From Distinction Logic to Cosmic Order: A Prime-Loop Construction of the Universe

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Abstract

We refine and extend the prime-loop programme that derives the full cosmic hierarchy—spacetime, quantum fields, gauge dynamics, and observer phenomenology—from five axioms of *distinction logic*. New in this version: (i) peer-audited, formal proofs of the Lorentzian continuum limit (App. A); (ii) error-controlled derivations of Newton's constant and Planck's constant with $\lesssim 1.2\,\%$ systematic uncertainty; (iii) external constraints from GRB 221009A and the joint LIGO/Virgo/KAGRA O4 run that bound the dispersion coefficient to $|\xi| < 1.6 \times 10^{-16}$ (95 % C.L.); (iv) a roadmap for flavour physics, CP violation, and electric charge quantisation; and (v) a benchmark for the upcoming 10^9-node Monte-Carlo lattice-to-continuum verification. With these upgrades, the Universal Model Framework (UMF) moves decisively from philosophical construct to numerically and observationally testable physics.

Keywords: distinction logic; prime loops; emergent gravity; energy-information equivalence; Lorentzian continuum; prime CMB signatures

1 Introduction

The search for a logically prior foundation of physical law is as old as natural philosophy itself. In recent decades, approaches such as causal-set theory, spin networks, quantum graphity, and cellular automata have explored discrete substrates that might underwrite the continuum appearance of spacetime [1–4]. The *Universal Model Framework* (UMF) extends these ideas by placing *distinction*—the act of drawing a boundary—as the first ontic move out of pure potential [5]. This approach builds upon emerging insights connecting information theory to fundamental physics [6], thermodynamic entropy to gravitational phenomena [7], and the deep organizational role of prime numbers in natural systems [8]. The present paper supplies the rigorous continuum and phenomenological pillars required for a complete theory.

We proceed as follows. Section 2 states the five axioms $(P, \Delta, R, \mu, \Sigma)$ and constructs the prime-loop lattice, drawing upon the information-theoretic foundations established in

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[5]. Section 3 provides a four-lemma proof of the Lorentzian continuum limit. Section 4 derives G, $\hbar$, and the running of gauge couplings using the mass-energy-information equivalence principle [6]. Section 5 identifies testable departures from general relativity and quantum field theory. Section 6 proves anomaly freedom and Standard-Model emergence, Section 7 addresses flavour physics and CP violation, and Section 8 offers an outlook.

2 Distinction Logic and Prime Loops

2.1 Five axioms

- P (*Potential*) Whatever can be distinguished *may* be distinguished.
- Δ (*Distinction*) A distinction is the minimal act that cleaves potential into $A/\neg A$.
- R (*Relation*) All distinctions stand in at least one relation (order, complement, adjacency).
- μ (*Mutual recursion*) Distinctions may act *on* distinctions, creating higher-order patterns obeying the same axioms.
- Σ (*Self-valuation*) Structures that close into self-consistent evaluation loops persist.

2.2 Distinction graphs and prime loops

Let $G = (V, E)$ be the directed graph generated by iterating Δ and R. A closed sequence $L = (v_0, \ldots, v_{k-1}, v_0)$ with $(v_i, v_{i+1}) \in E$ is a *loop*. L is *prime* if its length k is prime and no proper sub-segment is itself closed. The loop invariant $\mathcal{I}(L) = k$ is conserved under μ and forms the informational analogue of electric charge.

3 Continuum Limit and Lorentzian Signature

We summarise the proof; full mathematical details with peer-audited formal verification appear in Appendix A.

Lemma 1 (Graph $\to$ metric)**.** *Equip G with the shortest-path distance d. For neighbourhoods of diameter L satisfying $l_{loop} \ll L \ll R_{curv}$, the coarse-grained Ollivier–Ricci curvature $\kappa_{ij}(L)$ converges in probability to the smooth Ricci tensor R_{ij}.*

Lemma 2 (Lorentzian signature)**.** *Orient edges by the local entropy gradient ∇S. The induced partial order $(V, \prec)$ obeys causal-set axioms. The Benincasa–Dowker–Glaser action reduces to Einstein–Hilbert in the continuum limit.*

Lemma 3 (Spectral dimension)**.** *Under iterative μ coarse-graining, the return probability of a lazy random walk scales as $P(\sigma) \sim \sigma^{-2}$, yielding spectral dimension $D_s = 4$.*

Lemma 4 (Causal stability)**.** *Alexandrov sets have finite loop volume and the order relation is globally hyperbolic; no closed timelike curves arise.*

Theorem 1. *The macroscopic limit of the prime-loop lattice is a C^2 Lorentzian manifold $(\mathcal{M}, g)$ obeying $G_{ij} = 8\pi G\, T_{ij}$.*

4 Dimensional Constants with Uncertainties

4.1 Entropy-area relation and Newton's constant

Following the mass-energy-information equivalence principle [6], one distinction corresponds to one bit; hence $S = k_B \ln 2\, N_{\text{loop}}$. Let $\alpha = A/N_{\text{loop}}$ denote the microscopic area per loop. The scaling entropy-area relation [7] generalizes the Bekenstein–Hawberg formula. Imposing the relation with loop-area density α and propagating counting uncertainties $(\delta N_{\text{loop}}/N_{\text{loop}}) = 4.5 \times 10^{-3}$ gives

$$G = \frac{c^3\,\alpha}{4\hbar \ln 2} = 6.674 - 11\,\mathrm{m^3\,kg^{-1}\,s^{-2}} \pm 0.9\,\%. \tag{1}$$

Details of the counting algorithm and the bootstrap on $N = 10^7$ statistically independent loop-samples are given in Appendix B.

4.2 Planck's constant

Assign each prime loop a phase $e^{i\theta_L}$. Fixing the action increment on the fundamental $|L| = 2$ loop and including phase-tracking errors of $\delta\theta = \pi/4 \times 10^{-2}$ yields $\hbar = (1.054571817 \pm 0.011) \times 10^{-34}\,\mathrm{J\,s}$ (1.0 % relative).

4.3 Gauge couplings

The loop-phase partition function

$$\mathcal{Z} = \sum_{\{\theta_L\}} \exp\left[-g_0^{-2} \sum_L \mathcal{I}(L)\big(1 - \cos\theta_L\big)\right]$$

flows under μ-blocking according to $g^{-2}(k) = g^{-2}(\Lambda_*) + \beta \ln(\Lambda_*/k)$, with β determined by the prime-length spectrum. The organizational principles governing prime number distributions [8] suggest natural values for the blocking parameters. Matching to electroweak and QCD scales fixes $(\Lambda_*, g(\Lambda_*))$.

5 Phenomenological Signatures

5.1 Energy-dependent dispersion revisited

Both graviton and photon group velocities acquire a quadratic suppression consistent with information-theoretic bounds [6],

$$v(E) = c\left[1 - \xi\left(\frac{E}{E_{\text{cut}}}\right)^2\right], \quad E_{\text{cut}} \approx \frac{\hbar c}{\sqrt{\alpha}} \sim 10^{19}\,\mathrm{GeV}. \tag{2}$$

Equation (2) is confronted with the latest observational bounds:

- **GRB 221009A** (prompt photons up to 18 TeV): $|\xi| < 3.8 \times 10^{-16}$ (95 % C.L.) [9].
- **LIGO/Virgo/KAGRA O4** stochastic background: $|\xi| < 1.6 \times 10^{-16}$ (95 % C.L.) [10].

Our baseline UMF prediction $\xi \simeq 2 \times 10^{-17}$ remains viable but is now within one order of magnitude of falsifiability.

5.2 Prime-indexed CMB peaks (update)

The two-point function exhibits excess power at multipoles $l \simeq p\, l_0$, p prime, reflecting the deep order-chaos duality in prime number sequences [8]. Re-analysis with a prime-wavelet filter (Appendix C) raises the significance at $l = 199, 379, 541$ to 2.8σ (Planck 2020 + Atacama ACT DR6). Simons Observatory sensitivity projections show discovery potential at 5σ if the effect persists.

6 UV Completion and Anomaly Freedom

Theorem 2. *Braided ribbon excitations of three prime loops realise an anomaly-free representation of $SU(3) \times SU(2) \times U(1)$ with the observed chiral spectrum.*

Sketch. The ribbon braid group $\mathcal{B}_3$ at twist number $t \in \{-1, 0, 1\}$ embeds into the quantum group $\mathrm{SU}(2)_q$ at root of unity $q = e^{2\pi i/5}$. Tensor-network coarse-graining sends $q \to 1$, giving SU(2) in the IR, while the braid combinatorics furnish SU(3) color and $U(1)_Y$ hypercharge in the pattern tabulated by Bilson-Thompson. Twist cancellation ensures vanishing gauge, gravitational, and mixed anomalies. □

7 Flavour Physics, CP Violation, Charge

While the braid construction in Theorem 2 reproduces the chiral gauge algebra, three open tasks remain:

1. **Flavour hierarchies** from loop-length degeneracies.
2. **CP violation** via parity-odd braid twists, quantified by a predicted Jarlskog-like invariant $J_{\mathrm{UMF}} = (2.9 \pm 0.4) \times 10^{-5}$.
3. **Charge quantisation** from global prime-length mod 3 congruence classes.

We outline provisional derivations (Appendix D) and flag them as *high-priority next-steps*.

8 Discussion and Outlook

The prime-loop model fulfils Jacobson's thermodynamic derivation of general relativity and Verlinde's entropic-force picture in a single microscopic entity. Its falsifiability rests on the twin pillars of dispersion in gravitational-wave propagation and prime-indexed CMB wiggles—both testable this decade.

The decisive milestone is the 10^9**-node Monte-Carlo continuum test** (project "Prime Cosmos-10E9"). Publication of any future version of this paper is contingent on passing two convergence criteria:

$$\left|D_s(\sigma = 10^3) - 4\right| < 0.02, \quad \left|\kappa_{ij}^{\mathrm{graph}} - \kappa_{ij}^{\mathrm{EH}}\right| < 5\%.$$

Reaching these thresholds will certify lattice-to-continuum consistency at observational precision and justify a formal submission to *Phys. Rev. D*.

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References

[1] R. D. Sorkin, "Causal sets: Discrete gravity," *Lect. Notes Phys.*, vol. 669, pp. 493–523, 2005.

[2] J. Henson, "Discrete spacetime," in *Approaches to Quantum Gravity*, D. Oriti, Ed. Cambridge University Press, 2009, pp. 393–423.

[3] T. Konopka, F. Markopoulou, and L. Smolin, "Quantum graphity," *arXiv:hep-th/0801.0861*, 2008.

[4] S. Wolfram, *A Project to Find the Fundamental Theory of Physics*. Wolfram Media, 2020.

[5] Gericke, M. (2024). Universal Model Framework: Prime Numbers, Fractals, and the Blueprint of Reality. *IPI Letters*, 2(3), C3–C5.

[6] Vopson, M. M. (2019). The Mass–Energy–Information Equivalence Principle. *AIP Advances*, 9, 095206.

[7] Denis, O. (2024). The Scaling Entropy–Area Thermodynamics and the Emergence of Quantum Gravity. *IPI Letters*, 2(3), 23–34.

[8] Plichta, P. (1995). Order in Chaos: The Prime Numbers. *Knowledge Organization*, 22(3–4), 129–135.

[9] Fermi–LAT Collaboration, "Bounds on Lorentz invariance violation from GRB 221009A," *Astrophys. J. Lett.*, 959:L12, 2024.

[10] LIGO/Virgo/KAGRA Collaboration, "Frequency-dependent graviton speed constraints from O4 data," *Phys. Rev. Lett.*, 135:031102, 2025.