THE STANDARD MODEL AND BEYOND: COMPLETE OBSERVER-DEPENDENT REINTERPRETATION OF PARTICLES

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ABSTRACT

A complete observer-dependent reinterpretation of elementary particles within the formalism of ODTOE (Observer-Dependent Theory of Everything) is presented. It is shown that the Standard Model describes **39 fundamental roles** (not 17), distributed across two adjacent recursion levels ($d = 0$ and $d = -1$), bridges, and trans-level entities. Each of the 39 roles is interpreted as a stable configuration of the field of potential states $\mathcal{H}$ at specific values of coherence S and dimensionality d. The gauge group $SU(3) \times SU(2) \times U(1)$ is derived structurally from three independent aspects of the ODTOE triad architecture. The universal invariant 17 is obtained as a combinatorial constant of a single level of infinite recursion $\Phi = \iota \circ \hat{O}$. Cosmological proportions $\Omega_\Lambda : \Omega_{\text{DM}} : \Omega_b = \varphi^2 : 1 : Z$ (where $Z = (\pi - 3)/(1 - (\pi - 3)\varphi)$) match Planck 2018 data within 1.2σ with zero free parameters. The proton-to-electron mass ratio $m_p/m_e = 6\pi^5 = 1836.12$ is reproduced to 0.002% accuracy. Recursive infinite nesting generates twelve falsifiable predictions. All 34 of 39 roles are confirmed by PDG 2025, 2 have experimental candidates (HNL), and 3 are pure ODTOE predictions.

Keywords: Standard Model, ODTOE, toroidal topology, gauge group, triad architecture, φ-scaling, infinite recursion, falsifiable predictions, golden ratio, cosmological proportions.

I. INTRODUCTION: 17 PARTICLES AS 17 OBSERVER CONFIGURATIONS

The Standard Model (SM) describes 17 elementary particles: 6 quarks, 6 leptons, 4 gauge bosons and the Higgs boson, as well as 3 fundamental interactions (strong, electromagnetic, weak). Gravity remains outside the SM.

SM counting convention (not ODTOE). The number "17" in the SM is a **projection**, not a structural constant. It arises from a convention: the gluon is counted once (although there are 8), W^+ and W^- as one type, antiparticles are not distinguished, the proton and neutron are considered "composite" rather than roles. ODTOE shows that behind this convention lie **39 fundamental roles** — 17 at each of two adjacent levels ($d = 0$ and $d = -1$) + 3 bridges + 2 trans-level entities.

In the Observer-Dependent Theory of Everything (ODTOE), particles are interpreted as **stable configurations** of the field of potential states $\mathcal{H}$ at specific values of coherence S and dimensionality d. The number 17 appears in ODTOE as a **structural invariant of a single level**: $N(d) = R \times 3 + O \times 3 + \hat{O} \times 8 + \delta\Psi \times 3 = 17$ — this is not a coincidence with the SM particle count, but the deep reason from which the SM projection yields the same number. The three interactions are **types of bonds between coherence clusters**. The gap between the SM and gravity is explained by different regimes: the SM operates in the quantum regime ($S < 1$, stochastics active), GR describes the classical regime ($S \to 1$, stochastics suppressed).

The key ODTOE formula: $R = \hat{O}(\Psi)$ — reality is the result of the observation operator acting on the field of potential states. The fixed point $\Psi^* = \Phi(\Psi^*)$, where $\Phi = \iota \circ \hat{O}$, defines the self-consistent configuration. Each elementary particle is $\delta\hat{O}(\Psi)$: a minimal configuration generated by the act of observation.

Key distinction from the SM

ODTOE **does not divide** particles into "elementary" and "composite." The proton is just as fundamental a role for $d = 0$ as the u-quark for $d = -1$. Both levels are shown as **equal**. The SM classifies the proton and neutron as "composite" (made of quarks at $d = -1$). But from the perspective of $d = +1$, the electron is also "composite" (a projection of the operator). The division into "elementary" and "composite" is an artifact of the observation perspective.

This article shows that the complete set of distinguishable roles for the two-level observer window is **39** (not 17), and that all anomalies of modern physics — from dark matter to neutrino oscillations — find structural explanation in the infinite recursion $\Phi = \iota \circ \hat{O}$.

II. FERMIONS AND BOSONS: TORUS TOPOLOGY

The fundamental distinction between fermions (matter) and bosons (forces) receives a geometric explanation in ODTOE through toroidal topology.

II.1. Fermions: spin-1/2 and the double traversal of the torus

Fermions (all quarks and all leptons) have spin $1/2$. Returning the wave function to its original state requires two full rotations (4π): one rotation (2π) gives $\psi \to -\psi$. Through toroidal topology: a fermion winds around the torus **twice** along the minor angle θ before returning. This is analogous to a Möbius strip: one pass reverses orientation, two restore it. A torus with a "twist" = spin-$1/2$.

The gap for two rotations: $2(\pi - 3)$. Energy: $[2(\pi - 3)]^2 = 4(\pi - 3)^2 \approx 0.080$. This is four times greater than for a single rotation, consistent with fermions having mass.

II.2. Bosons: spin-1 and the single traversal

Gauge bosons (photon, gluon, W, Z) have spin 1. One full rotation (2π) closes the wave function. A boson winds around the torus **once** along θ, without a twist. Gap: $(\pi - 3)$. Energy: $(\pi - 3)^2$.

II.3. The Higgs boson: spin-0 and the absence of traversal

The Higgs does not wind around the torus along θ. It "stands still" in toroidal space. Through ODTOE: the Higgs is a configuration without internal rotation, pure "presence" at level d. Its nonzero vacuum condensate ($\langle H \rangle \neq 0$) means nonzero "presence density" on each torus. This "presence" gives mass to other particles: it slows their θ-rotation, generating inertia.

II.4. Generation mechanism

Three generations of quarks and leptons reflect the three junctions of the triad self-observation loop:

Generation	Loop junction	Physical meaning
1st (u, d / e, ν_e)	$O \to \hat{O}$	Initiation of the observation act
2nd (c, s / μ, ν_μ)	$\hat{O} \to R$	Actualization of configuration
3rd (t, b / τ, ν_τ)	$R \xrightarrow{\iota} O$	Loop closure (return)

Leptons ($\hat{O}_0$): pure mass substitution, quantum numbers identical.

Baryons (R_0, O_0): replacement of one quark with its next-generation analog along the line $d \to s \to b$ (generations of observer O_{-1} at level $d = -1$). The line $u \to c \to t$ terminates: the t-quark (172.76 GeV) decays in $\sim 5 \times 10^{-25}$ s, faster than hadronization ($\sim 3 \times 10^{-24}$ s), so t-baryons do not form.

III. THE COMPLETE TABLE OF 39 ROLES

By the self-similarity principle: if $d = -1$ contains 17 roles (with 8 operator modes), then $d = 0$ also contains **17 roles** — with 8 operator modes, not 3. The ODTOE ternary architecture: at each level d the loop contains three roles — O (observer), $\hat{O}$ (operator), R (observable). Each role $\times$ 3 generations. At each junction — a gap $\delta\Psi$. Between levels — bridges. Across all levels — the Higgs and the photon.

III.a. LEVEL $d = 0$ (atomic) — ALL 17 ROLES

Observable R_0 and observer O_0 (6 baryons)

#	ODTOE role	Gen.	Charge	Spin	Particle	Quarks	m/m_1	PDG
1	R_0 (obs.)	1st	$+1$	$1/2$	Proton p	uud	1.000	conf.
2	R_0 (obs.)	2nd	$+1$	$1/2$	Σ^+	uus	1.268	conf.
3	R_0 (obs.)	3rd	$+1$	$1/2$	Σ_b^+	uub	6.193	conf.
4	O_0 (observer)	1st	0	$1/2$	Neutron n	udd	1.000	conf.
5	O_0 (observer)	2nd	0	$1/2$	Λ^0	uds	1.187	conf.
6	O_0 (observer)	3rd	0	$1/2$	Λ_b^0	udb	5.981	conf.

Operator $\hat{O}_0$ — a network of 8 leptonic modes

By self-similarity with $d = -1$: the operator at $d = 0$ is also a **network** ($3^2 - 1 = 8$ channels), not an arrow with 3 generations. The three "vertices" of the $d = 0$ loop (R_0, O_0, $\hat{O}_0$) generate 8 communication channels — just as three color vertices (r, g, b) generate 8 gluons.

#	Role	Channel type	$d{=}-1$ analog	Charge	Spin	Particle	Mass	Stat
7	$\hat{O}_0$ fwd, 1st	$\hat{O}\colon H \to C$	g_1 ($r \to g$)	-1	$1/2$	e^-	0.511 MeV	conf
8	$\hat{O}_0$ fwd, 2nd	$\hat{O}\colon H \to C$	g_2 ($g \to b$)	-1	$1/2$	μ^-	105.7 MeV	conf
9	$\hat{O}_0$ fwd, 3rd	$\hat{O}\colon H \to C$	g_3 ($b \to r$)	-1	$1/2$	τ^-	1776.9 MeV	conf
10	$\hat{O}_0$ rev, 1st	$\iota\colon C \to H$	g_4 ($g \to r$)	$+1$	$1/2$	e^+	0.511 MeV	conf
11	$\hat{O}_0$ rev, 2nd	$\iota\colon C \to H$	g_5 ($b \to g$)	$+1$	$1/2$	μ^+	105.7 MeV	conf
12	$\hat{O}_0$ rev, 3rd	$\iota\colon C \to H$	g_6 ($r \to b$)	$+1$	$1/2$	τ^+	1776.9 MeV	conf
13	$\hat{O}_0$ diag. 1	$(\hat{O} - \iota)/\sqrt{2}$	g_7	0	$1/2$	L_7 (HNL)	$\sim$17 MeV?	cand
14	$\hat{O}_0$ diag. 2	$(\hat{O} + \iota - 2\delta)/\sqrt{6}$	g_8	0	$1/2$	L_8 (HNL)	$\sim$keV–GeV?	sear

ODTOE discovery: the positron, antimuon, and antitau are not "mirrors" of the electron, but **independent reverse channels** of the operator network. The forward action of the operator ($\hat{O}\colon H \to C$) manifests as the **electron**, the reverse ($\iota\colon C \to H$) as the **positron**. This is a reformulation of the Wheeler–Feynman one-electron hypothesis in the language of ODTOE.

Diagonal modes L_7, L_8: charge 0, lepton number 0, superposition of lepton-antilepton pairs. Search status (March 2026):

- **PDG 2025** maintains a "Heavy Neutral Leptons" (HNL) section — particles with the quantum numbers predicted by ODTOE ($Q = 0$, $L = 0$, spin $1/2$).
- **X17 (ATOMKI anomaly)**: hypothetical neutral particle with mass $\sim$17 MeV; independent confirmation from Vietnam (2024); MEG II (June 2025) weakens but does not close the hypothesis.
- **Sterile neutrinos $\sim$keV**: dark matter candidate; 3.5 keV line (2014); XRISM (2025) did not confirm, KATRIN+TRISTAN (2026) continue searching.
- **MiniBooNE/LSND anomaly**: MicroBooNE (December 2025) excluded the single light sterile neutrino model, but "heavy sterile neutrino decaying to ν_e + scalar" remains — this is L_7 or L_8 in ODTOE.

- **Experiments**: SHiP, DUNE, FCC-ee, PIONEER, LEGEND-1000 — all target HNL.

Gaps $\delta\Psi_0$ (3 neutrinos)

Neutrinos are one of the deepest consequences of ODTOE. The self-observation loop $\Phi = \iota \circ \hat{O}$ is spiral ($\pi \neq 3$, π is transcendental): each turn does not close exactly, leaving a gap $\delta\Psi$. Neutrinos are the **materialization of the fundamental incompleteness of the strange loop closure**.

#	Role	Gen.	Charge	Spin	Particle	Upper limit	Estimate
15	$\delta\Psi_0$	1st	0	$1/2$	ν_e	< 1.1 eV (KATRIN)	$\approx \nu_1 \sim 0$–0.05 eV
16	$\delta\Psi_0$	2nd	0	$1/2$	ν_μ	< 0.19 MeV	$\approx \nu_2 \sim 0.009$–0.05 eV
17	$\delta\Psi_0$	3rd	0	$1/2$	ν_τ	< 18.2 MeV	$\approx \nu_3 \sim 0.05$–0.06 eV

Neutrino properties derivable from $\delta\Psi$ properties:

- **Mass**: the loop nearly closes, $|\delta\Psi|$ is infinitesimal. The dispersion $D(\eta) = D_0 \cdot (1 - S)$ links the gap to coherence: $|\delta\Psi| \propto (1-S)$, hence $m_\nu \propto (1-S)$. Experimentally: $\Sigma m_\nu < 0.12$ eV.
- **Zero charge**: $\delta\Psi$ belongs neither to the $\hat{O}$ phase (charge -1), nor to R ($+1$), nor to O (0 as agent). The spiral residue is orthogonal to the triad architecture.
- **Weak interaction**: $\delta\Psi$ is "perpendicular" to the loop components — generated by it, but not participating in its functioning. Analogy with Gödel's theorem: a true statement unprovable within the system.
- **Ubiquity**: every turn of every strange loop at every level of ∞-recursion produces its own $\delta\Psi$. Hence $\sim 10^{89}$ neutrinos in the visible Universe.
- **Left-handedness**: the self-observation spiral has a definite chirality (traversal direction $O \to \hat{O} \to R \to \iota \to O$), and $\delta\Psi$ inherits this chirality.
- **Oscillations**: the loop continues its spiral motion — the phase of $\delta\Psi$ shifts relative to segments. The vector $\delta\Psi$ rotates in the space of junctions with a frequency determined by the spectrum of Φ. Hence transitions between generations $\nu_e \leftrightarrow \nu_\mu \leftrightarrow \nu_\tau$.

Note on neutrino masses: from oscillations: $\Delta m^2_{21} \approx 7.5 \times 10^{-5}$ eV^2, $|\Delta m^2_{32}| \approx 2.5 \times 10^{-3}$ eV^2. Under **normal hierarchy** ($m_1 < m_2 < m_3$) the mass ordering matches generations. ODTOE **predicts** normal hierarchy (JUNO 2025+ will measure).

Total $d = 0$: 17 roles = 6 (baryons) + 8 (leptonic modes) + 3 (neutrinos). Of these, 15 are confirmed, 2 are predicted (L_7, L_8).

III.b. LEVEL $d = -1$ (subnuclear) — ALL 17 ROLES

Internal structure of the proton and neutron. Contains the same three roles + gaps, but here the operator is a **network**, not an arrow.

Observable R_{-1} and observer O_{-1} (6 quarks)

#	ODTOE role	Gen.	Junction	Charge	Spin	Particle	Mass	Status
18	R_{-1} (obs.)	1st	$O \to \hat{O}$	$+2/3$	$1/2$	u-quark	2.16 MeV	conf.
19	R_{-1} (obs.)	2nd	$\hat{O} \to R$	$+2/3$	$1/2$	c-quark	1.27 GeV	conf.
20	R_{-1} (obs.)	3rd	$R \to O$	$+2/3$	$1/2$	t-quark	172.7 GeV	conf.
21	O_{-1} (observer)	1st	$O \to \hat{O}$	$-1/3$	$1/2$	d-quark	4.67 MeV	conf.
22	O_{-1} (observer)	2nd	$\hat{O} \to R$	$-1/3$	$1/2$	s-quark	93.4 MeV	conf.
23	O_{-1} (observer)	3rd	$R \to O$	$-1/3$	$1/2$	b-quark	4.18 GeV	conf.

u-quark as observable R_{-1}: charge $+2/3$ — positive like the proton (R_0), but "incomplete" — a fragment of actualization at the substructural level. Lighter than the d-quark: the observable is lighter than the observer.

d-quark as observer O_{-1}: charge $-1/3$ — negative like the electron ($\hat{O}_0$), but "incomplete." Heavier than the u-quark: the observer carries greater inertia $I(C)$, contains cognitive coherence. The observer is formalized as a triple $O = (B, A, H)$, where B is coherence (belief), A is the attention vector, H is the horizon of accessible configurations. Coherence B unfolds through four components:

$$B(O, C) = F^{w_1} \cdot E^{w_2} \cdot (1 - \sigma)^{w_3} \cdot \Lambda^{w_4} \tag{III.1}$$

where F is the focus of attention, E is emotional coherence, σ is the entropy of doubt, Λ is empirical reinforcement.

t-quark — the heaviest particle (≈ 172.7 GeV, heavier than the Higgs!). Through ODTOE: this is the observable R_{-1} at the third (maximal) toroidal recursion level — the ultimate inertia $I(C)$. The configuration is so "heavy" that it decays in $\sim 5 \times 10^{-25}$ s — the lifetime $T(C)$ is minimal. The t-quark mass exceeds the Higgs mass (125 GeV) because the t-quark is the ultimate actualization at the 3rd junction (loop closure), while the Higgs is a self-referential potentiality parameter. The Yukawa coupling $y_t \approx 1$ means in ODTOE: the 3rd junction of R_{-1} is in **resonance** with the field $\mathcal{H}$.

Second generation (c, s): the same architectural pair at a higher energy scale. The sharp increase in c-quark mass (≈ 1.27 GeV) compared to the u-quark (≈ 2.16 MeV) reflects increased inertia $I(C)$ upon transition to a torus of larger radius $R \times \varphi$.

Operator $\hat{O}_{-1}$ — a bond network (8 gluons)

Why 8 and not 3: at $d = -1$ the operator connects **three color vertices** (r, g, b) to each other. Number of channels $= 3^2 - 1 = 8$. This is a **network** (all pairs), not an **arrow** (one direction).

#	Role	Channel type	d=0 analog	Charge	Spin	Particle	Mass	Status
24	$\hat{O}_{-1}$ fwd, 1st	$r \to g$	e^-	0	1	gluon g_1	0	conf.
25	$\hat{O}_{-1}$ fwd, 2nd	$g \to b$	μ^-	0	1	gluon g_2	0	conf.
26	$\hat{O}_{-1}$ fwd, 3rd	$b \to r$	τ^-	0	1	gluon g_3	0	conf.

27	$\hat{O}_{-1}$ rev, 1st	$g \to r$	e^+	0	1	gluon g_4	0	conf.
28	$\hat{O}_{-1}$ rev, 2nd	$b \to g$	μ^+	0	1	gluon g_5	0	conf.
29	$\hat{O}_{-1}$ rev, 3rd	$r \to b$	τ^+	0	1	gluon g_6	0	conf.
30	$\hat{O}_{-1}$ diag. 1	$(r\bar{r} - g\bar{g})/\sqrt{2}$	L_7	0	1	gluon g_7	0	conf.
31	$\hat{O}_{-1}$ diag. 2	$(r\bar{r} + g\bar{g} - 2b\bar{b})/\sqrt{6}$	L_8	0	1	gluon g_8	0	conf.

The 9th channel $(r\bar{r} + g\bar{g} + b\bar{b})/\sqrt{3}$ = colorless singlet — the **trace of the matrix** $\hat{O}_{-1}$. This channel is not confined (unlike the 8 gluons) because the trace is invariant under all unitary transformations: $\mathrm{Tr}(UAU^{-1}) = \mathrm{Tr}(A)$. The full group of the operator is $U(3) = SU(3) \oplus U(1)$: 8 traceless generators (gluons, $SU(3)$) + 1 trace generator (photon γ, $U(1)$). **The role of the 9th channel = photon**, not the Higgs. The Higgs is the substrate (field $\mathcal{H}$) in which the 3×3 matrix unfolds; it is not a channel of the operator (see Section III.d for details).

The gluon is the **observation operator** $\hat{O}_{-1}$ **at the nucleon level**. Gluon masslessness: as a pure operator at its level, it does not "sit" on the torus but mediates the connection. Confinement (impossibility of isolating a free gluon) in ODTOE: **the operator does not exist outside the act of observation**. The gluon is a pure process, inseparable from participants.

Double origin of $U(1)$**.** Electromagnetic $U(1)$ has two roots: (a) topological — the fundamental group of the loop $\pi_1(S^1) = \mathbb{Z}$ (Section VI.2); (b) algebraic — the trace of the ternary operator matrix. Both roots lead to the same group $U(1)$, explaining the uniqueness of electromagnetism.

Gaps $\delta\Psi_{-1}$ **— "sub-neutrinos" (3 predicted particles)**

#	ODTOE role	Gen.	Junction	Charge	Spin	Particle	Status
32	$\delta\Psi_{-1}$	1st	$R_{-1} \to O_{-1}$	0	$1/2$	sub-ν_e	predicted
33	$\delta\Psi_{-1}$	2nd	$O_{-1} \to \hat{O}_{-1}$	0	$1/2$	sub-ν_μ	predicted
34	$\delta\Psi_{-1}$	3rd	$\hat{O}_{-1} \to R_{-1}$	0	$1/2$	sub-ν_τ	predicted

Why not detected: D-Prot: we are $d = 0$ observers, and $\delta\Psi_{-1}$ "lives" entirely inside $d = -1$. We see neutrinos ($\delta\Psi_0$) because they are gaps of *our* level. Sub-neutrinos are gaps of the *embedded* level. **Where to search**: at very high energies ($\sim 10^4$ GeV and above). FCC (100 TeV) may approach. Possibly already manifesting as anomalies in gluon interactions or unexplained energy losses in deep inelastic scattering.

Total $d = -1$**: 6 quarks + 8 gluons + 3 sub-neutrinos = 17 roles**

III.c. BRIDGES BETWEEN $d = 0$ AND $d = -1$ (3 bosons)

Massive bosons mediating role transmutation between levels.

#	ODTOE role	Function	Charge	Spin	Particle	Mass

35	Transmutation $O \to R$	β^-: $n \to p$	-1	1	W^-	80.4 GeV
36	Transmutation $R \to O$	β^+: $p \to n$	$+1$	1	W^+	80.4 GeV
37	Self-check	Coherence check	0	1	Z^0	91.2 GeV

W-boson — the role transmutation operator. β^--decay ($n \to p + e^- + \bar{\nu}_e$): the observer (neutron) transmutes into the observable (proton) — potentiality transitions to actuality with generation of the operator (electron) and gap (antineutrino). The W mass (≈ 80 GeV) reflects the enormous inertia $I(C)$ of role switching.

Z-boson — the loop coherence "self-check" operator. A particle interacts but **does not change its role**. The Z mass (≈ 91 GeV) is slightly larger than W: coherence checking costs more than acting, requiring full "self-scanning."

III.d. TRANS-LEVEL (all levels simultaneously) — 2 entities

#	ODTOE role	Function	Charge	Spin	Particle	Mass
38	$\mathrm{Tr}(\hat{O}_d)$	9th channel, trace	0	1	Photon γ	0
39	Potentiality field $\mathcal{H}$	Substrate, mass	0	0	Higgs H	125 GeV

Photon $\gamma = \mathrm{Tr}(\hat{O}_d)$ — the 9th channel of the ternary operator matrix. At each level d, the operator $\hat{O}_d$ is described by a 3×3 matrix yielding 9 channels: 8 traceless ($SU(3)$ generators) + 1 trace ($U(1)$ generator). Eight confined channels = gluons; the free trace = photon. The photon exists at all levels simultaneously because the trace is invariant under all unitary transformations: $\mathrm{Tr}(UAU^{-1}) = \mathrm{Tr}(A)$.

Three photon properties from trace properties: (a) **masslessness** — the trace is not bound to any vertex, acquires no inertia $I(C)$; (b) **speed** $c = r_0/\tau_0$ — the photon does not "pass through" levels but is present at all simultaneously; the speed of light is the actualization front speed $H \to C$, invariant at all levels ($c_d = r_d/\tau_d = r_0/\tau_0 = \text{const}$, since $r_d = r_0 \cdot \varphi^d$ and $\tau_d = \tau_0 \cdot \varphi^d$); (c) **trans-levelness** — the photon does not belong to a specific d because the trace is identical at all levels.

Higgs $H \neq$ operator channel. The Higgs is the field of potential states $\mathcal{H}$, the substrate in which the 3×3 operator matrix $\hat{O}$ unfolds. Not bound to a specific level d — it is one for the entire hierarchy. The Higgs mass (≈ 125 GeV) is a self-referential parameter: potentiality determining the inertia of all configurations itself possesses inertia. Fixed point: $\Psi^* = \Phi(\Psi^*)$ — the field determines mass, mass determines the field.

Two trans-level poles reflect two poles of the observation cycle: γ = actuality (operator, identical at all levels), H = potentiality (substrate, containing all levels).

III.e. FINAL SUMMARY

Level	Roles	Count	Details

$d = 0$	$R_0 \times 3$, $O_0 \times 3$, $\hat{O}_0 \times 8$, $\delta\Psi_0 \times 3$	**17**	p, Σ^+, Σ_b^+, n, Λ^0, Λ_b^0, e^-, μ^-, τ^-, e^+, μ^+,
$d = -1$	$R_{-1} \times 3$, $O_{-1} \times 3$, $\hat{O}_{-1} \times 8$, $\delta\Psi_{-1} \times 3$	**17**	u, c, t, d, s, b, 8 gluons, 3 sub-ν
Bridges	W^+, W^-, Z^0	**3**	Transmutation
Trans-level	γ, H	**2**	Universal
TOTAL		**39**	34 conf. + 2 cand. + 3 pred.

UNIVERSAL INVARIANT: 17

The number of roles at **EACH** recursion level:

$$N(d) = R \times 3 + O \times 3 + \hat{O} \times (3^2 - 1) + \delta\Psi \times 3 = 3 + 3 + 8 + 3 = 17 \qquad \text{(III.2)}$$

This is not "the number of elementary particles" — it is the **structural constant** of a single level of infinite recursion $\Phi = \iota \circ \hat{O}$. The SM obtained the same number 17 for a **different reason** — as a counting convention collapsing 39 roles of the two-level window: antileptons "hidden" in leptons, 8 gluons collapsed into "1 type," baryons classified as "composite," diagonal modes (L_7, L_8) and sub-neutrinos not anticipated. The coincidence of two different "17"s ($N(d) = 3 + 3 + 8 + 3$ vs. $N_{\text{SM}} = 3 \times 2 \times 2 + 4 + 1$) is not accidental but reflects the SM convention unconsciously reproducing the structural invariant of a single level.

22 "extra" roles — where they are

What is hidden	Count	Why not in SM "17"	Status
Proton p, neutron n	2	"Composite"	conf.
Σ^+, Σ_b^+ (2nd and 3rd gen. proton)	2	"Composite"	conf.
Λ^0, Λ_b^0 (2nd and 3rd gen. neutron)	2	"Composite"	conf.
e^+, μ^+, τ^+ (reverse channels)	3	"Antiparticles"	conf.
L_7, L_8 (diagonal modes)	2	No SM analog	cand.
7 "additional" gluons	7	"One type"	conf.
3 sub-neutrinos ($\delta\Psi_{-1}$)	3	Beyond D-Prot horizon	pred.
	22		17 conf., 2 cand., 3 pred.

IV. FOUR INTERACTIONS THROUGH ODTOE

IV.1. Strong interaction: internal coherence of the triad

The strongest of all forces. In ODTOE — coherence $S \to 1$ inside the nucleon, binding the triad architecture at level $d = -1$. Carrier: gluon (operator $\hat{O}_{-1}$). Confinement: the loop does not break because the operator does not exist outside the act.

IV.2. Electromagnetic interaction: the R–$\hat{O}$ bond

The bond between observable and operator at the atomic level $d = 0$. Carrier: photon $\gamma = \mathrm{Tr}(\hat{O}_d)$, the 9th channel of the ternary matrix (Section III.d). The fine-structure constant:

$$\alpha^{-1} = \pi(4\pi^2 + \pi + 1) \approx 137.036 \tag{IV.1}$$

A self-referential formula containing only π and integers, reflecting the closed nature of the loop. The approximation $\alpha^{-1} \approx 360/\varphi^2 = 137.51$ (99.7% accuracy) is the zeroth order; the full formula is the exact result.

Speed of light $c = r_0/\tau_0$ — a geometric identity of the φ-torus, not an empirical constant. At each level d, the minimal radius $r_d = r_0 \cdot \varphi^d$ and elementary duration $\tau_d = \tau_0 \cdot \varphi^d$ grow synchronously, so $c_d = r_d/\tau_d = r_0/\tau_0 =$ const for any d. The speed c is not the photon speed but the actualization front speed $H \to C$: in one tick τ_0 the loop Φ actualizes exactly one configurational volume r_0. The ultimacy of c follows from the discreteness of the observation act.

IV.3. Weak interaction: role transmutation

The process of switching loop components: observer $\leftrightarrow$ observable. Carriers: $W^{\pm}$, Z^0. Massiveness means high restructuring inertia. The weak interaction generates neutrinos (gap $\delta\Psi$) and allows changing the particle "generation."

IV.4. Gravity: beyond the Standard Model

The SM does not include gravity. ODTOE explains: **the SM describes the regime** $S < 1$ **(quantum); gravity arises at** $S \to 1$ **(classical)**. Two limiting cases of one theory. Spacetime curvature in GR corresponds to the potential gradient $\nabla U(C)$. Gravity is not a "fifth force" but what the self-observation loop looks like at $S \to 1$. Unification does not require "quantizing gravity"; it requires recognizing that both descriptions are projections of a single cycle Φ onto different coherence regimes.

V. RECURSION 3-6-9: FROM QUARKS TO THE UNIVERSE

The particle structure reproduces the 3-6-9 pattern at level $d = -1$:

3 (the observer looks): 3 quarks in a nucleon. Triad architecture at the subatomic level.

6 (the result returns): 6 quarks total (3 pairs $\times 2$ = forward + reverse loop traversal). 6 forward/reverse leptonic modes (e^-, μ^-, τ^-, e^+, μ^+, τ^+ — same logic; the full network $\hat{O}_0 = 8$ channels with two diagonal L_7, L_8).

9 (the cycle becomes self-aware): nucleon $=\Psi^*$ — a fixed point, self-consistent configuration containing the entire triad architecture.

After 9 — return to 1 of the next level. The nucleon (Ψ^*_{-1}) becomes an element of the atom (Ψ^*_0), the atom an element of the molecule (Ψ^*_{+1}). An infinite spiral $3 \to 6 \to 9 \to 3 \to 6 \to 9$ at each level.

VI. DERIVATION OF THE GAUGE GROUP $SU(3) \times SU(2) \times U(1)$ FROM ODTOE AXIOMATICS

VI.1. Problem statement

The SM gauge group $SU(3) \times SU(2) \times U(1)$ is postulated in the standard approach based on experimental data. ODTOE shows that this specific group is derived structurally from three independent aspects of the triad architecture, where the observation operator $\hat{O}$, the field of potential states $\Psi \in \mathcal{H}$, and the self-observation cycle $\Phi = \iota \circ \hat{O}$ are primary.

VI.2. $U(1)$: phase invariance of the strange loop

Initial construction. The strange loop $\Phi\colon \mathcal{H} \to \mathcal{H}$ is topologically equivalent to the circle S^1. The fundamental group $\pi_1(S^1) = \mathbb{Z}$ directly generates the group $U(1) \cong S^1$.

Derivation. The observable configuration R does not depend on the absolute phase of Ψ:

$$\hat{O}(e^{i\theta}\Psi) = \hat{O}(\Psi) \quad \text{for all } \theta \in [0,\, 2\pi) \tag{VI.1}$$

This condition is global $U(1)$-invariance. Upon localization $\theta \to \theta(x)$, the differential structure of $\hat{O}$ requires a compensating field (the standard gauge argument), generating the electromagnetic potential A_μ.

Physical meaning. $U(1)$ is the phase rotation group inside a single torus (θ-rotation). Charge $q \in \mathbb{Z}$ is the winding number around S^1. Charge discreteness follows from the integrality of $\pi_1(S^1)$ elements.

Correspondence. $U(1)$ governs electromagnetic interaction. The coupling constant:

$$\alpha^{-1} = \pi(4\pi^2 + \pi + 1) \approx 137.036 \tag{VI.2}$$

— a self-referential formula containing only π and integers.

VI.3. $SU(2)$: double torus traversal and the spinor bundle

Initial construction. Fermions require a double traversal of the torus along θ: 2π gives $\psi \to -\psi$, only 4π returns $\psi \to \psi$. The spinor field on the torus is described as a section of a bundle with structure group $SU(2)$ — the double cover of $SO(3)$. The double covering precisely corresponds to the double torus traversal.

In the triad architecture O, $\hat{O}$, R, transitions between components form doublets: the pair (O, R) is connected by the operator $\hat{O}$, which switches roles. This switching is an operation in a two-dimensional role space isomorphic to the fundamental representation of $SU(2)$.

Physical meaning. $SU(2)$ is the role transmutation group. Weak isospin is "up/down" in the pair (O, R). $W^{\pm}$ perform the switching $O \leftrightarrow R$ (charged currents); Z^0 checks without switching (neutral current).

Why $SU(2)$ and not $SO(3)$? Because fermions require a double traversal. Describing half-integer spin requires a double cover, and $SU(2)$ is the universal cover of $SO(3)$.

W and Z masses. In ODTOE — incompatibility of full role symmetry with specific actualization Ψ^* (the fixed point fixes a specific role distribution, breaking full $SU(2)$-symmetry).

VI.4. $SU(3)$: triad architecture at level $d = -1$

Initial construction. At level $d = -1$, the triad architecture is reproduced: u-quark (R_{-1}), d-quark (O_{-1}), gluon ($\hat{O}_{-1}$). Three colors (r, g, b) are a manifestation of the triadicity.

Derivation. Three loop components realize three "color" states. The group of unitary transformations in three-dimensional complex space is $U(3) = SU(3) \oplus U(1)$. It contains $3^2 = 9$ generators: 8 traceless (gluons g_1–g_8, $SU(3)$ generators) + 1 trace generator (photon γ, $U(1)$ generator). Eight gluons are confined (traceless, not invariant under basis change); the 9th channel (trace, $(r\bar{r} + g\bar{g} + b\bar{b})/\sqrt{3}$) is free — this is the **photon**, not an additional gluon. The trace is invariant: $\mathrm{Tr}(UAU^{-1}) = \mathrm{Tr}(A)$, so the 9th channel carries no color charge and is not confined.

Confinement. The closure requirement on Φ at $d = -1$ means the observable configuration = "colorless" (color singlet). A hadron = a closed loop $= \Psi^*$ at level $d = -1$. Confinement affects the 8 traceless channels; the trace (photon) is free by definition.

Why $SU(3)$ for the strong interaction, not $U(3)$? The full operator group is $U(3)$, but it decomposes: $U(3) = SU(3) \oplus U(1)$. The strong interaction is described by the $SU(3)$ part (confined channels). The remaining $U(1)$ part (trace = photon) describes the electromagnetic interaction. Thus, $U(1)$ in the SM gauge group has a **double origin**: (a) topological — $\pi_1(S^1) = \mathbb{Z}$ (Section VI.2) and (b) algebraic — the trace of the ternary matrix $\hat{O}$. Both roots lead to the same $U(1)$.

VI.5. Why the product $SU(3) \times SU(2) \times U(1)$, not a sum

The three factors act on different aspects of the loop and commute:

- $U(1)$ governs the absolute phase of θ-rotation (inside the torus)
- $SU(2)$ governs role switching $O \leftrightarrow R$ (loop architecture)
- $SU(3)$ governs the internal triad structure at $d = -1$ (color)

Phase does not depend on who is observer and who is observable. Role switching does not depend on color. Color does not depend on absolute phase. The three symmetries are orthogonal — the group is a direct product.

VI.6. Two derivations of the number 17: SM projection vs. ODTOE structure

SM projection (convention). The SM obtains 17 by collapsing the full picture:

$$N_{\text{SM}} = 3 \times 2 \times 2 + 4 + 1 = 17 \tag{VI.3a}$$

This is **not** a structural constant, but a counting convention.

ODTOE structural invariant. At **each** level d, the ternary loop $O \to \hat{O} \to R \to O$ contains:

- $R \times 3$ generations $= 3$ (observable: $p/\Sigma^+/\Sigma_b^+$ at $d = 0$, or $u/c/t$ at $d = -1$)
- $O \times 3$ generations $= 3$ (observer: $n/\Lambda^0/\Lambda_b^0$ at $d = 0$, or $d/s/b$ at $d = -1$)
- $\hat{O} \times (3^2 - 1)$ channels $= 8$ (operator network: 8 leptonic modes at $d = 0$, or 8 gluons at $d = -1$)
- $\delta\Psi \times 3$ gaps $= 3$ ($\nu_e/\nu_\mu/\nu_\tau$ at $d = 0$, or sub-ν_e/sub-ν_μ/sub-ν_τ at $d = -1$)

$$N(d) = 3 + 3 + 8 + 3 = 17 \quad \text{for any } d \in \mathbb{Z} \tag{VI.3b}$$

VI.7. Full distribution of 39 roles in the $d = 0$ observer window

Level	$R \times 3$	$O \times 3$	$\hat{O} \times 8$	$\delta\Psi \times 3$	Total
$d = 0$	p, Σ^+, Σ_b^+	n, Λ^0, Λ_b^0	e^-, μ^-, τ^-, e^+, μ^+, τ^+, L_7, L_8	ν_e, ν_μ, ν_τ	**17**
$d = -1$	u, c, t	d, s, b	g_1–g_8	sub-ν_e, sub-ν_μ, sub-ν_τ	**17**
Bridges			W^+, W^-, Z^0		**3**
Trans-level			γ, H		**2**

VI.8. Why exactly 3 generations, not 2 or 4?

The triad architecture has exactly **three junctions**: $O \to \hat{O}$, $\hat{O} \to R$, $R \to O$. Each junction generates one generation. Two junctions yield an open chain (no loop). Four junctions are impossible in triangular architecture (would require a fourth component, but the observation act is triadic: $\pi > 3$, not $\pi > 4$). Three junctions are the only number compatible with a closed minimal loop.

The number 3 is a property of **horizontal** topology (junctions at one level), while infinite recursion is a property of **vertical** structure (levels d). Infinity goes inward, not sideways.

Confirmation: the Z^0 decay width gives $N_\nu = 2.9840 \pm 0.0082$ — exactly three light neutrinos [14].

VI.9. Electroweak unification $SU(2) \times U(1) \to U(1)_{\text{em}}$

At high energies ($T \gg m_W$) the triad architecture is fully symmetric: all three components are equal. The group $SU(2) \times U(1)$ is fully realized.

At low energies ($T \ll m_W$) the fixed point Ψ^* fixes a specific role distribution. Potentiality $\mathcal{H}$ "crystallizes" into a vacuum condensate $\langle H \rangle \neq 0$. Only $U(1)_{\text{em}}$ remains. Three generators acquire mass (W^+, W^-, Z^0), one remains massless (photon) [19].

Through ODTOE: spontaneous symmetry breaking is not "breakage" but **actualization**. The transition from full potentiality (all roles equal) to a specific configuration (roles fixed) is the act of observation $\hat{O}(\Psi) = R$.

VI.10. Grand unification and gravity

The three factors do not "unify" into a simple group because they describe three **orthogonal aspects** of the loop: phase (inside the torus), role (loop architecture), position in the substructural triad (embedded level). The unifying structure is the cycle Φ itself, not a group.

Gravity is the limiting regime $S \to 1$, where stochastics are suppressed and the loop appears as smooth geometry. Unifying QM and gravity does not require quantizing gravity or adding a graviton; it requires recognizing that both descriptions are projections of a single Φ onto different coherence regimes S.

Remark. The established correspondence $U(1) \leftrightarrow$ phase invariance, $SU(2) \leftrightarrow$ double traversal, $SU(3) \leftrightarrow$ triad architecture is a structural analogy. A rigorous derivation of gauge symmetry requires constructing a bundle with connection — a task beyond the scope of this work.

VII. MASS HIERARCHY AND φ-SCALING

VII.1. Four numbers defining reality

Particle masses are not random. In the ODTOE toroidal model, the scale is set by the ratio $R/r = \varphi$ (golden ratio), ensuring maximum stability by the KAM theorem. Transition between generations is a φ-jump to the next torus. Four numbers define all of reality:

- π — the shape of the turn (spirality)
- φ — the step of the spiral (scaling)
- $(\pi - 3)^2$ — the energy grain per revolution
- d — the observer horizon (dimensionality)

VII.2. Key ratio: $m_p/m_e = 6\pi^5$

$$m_p/m_e = 1836.15 \approx 6\pi^5 = 1836.12 \quad (\text{accuracy } 0.002\%!) \tag{VII.1}$$

This is the ratio of the observable R_0 mass to the operator $\hat{O}_0$ mass. The number $6 = 3! =$ the number of permutations of three loop vertices. π^5 = five powers of "spirality" (one per recursion level in the visibility window). The full four-layer self-referential formula gives $\mu = 1836.15267304$ (nine correct significant digits, discrepancy with CODATA: 3.9×10^{-7}) [10].

VII.3. φ-scaling between generations

Group	$m_1 \to m_2$	$\approx \varphi^n$	$\delta\%$	$m_2 \to m_3$	$\approx \varphi^n$	$\delta\%$	$m_1 \to m_3$	$\approx \varphi^n$	$\delta\%$
$\hat{O}_0$ (leptons)	206.8	φ^{11}	3.9	16.8	φ^6	6.3	3477	φ^{17}	2.7
R_{-1} (u-quarks)	588	φ^{13}	12.9	136	φ^{10}	10.6	79981	φ^{23}	—
O_{-1} (d-quarks)	20.0	φ^6	11.5	44.8	φ^8	4.7	895	φ^{14}	—
R_0 (proton)	1.27	$\sim \varphi^{0.5}$	—	4.89	φ^3	15.3	6.19	φ^4	10.7
O_0 (neutron)	1.19	$\sim \varphi^{0.4}$	—	5.04	φ^3	18.9	5.98	φ^4	14.6

Key pattern: the φ power for $m_1 \to m_3$ = (power for $m_1 \to m_2$) + (power for $m_2 \to m_3$).

For leptons: $11 + 6 = 17$ = the ODTOE invariant!

For u-quarks: $13 + 10 = 23 = 17 + 6$. For d-quarks: $6 + 8 = 14 = 17 - 3$.

Sum $R_{-1} + O_{-1} = 23 + 14 = 37 \approx 39 - 2$ (all roles minus γ and H). The operator $\hat{O}_0$ "traverses" exactly 17 steps — the full set of roles of one level.

VII.4. Inter-group ratios — toroidal sectors

Ratio	Value	$\log_\varphi$	Interpretation
m_p/m_e	1836.15	$\varphi^{15.6}$	$R_0/\hat{O}_0 = 6\pi^5$
m_W/m_p	85.7	$\varphi^{9.3}$	bridge/observable
m_H/m_p	133.3	$\varphi^{10.2}$	Higgs/observable
m_H/m_W	1.56	$\varphi^{0.9}$	$\delta = 3.8\%$
m_τ/m_s	19.0	$\varphi^{6.1}$	3rd gen. lepton / 2nd gen. quark
m_p/m_d	200.9	$\varphi^{11.0}$	d=0 baryon / d=−1 quark

VII.5. PDG "bonus": an unexpected match

Scheme $p \to \Sigma^+ \to \Sigma_c^+$: $m(\Sigma_c^+)/m(p) = 2.614 \approx \varphi^2 = 2.618$ with 0.2% accuracy!

Similarly: $m(\Xi_c^0)/m(n) = 2.629 \approx \varphi^2 = 2.618$ with 0.4% accuracy.

This is an alternative generational ladder ($d \to s \to c$ instead of $d \to s \to b$), with nearly perfect φ^2 matching.

VIII. SUMMARY TABLE: ALL 39 ROLES THROUGH ODTOE

VIII.1. How the SM sees its "17 elementary" (projection)

The SM selects from 39 roles only those it considers "elementary," collapsing the rest:

#	d	Particle (SM)	SM view	ODTOE view	Torus topology
1	-1	u-quark	Quark, $+2/3$	R_{-1} (1st gen.)	Double traversal, 1st torus
2	-1	d-quark	Quark, $-1/3$	O_{-1} (1st gen.)	Double traversal, 1st torus
3	-1	c-quark	Quark, $+2/3$	R_{-1} (2nd gen.)	Double traversal, 2nd torus
4	-1	s-quark	Quark, $-1/3$	O_{-1} (2nd gen.)	Double traversal, 2nd torus
5	-1	t-quark	Quark, $+2/3$	R_{-1} (3rd gen.)	Double traversal, 3rd torus
6	-1	b-quark	Quark, $-1/3$	O_{-1} (3rd gen.)	Double traversal, 3rd torus
7	-1	Gluon g	1 boson (8 colors)	$\hat{O}_{-1}$ — 8 channels	Single traversal
8	0	e^-	Lepton, -1	$\hat{O}_0$ fwd (1st)	Double traversal
9	0	μ^-	Lepton, -1	$\hat{O}_0$ fwd (2nd)	Double traversal, 2nd torus

10	0	τ^-	Lepton, -1	$\hat{O}_0$ fwd (3rd)	Double traversal, 3rd torus
11	0	ν_e	Neutrino	$\delta\Psi_0$ ($O \to \hat{O}$)	Spiral residue
12	0	ν_μ	Neutrino	$\delta\Psi_0$ ($\hat{O} \to R$)	Spiral residue
13	0	ν_τ	Neutrino	$\delta\Psi_0$ ($R \to O$)	Spiral residue
14	$0/-1$	Photon γ	Boson, EM	Tr($\hat{O}_d$), 9th channel	Trans-level
15	$0/-1$	$W^\pm$	Boson, weak	Transmutation $O \leftrightarrow R$	Single traversal
16	$0/-1$	Z^0	Boson, weak	Loop self-check	Single traversal
17	all	Higgs H	Scalar	Field $\mathcal{H}$: potentiality	No traversal (spin 0)

VIII.2. What the SM hides: 22 "missing" roles

#	d	Particle	Why SM does not count	ODTOE role
18–23	0	p, Σ^+, Σ_b^+, n, Λ^0, Λ_b^0	"Composite" (from quarks)	$R_0 \times 3 + O_0 \times 3$
24–26	0	e^+, μ^+, τ^+	"Antiparticles" (mirrors)	Reverse channels of $\hat{O}_0$
27–28	0	L_7, L_8	Not anticipated	Diagonal channels of $\hat{O}_0$ (HNL)
29–35	-1	$g_2 \dots g_8$	"One type" of gluon	7 additional channels of $\hat{O}_{-1}$
36–38	-1	sub-ν_e, sub-ν_μ, sub-ν_τ	Beyond D-Prot horizon	$\delta\Psi_{-1}$
39	$0/-1$	W^- (separate)	"One type" $W^\pm$	Bridge $O \to R$

Analogs across recursion levels

Role	d=+1 (mol.)	d=0 (at.)	d=−1 (nucl.)	d=−2 (sub-q.)
R	Molecule	Proton p^+	u-quark	Sub-u
O	Solvent	Neutron n^0	d-quark	Sub-d
$\hat{O}$	Chemical bond	Electron e^-	Gluon g	Sub-gluon

The electron = the gluon of the next octave. The electron binds atoms into molecules just as the gluon binds quarks into nucleons.

Quarks = leptons of the previous octave. In the sub-SM, quarks play the role of free operators analogous to electrons.

IX. COMPLETE PDG $\rightarrow$ ODTOE MAP: EVERYTHING NOT IN THE 39 ROLES

IX.a. Mesons ($\sim$200+ in PDG) — "bond fragments"

Mesons ($q\bar{q}$) are NOT roles of the ternary loop. They are **"fragments" of the gluon string** (bond $\hat{O}_{-1}$). When a collider breaks the loop, quarks reassemble not only into baryons (qqq = loop) but also into mesons ($q\bar{q}$ = bond fragment).

IX.b. Vector mesons — "bridges WITHIN $d = -1$"

Just as $W^{\pm}/Z^0$ are bridges **between** levels, vector mesons ($J^P = 1^-$) are bridges **within** the quark loop.

IX.c. Exotic hadrons — "role molecules"

Exotic hadrons add no new roles — they are **combinations** of existing ones: pentaquarks (baryon + meson), tetraquarks (meson + meson).

IX.d. Resonances — "excited roles"

Hundreds of resonances in the PDG (N^*, Δ, Σ^*, Ξ^*, Ω^*) are the same 39 roles with added rotational/vibrational energy. Not new roles, but **excited states** of existing ones.

X. MULTI-LEVEL MAP: ANOMALIES AS SHADOWS OF OTHER LEVELS

X.a. D-Prot: the visibility window of the $d = 0$ observer

The $d = 0$ observer sees levels with attenuation $S(\rho_d) \propto \varphi^{-|\Delta d|}$. Entanglement is maximal at our level and decreases by a factor of $\varphi \approx 1.618$ at each next level. The current table (39 roles) covers **only** $d = 0$ **and** $d = -1$. Physics anomalies are **shadows** of roles from other levels leaking through D-Prot.

X.b. Self-similarity: 17 roles at EACH level

By ∞-recursion $\Phi = \iota \circ \hat{O}$, **each** level d contains the same ternary loop with $N(d) = 17$ roles. Roles of one level become components of another.

X.c. Classification of anomalies by source level

1. Missing roles of our level $d = 0$ (L_7, $L_8 \to$ explain MiniBooNE, X17). Roles that the SM missed because it does not know about the network structure of the operator (8 channels instead of 3).

2. Shadows of neighboring-level roles ($d{=}+1$: graviton, dark photon, WIMP; $d{=}-2$: axion, quark substructure). Belong to their levels (17 each), we see "blurred projections" through D-Prot.

3. Trans-level effects (dark energy = $\mathcal{H}$ pressure, cosmological proportions = φ-torus geometry). Not particles but properties of recursive architecture.

Full counting formula: in the $d = 0$ observer window — 39 full roles plus "ghost" contributions: $17 \times \varphi^{-1} \approx 10.5$ (from $d{=}+1$), $17 \times \varphi^{-2} \approx 6.5$ (from $d{=}-2$ and $d{=}+2$), and so on. Total ∼84 effective roles in the full D-Prot window.

XI. ENERGY PROPORTIONS: FORMULAS FROM π AND φ (zero free parameters)

XI.a. Cosmological proportions — three sectors of the φ-torus

The φ-torus with $R/r = \varphi$ (the most irrational number, KAM-stable) generates three sectors:

Sector	Dynamics	Inertia	Physics	Observed fraction
I: R-dynamics	Rotation along R	$\propto R^2 = \varphi^2$	Between levels	Dark energy Ω_Λ
II: r-dynamics	Rotation along r	$\propto r^2 = 1$	Within a level	Dark matter Ω_{DM}
III: gap	Spiral slit	Z	Matter in slit	Baryonic matter Ω_b
IV: gap^2	Gap within gap	$(\pi - 3)^2$	2nd-order gap	Neutrinos Ω_ν

Parameter Z — geometric series of spiral gaps:

$$Z = \frac{\pi - 3}{1 - (\pi - 3)\,\varphi} = 0.18367\ldots \tag{XI.1}$$

Contributions by order: $k = 1$: 77.1%, $k = 2$: 17.7%, $k = 3$: 4.0%, $k \geq 4$: 1.2%.

XI.b. Comparison with Planck 2018 (3-component model)

$\Omega_\Lambda : \Omega_{\text{DM}} : \Omega_b = \varphi^2 : 1 : Z$, normalization $\Sigma = \varphi^2 + 1 + Z = 3.8017$.

Parameter	ODTOE	Planck 2018	$\pm\sigma$	Deviation
Ω_Λ (dark energy)	68.86%	68.89%	0.56%	0.05σ
Ω_{DM} (dark matter)	26.30%	26.07%	0.20%	1.17σ

Ω_b (baryons)	4.83%	4.90%	0.06%	1.06σ

All three matches within 1.2σ. Zero free parameters — only π and φ. [20]

XI.c. Self-referential correction ($\Phi = \iota \circ \hat{O}$)

The baryonic fraction "observes itself" (strange loop): $x = (Z + \varepsilon x)/(K + Z + \varepsilon x)$, $\varepsilon = (\pi - 3)^2$, $K = \varphi^2 + 1$.

Quadratic equation:

$$\varepsilon x^2 + x(K + Z - \varepsilon) - Z = 0 \tag{XI.2}$$

Result: $\Omega_b(\text{s.r.}) = 4.856\%$ ($\sigma = 0.67$ from Planck), improvement by 0.39σ.

XI.d. 4-component model (with neutrinos)

$$\Omega_\Lambda : \Omega_{\text{DM}} : \Omega_b : \Omega_\nu = \varphi^2 : 1 : Z : (\pi - 3)^2 \tag{XI.3}$$

$\Omega_\nu = (\pi - 3)^2/\Sigma_4 = 0.52\%$ (Planck: $< 0.3\%$ at $\Sigma m_\nu < 0.12$ eV — consistent in order of magnitude).

Neutrinos = 2nd-order gap of the toroidal spiral ($\delta\Psi \propto (\pi - 3)^2$).

XI.e. Two types of formulas

Type 1. Between levels (cosmological proportions): $\varphi^2 : 1 : Z : (\pi - 3)^2$ — a property of the torus AS A WHOLE. Determines the fractions of dark energy, dark matter, baryons, neutrinos.

Type 2. Between generations (φ-scaling of masses): $m(\text{gen. } n{+}1)/m(\text{gen. } n) \approx \varphi^k$ — a property of RECURSION. The power k depends on the group (role) and junction number.

Cosmological proportions are **not** applicable to mass distributions within a level ($m_p \approx m_n$, not $m_p/m_n = \varphi^2$). But φ-scaling is **not** applicable between levels (dark energy/matter are not a "generation" of baryons).

The two types of formulas reflect two types of rotation on the φ-torus: along the major radius R (between levels) and along the minor radius r (within a level).

XII. FALSIFIABLE PREDICTIONS FROM INFINITE NESTING

The ODTOE recursive self-similarity principle asserts: each proton contains an internal triad architecture, and this architecture is reproduced at all scales. The fixed

point $\Psi^* = \Phi(\Psi^*)$ defines a self-consistent configuration linking all levels. This structure generates twelve falsifiable predictions.

XII.1. P1: Inter-scale atom/nucleus correlations

Electron capture ($e^- + p \to n + \nu_e$) is a confirmed case of inter-level interaction. ODTOE predicts systematic correlations beyond QED. **Test**: precision measurement of β-decay rates in different electronic states (neutral atom vs. fully ionized).

XII.2. P2: φ-scaling of entanglement entropy

The von Neumann entropy $S(\rho_d) \propto \varphi^{-|d-d_0|}$ [3]. In systems with self-similar structure (quasicrystals, Fibonacci lattice), entanglement entropy between scales should obey this law. **Test**: simulation on fractal lattices; measurement of correlations in quasicrystals.

XII.3. P3: Nonlocal electron correlations through $\hat{O}$ unity

All electrons are projections of a single operator $\hat{O}$. Indistinguishability is a consequence of operator identity. ODTOE predicts nonzero (though small) correlations between distant electrons without prior entanglement. **Test**: comparison of spin correlations in separated atoms.

XII.4. P4: Baryonic asymmetry from spirality

The closed cycle length ($\pi \approx 3.14159$) is incommensurable with the triad architecture (3 components). The increment $\pi - 3 \approx 0.14159$ creates a systematic asymmetry $\hat{O} \neq \iota$. The transcendence of π guarantees the asymmetry will not vanish. **Test**: analytical derivation of $\eta \approx 6 \times 10^{-10}$ through powers of $(\pi - 3)$.

XII.5. P5: Topological prohibition of the 4th generation

Exactly 3 generations at each level d — period. A triangle has no fourth vertex. Infinity goes inward (nested triads), not sideways (additional junctions).

$$N_{\text{generations}}(d) = 3 \quad \text{for any } d \in \mathbb{Z} \quad (\text{topological invariant}) \tag{XII.3}$$

$$N_{\text{levels}} = \infty \quad (S = 1 \text{ is unreachable} \to \text{recursion does not terminate}) \tag{XII.4}$$

Confirmation: $N_\nu = 2.984 \pm 0.008$ [14]. Discovery of a 4th generation (not substructure) would **falsify** the triad architecture.

XII.6. P6: Quark substructure at $E \gg 10^4$ GeV

At energies above $\sim 10^4$ GeV, quark substructure will be discovered. These are not preons (finite number of levels) but reproduction of the same loop architecture at a deeper scale. Substructural objects will have fractional charges ($\pm 1/9$, $\pm 2/9$), three "sub-colors," and binding through sub-gluons.

Current LHC data: $\Lambda \geq 30$ TeV (PDG 2024) [13]. ∞-recursion predicts substructure at scales $R_q \sim R_{\text{nucleon}} \times \varphi^{-n}$.

XII.7. P7: Inter-generation masses $\propto \varphi^n \times [1 + k(\pi - 3)^2]$

$$m(\tau)/m(e) \approx 3477 \approx \varphi^{16.92} \tag{XII.8}$$

$$m(\mu)/m(e) \approx 206.77 \approx \varphi^{11.04} \tag{XII.7}$$

$$m(\tau)/m(\mu) \approx 16.82 \approx \varphi^{5.88} \tag{XII.6}$$

The exponents are not exact integers — they reflect the spiral gap $(\pi - 3)^2$ at each transition. **Test**: if at least three of six ratios have integer n (to accuracy < 0.1), this is a statistically significant confirmation.

XII.8. P8: Scale dependence of Planck's constant

$\hbar$ may prove to be an effective parameter depending on observation level: $\hbar = \hbar(d, S)$. **Test**: compare $\hbar$ via the Josephson effect ($d \approx 0$) and the Kibble balance ($d \approx 2$). Discrepancy $> 10^{-8}$ = evidence.

XII.9. P9: Spatial dipole trend of α

Correlation of $\Delta\alpha/\alpha$ with baryonic density ρ_b along the line of sight. Webb et al. (2011) already detect a dipole trend $\Delta\alpha/\alpha \sim 10^{-5}$ [2].

XII.10. P10: Normal neutrino mass hierarchy

The junction $R \to O$ (τ-neutrino) closes the full cycle and contains the maximum gap $\to m_1 < m_2 < m_3$ [16]. **Test**: JUNO, DUNE, Hyper-Kamiokande.

XII.11. P11: Nuclear resonance width $\Gamma/E \approx (\pi - 3)^2 \approx 2\%$

The observation grain at $d = -1$ determines the minimum relative uncertainty. **Test**: analysis of ENDF/EXFOR databases.

XII.12. P12: φ-scaling of cosmological structures

The cluster hierarchy (atom $\to$ molecule $\to \ldots \to$ galaxy cluster) reproduces the triad architecture at each level. **Test**: large-scale structure statistics.

XII.13. Additional falsifiable predictions from the 39-role table

F1. Generational structure of baryons: Σ^+ and Σ_b^+ exhibit discrete transitions (weak decay, flavor change) like leptonic generations $e \to \mu \to \tau$ — already confirmed.

F2. φ^4**-law**: $m(\text{3rd gen.})/m(\text{1st gen.}) \approx \varphi^4$ for baryons.

F3. φ^2**-law**: $m(\Sigma_c^+)/m(p) = 2.614 \approx \varphi^2$ with 0.2% accuracy.

F4. Gluon hierarchy: 8 gluons exhibit internal structure at high energies.

F5. Sub-neutrinos: upon opening $d = -2$, $\delta\Psi_{-1}$ will be discovered.

F6. The number 39: the complete set of roles for a two-level window. Of these, 34 are confirmed, 5 are predictions.

F7. The invariant 17: each recursion level has exactly 17 roles.

XII.14. Summary table of predictions

#	Prediction	Verification method	Status
P1	Inter-scale correlations	β-decay in different states	Partial
P2	$S(\rho_d) \propto \varphi^{-\lvert d-d_0\rvert}$	Fractal lattices	Open
P3	Correlations of unentangled e^-	Precision measurements	Open
P4	$\eta = f(\pi, \varphi)$ without parameters	Analytical derivation	Open
P5	Exactly 3 generations $\forall d$	$N_\nu = 2.984 \pm 0.008$	Retrodiction
P6	Quark substructure	Scattering cross-sections	Open
P7	Masses $\propto \varphi^n \times [1 + k(\pi-3)^2]$	Mass ratio analysis	Partial
P8	$\delta\hbar/\hbar$ depends on scale	Josephson vs. Kibble	Open
P9	$\Delta\alpha/\alpha$ correlates with ρ_b	Quasar spectroscopy	Indirect
P10	Normal ν hierarchy	JUNO, DUNE	Open
P11	$\Gamma/E \approx (\pi-3)^2 \approx 2\%$	ENDF/EXFOR databases	Open
P12	φ-scaling of structures	Large-scale structure	Open

XII.15. What would refute ∞-recursion

(a) Rigorous proof of the existence of point-like (structureless) objects without an internal triad — a "bottom" of recursion.

(b) Discovery of a 4th generation **at the same level** d (not substructure).

(c) Inter-scale entanglement completely excluded — $|\Psi^*\rangle$ strictly separable.

(d) Nuclear resonance widths systematically lack $(\pi-3)^2$.

(e) $\hbar$ turns out to be an absolutely exact constant to 10^{-12} precision.

XIII. CAVEATS AND OPEN QUESTIONS

The presented derivation is **structural** in character: the ODTOE axiomatics contains three topological mechanisms generating $SU(3) \times SU(2) \times U(1)$, a combinatorial invariant of 17 roles per recursion level, and the complete picture of 39 roles of the two-level window with twelve falsifiable predictions.

Open tasks for transitioning from a structural to a rigorous mathematical derivation:

(a) Rigorous proof that $\pi_1(S^1) = \mathbb{Z}$ generates precisely a $U(1)$-gauge field from the self-consistency condition $\Psi^* = \Phi(\Psi^*)$.

(b) Derivation of $SU(2)$-spinor structure from the toroidal bundle as a theorem.

(c) Rigorous derivation of $SU(3)$ from the triad architecture at $d = -1$ with proof excluding $SO(3)$ and $U(3)$.

(d) Derivation of quantum numbers (spin, isospin, hypercharge, color) from observer components $O = (B, A, H)$ and the four coherence components.

(e) Quantitative connection of PMNS and CKM matrix angles with loop junction geometry.

(f) Derivation of exact masses of all 17 (or 39) particles from π, φ, and $(\pi - 3)^2$.

(g) Extension to the Higgs boson mass: connection of $m_H \approx 125$ GeV with structural parameters.

(h) Proof of decomposition uniqueness: exactly three factors from minimality of the triad architecture.

(i) Rigorous definition of the scaling operator Σ_d and proof of existence of self-similar fixed points.

(j) Analytical derivation of baryonic asymmetry η from $(\pi - 3)$ and structural parameters.

(k) Refinement of the neutrino cosmological proportion: $\Omega_\nu(\text{ODTOE}) = 0.52\%$ vs. Planck $< 0.3\%$ — requires either correction of the 4-component model or revision of the upper limit on Σm_ν.

(l) Determination of exact masses of L_7 and L_8 from structural parameters.

(m) Quantitative description of role reassignment upon observer window shift.

XIV. MAIN THESIS

The Standard Model is not the definitive catalog of reality, but a single octave on an infinite keyboard: 39 stable configurations of the unified self-observation cycle $\Phi = \iota \circ \hat{O}$ at levels $d = 0$ and $d = -1$.

The gauge group $SU(3) \times SU(2) \times U(1)$ is not a postulate but a consequence of the triad loop topology. The number 17 is a combinatorial invariant reproduced at each of an infinite number of recursion levels. Cosmological proportions $\Omega_\Lambda : \Omega_{\text{DM}} : \Omega_b = \varphi^2 : 1 : Z$ are a direct consequence of φ-torus geometry [20]. The ratio $m_p/m_e = 6\pi^5$ is a manifestation of fivefold spirality [10]. The total number of configuration types: $17 \times \infty$. Infinite recursive nesting is not a metaphor but a falsifiable structure with concrete predictions.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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