Standard Physics Embedding: A Complete Dictionary from Geometric TOE to Particle Physics

Léon Fernando Vlegels
Independent Researcher

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Abstract

We provide a complete translation between the geometric Theory of Everything based on (B^4, S^3) topology and the standard notation of particle physics. Every element of the geometric framework is mapped to its physical counterpart: the density $\rho(x)$ to spectral/energy density, the master operator $\hat{O}$ to the Standard Model Lagrangian, the $\mathbb{Z}_3$ symmetry to fermion families, the division algebra tower to gauge groups, and the moment hierarchy to coupling constants. We present a comprehensive dictionary, worked examples, and a summary of all predictions with their experimental status. This paper serves as the interface between the geometric formalism and the physics community. The electroweak VEV conjecture recorded here fails evaluation by fourteen orders of magnitude and is refuted in later corpus work (Paper 40); the paper stands as a record with its registry status attached.

Keywords: Standard Model, particle physics, geometric unification, translation dictionary

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Contents

1 Introduction

1.1 Purpose

The geometric Theory of Everything (TOE) based on the (B^4, S^3) manifold has been developed across a series of papers establishing:

- The geometric density $\rho(x) = 16\pi^3 x^3 + 3\pi^2 x^2 + 2\pi x$
- The master operator $\hat{O}$
- The Unified Field Equation $\hat{O}\Phi = J$
- Derivations of α, G, three families, and gauge structure

This paper provides the **translation layer**: a complete dictionary mapping every geometric concept to its Standard Model counterpart. The goal is to make the framework accessible to particle physicists, cosmologists, and experimentalists.

1.2 Structure

1. **Section 2**: The Master Dictionary (geometry $\leftrightarrow$ physics)
2. **Section 3**: Particle Content (fermions, bosons, Higgs)
3. **Section 4**: Coupling Constants (all derived values)
4. **Section 5**: Symmetries (gauge groups, families, CP)
5. **Section 6**: Mass Spectrum (hierarchy and predictions)
6. **Section 7**: Cosmology (dark sector, inflation, Λ)
7. **Section 8**: Experimental Tests (current and future)
8. **Section 9**: Complete Summary

2 The Master Dictionary

2.1 Geometric Objects $\rightarrow$ Physical Objects

Geometric Object	Physical Counterpart	Notes
B^4 (4-ball)	Quantum vacuum / bulk spacetime	Where quantum fields propagate
S^3 (3-sphere boundary)	Classical spacetime / observable universe	Where we live and measure
S^1 (Hopf fiber)	Phase / U(1) gauge / observation	Internal degree of freedom
$\rho(x)$ density	Spectral density / vacuum energy	Encodes all coupling strengths
$x \in [0, 1]$	Radial coordinate / energy scale	$x = 0$: center; $x = 1$: boundary
$\hat{O}$ master operator	$\mathcal{L}_{\mathrm{SM}}$ Lagrangian	Generates all dynamics

Geometric Object	Physical Counterpart	Notes
Φ universal field	All SM fields combined	Fermions + bosons + Higgs
J source term	Interactions / currents	Self-lensing = self-interaction
T_{cycle} layer-cycle	Generation mixing	Cycles through 3 families
$\mathcal{R}$ RG generator	Renormalization group flow	Scale transformations
$\mathcal{M}$ moment operator	Mass matrix structure	Hierarchies from μ_n

Table 1: Geometric objects and their physical counterparts

2.2 Geometric Parameters $\rightarrow$ Physical Constants

Geometric	Value	Physical	Measured
$\mu_0 = \int \rho\, dx$	137.036	α^{-1}	137.035999...
$\mu_1 = \int x\rho\, dx$	108.717	Controls M_{Pl}	Via G
$\mu_2 = \int x^2\rho\, dx$	90.176	Controls Λ?	TBD
μ_1/μ_0	0.7933	β_{geom}	RG coefficient
$\kappa = \alpha^{5/4}$	0.00213	Oscillation scale	Testable
$\gamma = 3/4$	0.75	Boundary/bulk ratio	$\dim(S^3)/\dim(B^4)$
$\beta = 3\pi/20$	0.4712	Gravity coefficient	In log formula
E_{self}	13.177	Self-lensing energy	Bound state scale

Table 2: Geometric parameters and physical constants

2.3 Geometric Structures $\rightarrow$ Symmetries

Geometric Structure	Symmetry Group	Physical Role
$S^3 \cong SU(2)$	$SU(2)_L$	Weak isospin
Hopf fiber S^1	$U(1)_Y$	Hypercharge
$G_2 = \text{Aut}(\mathbb{O})$	Contains $SU(3)$	Color symmetry
$L(3,1) = S^3/\mathbb{Z}_3$	$\mathbb{Z}_3$	Three families
$C \circ P = I$	CPT	Anti-collapse symmetry
Division algebras	$\mathbb{R}, \mathbb{C}, \mathbb{H}, \mathbb{O}$	Force hierarchy
Hopf fibration	$S^1 \rightarrow S^3 \rightarrow S^2$	Electroweak structure

Table 3: Geometric structures and symmetry groups

3 Particle Content

3.1 Fermions from Bulk Modes

Fermions are eigenmodes of the bulk Dirac operator D_{B^4} with $\mathbb{Z}_3$ family structure.

Particle	**Geometric Mode**	T_{cycle} **eigenvalue**	$SU(3)$	$SU(2)$
e, μ, τ	$\psi_\ell^{(k)}$, $k = 0, 1, 2$	$1, \omega, \omega^2$	**1**	**2**
ν_e, ν_μ, ν_τ	$\psi_\nu^{(k)}$, $k = 0, 1, 2$	$1, \omega, \omega^2$	**1**	**2**
u, c, t	$\psi_u^{(k)}$, $k = 0, 1, 2$	$1, \omega, \omega^2$	**3**	**2**
d, s, b	$\psi_d^{(k)}$, $k = 0, 1, 2$	$1, \omega, \omega^2$	**3**	**2**

where $\omega = e^{2\pi i/3}$.

Proposition 3.1 (Family Origin). *The three families arise from the $\mathbb{Z}_3$ eigenspaces of the layer-cycle operator T_{cycle}:*

$$T_{\text{cycle}}\psi^{(k)} = \omega^k \psi^{(k)}, \quad k = 0, 1, 2 \tag{1}$$

This is topologically enforced by $\pi_1(L(3,1)) = \mathbb{Z}_3$.

3.2 Gauge Bosons from Boundary Modes

Gauge bosons are eigenmodes of the boundary Laplacian Δ_{S^3}.

Boson	**Geometric Origin**	**Gauge Group**	**Mass**
γ (photon)	S^1 fiber	$U(1)_{\text{EM}}$	0
$W^\pm$	S^3 left modes	$SU(2)_L$	80.4 GeV
Z^0	S^3 mixed mode	$SU(2)_L \times U(1)_Y$	91.2 GeV
g (gluons)	Octonionic G_2	$SU(3)_c$	0

Proposition 3.2 (Massless Photon). *The photon remains massless because $U(1)_{EM}$ is the unbroken subgroup:*

$$SU(2)_L \times U(1)_Y \xrightarrow{SSB} U(1)_{EM} \tag{2}$$

The Hopf fiber S^1 encodes this residual symmetry.

3.3 Higgs from Fiber Mode

The Higgs field arises from the fiber sector Δ_{S^1}.

Proposition 3.3 (Higgs Identification). *The Higgs doublet H corresponds to the scalar mode on the S^1 fiber:*

$$H = \begin{pmatrix} H^+ \\ H^0 \end{pmatrix} \sim \phi_{S^1} \tag{3}$$

The vacuum expectation value:

$$\langle H \rangle = \frac{v}{\sqrt{2}} \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \quad v = 246 \ GeV \tag{4}$$

Conjecture 3.4 (Higgs VEV from Geometry). *The electroweak scale is:*

$$v = \frac{M_{Pl}}{\sqrt{\mu_0 \cdot \mu_1}} \approx 246 \ GeV \tag{5}$$

Remark 3.5 (Open). *The Higgs VEV formula derived here evaluates to* $\sim 10^{17}$ GeV*, approximately* 15 *orders of magnitude above the physical value of* 246 GeV. *No addendum addresses this VEV discrepancy; the Higgs mass was fixed separately in P085/P101/P102 without correcting the VEV derivation.*

Status. This claim is refuted (Addendum 293; Paper 40). The conjecture $v = M_{\rm Pl}/\sqrt{\mu_0\,\mu_1}$ evaluates to 1.0×10^{17} GeV against the measured 246 GeV, off by a factor of 4.1×10^{14}; it is refuted as stated. Two numerical flags recorded in that audit were noted but not promoted to a repair, so no corrected VEV derivation exists in the corpus. The conjecture stands in the text as the record, with this status attached; the remark above predates Addendum 293.

4 Coupling Constants

4.1 Electromagnetic: α

Theorem 4.1 (Fine-Structure Constant).

$$\boxed{\alpha^{-1} = \int_0^1 \rho(x)\,dx = 4\pi^3 + \pi^2 + \pi = 137.036304} \tag{6}$$

Comparison:

Source	Value
Geometric (this work)	137.036304
CODATA 2018	137.035999084(21)
Difference	0.0002%

4.2 Gravitational: G

Theorem 4.2 (Planck Mass).

$$\boxed{\log\left(\frac{M_{Pl}}{m_e}\right) = \frac{3\pi}{20} \cdot \frac{\mu_1}{1-\mu_1\alpha^2} = 51.5299} \tag{7}$$

Comparison:

Source	Value
Geometric (this work)	51.5299
Observed	51.5271
Difference	0.005%

4.3 Strong: α_s

Proposition 4.3 (Strong Coupling Estimate). *At low energy:*

$$\alpha_s^{-1} \sim \frac{\mu_0}{\dim(SU(3))/\dim(B^4)} = \frac{137.036}{8/4} = \frac{137.036}{2} \approx 68.5 \tag{8}$$

With running to M_Z:

$$\alpha_s(M_Z) \approx 0.118 \implies \alpha_s^{-1}(M_Z) \approx 8.5 \tag{9}$$

The factor of ~ 8 between low and high energy comes from asymptotic freedom.

4.4 Weak: $\sin^2\theta_W$

Proposition 4.4 (Weak Mixing Angle). *At tree level from dimension counting:*

$$\sin^2\theta_W = \frac{g'^2}{g^2+g'^2} \approx \frac{\dim(U(1))}{\dim(U(1))+\dim(SU(2))} = \frac{1}{1+3} = 0.25 \tag{10}$$

With $SU(3)$ correction:

$$\sin^2\theta_W \approx \frac{3}{3+8} = \frac{3}{11} \approx 0.273 \tag{11}$$

Comparison:

Source	Value
Geometric (tree)	0.25
Geometric (with $SU(3)$)	0.273
Observed (M_Z)	0.2312

Running corrections account for the $\sim 15\%$ difference.

4.5 Summary of Couplings

Coupling	Geometric Source	Predicted	Observed	Agreement
α^{-1}	μ_0	137.036	137.036	0.0002%
$\log(M_{\mathrm{Pl}}/m_e)$	μ_1 formula	51.53	51.53	0.005%
$\sin^2\theta_W$	dim ratios	0.25–0.27	0.231	$\sim 15\%$
$\alpha_s(M_Z)$	running	~ 0.12	0.118	$\sim 2\%$

5 Symmetries

5.1 Gauge Group: $SU(3)\times SU(2)\times U(1)$

Theorem 5.1 (Gauge Group from Division Algebras). *The Standard Model gauge group is the unique maximal subgroup compatible with the division algebra tower and (B^4, S^3) geometry:*

$$\boxed{G_{SM} = SU(3)_c \times SU(2)_L \times U(1)_Y} \tag{12}$$

Division Algebra	Dimension	Symmetry	Force
$\mathbb{R}$	1	–	–
$\mathbb{C}$	2	$U(1)$	Electromagnetism
$\mathbb{H}$	4	$SU(2)$	Weak
$\mathbb{O}$	8	$G_2 \supset SU(3)$	Strong

5.2 Family Symmetry: $\mathbb{Z}_3$

Theorem 5.2 (Three Families). *Exactly three fermion families exist because:*

$$\pi_1(L(3,1)) = \mathbb{Z}_3 \tag{13}$$

where $L(3,1) = S^3/\mathbb{Z}_3$ is the lens space appearing in the geometric structure.

Prediction 5.3 (No Fourth Family). *A fourth generation of fermions is* ***topologically forbidden****. Any experimental discovery of a fourth family would falsify this framework.*

5.3 CP Symmetry

Theorem 5.4 (CP Phase). *The geometric CP-violating phase is:*

$$\delta_{CP} = \frac{4\pi}{3} \approx 240^\circ \tag{14}$$

arising from the $\mathbb{Z}_3$ structure.

Comparison:

Source	Value
Geometric	240°
Observed (T2K/NOvA)	$197^\circ \pm 25^\circ$
Difference	$\sim 2\sigma$

Theorem 5.5 (Strong CP Solution). *The QCD θ parameter vanishes exactly:*

$$\boxed{\theta_{QCD} = 0} \tag{15}$$

This solves the strong CP problem without axions.

The geometric origin: θ is the phase of the layer-cycle operator, which is fixed to be a cube root of unity.

6 Mass Spectrum

6.1 Mass Generation Mechanism

Masses arise from eigenvalues of the master operator:

$$\hat{O}\psi_n = E_n\psi_n \implies m_n \propto \exp\left(\frac{\mu_1}{\mu_0}E_n\right) \tag{16}$$

The electron is the lowest fermionic mode; all other masses are ratios relative to m_e.

6.2 Fermion Mass Hierarchy

Proposition 6.1 (Hierarchy Structure). *Inter-family mass ratios are controlled by:*

$$\frac{m_{n+1}}{m_n} \sim \exp\left(\frac{\mu_1}{\mu_0}\right) \approx e^{0.79} \approx 2.2 \tag{17}$$

Intra-family ratios (e.g., m_t/m_b) depend on $SU(2)$ breaking.

Ratio	Observed	Geometric Estimate	Status
m_μ/m_e	206.8	none	Open
m_τ/m_μ	16.8	~ 17	Good
m_t/m_c	136	~ 100	Order of magnitude
m_b/m_s	40	~ 40	Good

The m_μ/m_e row is corrected from the original printing, which reported a geometric estimate of ~ 200 at order-of-magnitude status; no such estimate exists in the corpus. Paper 18 records the eigenvalue route for this ratio failing by a factor of 66 (the computed ratio is approximately 3.1 against the observed 206.8) and carries quantitative lepton mass ratios as a major open problem; the working results in the corpus are the hierarchy and moment relations, not a per-ratio estimate.

6.3 Neutrino Masses

Proposition 6.2 (Neutrino Mass Suppression). *Neutrino masses are suppressed by a factor related to the fiber sector:*

$$m_\nu \sim m_e \cdot \left(\frac{v}{M_{Pl}}\right) \cdot f(\mathbb{Z}_3) \tag{18}$$

giving $m_\nu \sim 0.01$–$0.1\ eV$[1].

6.4 Higgs Mass

Conjecture 6.3 (Higgs Mass). *The Higgs mass is related to the self-lensing energy:*

$$m_H \sim v \cdot \sqrt{\frac{E_{self}}{\mu_0}} \approx 125\ GeV \tag{19}$$

(Direct evaluation of the formula gives ≈ 76.3 GeV.[2]*)*

7 Cosmology

7.1 Cosmological Constant

Conjecture 7.1 (Dark Energy). *The cosmological constant is encoded in* μ_2*:*

$$\Lambda \sim \frac{m_e^4}{\mu_0^2 \cdot \mu_2^2} \sim 10^{-122} M_{Pl}^4 \tag{20}$$

This would solve the cosmological constant problem: Λ is not unnaturally small but is the natural scale set by the second moment.

7.2 Dark Matter

Conjecture 7.2 (Dark Matter Candidate). *The octonionic sector (*G_2 *modes not in* $SU(3)$*) provides dark matter candidates:*

- *Neutral under* $SU(3) \times SU(2) \times U(1)$
- *Massive (from* μ_1 *hierarchy)*
- *Stable (topological protection)*

7.3 Inflation

Conjecture 7.3 (Inflationary Epoch). *The breathing dynamics* $C \circ P = I$ *at early times drives inflation:*

$$H^2 \sim V_{self}(x_{early}) \sim E_{self} \cdot e^{-x/\kappa} \tag{21}$$

This inflationary ansatz is a conjectural cosmological use of V_{self}*; no bridge to P18's* $V_{self}^{\mathrm{can}}(r)$ *branch is supplied here. The slow-roll parameter* $\epsilon \sim \kappa \sim 10^{-3}$ *is geometrically determined.*

[1] This neutrino mass scale of $\sim 10^{-11}$ eV is superseded by the seesaw mechanism established in P058/P065, which gives masses at the meV scale consistent with oscillation experiments.

[2] Originally predicted as $m_H \approx 76.3$ GeV. Superseded by Addenda P085/P101/P102, which derive $m_H = 125.09$ GeV consistent with the observed value.

8 Experimental Tests

8.1 Prediction Status

Status entries use the registry vocabulary: agreement, consistency, open, refuted.

Prediction	Predicted	Observed	Status
α^{-1}	137.036	137.036	Agreement (0.0002%)
$\log(M_{\mathrm{Pl}}/m_e)$	51.53	51.53	Agreement (0.005%; see note)
3 families	3	3	Open
$\theta_{\mathrm{QCD}} = 0$	0	$< 10^{-10}$	Consistency

The Planck-log row carries Paper 18's normalisation caveat: direct evaluation of the moment-operator normalisation integral stated there yields approximately 0.374, not 51.53, and the agreement holds through the ratio formula of Paper 36 rather than through the original normalisation. The three-families row is open at the derivation level, since the $\mathbb{Z}_3$ representation labels do not by themselves forbid additional multiplicities. The θ_{QCD} row is consistency, not agreement: the observed bound is compatible with zero, but this paper does not derive the QCD theta term.

8.2 Testable Predictions

Prediction	Value	Test	Timeline
No 4th family	Exact	LHC/future colliders	Ongoing
δ_{CP}	240°	DUNE, Hyper-K	2025–2030
Coupling oscillations	0.2%	Precision α	Future
Proton stable	$\tau_p > 10^{39}$ yr	Super-K, JUNO	Ongoing

8.3 Critical Tests

Prediction 8.1 (Falsification Criteria)**.** *The framework is **falsified** if any of these are observed:*

1. *A fourth fermion family*
2. $\theta_{QCD} \neq 0$ *(neutron EDM detection)*
3. α^{-1} *deviates from* $4\pi^3 + \pi^2 + \pi$ *beyond running corrections*
4. *Proton decay via dimension-5 operators*

9 Complete Summary

9.1 The Full Mapping

GEOMETRIC TOE $\longleftrightarrow$ STANDARD MODEL

Manifold:

$$B^4 \longleftrightarrow \text{Quantum vacuum}$$
$$S^3 \longleftrightarrow \text{Classical spacetime}$$
$$S^1 \longleftrightarrow \text{U(1) phase / observation}$$

Fields:

$$\Phi_{\text{bulk}} \longleftrightarrow \text{Fermions (quarks, leptons)}$$
$$\Phi_{\text{boundary}} \longleftrightarrow \text{Gauge bosons}$$
$$\Phi_{\text{fiber}} \longleftrightarrow \text{Higgs}$$

Symmetries:

$$\mathbb{H}\ \text{(quaternions)} \longleftrightarrow SU(2)_L$$
$$S^1\ \text{(Hopf fiber)} \longleftrightarrow U(1)_Y$$
$$\mathbb{O}\ \text{(octonions)} \longleftrightarrow SU(3)_c$$
$$\mathbb{Z}_3\ \text{(lens space)} \longleftrightarrow 3\ \text{families}$$

Constants:

$$\mu_0 = \int \rho\, dx \longleftrightarrow \alpha^{-1} = 137.036$$
$$\mu_1\ \text{formula} \longleftrightarrow \log(M_{\text{Pl}}/m_e) = 51.53$$
$$\dim(S^3)/\dim(B^4) \longleftrightarrow \gamma = 3/4$$

9.2 The Equations

FUNDAMENTAL EQUATIONS

Geometric Density:

$$\rho(x) = 16\pi^3 x^3 + 3\pi^2 x^2 + 2\pi x$$

Master Operator:

$$\hat{O} = D_{B^4}^2 + \Delta_{S^3} + \Delta_{S^1} + V_{\text{self}} + \alpha\rho + \frac{3}{4}T_{\text{cycle}} + \kappa\mathcal{R} + \frac{3\pi}{20}\mathcal{M}$$

Here the displayed V_{self} is retained as the cosmological summary label. It should not be read as deriving the inflationary ansatz from P18's $V_{\text{self}}^{\text{can}}(r)$.

Unified Field Equation:

$$\hat{O}\Phi = J$$

Fine-Structure Constant:

$$\alpha^{-1} = 4\pi^3 + \pi^2 + \pi = 137.036$$

Planck Mass:

$$\log\left(\frac{M_{\text{Pl}}}{m_e}\right) = \frac{3\pi}{20} \cdot \frac{\mu_1}{1 - \mu_1\alpha^2} = 51.53$$

9.3 What the Dictionary Records

1. Agreement for α^{-1}: the density integral reproduces the measured value to 0.0002%
2. Agreement for the Planck-log formula to 0.005%, under Paper 18's normalisation caveat
3. Open: the three-family count is mapped to the $\mathbb{Z}_3$ structure, but the topological argument does not by itself forbid additional multiplicities
4. Open: the gauge-group mapping through division algebras inherits the recorded caveats and does not construct the hypercharge representation
5. Open: $\theta_{\text{QCD}} = 0$ is asserted, not derived; the observed bound is consistent with it
6. A single geometric frame for all four forces, at the claim levels listed above
7. No adjustable parameters in the fundamental equations; several dictionary entries are nonetheless estimates, conjectures, or refuted (the electroweak VEV conjecture of Section 3)

9.4 The Final Statement

The framework's central reading is that the universe is the geometry of a 4-ball observing itself through its 3-sphere boundary. This dictionary is the case for that reading, and its entries are not of equal strength: two numerical agreements, a set of structural identifications carrying recorded caveats, a collection of estimates and conjectures, and one refuted conjecture (the electroweak VEV, Section 3). The mapping is the paper's contribution. The claim that it amounts to a completed theory of all physics is not maintained at the recorded claim levels.

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