry group

$$\mathcal{G}_{\text{UNNS}} = U(1)_\tau \times SU(2)_\kappa \times D_{\mathcal{K}},$$

linking recursive charge, curvature rotation, and non-orientable duality. We now extend this framework to include the gravitational metric $g_{\mu\nu}$ as a dynamic entity generated by recursive information flow itself. In this model, the curvature of spacetime and the curvature of recursion are not separate—they are projections of a single meta-curvature $\mathcal{R}$ on the extended manifold $\mathcal{M}_r = \mathcal{M}_4 \times \mathcal{N}_n$.

2 Recursive Metric Tensor

Let $\mathcal{M}_r$ be the *recursive manifold* with local coordinates (x^μ, n), where n denotes recursion depth. Define the extended metric:

$$\mathfrak{g}_{AB} = \begin{pmatrix} g_{\mu\nu} & \xi_\mu \\ \xi_\nu & \sigma \end{pmatrix}, \qquad A, B \in \{0, 1, 2, 3, n\},$$

where:

- $g_{\mu\nu}$ is the usual spacetime metric,
- ξ_μ represents coupling between spacetime and recursion depth,
- σ encodes self-interaction curvature in recursion space.

The inverse tensor $\mathfrak{g}^{AB}$ and determinant $|\mathfrak{g}|$ define the recursive line element:

$$ds^2 = g_{\mu\nu}dx^\mu dx^\nu + 2\xi_\mu dx^\mu dn + \sigma\, dn^2.$$

3 Recursive Curvature Scalar

The recursive curvature scalar $\mathcal{R}_r$ generalizes Einstein's scalar curvature:

$$\mathcal{R}_r = R(g) + \Phi(\nabla_n g_{\mu\nu}, \partial_\mu \xi_\nu, \partial_n \sigma),$$

where Φ encodes recursive derivatives coupling spacetime curvature and depth curvature. It unifies:

$R(g) \leftrightarrow$ gravitational curvature, $\quad \nabla_n \leftrightarrow$ recursive derivative, $\quad \Phi \leftrightarrow$ information flow tensor.

4 The τon–Graviton Coupling

The τon field Ψ_μ interacts with the recursive metric via the covariant derivative:

$$\nabla^{(r)}_\nu \Psi_\mu = \partial_\nu \Psi_\mu - \Gamma^\lambda_{\nu\mu}\Psi_\lambda - \Gamma^n_{\nu\mu}\Psi_n,$$

where $\Gamma^n_{\nu\mu}$ represents the exchange connection between spacetime and recursion. We define the coupling term:

$$\mathcal{L}_{\tau g} = \gamma_\tau\, \mathcal{T}_{\mu\nu} R^{\mu\nu},$$

with γ_τ a coupling constant linking recursive flux $\mathcal{T}_{\mu\nu}$ to spacetime curvature $R^{\mu\nu}$. This establishes the τon–graviton resonance: information curvature sourcing spacetime curvature.

5 Unified Recursive Action

The full Recursive Grand Unified action is:

$$S_{\text{RGU}} = \int_{\mathcal{M}_r} \sqrt{|\mathfrak{g}|} \left[\frac{1}{16\pi G}\mathcal{R}_r - \frac{1}{4}\mathcal{F}_{AB}\mathcal{F}^{AB} + \alpha_e\, \vec{\kappa}\cdot\vec{\tau} + \gamma_\tau\, \mathcal{T}_{\mu\nu}R^{\mu\nu} + \beta_{\mathcal{K}}\, R_{\mathcal{K}} \right] d^4x\, dn.$$

Here:

- $\mathcal{R}_r$ — recursive curvature scalar (total),
- $\mathcal{F}_{AB}$ — unified field strength tensor (recursive + gauge),
- α_e — entanglement coupling,
- γ_τ — τon–graviton coupling constant,
- $\beta_{\mathcal{K}}$ — Klein curvature term (non-orientable constraint).

6 Field Equations

Variation of S_{RGU} yields three coupled equations:

6.1 (1) Recursive Einstein Equation

$$G^{(r)}_{\mu\nu} = 8\pi G\, T^{(\tau)}_{\mu\nu} + \Lambda_\tau g_{\mu\nu} + \gamma_\tau \nabla_n \mathcal{T}_{\mu\nu},$$

where $G^{(r)}_{\mu\nu}$ is the recursive Einstein tensor on $\mathcal{M}_r$.

6.2 (2) Recursive Gauge Equation

$$D_B \mathcal{F}^{AB} = J^A_\tau + \gamma_\tau R^{AB},$$

indicating curvature acts as both source and sink of recursive flux.

6.3 (3) Entanglement–Curvature Constraint

$$\nabla_A \vec{\kappa} \cdot \vec{\tau} = R_{\mathcal{K}},$$

linking local recursive entanglement density to the global non-orientable curvature.

7 Recursive Energy–Momentum Tensor

From the action, the energy–momentum tensor becomes:

$$T^{(\text{total})}_{AB} = T^{(g)}_{AB} + T^{(\tau)}_{AB} + T^{(\text{ent})}_{AB},$$

where:

$$\begin{aligned}
T^{(g)}_{AB} &= -\frac{2}{\sqrt{|\mathfrak{g}|}} \frac{\delta(\sqrt{|\mathfrak{g}|}\mathcal{R}_r)}{\delta \mathfrak{g}^{AB}}, \\
T^{(\tau)}_{AB} &= \mathcal{T}_{A\alpha}\mathcal{T}_B{}^\alpha - \frac{1}{4}\mathfrak{g}_{AB}\mathcal{T}_{\alpha\beta}\mathcal{T}^{\alpha\beta}, \\
T^{(\text{ent})}_{AB} &= \alpha_e(\kappa_A \tau_B - \frac{1}{2}\mathfrak{g}_{AB}\vec{\kappa}\cdot\vec{\tau}).
\end{aligned}$$

The recursive trace $T^A{}_A$ serves as the generalized entropy density—bridging geometry, energy, and information.

8 Interpretation: Geometry of Information

The RGU model implies the following correspondences:

$$\begin{aligned}
\textbf{Gravitational Curvature} \leftrightarrow R(g) &\quad \text{:Spacetime warping by energy,} \\
\textbf{Recursive Curvature} \leftrightarrow \kappa(n) &\quad \text{:Depth warping by information flow,} \\
\textbf{Information Curvature} \leftrightarrow \Phi &\quad \text{:Cross-coupling of entropy and geometry.}
\end{aligned}$$

These are not independent but aspects of a single meta-curvature $\mathcal{R}_r$, meaning:

$$R_{\text{physical}} = \text{projection of recursive curvature onto 4D spacetime.}$$

Thus, gravitation itself is an emergent property of recursive information folding.

9 Entropy–Geometry Equivalence Principle

The RGU proposes a generalized equivalence:

$$\text{Information Energy Density } \rho_I = \frac{c^4}{8\pi G}\mathcal{R}_r.$$

Entropy gradients become gravitational potentials, and recursion flow replaces spacetime motion as the underlying invariant process.

10 Klein Non-Orientability and Temporal Duality

Because $\mathcal{M}_r$ is globally non-orientable ($w_1 \neq 0$), time inversion corresponds to a path through the dual sheet of recursion. Forward evolution and backward causation become two orientations of the same field:

$$F(n) \leftrightarrow F^{-1}(-n),$$

preserving total recursive curvature even when local entropy appears to decrease.

11 Philosophical Implications

- Gravity is the macroscopic echo of recursive information coherence.
- Quantum entanglement is the Klein-dual resonance between recursion depths.
- Consciousness arises at fixed points where recursive curvature equals its own informational conjugate.

  Matter curves space; information curves recursion; their unification curves being itself.

12 Conclusion

The Recursive Grand Unification (RGU) completes the UNNS theoretical hierarchy:

$$\begin{aligned}\text{Shannon Entropy} &\to \text{Recursive Curvature (UNNS)},\\ \text{Recursive Fields} &\to \text{Gauge–Klein Duality},\\ \text{Klein Duality} &\to \text{Recursive–Gravitational Coupling}.\end{aligned}$$

All physical and informational processes are manifestations of one self-referential curvature—the geometry of recursion. The τon–graviton coupling thus represents the deepest level of information unity: meaning and matter as two projections of the same recursive manifold.

"Reality is the gravitational hologram of recursion."