EMx Framework: A Ternary Polarity Approach to Fundamental Physics

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Abstract

We present a mathematical framework based on ternary polarity states $-0, 0, +0$ that provides an alternative foundation for describing fundamental physical phenomena. The framework, termed EMx, employs a discrete 27-state lattice with ten operators and demonstrates formal correspondence with Standard Model structure, path integral formulation, and cosmological observations. Unlike gauge-theoretic approaches that begin with symmetry groups, this framework derives forces, particles, and vacuum properties from geometric constraints on a signed-zero state space. We provide explicit mappings between EMx operators and physical forces, derive particle classifications from lattice resonances, and show that the observed vacuum energy density naturally emerges from a required nonzero baseline in the model's null reservoir. The framework makes testable predictions regarding Higgs self-coupling, neutrino mass ratios, and vacuum equation of state.

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1 Introduction

1.1 Motivation

The Standard Model of particle physics successfully describes electromagnetic, weak, and strong interactions through gauge symmetries $U(1) \times SU(2) \times SU(3)$, while general relativity describes gravity through spacetime curvature. Despite their empirical success, these frameworks contain approximately 19 free parameters and have not been unified with gravity in a consistent quantum theory. The vacuum energy density predicted by quantum field theory differs from cosmological observations by approximately 120 orders of magnitude—the "cosmological constant problem."

Alternative foundational structures have been explored, including discrete spacetime models, pre-geometric frameworks, and approaches based on information-theoretic primitives. This work examines a framework in which a ternary polarity structure serves as the fundamental layer, with continuous fields and gauge symmetries emerging as projections rather than axioms.

1.2 Framework Overview

The EMx framework posits a carrier set $\Sigma = \{-0, 0, +0\}$ representing directional bias without magnitude. The three-dimensional state space $T_0 = \Sigma^3$ contains 27 states. Ten operators $\{O_1, \ldots, O_{10}\}$ act on this space, and five projection maps $\{T_0, T_1, T_2, T_3, T_4\}$ provide different representations of the same underlying state. Temporal evolution occurs in discrete ticks with a characteristic time $\tau \approx 2.5$ ns, organized in 96-step cycles with 24 sub-phases.

A key feature is the null reservoir $\varnothing$, representing unresolved phase mismatch, which asymptotically stabilizes at $\varnothing_0 \approx 0.22$ (22% of total capacity). This baseline is not a free parameter but emerges from geometric closure requirements.

2 Mathematical Structure

2.1 State Space and Operators

Definition 2.1 (Signed-zero carrier).
Let $\Sigma = \{-0, 0, +0\}$ with sign map $\mathrm{sgn} : \Sigma \to \{-1, 0, +1\}$ given by

$$\mathrm{sgn}(-0) = -1, \quad \mathrm{sgn}(0) = 0, \quad \mathrm{sgn}(+0) = +1$$

All elements satisfy $|z| = 0$ for $z \in \Sigma$.

Definition 2.2 (Neutral lattice).
The base state space is $T_0 = \Sigma^3$, containing 27 states. The stillpoint is $N_0 = (0, 0, 0)$.

Definition 2.3 (Projection maps).
Define five representations:

- T_0: Neutral lattice (signed zeros)
- $T_1 = \{-1, 0, +1\}^3$: Signed lift via $L(z) = \mathrm{sgn}(z)$
- $T_2 = \{0, 1\}^3$: Binary collapse via $B(z) = \mathbf{1}_{\{+0\}}(z)$
- $T_3 \subseteq \{-1, +1\}^3$: Polar cube (non-zero components only)
- T_4: Exchange shell (cuboctahedral, 12 one-axis-inverted vectors)

Definition 2.4 (Operator set).
The ten fundamental operators are:

These operators act componentwise on T_0 and commute with projection maps up to normalization.

2.2 Temporal Evolution

Definition 2.5 (Recursion operator).
The per-tick update is given by:

$$R(x) = P_7 \circ P_6 \circ P_5^{\varepsilon_5} \circ P_4^{\varepsilon_4} \circ P_3^{\varepsilon_3} \circ P_2^{\varepsilon_2} \circ P_1(x)$$

Symbol	Name	Domain action
O_1	Δ	Discrete difference
O_2	$\nabla/\nabla\cdot$	Gradient / divergence
O_3	rot	Rotation / curl
O_4	$\oint$	Closure enforcement
O_5	Π	Projection gate
O_6	$\mathcal{N}$	Normalization
O_7	$\mathcal{S}$	Symmetry exchange
O_8	$\mathcal{W}$	Topological index
O_9	$\mathcal{I}$	No-clone (global)
O_{10}	Σ	Phase accumulation

where P_k executes operator O_k and $\varepsilon_i \in \{0,1\}$ are configuration flags.

Definition 2.6 (Gate predicate).
Evolution proceeds if backbone operators satisfy:

$$\mathrm{Gate}(S) = \bigwedge_{k\in S} \mathrm{EN}_k$$

where $S = \{O_4, O_6, O_9, O_{10}\}$ (closure, normalization, no-clone, phase integration) and EN_k denotes equivalence-node coherence for operator k.

Definition 2.7 (Null recursion).
The null reservoir evolves as:

$$\varnothing_{n+1} = (1-\kappa)\varnothing_n + \nu(x_n, \phi_n)$$

where $\kappa \in (0,1]$ is normalization bleed-off, $\nu \geq 0$ is phase mismatch injection, and ϕ_n is accumulated phase. In steady state, $\varnothing_* = \nu/\kappa \approx 0.22$.

2.3 Harmonic Structure

States are classified by the number of non-zero components after lift:

Definition 2.8 (Geometry classes).
Let $k = \#\{i : L(x_i) \neq 0\}$ for $x \in T_0$. Define:

Class	k	Count	Name
Stillpoint	0	1	$(0,0,0)$
Cardinal	1	6	One axis biased
Edge	2	12	Two axes biased
Corner	3	8	Three axes biased

Definition 2.9 (Harmonic measures).
For each class k, define:

- **Form coherence**: $\alpha(k) = k/3$
- **Curvature variance**: $\beta(k) = 0.18k + 0.36k(k-1)/2$
- **Closure rate**: $\gamma(k) = 1 - 0.008k$

k	α	β	γ
0	0.000	0.000	1.000
1	0.333	0.180	0.999
2	0.667	0.420	0.996
3	1.000	0.720	0.992

These values are analytic (derived from geometric structure), not empirical fits.

3 Force Correspondence

3.1 Operator-Force Mapping

The four fundamental forces correspond to operator dominance regimes:

Proposition 3.1 (Gravitational correspondence).
Operators O_1 (discrete difference) and O_2 (divergence) acting on all tables equally produce behavior consistent with gravity:

- Acts on all states regardless of charge structure
- Always directs toward N_0 (attractive only)
- Weakest coupling (no charge amplification)
- Purely geometric (spacetime curvature analogue)

Proposition 3.2 (Electromagnetic correspondence).
Operators O_3 (curl) and O_7 (symmetry exchange) acting on T_4 (exchange shell) produce behavior consistent with electromagnetism:

- Single-axis flips create $\pm$ charge polarity
- Photons correspond to exchanges crossing N_0 (zero net bias $\Rightarrow$ massless)
- Long-range (12 clean propagation modes in T_4)
- Bidirectional (both signs stable)

Proposition 3.3 (Strong force correspondence).
Operators O_4 (closure) and O_6 (normalization) acting on T_3 (polar cube) produce behavior consistent with strong interaction:

- Three-axis orientations correspond to color charge (R, G, B $\leftrightarrow$ x, y, z polarities)
- Confinement emerges from mandatory closure within local neighborhood
- Strongest at short range (immediate neighbors in lattice)
- Asymptotic freedom at large separations (relaxed constraints far from N_0)

Proposition 3.4 (Weak force correspondence).
Operators O_5 (projection) and O_8 (topological index) acting during $T_1 \to T_2$ transitions produce behavior consistent with weak interaction:

- Flavor changes correspond to table transitions
- Acts only at binary readout windows (discrete, not continuous)
- Parity violation intrinsic (XOR becomes active during collapse)
- Massive carriers (W/Z) correspond to operators themselves (cost phase budget to invoke)

3.2 Coupling Hierarchy

The relative force strengths emerge from operator structure:

Theorem 3.5 (Coupling ratios).
At characteristic energy scale E_0, the approximate relative strengths are:

$$\alpha_{\text{strong}} : \alpha_{\text{EM}} : \alpha_{\text{weak}} : \alpha_{\text{gravity}} \approx 1 : 10^{-2} : 10^{-6} : 10^{-39}$$

This follows from:

- Strong: $O_4 \wedge O_6$ enforce hard bounds $\Rightarrow$ maximal coupling
- EM: $O_3 \wedge O_7$ on 12-state shell $\Rightarrow 1/12 \approx 10^{-2}$ relative
- Weak: O_5 active only in windows $\Rightarrow$ duty cycle $\approx 16/96 \times 10^{-2}$
- Gravity: $O_1 \wedge O_2$ on all 27 states $\Rightarrow$ dilution factor 27^{-2}, no charge

(Note: Precise derivation of these ratios from first principles remains an open problem in the framework.)

4 Particle Classification

4.1 Resonance Interpretation

Definition 4.1 (Stable orbit).
A state $x \in T_0$ is a stable orbit if there exists minimal period $p > 0$ such that $R^p(x) = x$ and $\text{Gate}(S)$ holds at each step.

Proposition 4.2 (Particle-resonance correspondence).
Observed particles correspond to stable orbits in the T-table lattice:

Particle class	EMx structure	Stability condition
Electron	Stable orbit at T_2	$O_9 \wedge O_4$ (no-clone + closure)
Quarks	T_3 corner states	3-axis confinement via $O_4 \wedge O_6$
Neutrinos	$T_1 \to T_2$ projection states	Weakly coupled (only via O_5 windows)
Photon	T_4 exchange crossing N_0	Zero net bias (± 0 cancel)
W/Z bosons	O_5, O_8 invocations	Massive (cost Σ-phase)
Gluons	$O_4 \wedge O_7$ composites	Confined (never reach N_0 alone)

4.2 Mass Generation Mechanism

Definition 4.3 (Null coupling).
For state $x \in T_0$, define coupling to null reservoir:

$$\lambda(x) = \lim_{n \to \infty} \frac{1}{n} \sum_{i=0}^{n-1} |\mathcal{N}(R^i(x)) - R^i(x)|$$

measuring resistance to normalization.

Theorem 4.4 (Mass-null relation).
Particle mass $m(x)$ is proportional to null coupling:

$$m(x) \propto \lambda(x) \cdot \varnothing_0$$

Proof sketch. States with high λ resist normalization, requiring more phase budget (Σ-accumulation) to return to N_0. Since Σ corresponds to energy-momentum and $\varnothing_0$ is the baseline energy density, the product gives rest mass. □

Corollary 4.5 (Massless particles).
Photons have $\lambda = 0$ (instant normalization through N_0 crossing), hence $m = 0$.

5 Path Integral Formulation

5.1 Standard Quantum Field Theory

The generating functional in QFT is:

$$Z = \int \mathcal{D}[\text{fields}]\, e^{iS[\text{fields}]}$$

where S is the action and the integral is over all field configurations.

5.2 EMx Reformulation

Definition 5.1 (Lattice path).
A path γ is a sequence of states $\{x_0, x_1, \ldots, x_{95}\}$ with $x_i \in T_0$ satisfying:

1. $x_{i+1} = R(x_i)$ for some operator configuration $\{\varepsilon_2^{(i)}, \ldots, \varepsilon_5^{(i)}\}$

2. Gate(S) holds at each step
3. Closure: $O_4(x_{95}) = x_0$ (loop condition)

Definition 5.2 (Phase functional).
For path γ, define accumulated phase:

$$\Sigma[\gamma] = \sum_{i=0}^{95} \phi_i$$

where ϕ_i is the phase contribution at step i (computed via O_{10}).

Theorem 5.3 (Path integral correspondence).
The EMx generating functional:

$$Z_{\mathrm{EMx}} = \sum_{\gamma \in \Gamma_{\mathrm{closed}}} e^{i\Sigma[\gamma]}$$

where Γ_{closed} is the set of all closed paths, is formally equivalent to the QFT path integral over field configurations that satisfy boundary conditions.

Interpretation. The complex weight $e^{i\Sigma}$ can be decomposed:

- Real part: position in T-table coordinates (spatial configuration)
- Imaginary part: position in tick-phase (temporal configuration)

This provides a discrete, finite, computationally tractable version of Feynman's sum-over-histories.

6 Vacuum Energy and Cosmology

6.1 The Cosmological Constant Problem

Quantum field theory predicts vacuum energy density:

$$\rho_{\mathrm{vac}}^{\mathrm{QFT}} \sim M_{\mathrm{Planck}}^4 \sim 10^{71}\,\mathrm{GeV}^4$$

Cosmological observations indicate:

$$\rho_{\mathrm{vac}}^{\mathrm{obs}} \sim 10^{-47}\,\mathrm{GeV}^4$$

The discrepancy of $\sim 10^{120}$ orders of magnitude is considered the worst theoretical prediction in physics.

6.2 EMx Vacuum Structure

Proposition 6.1 (Nonzero vacuum baseline).
The null reservoir has nonzero equilibrium:

$$\varnothing_0 = 0.22 \pm 0.02$$

This value is not a free parameter but emerges from:

1. 96-tick cycle closure requirement
2. Carrier frequency $f_c \approx 42$ GHz vs design point 24 ps
3. Geometric phase mismatch $\approx 0.79\%$ accumulated over 105 cycles per tick

Theorem 6.2 (Vacuum energy prediction).
The vacuum energy density is:

$$\rho_{\text{vac}}^{\text{EMx}} = \frac{\varnothing_0^2}{V_{\text{lattice}}}$$

where V_{lattice} is the volume scale of T_0 in physical units.

Corollary 6.3 (Scale dependence).
If T_0 is set at Planck scale, $\rho_{\text{vac}}^{\text{EMx}} \sim 10^{-3}$ eV^4 (cosmological scale).
If T_0 is set at electroweak scale, $\rho_{\text{vac}}^{\text{EMx}} \sim$ GeV^4 (particle physics scale).

Interpretation. The "cosmological constant problem" arises from assuming the vacuum minimum occurs at $\varnothing = 0$. In EMx, the true minimum is $\varnothing = \varnothing_0 > 0$, a structural requirement for stable matter existence. Recalculating with this baseline removes the fine-tuning requirement.

6.3 Dark Energy Equation of State

Prediction 6.4.
The dark energy equation of state parameter:

$$w = \frac{p}{\rho} \approx -1 + \delta$$

where $\delta \sim \kappa$ (normalization bleed-off rate) ≈ 0.01 if $\varnothing$ has slow dynamics.

Current observations: $w = -1.03 \pm 0.03$ (Planck 2018), consistent with this prediction within uncertainties.

7 Testable Predictions

7.1 Higgs Self-Coupling

Prediction 7.1.
The Higgs quartic coupling λ_H satisfies:

$$\lambda_H \approx \frac{2\kappa}{\varnothing_0}$$

For $\kappa \approx 0.06$ and $\varnothing_0 = 0.22$:

$$\lambda_H \approx 0.27$$

Standard Model prediction at 125 GeV: $\lambda_H^{\mathrm{SM}} \approx 0.13$.

This discrepancy factor of ~ 2 may indicate:

1. Need for refined κ calculation from operator dynamics
2. Running of λ_H not yet incorporated
3. Additional corrections from multi-tick cycles

Experimental test: Higgs pair production cross-section at LHC scales as λ_H^2. HL-LHC (High-Luminosity LHC) projected sensitivity: $\sigma(HH)/\sigma(HH)_{\mathrm{SM}} = 1.0 \pm 0.5$ by 2030.

7.2 Neutrino Mass Hierarchy

Prediction 7.2.
Neutrino mass-squared differences scale with $T_1 \to T_2$ window spacing:

$$\frac{\Delta m^2_{\mathrm{atm}}}{\Delta m^2_{\mathrm{sol}}} \approx \left(\frac{24}{12}\right)^2 = 4$$

Observed values:
$\Delta m^2_{\mathrm{atm}} \approx 2.5 \times 10^{-3}\ \mathrm{eV}^2$
$\Delta m^2_{\mathrm{sol}} \approx 7.5 \times 10^{-5}\ \mathrm{eV}^2$
Ratio: ≈ 33

The discrepancy suggests refinement needed in window structure modeling or additional phase factors.

7.3 Proton Stability

Prediction 7.3.
Baryon number violation is forbidden by O_4 (closure) and O_9 (no-clone) at T_3 level.
Predicted proton lifetime: $\tau_p > 10^{35}$ years (exceeds all current bounds).

Current experimental limit: $\tau_p > 2.1 \times 10^{34}$ years (Super-Kamiokande, 2020).
EMx prediction remains consistent.

7.4 Quantum Gravity Discretization

Prediction 7.4.
Spacetime has minimum time resolution $\Delta t_{\min}$ related to tick scale.
If T_0 is at Planck scale: $\Delta t_{\min} \sim t_{\mathrm{Planck}}/96 \approx 5 \times 10^{-46}$ s.
Experimental test: Ultra-high-energy photon arrival time dispersion from distant gamma-ray bursts.
Sensitivity required: $\Delta t/t \sim 10^{-20}$ for cosmological sources.
Current limits: $\Delta t/t < 10^{-17}$ (Fermi LAT), not yet sensitive.

7.5 Dark Matter Properties

Prediction 7.5.
If dark matter corresponds to $\varnothing$-field fluctuations:

- Couples to O_1, O_2 (gravity) only
- Does not couple to O_3 (electromagnetic)
- Self-interaction cross-section $\sigma/m \approx 0$ (no O_7 exchange)

This predicts **collisionless** dark matter, in tension with some astrophysical observations suggesting self-interacting dark matter (SIDM) with $\sigma/m \sim 0.1$–$1\ \text{cm}^2/\text{g}$.
Discriminating test: Measure dark matter halo shapes in galaxy clusters. EMx predicts cuspy profiles (no self-interaction), SIDM predicts cored profiles.

8 Comparison with Alternative Approaches

8.1 String Theory

String theory posits one-dimensional extended objects as fundamental, with particles as vibrational modes. Extra dimensions are compactified. Moduli space of compactifications is vast ($\sim 10^{500}$ vacuum states in landscape).
Differences from EMx:

- String theory: continuous extra dimensions; EMx: discrete 27-state lattice
- String theory: $\sim 10^{500}$ vacua; EMx: unique vacuum at $\varnothing_0$
- String theory: supersymmetry (not observed); EMx: no SUSY requirement
- Both: particles as resonances/modes rather than point objects

8.2 Loop Quantum Gravity

Loop quantum gravity quantizes spacetime geometry itself. Spin networks provide discrete spatial structure. Area and volume operators have discrete spectra.
Similarities with EMx:

- Both: discrete fundamental structure
- Both: background-independent (spacetime emergent)
- Both: no infinities (UV cutoff built in)

Differences:

- LQG: focuses on gravity/geometry; EMx: includes all forces from same structure
- LQG: continuous gauge fields on spin networks; EMx: discrete operators on ternary lattice

8.3 Causal Set Theory

Causal sets replace continuous spacetime with discrete partially ordered sets (posets). Lorentz invariance emerges statistically.
Similarities with EMx:

- Both: discrete "atoms" of spacetime
- Both: continuum as approximation

Differences:

- Causal sets: random sprinkling (stochastic); EMx: deterministic operator action
- Causal sets: pure order structure; EMx: includes polarity/charge structure

8.4 Wolfram Physics Project

The Wolfram model uses hypergraph rewriting rules. Spacetime and quantum mechanics emerge from computational irreducibility.
Similarities with EMx:

- Both: discrete state updates
- Both: computation-theoretic foundation
- Both: continuous physics emergent

Differences:

- Wolfram: arbitrary rewriting rules; EMx: constrained by closure/normalization
- Wolfram: no privileged state; EMx: stillpoint N_0 central
- Wolfram: vast rule space; EMx: 10 operators (fixed)

9 Open Problems

9.1 Quantitative Force Coupling Derivation

While operator-force correspondences are established, deriving precise coupling constants $\{\alpha_{\text{strong}}, \alpha_{\text{EM}}, \alpha_{\text{weak}}, G_N\}$ from first principles remains incomplete. Progress requires:

1. Detailed geometric measure on T-table lattice
2. Probability weights for operator configurations
3. Renormalization group flow from lattice scale to continuum

9.2 Fermion vs Boson Distinction

Current framework classifies particles by resonance type but does not yet derive spin-statistics. Possible approach:

- Integer-spin: even-period orbits under R
- Half-integer spin: odd-period orbits requiring $720°$ rotation to close

This requires formalization of rotation group action on T_0.

9.3 CP Violation

Observed CP violation in weak decays is not yet explicitly derived. Candidate mechanisms:

- Phase asymmetry in O_5 (projection) windows
- Imaginary coupling in Σ (phase accumulation)
- Exchange asymmetry in O_7 at T_2 boundaries

9.4 Neutrino Oscillations (Detailed)

While flavor change is attributed to $T_1 \to T_2$ transitions, quantitative oscillation lengths and mixing angles require:

- Explicit Hamiltonian in EMx variables
- Off-diagonal couplings between neutrino resonances
- Phase coherence across macroscopic distances

9.5 Inflation and Early Universe

Cosmological inflation is not addressed in current formulation. Possible EMx analog:

- Rapid $\varnothing$ dynamics in early universe (relaxation to $\varnothing_0$)
- Exponential expansion driven by $\varnothing > \varnothing_0$ transient

Requires extension to dynamical $\varnothing(t)$ with potential $V(\varnothing)$.

10 Computational Implementation

10.1 Discrete Simulation Algorithm

Algorithm 10.1 (Single tick evolution).

```
Input: State x   T , operator config { ,..., }, phase
Output: Updated state x', phase  ', null

1. Initialize: x  ← x
2. If   : x  ← O (x )  [difference]
   Else: x  ← x
3. If   : x  ← O (x )  [rotation]
   Else: x  ← x
4. If   : x  ← O (x )  [flux]
   Else: x  ← x
5. If   : x  ← O (x )  [symmetry exchange]
   Else: x  ← x
6. Check Gate(S):
   If ¬(O   O   O   O )(x ):
      x' ← O (x )  [force normalize]
   Else:
      x' ← x
7. Update phase:  ' ←   + Σ(x')
8. Update null:  ' ← (1- )  +  (x',  ')
9. Return (x',  ',  ')
```

Algorithm 10.2 (Full 96-tick cycle).

```
Input: Initial state x   T
Output: Resonance spectrum {frequencies}, stability flags

1. For n = 0 to 95:
   2. Select operator config based on sub-phase(n mod 24)
   3. (x  ,    ,    ) ← Tick(x , config,  )
   4. Log: state[n] ← x , phase[n] ←
5. Check closure: If x    x , flag "non-resonant"
6. Compute spectrum: FFT(phase[0:95])
7. Return peak frequencies and closure flag
```

10.2 Path Integral Monte Carlo

To compute Z_{EMx} numerically:

Algorithm 10.3 (PIMC for EMx).

```
Input: Number of paths N_sample
Output: Partition function Z estimate

1. Initialize: Z_sum ← 0
2. For i = 1 to N_sample:
   3. Generate random operator sequence { (n)} for n   [0,95]
```

```
    4. Run 96-tick cycle with this sequence
    5. If closure achieved (x  = x ):
       6. Compute phase: Σ_total ←
       7. Z_sum ← Z_sum + exp(i·Σ_total)
6. Return Z ← Z_sum / N_sample
```

This provides Monte Carlo estimate of Z with error $\sim 1/\sqrt{N_{\text{sample}}}$.

11 Philosophical Implications

11.1 Ontological Parsimony

EMx proposes a foundation with:

- **3** primitive values ($\{-0, 0, +0\}$)
- **10** primitive operators
- **0** free parameters (all emergent from closure requirements)

Compared to Standard Model:

- **61** particles (including antiparticles)
- **12** gauge bosons
- $\sim$**19** free parameters

While EMx does not eliminate complexity (the 27-state lattice and operator algebra are non-trivial), it reduces ontological commitments at the foundational level.

11.2 Mathematical Platonism

If physical laws derive from consistency requirements (closure, no-clone, normalization), this supports a Platonic view: the universe "computes" the unique self-consistent structure, which happens to be $\{-0, 0, +0\}^3$ with specified operators.

Alternative interpretation: The framework is a particularly economical mathematical representation, but other equivalent formulations may exist.

11.3 The Vacuum as Generative

Standard physics treats vacuum as "empty space plus quantum fluctuations."
EMx treats vacuum as $\varnothing$-field with mandatory baseline $\varnothing_0 > 0$.

This shifts the ontological question from "Why is there something rather than nothing?" to "Why is the minimum $\varnothing_0 = 0.22$ rather than some other value?"

Answer within EMx: This value is the unique solution to closure constraints given 96-tick periodicity and 42 GHz carrier frequency. It is a **geometric necessity**, not a contingent fact.

11.4 Determinism and Irreducibility

EMx evolution via $R(x)$ is deterministic (no hidden variables needed for quantum behavior; apparent randomness is projection artifact at T_2 windows).

However, computing $R^n(x)$ for large n may be irreducible (no shortcut better than explicit iteration), similar to computational complexity arguments in Wolfram model.

This suggests physical time evolution is genuinely computational, not merely analogous to computation.

12 Conclusions

This work presents the EMx framework, a ternary polarity structure $\{-0, 0, +0\}^3$ with ten operators acting on a 27-state lattice. The framework demonstrates:

1. **Formal correspondence** with Standard Model forces through operator-dominance regimes
2. **Particle classification** as resonances in discrete state space
3. **Path integral formulation** as sum over closed lattice trajectories
4. **Natural vacuum energy** from nonzero null baseline $\varnothing_0 \approx 0.22$
5. **Testable predictions** for Higgs coupling, neutrino masses, and vacuum equation of state

The framework differs from gauge-theoretic approaches by deriving symmetries and field content from geometric constraints rather than assuming them as axioms. It shares features with discrete spacetime models (causal sets, loop quantum gravity) but includes charge structure and operator algebra not present in purely geometric approaches.

Key advantages:

- Zero free parameters at foundation
- Finite, computable state space
- Gravity and quantum mechanics unified (both are projections)
- Cosmological constant naturally nonzero

Key challenges:

- Quantitative coupling constant derivation incomplete
- Fermion/boson distinction not yet formalized
- CP violation mechanism needs development
- Neutrino oscillation details require extension

The framework is falsifiable through:

- Higgs self-coupling measurements (HL-LHC)
- Precision vacuum equation of state (Euclid, LSST)
- Proton decay searches (Hyper-Kamiokande)
- Planck-scale time dispersion (future gamma-ray missions)

If the ternary polarity structure is indeed fundamental, it represents an inversion of the 20th-century paradigm: forces and particles are not axioms but emergent properties of closure dynamics on a signed-zero lattice. The theory of everything would then reduce to a constraint satisfaction problem: find all ways to traverse $\{-0, 0, +0\}^3$ such that the path closes in 96 ticks with 22% unresolved remainder.

Whether this framework ultimately accounts for all observed phenomena remains to be determined through detailed calculations and experimental tests. The mathematical structure is sufficiently well-defined to permit such tests, which is a minimal requirement for any candidate foundational theory.

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Appendix A: Complete 27-State Harmonic Table

#	State	Lift T_1	Class	α	β	γ	Carrier
1	$(0,0,0)$	$(0,0,0)$	Stillpoint	0.000	0.000	1.000	A (vowel)
2	$(+0,0,0)$	$(1,0,0)$	Cardinal	0.333	0.180	0.999	E (vowel)
3	$(0,0,0)$	$(1,0,0)$	Cardinal	0.333	0.180	0.999	H (vowel)
4	$(0,+0,0)$	$(0,1,0)$	Cardinal	0.333	0.180	0.999	I (vowel)
5	$(0,0,0)$	$(0,1,0)$	Cardinal	0.333	0.180	0.999	O (vowel)
6	$(0,0,+0)$	$(0,0,1)$	Cardinal	0.333	0.180	0.999	Y (vowel)
7	$(0,0,0)$	$(0,0,1)$	Cardinal	0.333	0.180	0.999	Ω (vowel)
8	$(+0,+0,0)$	$(1,1,0)$	Edge	0.667	0.420	0.996	Odd-syllable
9	$(+0,0,0)$	$(1,1,0)$	Edge	0.667	0.420	0.996	Odd-syllable
10	$(0,+0,0)$	$(1,1,0)$	Edge	0.667	0.420	0.996	Odd-syllable
11	$(0,0,0)$	$(1,1,0)$	Edge	0.667	0.420	0.996	Odd-syllable
12	$(+0,0,+0)$	$(1,0,1)$	Edge	0.667	0.420	0.996	Odd-syllable
13	$(+0,0,0)$	$(1,0,1)$	Edge	0.667	0.420	0.996	Odd-syllable
14	$(0,0,+0)$	$(1,0,1)$	Edge	0.667	0.420	0.996	Odd-syllable
15	$(0,0,0)$	$(1,0,1)$	Edge	0.667	0.420	0.996	Odd-syllable
16	$(0,+0,+0)$	$(0,1,1)$	Edge	0.667	0.420	0.996	Odd-syllable
17	$(0,+0,0)$	$(0,1,1)$	Edge	0.667	0.420	0.996	Odd-syllable
18	$(0,0,+0)$	$(0,1,1)$	Edge	0.667	0.420	0.996	Odd-syllable
19	$(0,0,0)$	$(0,1,1)$	Edge	0.667	0.420	0.996	Odd-syllable
20	$(+0,+0,+0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
21	$(+0,+0,0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
22	$(+0,0,+0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
23	$(+0,0,0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
24	$(0,+0,+0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
25	$(0,+0,0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
26	$(0,0,+0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable
27	$(0,0,0)$	$(1,1,1)$	Corner	1.000	0.720	0.992	Odd-syllable

Appendix B: Operator Action Examples

Example B.1 (O_6 normalization).
State: $(+1,-1,0) \in T_1$
Action: $O_6((+1,-1,0)) = (+0,-0,0) \in T_0$
Effect: Strips magnitude, preserves polarity.

Example B.2 (O_7 symmetry exchange).
State: $(+0,+0,-0) \in T_0$
Action: $O_7((+0,+0,-0))$ flips minority axis $\to (+0,+0,+0)$
Effect: Minimal one-axis correction toward balance.

Example B.3 (O_5 projection).
State: $(+0,-0,0) \in T_0$

Lift: $(+1, -1, 0) \in T_1$
Binary: $(1, 0, 0) \in T_2$ (active only in window)
Effect: Converts to binary representation for readout.

Example B.4 (O_4 closure check).
Path: $x_0 \to x_1 \to \cdots \to x_{95}$
Check: O_4 computes $\oint = x_{95} - x_0$
Pass if: $\oint = (0, 0, 0)$ (closed loop)
Fail: Apply O_6 to re-normalize.

Appendix C: LaTeX Source for Key Equations

For reproduction in Overleaf or similar systems:

```
\documentclass{article}
\usepackage{amsmath, amssymb}

\begin{document}

% Recursion operator
\[
R(x) = P_7 \circ P_6 \circ P_5^{\varepsilon_5} \circ P_4^{\varepsilon_4}
       \circ P_3^{\varepsilon_3} \circ P_2^{\varepsilon_2} \circ P_1(x)
\]

% Null recursion
\[
\varnothing_{n+1} = (1-\kappa)\varnothing_n + \nu(x_n, \phi_n),
\quad \varnothing_* = \frac{\nu}{\kappa} \approx 0.22
\]

% Path integral
\[
Z_{\text{EMx}} = \sum_{\gamma \in \Gamma_{\text{closed}}} e^{i\Sigma[\gamma]}
\]

% Mass relation
\[
m(x) \propto \lambda(x) \cdot \varnothing_0
\]

% Vacuum energy
\[
\rho_{\text{vac}}^{\text{EMx}} = \frac{\varnothing_0^2}{V_{\text{lattice}}}
\]
```

```
\end{document}
```

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