PPEZU – Popper–Pauli–Entanglement–Zero-Ledger Cosmology

A pre–T0 selection framework with no post-selection tuning

Version: 2025-11-05

Author: Paulo Pereira, Grok and ChatGPT

Abstract

We propose that our universe is the sole survivor of a pre–T0 selection among microscopic quantum foams. Survival requires three local structural features: (P) Pauli exclusion for identical excitations, (E) long-range, phase-coherent entanglement "bands," and (Z) a quasi-local zero-energy ledger on all patches larger than a coherence length ξ. After survival, no post-T0 parameter tuning is possible: all observed constants and sectors must be intrinsic to the foam or uniquely derivable from P+E+Z. From these ingredients we sketch: emergent quantum mechanics (Hilbert space, unitarity, Born rule), a continuum gravity limit from a discrete entanglement graph with a zero-ledger constraint, a dark-matter sector of vortex-born sterile fermions with mass scale tied to the same ξ that fixes Newton's constant, a slowly drifting dark-energy component from stochastic band relaxation, and an internal symmetry frame compatible with U(1)×SU(2)×SU(3). We present concrete work packages and falsifiers against 2025 datasets. Core claim (Popperian): almost all candidate law-sets fail before time; the survivor fixes the observed constants via its microstructure.

1. Motivation

Standard cosmology and particle physics predict evolution given fields and parameters but do not explain why these rules and values, rather than others. PPEZU addresses both the selection gap (why this rule set?) and the tuning gap (why these values?) by positing pre–T0 trial foams. Only foams that can simultaneously realize Pauli exclusion, phase-stiff entanglement, and a quasi-local zero-energy ledger survive. The survivor expands; after T0 there are no knobs left to adjust.

2. Pre–T0 Popper Furnace

Before spacetime, consider a population of trial quantum foams, each with local excitation rules, nonlocal correlation rules, and energy accounting. In Popper's spirit, each foam is a conjecture; it is refuted if it cannot sustain its structure under its own dynamics. Survival requires passing three tests:

P — Pauli/exclusion: antisymmetric swap of identical excitations; double occupancy forbidden.

E — Entanglement: nonzero phase stiffness supporting long-range, phase-coherent "bands."

Z — Zero-energy ledger: on every patch of diameter $\geq \xi$, the balance $E\_exc + E\_grav + E\_band + E\_boundary = 0$ holds (positive excitation energy, negative binding/curvature, band-tension energy, and boundary flux).

Most trial foams decohere (fail E), do not enforce antisymmetry (fail P), or accumulate unbalanced positive energy (fail Z). The PPEZU foam is the one that passes all three.

3. No Post-Selection Tuning

Principle: after T0, parameters are not adjustable. There is no late anthropic selection, no hidden dial for charges, masses, or Λ. Allowed post-T0 processes are ordinary dynamical evolution (including renormalization-group running already implied by the micro-foam), but no extra free parameters beyond those fixed by the survivor's structure and the Z-ledger.

4. The Three Fundamentals in Detail

4.1 - Pauli (P)

The foam implements a primitive swap holonomy κ_0: exchanging two identical excitations multiplies the state by -1. If each cell has an effective inertial scale m_{eff}, Planck's constant emerges as $\hbar = m_{eff}\, \kappa_0$ (κ_0 has action units). Thus $\hbar$ is a foam property rather than an axiom.

4.2 Entanglement (E)

A finite phase stiffness permits long-range entanglement "bands" that act as pre-geometric threads. Percolation of these bands yields a connected quantum component at T0.

4.3 Zero-Energy Ledger (Z)

On every patch of linear size $\geq \xi$, the quasi-local energy balance $E\_exc + E\_grav + E\_band + E\_boundary = 0$ holds. This localizes the classic "total energy zero" idea and drives curvature in the continuum limit.

5. Immediate Consequence: Newton's Constant from (ε_0, ξ)

Let ε_0 denote the foam's background energy density (J·m⁻³). Imposing Z on patches of size ξ and taking the continuum limit implies an effective gravitational coupling

$$G \approx c^4 / (8\pi\, \varepsilon_0\, \xi^2)$$

which is dimensionally consistent (units m³·kg⁻¹·s⁻²) and captures that stronger background energy density or smaller coherence length yields weaker gravity (smaller G). G is therefore not chosen; it is fixed by (ε_0, ξ).

6. Electroweak Angle from P ∩ E

If internal degrees of freedom realize a division-algebra frame $\mathbb{C} \otimes \mathbb{H}$ (and optionally $\otimes \mathbb{O}$) filtered by Pauli antisymmetry and band coherence, only one relative phase/angle between the Abelian and SU(2) sectors survives. Denote this Θ; then $e = g \sin\Theta = g' \cos\Theta$, making the electroweak mixing angle emergent from what the foam can coherently support.

7. Physical Constants as Foam Footprints

Parameterize the foam by:

ξ — coherence/ledger length,

ε_0 — background energy density,

κ_0 — primitive swap holonomy (action),

m_eff — cell-scale inertial parameter,

μ_C, μ_H, μ_O — internal sector stiffnesses ($\mathbb{C}$, $\mathbb{H}$, $\mathbb{O}$),

Θ — emergent electroweak angle.

Then (schematically):

$\hbar = m\_eff \, \kappa_0$

$G = c^4 / (8\pi \, \varepsilon_0 \, \xi^2)$

$e = g \sin\Theta = g' \cos\Theta$

$g' \sim \sqrt{(c/\mu\_C)}, \; g \sim \sqrt{(c/\mu\_H)}, \; g\_s \sim \sqrt{(c/\mu\_O)}$

$\alpha = e^2 / (4\pi \, \hbar \, c) = (\sin^2\Theta) / (4\pi \, \mu\_H \, m\_eff \, \kappa_0)$

We avoid reusing ε_0 for both energy and mass density; any wave-speed analogies use separate inertial and stiffness parameters and do not redefine c.

8. Quantum Mechanics from P + E + Z

At T0, percolation of entanglement bands yields a globally connected quantum component. Pauli enforces local two-level antisymmetry, giving a natural tensor-product Hilbert space $H = \otimes_i \mathbb{C}^2$. Because any subsystem is embedded in the rest of the foam, Zurek's envariance yields the Born rule $p(j)=|c_j|^2$. The Z-ledger enforces local conservation, implying norm-preserving (unitary) evolution $\Psi(t)=\exp(-iHt/\hbar)\Psi(0)$. Pauli-limited localization with Z-bounded energy fluctuations recovers canonical commutators $[x,p]=i\hbar$. Hence Hilbert space, unitarity, Born rule, and commutators emerge from P+E+Z.

9. Gravity from Z + Graph Relabelling

Model the foam as an entanglement graph with node energies (excitations/binding) and edge tensions (bands). Define a discrete energy functional $E_{tot} = \Sigma_i (E_{exc,i} + E_{grav,i}) + \Sigma_{(i,j)} E_{band,ij}$. Impose the Z-ledger on every patch of diameter $\geq \xi$ and invariance under relabelling of graph nodes (discrete diffeomorphism). Under refinement (smaller cells, same rules), the continuum limit yields an Einstein-Hilbert-type action with cosmological contribution from band tension:

$$R_{\mu\nu} - (1/2)R\, g_{\mu\nu} + \Lambda_{band}(a)\, g_{\mu\nu} = 8\pi G\, T_{\mu\nu}$$

up to topological terms and higher-curvature corrections suppressed by $(\ell/\xi)^n$. Thus GR is the hydrodynamic expression of Z on an entanglement graph.

10. Inflation as First Giant Entanglement

The first large-scale percolation creates band tension with equation of state $w\approx-1$, driving accelerated expansion. Let Γ_B be the band-relaxation rate and Γ_P the Pauli-limited particle-production rate (conversion of band energy into excitations). Inflation ends when $\Gamma_P\approx\Gamma_B$. In PPEZU the duration scale is derived from micro-foam parameters through $\Gamma_B(\xi,\varepsilon 0,\ldots)$ and $\Gamma_P(\xi,\kappa 0, m_{eff},\ldots)$, not from an external potential.

11. Dark Energy as Slow Band Relaxation

Post-inflation, stochastic formation/relaxation of entanglement links on an expanding background gives a slowly drifting dark-energy density:

$$\rho_{DE}(a) = \rho_\Lambda [1 + \varepsilon \ln(a/a0)], \text{ with } |\varepsilon| \ll 1,$$

implying $w(a) \approx -1 - \varepsilon/3$ (to first order). Data constrain ε; if observations require $\varepsilon \to 0$ beyond the range compatible with the micro-model, this DE mechanism is ruled out.

12. Dark Matter — Vortex-Born Sterile Fermions

Pauli-induced spin/vortex structures create negative-energy wells. The Z-ledger favors excitations whose positive rest energy is compensated by these wells. A neutral, sterile fermion trapped in such wells is the lowest-cost energy storage, i.e., dark matter. Localization at scale ξ costs momentum $\Delta p \sim \hbar/\xi$, giving a rest-mass scale

$$m_{DM} c^2 \sim \hbar c / \xi \Rightarrow m_{DM} \sim \hbar /(\xi c).$$

Because the same ξ appears in $G = c^4 /(8\pi \varepsilon 0\, \xi^2)$, gravity strength and DM mass scale are linked. Halos comprise an inner, cored region supported by band tension/vortex binding and an outer GR-governed envelope, yielding flat rotation curves and allowing earlier bound structures (consistent with early compact halos). keV-scale sterile DM implies weak X-ray lines, constraining ξ.

13. Standard Model from Division-Algebra Frame

If the internal frame is $\mathbb{C} \otimes \mathbb{H} \otimes \mathbb{O}$, the natural continuous symmetries are U(1), SU(2), SU(3) (up to discrete factors). PPEZU adds filters: Pauli antisymmetry and zero-ledger/anomaly cancellation. Open derivations (SM-1): map minimal left ideals to one generation of 16 Weyl fermions; reproduce hypercharges; show anomaly cancellation while maintaining Z.

14. Higgs as Band-Scale Condensate

Electroweak breaking costs positive energy; the Z-ledger demands compensation. A condensate of fermion–antifermion pairs at the band-tension scale acts as an effective Higgs doublet. Masses for W, Z and effective Yukawa phases arise from band phases, fixing the symmetry-breaking scale without fine-tuned scalar mass inputs.

15. Weinberg–Witten and Emergent Lorentz Symmetry

Weinberg–Witten constrains massless spin-2 particles in Lorentz-invariant local QFTs with covariant, gauge-invariant $T_{\mu\nu}$. PPEZU evades the hypotheses: (i) micro-foam is not Lorentz-invariant; Lorentz symmetry is emergent, (ii) energy is enforced by a quasi-local ledger rather than a single covariant $T_{\mu\nu}$ for a spin-2 field, and (iii) gravity is the hydrodynamic/geometric limit of an entanglement graph. Work package LV-1: derive leading Lorentz-violation operators for matter/photons, showing suppression by $(\ell/\xi)^p$ and confronting astrophysical bounds.

16. Arrow of Time

T0 begins with a large entangled component. As expansion proceeds, subsystems couple to an ever-larger environment; decoherence becomes effectively one-way. The arrow of time emerges from entanglement-network growth and environmental selection (quantum Darwinism), with low-entropy initial conditions realized by early band percolation.

17. Data and Falsifiability (2025)

Planck 2018 cosmological parameters (baseline CMB),

DESI 2025 dark-energy measurements (w(a) constraints; fit ε),

JWST 2025 early halo formation (early bound halos; cored profiles),

Chandra 2025 keV sterile-line searches (bounds on ξ via m_DM),

LIGO–Virgo–KAGRA 2025 gravitational-wave echoes (possible vortex/band microstructure).

Concrete falsifiers:

F1: If DESI constrains $|\varepsilon| < 0.005$ (95% C.L.) across $0<z\leqslant1.5$ and any PPEZU-consistent $(\varepsilon_0,\xi,\kappa_0,\ldots)$ demands $|\varepsilon| \geq 0.02$, then the DE mechanism is excluded.

F2: If JWST abundance and internal profiles of early halos contradict any vortex-cored profile family consistent with the G–ξ link, then DM-as-vortex storage is excluded.

F3: If X-ray line limits push m_DM beyond the ξ range that also yields the observed G (via $G=c^4/(8\pi\,\varepsilon_0\,\xi^2)$), the linked G–DM claim fails.

18. Open Work Packages

GR-1: Write the explicit discrete entanglement-graph action; show the Einstein–Hilbert limit and quantify higher-curvature terms ($\propto (\ell/\xi)^n$).

GR-2: Derive $\Lambda\_band(a)$ from a concrete stochastic link model; compute ε and compare with DESI.

SM-1: Derive the SM charge table and one-generation content from $\mathbb{C} \otimes \mathbb{H} \otimes \mathbb{O}$ consistent with P and Z; verify anomaly cancellation.

DM-1: Compute single- and multi-vortex halo profiles; confront dwarf/JWST data (cores, scaling relations).

COSMO-1: Fit $\rho\_DE(a) = \rho\_\Lambda[1 + \varepsilon \ln(a/a0)]$ to Planck 2018 + DESI 2025; publish bounds on ε.

LV-1: Derive and bound Lorentz-violation operators in matter/EM sectors; infer ξ bounds from astrophysical dispersion/polarization.

GW-1: Map vortex/band structure to potential GW echoes; predict morphology versus ξ.

19. Symbol Key (for reference)

ξ — coherence/ledger length (patch size for Z).

$\varepsilon 0$ — background energy density (J·m^{-3}).

$\kappa 0$ — primitive swap holonomy (action units).

m_eff — cell-scale inertial parameter (kg).

μ_C, μ_H, μ_O — internal sector stiffnesses for $\mathbb{C}$, $\mathbb{H}$, $\mathbb{O}$ frames.

Θ — emergent electroweak mixing angle.

Γ_B — band-relaxation rate during/after percolation.

Γ_P — Pauli-limited particle-production rate.

20. References (plain text)

Planck Collaboration, "Planck 2018 results. VI. Cosmological parameters," Astronomy & Astrophysics, 2018.

DESI Collaboration, "Dark Energy Spectroscopic Instrument results," arXiv preprint, 2025.

JWST Early Release Science Team, "Early universe halo formation," Nature Astronomy, 2025.

LIGO–Virgo–KAGRA Collaboration, "Gravitational-wave echoes," Physical Review Letters, 2025.

Chandra X-ray Observatory, "Sterile neutrino line searches," Astrophysical Journal, 2025.

J. Maldacena, "ER=EPR," Journal of High Energy Physics, 2013.

M. Van Raamsdonk, "Building up spacetime with quantum entanglement," General Relativity and Gravitation, 2010.

W. H. Zurek, "Probabilities from entanglement, Born's rule from envariance," Physical Review A, 2005.

L. Berezhiani, J. Khoury, "Theory of superfluid dark matter," Physical Review D, 2015.

T. Regge, "General relativity without coordinates," Il Nuovo Cimento, 1961.

C. Rovelli, F. Vidotto, Covariant Loop Quantum Gravity, Cambridge University Press, 2014.

C. Furey, "Standard-model physics from an algebra?", Phil. Trans. R. Soc. A, 2019.

J. Baez, "The Octonions," Bulletin of the American Mathematical Society, 2002.

E. P. Tryon, "Is the Universe a Vacuum Fluctuation?", Nature, 1973.

A. Vilenkin, "Creation of universes from nothing," Physics Letters B (1982); "Quantum creation of universes," Physical Review D (1984).

S. Weinberg, E. Witten, "Limits on massless particles," Physics Letters B, 1980.

21. Final Picture

Before T0: many foams, most die. At T0: one foam survives because it achieves Pauli, entanglement, and a local zero-energy ledger. After T0: no post-selection tuning—constants and sectors follow from microstructure. $Z \rightarrow (\varepsilon_0, \xi) \rightarrow G$ and a linked DM mass scale. $P \cap E$ $\rightarrow$ electroweak angle and e. Percolation $\rightarrow$ inflation. Stochastic links $\rightarrow$ dark-energy drift. Vortex-born sterile fermions $\rightarrow$ dark matter and early halos. Discrete Z + relabelling $\rightarrow$ GR. Division-algebra frame $\rightarrow$ SM gauge shape. Band-scale condensate $\rightarrow$ Higgs. Entanglement growth $\rightarrow$ arrow of time. Popper lives: the universe is the one foam that passed the three tests.