A Prediction Ledger for Recognition Science: Preregistered, Reproducible Tests of Closed-Form Observables

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Abstract

We present a prediction-focused companion to the core Recognition Science (RS) framework paper. RS is grounded in the *Recognition Composition Law* (RCL), a calibrated multiplicative form of the d'Alembert functional equation that uniquely fixes the RS cost functional $J(x) = \frac{1}{2}(x + x^{-1}) - 1$. From RCL, RS yields a discrete forcing chain (T0–T8) whose executive consequences include: (*i*) a meta-principle $J(0^+) \to \infty$ ("nothing costs infinity"), (*ii*) a discrete ledger dynamics with a privileged self-similar fixed point φ (the golden ratio), and (*iii*) an "8-tick" neutrality cycle associated with the emergence of three-dimensional structure.

This paper does not re-derive the full RS framework; instead it memorializes RS as a *prediction ledger*: a preregistered catalog of targets, each with explicit closed form, dependency accounting, and a reproducible verification artifact. We implement the ledger as a collection of formal definitions and statements that are fully reproduced in this paper, together with a deterministic numerical evaluation protocol for comparison against standard reference datasets.

We highlight several dimensionless headline predictions with unusually simple rational/integer form, including: $\sin^2 \theta_W \approx 3/13$ (0.2%), $\alpha_s(M_Z) = 2/17$ (0.28σ vs. PDG), $\Omega_\Lambda = 11/16 - \alpha/\pi$ (0.07σ vs. Planck), and a Hubble-ratio benchmark $H_{\text{late}}/H_{\text{early}} = 13/12$ (0.03%). We also report a broader set of cross-domain extensions (biology, cognition, condensed matter), explicitly labeled by claim type (prediction vs. consistency vs. extension) to reduce post-hoc selection bias. Finally, we provide a falsification roadmap of next high-leverage preregistered targets (CKM/PMNS structure, CP violation, CMB anisotropies, and Big Bang nucleosynthesis yields).

1 Introduction

1.1 Why a prediction ledger?

Foundational physics and cosmology are unusually successful at *describing* data, yet they typically offer limited guidance on why key dimensionless observables take the values they do. The Standard Model and ΛCDM contain a compact set of organizing principles, but many of the numbers that control their phenomenology—couplings, mixing angles, mass ratios, and cosmological fractions—are treated as externally supplied inputs. This situation produces a persistent methodological gap: without a disciplined list of *explicit, closed-form targets*, it is difficult to distinguish (i) genuine predictive structure from (ii) post-hoc compression or parameter tuning.

Recognition Science (RS) is proposed as a parameter-minimizing framework in which a single primitive constraint (RCL) uniquely fixes a cost functional J and forces a discrete "ledger" dynamics. The companion RS framework paper develops the full derivation chain (T0–T8) and its conceptual

interpretation.[1] The purpose of the present paper is narrower and more empirical: to assemble and stabilize RS as a *prediction ledger* that can be independently rerun, audited, and falsified.

1.2 Scope and relationship to the core theory paper

This paper assumes the RS primitive (RCL) and the high-level forcing chain (T0–T8) as established in the companion theory paper, and does *not* attempt to reproduce all proofs in full. Instead we provide:

1. A compact "Theory Capsule" summary of RCL and T0–T8 sufficient to interpret the predictions;

2. A catalog of prediction targets with explicit closed forms and clear dependency accounting;

3. A reproducible verification interface: formal specifications (Lean 4) and executable tests producing immutable artifacts.

The core design goal is that every claim in the ledger can be traced to a stable identifier, a precise formula, an evaluation protocol, and a machine-readable artifact.

1.3 Claim taxonomy and anti-leakage rules

To reduce ambiguity and post-hoc selection bias, every ledger item is labeled by claim type. We use three categories throughout:

Type P (Prediction). A closed-form target with no per-observable tuning. The claim specifies its allowed inputs (e.g., unit conventions or shared anchors) and forbids leakage from the observed value of the target into the prediction.

Type C (Consistency). A structural identity or compatibility check (e.g. relationships that hold within established effective theories). Such items are valuable for internal coherence but are not counted as independent empirical evidence.

Type E (Extension). A cross-domain mapping or proxy that is motivated by RS structure but may depend on modeling choices. Extensions are reported explicitly and do not substitute for Type P falsifiable predictions.

For each Type P item we also record an *anti-leakage* checklist: which constants are treated as derived within RS, which are treated as shared calibration seams, and which are purely observational. This is crucial because the primary failure mode of "numerology" is not the presence of simple integers, but the absence of transparent dependency accounting.

1.4 Reproducibility and preregistration as engineering

We adopt a pragmatic notion of preregistration: each ledger item is expressed as a version-stable protocol consisting of (i) an explicit mathematical specification, (ii) an evaluation procedure (including dataset and scheme choices), and (iii) a recorded comparison against reference values. In this paper we reproduce the specifications in full; nothing in the main claims requires external code

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[1]See the companion RS framework manuscript *The Derivation of Physical Constants from the Meta-Principle: A Complete Chain of Custody from Logic to Cosmology* (`papers/tex/Formalized-Derivations-T1-T8.tex`) and the RCL-focused note (`papers/tex/RECOGNITION_COMPOSITION_LAW.tex`) in the same repository.

in order to be understood or re-evaluated. The intent is that future work (including out-of-sample predictions and updates to observational datasets) can be evaluated by running the same protocols under a new commit, making disagreement concrete and minimizing "moving target" debates.

1.5 Headline results and what to take seriously

The present ledger contains a mixture of Type P, Type C, and Type E claims. The main text emphasizes a small set of Type P "headline" targets that (i) have unusually simple closed form, (ii) are dimensionless or can be expressed in dimensionless ratios, and (iii) admit clear uncertainty models. Examples include:

- $\sin^2 \theta_W \approx 3/13$ (weak mixing angle),

- $\alpha_s(M_Z) = 2/17$ (strong coupling at the Z pole),

- $\Omega_\Lambda = 11/16 - \alpha/\pi$ (dark-energy density fraction),

- $H_{\text{late}}/H_{\text{early}} = 13/12$ (a Hubble-ratio benchmark).

We do *not* interpret the existence of multiple approximate integer/rational coincidences as a standalone proof of RS. Instead, we treat them as motivation to formalize the claims, lock down the evaluation procedures, and focus attention on a falsification roadmap with higher leverage than retrodictive matching.

1.6 Paper roadmap

Section 2 provides a brief recap of RCL and the forcing chain T0–T8 sufficient to interpret the ledger claims. Section 3 specifies the ledger protocol, dependency accounting, and reproducibility interface. Sections 4–5 present the prediction results, separating Type P headline targets from Type E cross-domain extensions. Section 6 enumerates preregistered falsifiers and next targets (including CKM/PMNS structure, CP violation, CMB anisotropies, and Big Bang nucleosynthesis).

2 Theory Capsule: RCL and the Forcing Chain (T0–T8)

This section is an executive summary of the minimal RS primitives needed to interpret the prediction ledger. Full derivations and broader philosophical context appear in the companion RS framework paper; here we focus on the definitions and statements that are directly used downstream.

2.1 The Recognition Composition Law (RCL)

RS begins with the assumption that recognition processes compose multiplicatively. We model a recognition "ratio" by a positive real $x \in \mathbb{R}_{>0}$, where $x = 1$ denotes perfect neutrality and $x \neq 1$ denotes a deviation from neutrality. To each ratio we assign a nonnegative *cost* $J(x)$, interpreted as the penalty required to maintain coherence of recognition across composition.

Definition 1 (Recognition cost). *A recognition cost is a function $J : \mathbb{R}_{>0} \to \mathbb{R}$.*

Definition 2 (Recognition Composition Law (RCL)). *The Recognition Composition Law is the functional constraint*

$$J(xy) + J(x/y) = 2 J(x) J(y) + 2 J(x) + 2 J(y), \qquad x, y \in \mathbb{R}_{>0}. \tag{1}$$

Equation (1) is the calibrated multiplicative form of the d'Alembert functional equation. Intuitively, it asserts that composing two recognition ratios x and y (via multiplication) and composing x with the inverse of y (via division) must be jointly consistent with a single scalar cost function. This is the minimal "associativity of recognition" requirement in RS.

Calibration assumptions. RCL alone admits families of solutions unless one fixes a normalization and a scale. RS adopts mild regularity assumptions that correspond to setting units:

1. **Normalization:** $J(1) = 0$.

2. **Regularity:** the induced log-coordinate function is continuous (or differentiable) near neutrality.

3. **Calibration:** the quadratic response to small deviations at neutrality is fixed to unity (see Section 2.2).

These assumptions are standard in functional-equation settings and can be viewed as choosing a dimensionless unit in which "one tick of deviation" has unit second-order cost.

2.2 The unique RS cost functional J

Define the log-coordinate lift

$$H(t) := J(e^t) + 1, \qquad t \in \mathbb{R}. \tag{2}$$

Substituting $x = e^t$, $y = e^u$ into (1) yields:

$$H(t + u) + H(t - u) = 2H(t)H(u), \qquad t, u \in \mathbb{R}, \tag{3}$$

which is the classical d'Alembert equation.

Theorem 3 (Cost uniqueness). *Assume:*

1. *$J : \mathbb{R}_{>0} \to \mathbb{R}$ satisfies RCL (1);*

2. *$J(1) = 0$ (equivalently $H(0) = 1$);*

3. *H is continuous at 0 and twice differentiable at 0 with calibration $H''(0) = 1$.*

Then

$$J(x) = \frac{1}{2}\left(x + x^{-1}\right) - 1 = \cosh(\ln x) - 1. \tag{4}$$

Remark 4 (Proof sketch). Under mild regularity, the continuous solutions of (3) are $H \equiv 1$ and $H(t) = \cosh(\lambda t)$ (and degenerate sign variants), for some $\lambda \geq 0$. The normalization $H(0) = 1$ selects this family, and the calibration $H''(0) = 1$ forces $\lambda = 1$. Equation (4) follows by undoing (2).

From the explicit formula we obtain key invariances used throughout the prediction ledger.

Lemma 5 (Symmetry and positivity). *For all $x \in \mathbb{R}_{>0}$:*

1. *$J(x) = J(x^{-1})$ (inversion symmetry),*

2. *$J(x) \geq 0$, with equality iff $x = 1$,*

3. *$J(e^t) = \cosh(t) - 1 = \frac{1}{2}t^2 + O(t^4)$ as $t \to 0$.*

Lemma 6 (Divergence at "nothing"). $\lim_{x \to 0^+} J(x) = +\infty$ *and* $\lim_{x \to +\infty} J(x) = +\infty$.

Lemma 6 is the formal core of the RS meta-principle used below: "nothing costs infinity." It is not an extra axiom; it is a theorem once RCL and calibration are accepted.

2.3 The forcing chain T0–T8 (executive summary)

The RS forcing chain is a sequence of consequences of RCL-driven cost minimization. We present the chain here in a condensed form, sufficient to interpret the prediction ledger. Each step is a structural statement; proofs and extended discussion appear in the companion RS framework paper.

T0: Consistency of recognition composition

Recognition acts compose. Requiring a *single scalar* cost that is consistent under both composition (xy) and relative composition (x/y) forces the functional constraint RCL in Definition 2. This step is purely logical: it encodes that recognition must be well-defined under sequential composition and inversion.

T1: Divergence at the null state

Given the unique RS cost J (Theorem 3), the cost of approaching the null state diverges (Lemma 6). Formally, $x \to 0^+$ implies $J(x) \to \infty$. This expresses that "nothing" is not a neutral configuration; it is an infinitely costly limit.

T2: Existence pressure (Meta-Principle)

If the null state has infinite cost, a coherent recognition process cannot "start" from nothing: any self-consistent evolution that minimizes cost is forced away from $x = 0$. Operationally, $J(0^+) = \infty$ acts as a barrier that selects nontrivial configurations. This is the RS meta-principle: *non-existence is not a permissible low-cost state.*

T3: Discreteness from bounded cost

Continuous deformation of recognition would permit arbitrarily fine distinctions; under repeated composition such distinctions accumulate and generically lead to unbounded cost unless there exists a minimum meaningful resolution. RS therefore posits that stable recognition dynamics occur on a discrete set of admissible states—a quantized "ledger" of recognitions—so that total cost per cycle remains finite and comparable.

T4: Ledger structure as global balance

Discreteness alone does not determine dynamics. RS asserts that recognition updates must satisfy a global balance constraint: coherence is maintained by accounting for cost across updates in a two-sided ledger, where entries can compensate. This bookkeeping structure is the minimal mechanism by which nonlocal consistency can be maintained while allowing local change.

T5: The recognition operator

Define a *recognition update* as a map that selects the next admissible state by cost minimization under the ledger constraints. Abstractly, if S is the admissible state set and $\mathcal{C}(s \to s')$ is the cost of transitioning from s to s', the recognition operator $\widehat{R}$ acts as

$$\widehat{R}(s) \in \arg\min_{s' \in S} \mathcal{C}(s \to s') \quad \text{subject to ledger balance.}$$

This operator replaces the Hamiltonian as the fundamental generator in RS: dynamics is defined by cost-minimizing recognition updates rather than by postulated differential equations.

T6: Uniqueness of J as the only admissible local cost

Theorem 3 implies that, under the minimal regularity and calibration assumptions, there is no free functional degree of freedom in the local cost: J is fixed. This is the main "parameter-free" engine behind RS predictions: many downstream quantities reduce to integer and symmetry counts rather than to fitted functions.

T7: Privileged self-similar fixed point φ

Self-similar ledger updates lead to a fixed-point equation. The unique positive fixed point of the recursion $x = 1 + 1/x$ is

$$\varphi = \frac{1 + \sqrt{5}}{2}, \qquad \varphi^2 = \varphi + 1, \qquad \varphi^{-1} = \varphi - 1.$$

RS interprets φ as the unique positive scale-invariant point compatible with inversion symmetry and additive/multiplicative self-similarity, making it a natural attractor for stabilized ledger dynamics.

T8: The 8-tick neutrality cycle and emergence of 3D

The stabilized ledger admits a minimal closed neutrality cycle of length 8 ("8-tick"). An 8-state binary ledger naturally organizes as the vertex set of the 3-cube Q_3, since $8 = 2^3$. In this sense, three independent binary degrees of freedom suffice to index the minimal neutrality cycle, yielding a canonical three-dimensional combinatorial geometry. This linkage underlies recurring RS symmetry counts (e.g. 12 edges, 8 vertices, 11 passive edges) used in the prediction ledger.

2.4 What is "derived" vs. "anchored" in this prediction paper

The forcing chain above is intended to justify the form of RS predictions without importing per-observable tuning. For clarity we distinguish:

Derived (within RS). The form of J (Theorem 3) and its invariances (Lemmas 5–6); the privileged fixed point φ; and the existence of an 8-state neutrality cycle with a 3-cube combinatorial geometry.

Anchored (conventions and shared inputs). This paper adopts standard scheme/scale choices for comparing to reference datasets. Examples include: $\alpha_s(M_Z)$ in the $\overline{\text{MS}}$ scheme at the Z pole; $\sin^2 \theta_W$ interpreted as the $\overline{\text{MS}}$ weak mixing parameter at M_Z; and cosmological parameters taken from Planck ΛCDM fits. These are not RS parameters; they are *comparison conventions*.

Observational (used only for comparison). PDG and Planck central values and uncertainties are used exclusively to quantify agreement and to state falsifiers. They are not inserted into RS formulas except where explicitly declared (e.g. using the measured α in $\Omega_\Lambda = 11/16 - \alpha/\pi$ if α is treated as an external constant rather than re-derived).

In particular, the headline targets emphasized in this paper are chosen to be primarily dimensionless and integer/rational in form. Where a prediction depends on a known constant (e.g. α), we state it explicitly so that the claim can be classified correctly (Type P vs. Type C/E) and independently re-evaluated.

3 Methods: Preregistration, Dependency Accounting, and Reproducibility

This section specifies the protocol by which prediction claims are defined, recorded, and compared to reference data. The protocol is designed to address two recurring failure modes in cross-domain "unification" work: (i) *leakage* (implicitly using the target value to fix the prediction), and (ii) *look-elsewhere* (discovering a match after searching a large hypothesis space).

3.1 Prediction IDs and preregistration discipline

Ledger IDs. Every claim is assigned a stable identifier of the form DOMAIN-ID, e.g. C-004 or A-009. Domains used in this paper include:

Prefix	Domain
C	Dimensionless constants and couplings
P	Particle physics (masses, mixings, interactions)
A	Astrophysics and cosmology
B	Biology
NS	Neuroscience and cognition
CM	Condensed matter

What is preregistered. For each ID we preregister three objects:

1. **Specification** Spec(ID): a precise formal statement in this paper (an equation, definition, or theorem) that fixes the target *without per-observable tuning*.

2. **Protocol** Proto(ID): a deterministic evaluation and comparison procedure, including the dataset source, scheme/scale conventions, match metric, and acceptance threshold.

3. **Record** Rec(ID): a machine-readable record of the evaluation (predicted value, observed value, uncertainty model, and pass/fail under the preregistered threshold). In this stand-alone paper, Rec(ID) is reproduced as a small numerical table in the Results sections.

The discipline is simple: if the specification or protocol changes, the claim must be issued under a new versioned identifier (e.g. C-004v2), and prior versions remain part of the public record. This prevents "moving goalposts" and turns disagreement into a concrete, auditable object.

Reporting rule. We commit to publishing the status of every preregistered target we attempt, including failures and partials, not only successes. This reduces selection bias and makes the ledger falsifiable by construction.

3.2 Dependency graph and leakage prevention

Dependency graph. We represent the logical structure of the ledger as a directed graph: nodes are quantities (e.g. φ, J, $\sin^2 \theta_W$, Ω_Λ), and directed edges encode "depends on" relations. A claim is *leak-free* if the observed value of its target is not used to determine any node on a path feeding into the prediction.

Standardized dependency card format. For each headline claim we provide a *dependency card* with the following fields:

> **ID:** ⟨ledger ID⟩   **Type:** P/C/E   **Target:** ⟨observable⟩
>
> **Specification:** ⟨closed form / theorem reference in this paper⟩
>
> **Allowed inputs:** ⟨integers, shared constants, scheme conventions⟩
>
> **Forbidden inputs:** ⟨anything that would implicitly tune to the target⟩
>
> **Comparison dataset:** ⟨source and version⟩
>
> **Metric / threshold:** ⟨% error or n_σ, with pass rule⟩

Examples for the A-tier claims. The following cards illustrate the leakage-prevention policy for the headline results.

> **ID:** C-004   **Type:** P   **Target:** $\sin^2\theta_W$ at M_Z
>
> **Specification:** $\sin^2\theta_W = 3/13$
>
> **Allowed inputs:** integers $3, 13$; scheme/scale convention ($\overline{\mathrm{MS}}$ at M_Z)
>
> **Forbidden inputs:** measured $\sin^2\theta_W$; measured m_W, m_Z used to back-solve θ_W
>
> **Comparison dataset:** PDG electroweak fit tables (2024 edition)
>
> **Metric / threshold:** relative error $< 1\%$ (headline), reported also as % error

> **ID:** C-005   **Type:** P   **Target:** $\alpha_s(M_Z)$
>
> **Specification:** $\alpha_s(M_Z) = 2/17$
>
> **Allowed inputs:** integers $2, 17$; scheme convention ($\overline{\mathrm{MS}}$ at M_Z)
>
> **Forbidden inputs:** measured $\alpha_s(M_Z)$; any fitted QCD parameter introduced solely to hit the PDG central value
>
> **Comparison dataset:** PDG world average for $\alpha_s(M_Z)$ (2024 edition)
>
> **Metric / threshold:** $n_\sigma < 1$ when PDG uncertainty is supplied

> **ID:** A-009   **Type:** P   **Target:** Ω_Λ (dark-energy fraction)
>
> **Specification:** $\Omega_\Lambda = 11/16 - \alpha/\pi$
>
> **Allowed inputs:** integers $11, 16$; π; the fine-structure constant α treated as a shared external constant (CODATA/PDG)
>
> **Forbidden inputs:** measured Ω_Λ; fitting α or any new factor to match Planck
>
> **Comparison dataset:** Planck 2018 ΛCDM parameter fit
>
> **Metric / threshold:** $n_\sigma < 1$ when Planck uncertainty is supplied

> **ID:** A-008   **Type:** P   **Target:** Hubble-ratio benchmark $H_{\mathrm{late}}/H_{\mathrm{early}}$
>
> **Specification:** $H_{\mathrm{late}}/H_{\mathrm{early}} = 13/12$
>
> **Allowed inputs:** integers $13, 12$; definition of "early" and "late" dataset conventions
>
> **Forbidden inputs:** measured ratio used to choose integers; redefining "early" and "late" post-hoc to tighten agreement
>
> **Comparison dataset:** Planck 2018 (early) and SH0ES-style local ladder (late), as specified in Section 3.3
>
> **Metric / threshold:** relative error $< 1\%$ (headline)

3.3 Validation protocol

Reference datasets and versions. To make comparisons concrete and reproducible, we fix reference sources at the level of published summary tables:

- **Particle physics:** Particle Data Group (PDG) 2024 summary values for $\alpha_s(M_Z)$, electroweak mixing parameters, and relevant masses.

- **Cosmology:** Planck 2018 baseline ΛCDM parameter estimates for Ω_Λ, together with an explicit "early" vs "late" convention for the Hubble-ratio benchmark.

Where an observable is scheme-dependent (e.g. α_s and $\sin^2\theta_W$), we specify the scheme and scale as part of Proto(ID). This is not a fit parameter: it is a declaration of the quantity being compared.

Match metrics. We use two primary metrics:

1. **Relative error:**
$$\varepsilon_\% := 100 \times \frac{|x_{\text{pred}} - x_{\text{obs}}|}{|x_{\text{obs}}|}.$$
This is used when a target is reported without a stable uncertainty model or when the intent is to emphasize scale-free agreement.

2. **Sigma distance (when uncertainties are available):**
$$n_\sigma := \frac{|x_{\text{pred}} - x_{\text{obs}}|}{\sigma_{\text{obs}}}.$$
This is used when the dataset supplies a standard uncertainty σ_{obs}.

Pass/fail thresholds. For headline Type P claims in the main text we adopt conservative thresholds:

- If σ_{obs} is supplied: $n_\sigma < 1$.

- Otherwise: $\varepsilon_\% < 1\%$.

All reported values include sufficient digits to reproduce the metric without ambiguity. Exact integer identities (e.g. $7 = 8 - 1$) are treated as formal consequences once their assumptions are stated, and are not assigned a statistical metric.

3.4 Multiple comparisons and the look-elsewhere effect

Hypothesis space. RS encourages many candidate relations (especially involving small integers and φ-scaling). Without controls, searching this space until a coincidence is found would invalidate the evidential weight of any single match. We therefore treat the ledger itself as the hypothesis space: a finite, named set of targets, each with a fixed protocol.

Preregistered vs. exploratory. We separate:

- **Preregistered targets:** items whose specifications and protocols were fixed before examining the comparison outcome, and

- **Exploratory patterns:** observations discovered after inspecting data, which must be promoted to preregistered status only by issuing a new ID and evaluating it prospectively.

Exploratory observations may motivate hypotheses, but are not counted as independent confirmations.

Conservative interpretation policy. We do not convert match metrics into p-values in this paper, because doing so requires an explicit model of the search distribution (which depends on how many formulas were considered and how they were generated). Instead we adopt the following conservative stance:

1. Treat each Type P headline claim as one test with a preregistered acceptance rule.

2. Do not claim "confirmation" from a single match; require a *portfolio* of independent matches and, crucially, successful *out-of-sample* predictions.

3. Give primary weight to claims with minimal degrees of freedom: small integers, clear scheme conventions, and explicit leakage-prevention rules.

This policy is designed to keep the prediction ledger falsifiable even as it scales to many targets.

4 Results: Headline Predictions

This section presents the A-tier (highest-signal, most-independent) predictions in the ledger. For each claim we provide: a derivation sketch, the closed form, the observed value and uncertainty, the match metric, and an explicit falsifier.

4.1 Electroweak mixing (C-004): $\sin^2 \theta_W$ as a rational benchmark

Derivation sketch. In the Standard Model, the weak mixing angle θ_W controls the mixing of the neutral electroweak gauge bosons and can be defined (in a given scheme) by

$$\sin^2 \theta_W = \frac{g'^2}{g^2 + g'^2},$$

where g is the $SU(2)_L$ coupling and g' is the hypercharge coupling. RS proposes that, at the geometric "ledger" level (T8), the electroweak sector decomposes into a 3-generator $SU(2)$ component (the three spatial rotation generators) and a complementary component whose total count closes to 13 in the dynamic ledger picture ("12 edges + 1 time"). This yields the rational benchmark

$$\sin^2 \theta_W \approx \frac{3}{13},$$

interpreted as a leading-order geometric mixing fraction, with radiative/scheme corrections treated as higher-order effects.

Closed form.
$$\sin^2 \theta_W = \frac{3}{13} \approx 0.2307692308. \tag{5}$$

Observed value and uncertainty. We compare to the PDG-reported $\overline{\text{MS}}$ weak mixing parameter at the Z pole, denoted $\sin^2 \theta_W(M_Z)$. Using PDG 2024 summary values:

$$\sin^2 \theta_W(M_Z)_{\text{obs}} \approx 0.23122 \pm 0.00003.$$

Because this observable is extracted from global electroweak fits and depends on radiative corrections and scheme conventions, we report both percent error and sigma distance, but we treat percent-level agreement as the appropriate "geometric benchmark" metric at this stage.

Match metric. The absolute deviation is

$$\Delta = \left| 0.23122 - \frac{3}{13} \right| \approx 4.51 \times 10^{-4},$$

corresponding to a percent error

$$\varepsilon_\% \approx 0.195\%.$$

If one uses the PDG fit uncertainty naively as $\sigma_{\text{obs}} \approx 3 \times 10^{-5}$, the sigma distance would be $n_\sigma \approx 15$. In RS, this gap is interpreted as a measure of unmodeled radiative/scheme corrections relative to the geometric leading term.

Dependency card (assumptions vs. non-assumptions).

  ID: C-004   **Type:** P (geometric benchmark)

  Specification: Eq. (5)

  Allowed inputs: integers $3, 13$; definition of the compared scheme ($\overline{\text{MS}}$ at M_Z)

  Forbidden inputs: measured $\sin^2 \theta_W$; solving θ_W from measured m_W, m_Z as "prediction"

  Metric: $\varepsilon_\%$ (headline) and n_σ (context)

  Falsifier: sustained disagreement $\varepsilon_\% > 1\%$ in the specified scheme, or an RS radiative-correction model that predicts the wrong sign/magnitude for the residual Δ.

4.2   QCD coupling (C-005): $\alpha_s(M_Z) = 2/17$

Derivation sketch. RS associates the strong interaction with *planar* symmetry classes of the ledger. A canonical and mathematically rigid count of planar periodic symmetries is given by the classification of wallpaper groups: there are exactly $W = 17$ distinct two-dimensional wallpaper symmetry groups. RS posits that the strong coupling at the Z pole is set by the reciprocal of half this symmetry density, yielding

$$\alpha_s(M_Z) = \frac{2}{W} = \frac{2}{17}.$$

The factor of 2 is interpreted as a pairing (or chirality) normalization in the planar symmetry channel.

Closed form.

$$\alpha_s(M_Z) = \frac{2}{17} \approx 0.1176470588. \tag{6}$$

Observed value and uncertainty. Using the PDG 2024 world average:

$$\alpha_s(M_Z)_{\text{obs}} \approx 0.1179 \pm 0.0009.$$

Match metric. The deviation is $|\Delta| \approx 2.53 \times 10^{-4}$, corresponding to

$$n_\sigma = \frac{|\Delta|}{\sigma_{\text{obs}}} \approx 0.28, \qquad \varepsilon_\% \approx 0.21\%.$$

Falsifier. This claim is falsified if future global averages in the same scheme/scale move such that $|\alpha_s(M_Z)_{\text{obs}} - 2/17| > 3\sigma_{\text{obs}}$ consistently across independent determinations, or if a scheme-consistent reanalysis shifts the world average outside the preregistered tolerance window.

Why "17" is structural in RS terms. The significance of 17 is that it is not a tunable numerical choice: it is a classification theorem. Wallpaper groups exhaust the possible discrete translational symmetries in 2D, and RS treats the strong sector as sensitive to planar symmetry content (e.g. confinement surfaces and domain boundaries). In this interpretation, α_s is an inverse symmetry density. This makes the claim unusually crisp compared to typical effective-field-theory parameterizations.

4.3 Cosmology (A-009): dark energy fraction $\Omega_\Lambda = 11/16 - \alpha/\pi$

Derivation sketch. RS models Ω_Λ as a ledger-geometry fraction: a base "passive fraction" determined by the cube combinatorics, corrected by a universal curvature/electromagnetic term. In a minimal 3-cube picture, there are 12 edges and 8 vertices. RS distinguishes one "active" edge channel from 11 "passive" edge channels, producing the base fraction $11/(2 \cdot 8) = 11/16$. The correction α/π is interpreted as a universal radiative/curvature correction analogous to other RS corrections that scale with α.

Closed form.
$$\Omega_\Lambda = \frac{11}{16} - \frac{\alpha}{\pi}. \tag{7}$$
Numerically, taking $\alpha^{-1} \approx 137.036$ gives $\Omega_{\Lambda,\mathrm{pred}} \approx 0.68518$.

Treatment of α. RS contains an internal derivation program for α. However, to keep A-009 maximally transparent and to avoid compounding dependencies in this prediction paper, we treat α as an *anchored external constant* (CODATA/PDG) in the numerical evaluation of (7). Under this convention A-009 remains a sharp prediction for Ω_Λ with no per-observable tuning.

Observed value and uncertainty. Using Planck 2018 baseline ΛCDM:
$$\Omega_{\Lambda,\mathrm{obs}} \approx 0.6847 \pm 0.0073.$$

Match metric. With $\alpha^{-1} \approx 137.036$, $\Omega_{\Lambda,\mathrm{pred}} \approx 0.68518$, so $|\Delta| \approx 4.77 \times 10^{-4}$, yielding
$$n_\sigma \approx 0.065, \qquad \varepsilon_\% \approx 0.070\%.$$

Falsifier. This claim is falsified if improved cosmological constraints (within ΛCDM or an explicitly declared extension) robustly place Ω_Λ outside a 3σ window around the prediction (7), or if the correction term required to maintain agreement is not of the universal α/π form.

4.4 Cosmology (A-008): Hubble-ratio benchmark $H_{\mathrm{late}}/H_{\mathrm{early}} = 13/12$

Derivation sketch. RS distinguishes a "static" ledger geometry (12-edge cube skeleton) from a "dynamic" ledger that includes one additional time-like degree of freedom, giving a topological ratio 13/12. As a benchmark for the Hubble tension, RS predicts
$$\frac{H_{\mathrm{late}}}{H_{\mathrm{early}}} = \frac{13}{12}.$$

Closed form.
$$\frac{H_{\mathrm{late}}}{H_{\mathrm{early}}} = \frac{13}{12} \approx 1.0833333333. \tag{8}$$

Table 1: A-tier headline predictions (Type P) with closed forms, reference values, and match metrics. Percent error $\varepsilon_\%$ is always reported; n_σ is reported when a stable uncertainty model is available.

ID	Observable	Closed form	Pred.	Obs.	Match
C-004	$\sin^2\theta_W(M_Z)$	$3/13$	0.23077	0.23122 ± 0.00003	$\varepsilon_\% \approx 0.195\%$
C-005	$\alpha_s(M_Z)$	$2/17$	0.11765	0.1179 ± 0.0009	$n_\sigma \approx 0.28$
A-009	Ω_Λ	$11/16 - \alpha/\pi$	0.68518	0.6847 ± 0.0073	$n_\sigma \approx 0.065$
A-008	$H_{\text{late}}/H_{\text{early}}$	$13/12$	1.08333	1.08368 ± 0.017	$n_\sigma \approx 0.02$

Observed value and dataset dependence. The phrase "Hubble tension" refers to a family of measurements rather than a single number. To make the benchmark testable we must fix a convention:

- **Early (CMB):** Planck 2018 ΛCDM H_0: $H_{\text{early}} \approx 67.4 \pm 0.5 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

- **Late (distance ladder):** SH0ES-style local ladder: $H_{\text{late}} \approx 73.04 \pm 1.04 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

Under this convention,

$$\left(\frac{H_{\text{late}}}{H_{\text{early}}}\right)_{\text{obs}} = \frac{73.04}{67.4} \approx 1.0836795.$$

Propagating uncertainties assuming independence gives a ratio uncertainty $\sigma_r \approx r\sqrt{(\sigma_{\text{late}}/H_{\text{late}})^2 + (\sigma_{\text{early}}/H_{\text{early}})^2} \approx$ 0.017.

Match metric. The deviation is $|\Delta| \approx 3.46 \times 10^{-4}$, giving

$$\varepsilon_\% \approx 0.032\%, \qquad n_\sigma \approx \frac{3.46 \times 10^{-4}}{0.017} \approx 0.02.$$

Falsifier. This benchmark is falsified if future early-vs-late determinations converge in a way that makes the ratio inconsistent with $13/12$ under the same fixed convention (e.g. if the ratio is driven toward 1 or toward a value differing by more than 1%), or if any redefinition of "early" and "late" required to preserve agreement violates the preregistered convention.

4.5 Summary table (Table 1)

5 Results II: Electroweak Mass Block (Consistency and Partial Predictions)

This section records two closely related topics: (i) a structural electroweak mass relation that is a Standard Model identity once the weak mixing angle is defined, and (ii) the current status of the Higgs mass within RS, including the "$125 = 5^3$" observation.

5.1 $m_W/m_Z = \cos\theta_W$ (Type C consistency)

Statement and classification. In the Standard Model Higgs mechanism, the tree-level gauge-boson masses satisfy

$$\frac{m_W}{m_Z} = \cos\theta_W. \tag{9}$$

As written, Eq. (9) is a **Type C** claim: it is an identity given the definitions of m_W, m_Z, and θ_W in the same scheme. It is *not* counted as an independent empirical success.

Formal derivation (tree level). Let $v > 0$ be the Higgs vacuum expectation value and $g, g' > 0$ the $SU(2)_L$ and $U(1)_Y$ gauge couplings. The Higgs mechanism yields the mass relations

$$m_W = \frac{gv}{2}, \qquad m_Z = \frac{v}{2}\sqrt{g^2 + g'^2}. \tag{10}$$

Define the weak mixing angle θ_W by

$$\cos\theta_W := \frac{g}{\sqrt{g^2 + g'^2}}, \qquad \sin\theta_W := \frac{g'}{\sqrt{g^2 + g'^2}}. \tag{11}$$

Dividing the two relations in (10) gives

$$\frac{m_W}{m_Z} = \frac{gv/2}{(v/2)\sqrt{g^2 + g'^2}} = \frac{g}{\sqrt{g^2 + g'^2}} = \cos\theta_W,$$

which is Eq. (9).

Using an RS θ_W benchmark. If RS supplies an independent benchmark for $\sin^2\theta_W$ (as in C-004), then Eq. (9) becomes a derived ratio prediction *conditional on that benchmark*. Using $\sin^2\theta_W = 3/13$, we obtain

$$\cos\theta_W = \sqrt{1 - \sin^2\theta_W} = \sqrt{\frac{10}{13}} \approx 0.87706.$$

The PDG mass ratio from the illustrative values $m_W \approx 80.3692$ GeV and $m_Z \approx 91.1876$ GeV is

$$\left(\frac{m_W}{m_Z}\right)_{\text{obs}} \approx 0.88136,$$

corresponding to a percent difference of order 0.5%. This comparison is *not* treated as an additional independent confirmation beyond C-004; it is recorded as a sanity check that the benchmark is in the correct ballpark at the tree-level identity.

Falsifier (consistency-level). As a Type C identity, Eq. (9) is falsified only by a failure of the electroweak gauge structure itself. Conditional on C-004, a meaningful RS falsifier would require a concrete RS model of scheme/radiative corrections; absent that, we do not treat small percent-level residuals as decisive.

5.2 Higgs mass status (P-017): m_H as a pattern vs. a prediction

What would constitute a Type P Higgs prediction. In the Standard Model,

$$m_H^2 = 2\lambda v^2, \tag{12}$$

where $v \approx 246$ GeV is the Higgs vacuum expectation value and λ is the Higgs self-coupling. A parameter-free RS prediction of m_H would therefore require RS to fix *both* the electroweak scale v and the dimensionless coupling λ (or an equivalent mass scale) without importing m_H itself.

Section 2.2 provides an RS-motivated dimensionless quantity: the curvature of the unique cost functional at the privileged fixed point,

$$J''(\varphi) = \frac{1}{\varphi^3} \approx 0.236.$$

This suggests (at most) that a dimensionless coupling in a symmetry-breaking potential could scale like $\lambda \propto 1/\varphi^3$, but *the proportionality constant and the mapping to the electroweak scale are not fixed in this paper.* Consequently, we do not claim a Type P RS prediction for m_H here.

Classification used in this paper. We record P-017 as a **Type E (extension/pattern)** item: it is a notable numerical and structural coincidence that may guide further RS development, but it is not counted among the independent A-tier predictions.

The "$125 = 5^3$" observation. The measured Higgs mass is

$$m_H \approx 125.25 \pm 0.11 \text{ GeV}.$$

The cube of the Fibonacci number 5 is $5^3 = 125$. The relative deviation is

$$\varepsilon_\% = 100 \times \frac{|125.25 - 125|}{125.25} \approx 0.20\%.$$

We emphasize: this is a *pattern observation*, not a derivation. Its relevance is that RS frequently singles out small integers and Fibonacci/φ-related structures; 5 is the Fibonacci index at which such structures become ubiquitous in planar and quasicrystalline geometry.

Additional electroweak ratios (context only). Two dimensionless ratios often discussed in RS contexts are:

$$\frac{m_H}{m_W} \approx \frac{125.25}{80.3692} \approx 1.558, \qquad \frac{m_H}{v} \approx \frac{125.25}{246.22} \approx 0.509.$$

The first is within a few percent of $\varphi \approx 1.618$; the second is close to $1/2$. In this paper these are reported as descriptive structure, not as independent predictions.

Falsifier (future Type P commitment). Once RS supplies a parameter-free mapping that fixes λ (or an equivalent dimensionless coupling) and v from ledger geometry, P-017 becomes a genuine Type P target and is immediately falsifiable by mismatch with the measured Higgs mass and its uncertainty. Until that mapping is specified, we treat P-017 strictly as Type E.

6 Results III: Cross-Domain Extensions (Type E; Supplement-first)

This section records cross-domain regularities that appear to echo RS motifs (small integers, φ-scaling, and 8-tick structure). These items are **explicitly labeled Type E** because they typically involve modeling choices ("proxies") that are not yet fixed by the core RS forcing chain. They are included to memorialize empirical patterns, to propose mechanistic hypotheses, and to identify concrete next steps that could promote selected items to Type P status in future work.

6.1 Biology

B-010: Genetic code compression (64 codons → 20 amino acids)

Observation. The canonical genetic code maps 64 triplet codons (from a 4-letter nucleotide alphabet) onto approximately 20 amino acids plus stop signals. The raw redundancy ratio is therefore

$$R_{\text{code}} := \frac{64}{20} = 3.2. \tag{13}$$

RS-motivated compression hypotheses suggest that low-cost encodings tend to align with low-complexity φ-scaled ratios. The simplest such candidate is 2φ:

$$2\varphi = 2 \cdot \frac{1 + \sqrt{5}}{2} = 1 + \sqrt{5} \approx 3.2360679. \tag{14}$$

Comparing (13) to (14) yields a relative discrepancy $\varepsilon_\% \approx 1.1\%$.

Derived vs. chosen proxy.

- **Derived (structural):** $64 = 4^3$ arises from a 4-letter alphabet and a triplet code; 2φ is a low-complexity RS primitive once φ is fixed by T7.

- **Chosen proxy:** interpreting $R_{\text{code}} = 64/20$ as the relevant scalar "compression objective" (rather than, e.g., 61/20, inclusion of stop codons, degeneracy structure, or error-correcting capacity) is a modeling choice.

Classification and falsifier. We classify B-010 as **Type E**. A future upgrade to Type P would require RS to specify a unique objective functional on genetic-code space whose minimizer forces a φ-related redundancy, and to do so without selecting the target ratio post-hoc. A falsifier would then be a predicted redundancy (or degeneracy spectrum) that disagrees with observed code statistics across organisms, including known code variants (e.g. mitochondrial codes).

B-013: ATP hydrolysis energy scaling (proxy quantization)

Observation and chosen ratio. A commonly quoted biochemical free-energy release for ATP hydrolysis under standard biochemical conditions is on the order of $\Delta G \sim 30.5$ kJ/mol. Converting to an energy per molecule in eV using $1\,\text{eV} \approx 96.485$ kJ/mol gives

$$E_{\text{ATP}} \approx \frac{30.5}{96.485} \text{ eV} \approx 0.316 \text{ eV}. \tag{15}$$

As an RS-motivated proxy, we compare E_{ATP} to the φ-scaled energy unit

$$E_\star := \varphi^{-3} \text{ eV} \approx 0.236 \text{ eV}. \tag{16}$$

The resulting dimensionless ratio is

$$\frac{E_{\text{ATP}}}{E_\star} \approx \frac{0.316}{0.236} \approx 1.339. \tag{17}$$

Notably,

$$\varphi^{3/5} \approx 1.3347, \tag{18}$$

so the ratio (17) is within $\sim 0.3\%$ of $\varphi^{3/5}$.

Derived vs. chosen proxy.

- **Derived (structural):** φ is fixed by T7; φ^{-3} is a canonical low-complexity ladder element.

- **Chosen proxy (modeling degrees of freedom):** the selection of (i) a representative biochemical ΔG value (it varies with conditions), (ii) the comparison unit $E_\star = \varphi^{-3}\,\text{eV}$, and (iii) the low-denominator exponent 3/5 as a "simple" representation of the implied φ-exponent are modeling choices.

Classification and falsifier. We classify B-013 as **Type E**. To become Type P, RS would need to derive a unique biochemical energy quantum (or a bounded interval) from ledger dynamics and to specify the relevant thermodynamic conditions under which the comparison is meaningful. A falsifier would be an RS-derived energy scale that is incompatible with ATP hydrolysis (and related nucleotide triphosphates) across a range of physiological conditions.

6.2 Neuroscience and cognition

NS-007: Miller's law (7±2) as an 8-tick "observer slot" constraint

Observation. In classic cognitive psychology, short-term/working memory capacity is often summarized as "7 ± 2" items (Miller's law), with substantial task- and training-dependence through chunking.

RS-motivated framing (exact integer core). RS proposes an 8-tick neutrality cycle (T8). As a minimal interpretive hypothesis, suppose one tick is reserved for meta-cognitive control (an "observer" slot) required to maintain coherence across the cycle. Then the content capacity per cycle is

$$C_{\mathrm{WM}} := 8 - 1 = 7. \tag{19}$$

The "± 2" range is interpreted as variability in effective chunking and synchronization efficiency around the nominal cycle capacity.

Mechanistic hypothesis: nested oscillations. A frequently discussed neurophysiological mechanism for capacity limits is theta–gamma nesting: gamma bursts encode discrete items within a slower theta cycle. Using representative frequencies (gamma ~ 40 Hz, theta ~ 6 Hz) gives

$$\frac{f_\gamma}{f_\theta} \approx \frac{40}{6} \approx 6.67, \tag{20}$$

which is of the correct order to support ~ 7 gamma packets per theta cycle. In RS terms, the 8-tick cycle is hypothesized to manifest at biological time scales via this nested oscillatory organization.

Derived vs. chosen proxy.

- **Derived (structural):** the existence of an 8-tick cycle (T8).

- **Chosen proxy:** allocating exactly one tick to an "observer" process; selecting representative theta/gamma frequencies; and identifying oscillatory nesting as the primary mechanism for item capacity.

Classification and falsifier. We classify NS-007 as **Type E**. A falsifier for the mechanistic component would be a robust, replicated demonstration that working-memory item capacity is not constrained by theta–gamma nesting or any cycle-based multiplexing mechanism. A falsifier for the structural RS mapping would be an RS derivation of 8-tick dynamics that implies a substantially different capacity prediction.

6.3 Condensed matter

Curie temperature ratios as φ-scaled structure

Observation. Elemental ferromagnets exhibit characteristic Curie temperatures, e.g. (approximate values):

$$T_C(\mathrm{Fe}) \approx 1043 \text{ K}, \qquad T_C(\mathrm{Co}) \approx 1394 \text{ K}, \qquad T_C(\mathrm{Ni}) \approx 631 \text{ K}.$$

The cobalt-to-iron ratio is

$$\frac{T_C(\mathrm{Co})}{T_C(\mathrm{Fe})} \approx \frac{1394}{1043} \approx 1.3366. \tag{21}$$

This is close to $\varphi^{3/5} \approx 1.3347$ with a relative discrepancy $\sim 0.14\%$.

Derived vs. chosen proxy.

- **Derived (structural):** φ provides a low-complexity scaling ladder.

- **Chosen proxy:** selecting a specific ratio (Co/Fe), using approximate T_C values (which are material- and measurement-dependent), and selecting the low-denominator exponent 3/5.

Classification and falsifier. We classify this as **Type E**. A future Type P version would require RS to derive (i) which materials define the canonical comparison class, (ii) which thermodynamic definition of T_C is the correct one for the ledger mapping, and (iii) why the exponent 3/5 is forced rather than fit.

HCP c/a ratio and proximity to φ

Observation. For an ideal close-packed hard-sphere hexagonal lattice, the geometric ratio is

$$\left(\frac{c}{a}\right)_{\text{ideal}} = \sqrt{\frac{8}{3}} \approx 1.63299. \tag{22}$$

The golden ratio is $\varphi \approx 1.61803$, giving a relative separation $\varepsilon_\% \approx 0.92\%$.

Derived vs. chosen proxy.

- **Derived (geometric):** Eq. (22) is a classical packing result.

- **Chosen proxy:** treating proximity of $\sqrt{8/3}$ (or empirical HCP c/a values) to φ as meaningful evidence of RS structure rather than coincidental geometric proximity.

Classification and falsifier. We classify this as **Type E**. A meaningful falsifier would require a sharpened RS claim specifying a distributional prediction for empirical HCP c/a ratios across elements and alloys, including predicted deviations from the ideal value and their correlation with other RS quantities.

7 Robustness and Ablations

This section evaluates how sensitive the headline claims are to dataset versions, anchoring choices, and to the core RS structural motifs φ and the 8-tick cycle. The intent is not to "optimize" agreement, but to make explicit what would have to change in order for the ledger to fail.

7.1 Version robustness (PDG/Planck year sensitivity)

C-005 $(\alpha_s(M_Z) = 2/17)$. The PDG world average for $\alpha_s(M_Z)$ is a long-running global fit that has remained close to ~ 0.118 for many years. Because the RS value $2/17 \approx 0.11765$ is fixed exactly, the question of version robustness reduces to whether future PDG updates move the world average systematically away from this rational. Given the current quoted uncertainty scale ($\sigma \sim 10^{-3}$), the claim would only be threatened by a sustained shift at the few-10^{-3} level (several sigma), not by typical year-to-year drift.

A-009 ($\Omega_\Lambda = 11/16 - \alpha/\pi$). Planck 2018 provides a baseline ΛCDM estimate of Ω_Λ with uncertainty of order 10^{-2}. The RS prediction differs from the Planck 2018 central value by $\sim 5 \times 10^{-4}$, so the comparison is robust to small updates in Planck-like analyses. However, the longer-term risk is conceptual rather than numerical: if future cosmological datasets robustly favor extensions that shift the inferred Ω_Λ (or replace it with evolving dark energy, $w \neq -1$), then the correct comparison object must be explicitly redefined. This is not a loophole: it is an explicit falsification pathway.

C-004 ($\sin^2 \theta_W \approx 3/13$). The dominant "version" sensitivity for the weak mixing parameter is not the calendar year but the *scheme definition*. For example, the on-shell definition $\sin^2 \theta_W^{\mathrm{OS}} := 1 - (m_W/m_Z)^2$ differs substantially from $\sin^2 \theta_W^{\overline{\mathrm{MS}}}(M_Z)$. Accordingly, C-004 should be interpreted as a benchmark for a specified scheme/scale, not as a scheme-invariant identity. Year-to-year updates in the PDG electroweak fit are expected to be subdominant compared to scheme choices and radiative corrections.

A-008 (Hubble-ratio benchmark $13/12$**).** The "Hubble tension" does not define a unique scalar without choosing what counts as an "early" and "late" measurement. The ratio test is therefore *conditionally robust*: it is robust only within the preregistered convention (e.g. Planck-like CMB inference for "early" and SH0ES-like ladder inference for "late"). If alternative late-time determinations shift the late value toward the early value, the ratio will move toward 1 and the $13/12$ benchmark will fail under the same convention. This dataset dependence is intrinsic and is recorded as part of the protocol, not treated as an after-the-fact choice.

7.2 Parameter and anchor sensitivity (including calibration seams)

Dimensionless-first design. The A-tier set was selected to minimize dependence on calibration seams that convert RS-internal units to SI. In particular, C-005 and C-004 are pure rational benchmarks for dimensionless couplings, and A-009 is a dimensionless fraction built from integers, π, and α. As a result, the numerical stability of these claims is dominated by observational uncertainty and scheme conventions rather than by fragile unit conversions.

Sensitivity of A-009 to α. With $\Omega_\Lambda = 11/16 - \alpha/\pi$, the dependence on α is linear:

$$\frac{\partial \Omega_\Lambda}{\partial \alpha} = -\frac{1}{\pi}.$$

The fine-structure constant is known to extremely high precision compared to cosmological parameter uncertainties, so treating α as an external anchor introduces negligible numerical uncertainty at the scale of Planck error bars. The dominant uncertainty is therefore the cosmological inference of Ω_Λ, not the value of α.

Scheme anchors for couplings. $\alpha_s(M_Z)$ and $\sin^2 \theta_W(M_Z)$ are not single numbers independent of convention; they depend on renormalization scheme and scale. This paper treats the scheme/scale declaration as an *anchor* (a choice of comparison object), not a fit parameter. A robust RS account of these quantities should eventually include a principled mapping between ledger geometry and a preferred scheme, or predict scheme-running corrections; until then, the geometric benchmarks should be interpreted at the declared comparison point only.

Cross-domain extension sensitivity. Type E items are typically far more sensitive to proxy choices than the A-tier claims. Examples:

- In B-010, choosing 64/20 versus 61/20 changes the redundancy scalar by $\sim 5\%$.

- In B-013, the biochemical free energy ΔG varies with conditions; changing the assumed hydrolysis energy across a plausible range shifts the inferred eV value and therefore the φ-ratio match.

- In NS-007, the theta and gamma frequency bands are broad; the ratio f_γ / f_θ can vary by tens of percent across tasks, subjects, and measurement choices.

These sensitivities are not defects; they are precisely why these items are labeled Type E pending a unique RS prescription of the relevant proxy.

7.3 Ablations: replacing φ or perturbing the 8-tick cycle

Ablating φ. Many Type E extensions are explicitly φ-based. If φ were replaced by a different constant ψ, then 2φ in B-010 and the φ-ladder scalings in B-013 and CM regularities would generically shift. For example, matching the genetic-code redundancy ratio $64/20 = 3.2$ by a "2ψ" rule would force $\psi = 1.6$. The RS fixed point $\varphi \approx 1.618$ differs by $\sim 1.1\%$, which is precisely the reported mismatch. Thus, the claimed proximity is fragile under replacement of φ, and its persistence is itself an empirical clue about whether φ is privileged.

Ablating the 8-tick. The A-tier cosmology relations (A-009 and A-008) lean heavily on the T8 structure: $8 = 2^3$ supports the cube combinatorics (8 vertices, 12 edges) and the derived counts (e.g. "11 passive edges"). If the neutrality cycle length were $N \neq 8$, the associated hypercube geometry would change. For instance, if $N = 16 = 2^4$ (a 4-cube), the vertex count would be 16 and the edge count would be $4 \cdot 2^3 = 32$; a naive "passive fraction" analog $(32 - 1)/(2 \cdot 16) = 31/32 \approx 0.969$ would be incompatible with $\Omega_\Lambda \approx 0.685$. Thus A-009 functions as a stringent structural test of the 8-tick/cube picture: changing the tick count typically destroys the integer geometry that produces the observed-scale fraction.

Perturbing the tick rather than replacing it. The relevant ablation is not only "8 vs. not 8," but also whether the 8-tick is *dominant* in the dynamics. If the effective cycle were noisy or allowed persistent leakage between ticks, then integer-count predictions tied to exact cube combinatorics would degrade into fuzzy ranges. In that regime the framework would need to predict *distributions* (not exact integers) for observables such as Ω_Λ and the Hubble benchmark ratio, and the ledger would have to be reformulated accordingly. The present work treats the 8-tick as an exact structural feature, making these predictions sharp and falsifiable.

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9 Falsification Roadmap

The strongest argument for RS is not retrospective matching but a disciplined pipeline of out-of-sample targets with explicit failure criteria. This section enumerates the next high-leverage preregistered targets and specifies what would count as a decisive failure.

9.1 Next high-leverage targets (preregistered)

We preregister the following "Tier 1" targets as the next decisive tests of RS. These are chosen because they are central to the Standard Model/ΛCDM parameter stack and because upcoming data is expected to sharpen their uncertainties substantially.

P-022: CKM matrix elements (quark mixing)

Target. Predict the CKM matrix V_{CKM} (or an equivalent minimal parametrization) in a scheme-consistent way. Operationally we will evaluate one of the following preregistered target sets:

- **Wolfenstein parameters** $(\lambda, A, \bar{\rho}, \bar{\eta})$, or

- **A minimal element set** $(|V_{us}|, |V_{cb}|, |V_{ub}|, |V_{td}|)$ together with a CP-violating measure such as the Jarlskog invariant J_{CKM}.

The choice of which set is used must be fixed at the time the RS closed form is stated, and must be held constant for evaluation.

Reference datasets. Global-fit summaries from PDG (for central values and covariance where available), cross-checked against independent global-fit frameworks (e.g. CKMfitter/UTfit-style analyses).

P-023: PMNS matrix elements (neutrino mixing)

Target. Predict the PMNS mixing angles and (if possible) the leptonic CP phase:

$$\sin^2\theta_{12}, \quad \sin^2\theta_{23}, \quad \sin^2\theta_{13}, \quad \delta_{\mathrm{CP}},$$

and specify whether RS implies normal or inverted mass ordering.

Reference datasets. Global neutrino oscillation fits (NuFIT-style analyses) and the primary-experiment likelihood constraints (reactor, accelerator, atmospheric).

P-024: CP violation parameter(s)

Target. Predict CP violation in at least one sector in a way that cannot be reabsorbed into convention:

- **Quark sector:** the Jarlskog invariant J_{CKM} or an equivalent CP-odd invariant derived from a predicted CKM matrix.

- **Lepton sector:** δ_{CP} (and, if RS extends to Majorana structure, a preregistered prediction for neutrinoless double beta decay observables).

Reference datasets. For quarks: PDG/global unitarity-triangle fits; for leptons: long-baseline accelerator constraints and global-fit posteriors for $\delta_{\rm CP}$.

A-011: CMB anisotropies (shape-level predictions)

Target. Move beyond scalar parameter matches and predict *shape information* in the CMB angular power spectra. To make this falsifiable without requiring a full Boltzmann-code reproduction in this paper, we preregister a summary-statistic target set derived from the spectra:

- the acoustic angular scale ℓ_A (or equivalently the first-peak position ℓ_1),

- ratios of peak positions ℓ_2/ℓ_1, ℓ_3/ℓ_1,

- ratios of peak heights C_{ℓ_2}/C_{ℓ_1}, C_{ℓ_3}/C_{ℓ_1},

- a damping-tail slope proxy from a fixed high-ℓ window.

RS must provide explicit closed forms (or a finite-parameter-free construction) for these summary statistics in terms of derived RS primitives and preregistered anchors.

Reference datasets. Planck 2018 TT/TE/EE spectra as baseline, with future cross-checks from next-generation CMB surveys.

A-012: Big Bang nucleosynthesis (BBN) yields

Target. Predict primordial light-element abundances (at minimum):

$$Y_p \text{ (He-4 mass fraction)}, \qquad \text{D/H}, \qquad \text{and one additional yield (e.g. Li-7/H).}$$

RS must specify the baryon-density input it implies (or derive it), and whether the prediction is a direct RS output or RS+standard-nuclear-network output under preregistered nuclear-rate inputs.

Reference datasets. Primordial abundance measurements from metal-poor systems (He-4), quasar absorption systems (D/H), and corresponding community-accepted compilations, cross-checked against CMB-inferred baryon density.

Remaining Tier 1 unifications

Targets. We also preregister the following as Tier-1-but-longer-horizon commitments:

- **Higgs self-coupling** λ (distinct from the Higgs mass; see Eq. (12)),

- **Absolute neutrino mass scale** (e.g. via m_β and Σm_ν),

- **Baryon asymmetry** η_B or an RS-derived baryogenesis mechanism tied to CP structure,

- **Dark energy equation of state** w (test of strict $w = -1$ vs evolving dark energy).

9.2 Concrete falsifiers

For each preregistered target, RS is falsified if the final closed form (as stated prior to looking at the comparison outcome under the preregistered protocol) violates the following thresholds.

Matrix targets (CKM/PMNS). When a covariance matrix is available from the reference fit, we will compute a chi-square:

$$\chi^2 = (x_{\mathrm{pred}} - x_{\mathrm{obs}})^\top \Sigma^{-1} (x_{\mathrm{pred}} - x_{\mathrm{obs}}),$$

and declare failure if χ^2 exceeds the 99% quantile for the corresponding degrees of freedom. When only per-parameter uncertainties are available, we will use the conservative rule:

- **Fail** if any preregistered element/parameter deviates by $> 3\sigma$ *and* the deviation persists across at least two independent fit frameworks or datasets.

CP violation. For J_{CKM} (or an equivalent invariant), we treat it as a scalar target and apply the 3σ failure rule above. For δ_{CP}, because current uncertainties can be broad and non-Gaussian, we preregister a robust criterion:

- **Fail** if the RS-predicted interval (or point value with stated tolerance) has posterior probability $< 1\%$ under the global-fit posterior at the time of evaluation.

CMB anisotropy summary statistics. For each preregistered summary statistic (peak positions/heights/damping proxy), we will use $\varepsilon_\%$ and n_σ when uncertainties are supplied. We declare:

- **Fail** if any two independent summary statistics differ by $> 3\sigma$, or if the overall summary-statistic chi-square exceeds the 99% quantile.

This "two-strike" rule prevents declaring failure from a single potentially mis-modeled proxy while still making the prediction sharply falsifiable.

BBN yields. For Y_p and D/H we apply the 3σ rule against observational compilations, with the added requirement that the assumed nuclear rates and baryon-density input be preregistered and fixed. For Li-7/H (given known systematic tensions in the "lithium problem"), we will treat the claim as falsified if RS both (i) predicts standard-network Li-7/H and (ii) does not provide an explicit mechanism for depletion or observational bias while still matching D/H and Y_p.

9.3 Timeline: what will decide what, and when

The roadmap above interacts with real experimental schedules. We therefore group the next tests by expected decision horizon, using broad windows rather than single dates.

Near-term (2026–2029).

- **CKM refinements:** continued improvements from B-factories and hadron experiments, together with lattice-QCD improvements that reduce hadronic uncertainties in $|V_{cb}|$, $|V_{ub}|$, and unitarity-triangle constraints.

- **Neutrino ordering:** medium-baseline reactor and atmospheric analyses are expected to sharpen the normal vs inverted ordering question.

- **BBN cross-checks:** additional high-quality D/H measurements and helium-systematics reductions in metal-poor systems.

Medium-term (late 2020s–early 2030s).

- **Leptonic CP phase:** next-generation long-baseline neutrino experiments are expected to substantially sharpen constraints on δ_{CP}.

- **CMB anisotropy improvements:** next-generation CMB surveys (ground-based and satellite) will refine peak/damping-tail measurements and polarization systematics, tightening summary-statistic uncertainties used in A-011.

Longer-term (2030s).

- **Higgs self-coupling:** high-luminosity collider programs are expected to improve direct constraints on the Higgs self-interaction λ, enabling a genuine Type P test once RS supplies a parameter-free λ prediction.

- **Absolute neutrino mass scale:** combinations of beta-decay endpoint experiments, cosmological constraints on Σm_ν, and neutrinoless double beta decay (if neutrinos are Majorana) will progressively close the allowed region.

The guiding principle is that RS should "front-load" the highest-leverage targets: CKM/PMNS/CP and CMB/BBN. These represent stringent, multi-parameter tests where post-hoc fitting is difficult and where independent experimental programs will continue to tighten uncertainties.

10 Discussion

10.1 Unifying motifs: recurring integers and the φ-ladder

One of the striking features of the A-tier ledger is that the closed forms are dominated by a small set of integers and one irrational constant:

$$8, \ 11, \ 12, \ 13, \ 16, \ 17, \ \varphi.$$

These are not arbitrary numerology in the RS framing; they have specific structural meanings:

- **8** arises as the minimal neutrality cycle (T8) and as the vertex count of the 3-cube Q_3 via $8 = 2^3$.

- **12** is the edge count of Q_3, supporting the "static" ledger picture.

- **13** appears as "12 edges + 1" in the "dynamic" ledger picture (including a time-like degree), and enters the Hubble-ratio benchmark 13/12 and the electroweak benchmark 3/13.

- **11** appears as "12–1" when distinguishing one active edge channel from the passive complement, producing the base fraction 11/16 in A-009.

- **16** appears as $2 \cdot 8$, a doubling of the 8-tick structure in the same A-009 denominator.

- **17** appears as a rigid classification count: the number of wallpaper groups, used in C-005.

- φ appears as the unique positive self-similar fixed point (T7) and provides a "ladder" of low-complexity scalings φ^n and $\varphi^{p/q}$ that recur in the Type E extensions and in RS-internal scaling heuristics.

The combination of (i) hypercube combinatorics (8,12), (ii) dynamic augmentation (13), (iii) complements (11), and (iv) planar classification (17), suggests that a large fraction of the parameter stack might be interpretable as geometry and symmetry *counts* rather than as continuous free parameters.

10.2 Why symmetry counts might map to couplings (without overclaiming)

In effective field theory, couplings encode the strength of interactions after integrating out unobserved degrees of freedom. In RS, the analogous objects are "recognition channels" that must maintain coherence under composition, with cost controlled by J. A natural hypothesis is: *the effective strength of a channel is inversely related to the density of distinct symmetry classes that can realize that channel.*

This hypothesis is plausible but not automatically true. The main reasons it is attractive are:

1. **Rigidity:** symmetry counts (e.g. wallpaper groups) are discrete and cannot be tuned continuously, producing sharp predictions.

2. **Universality:** symmetry classifications are independent of microscopic details and depend only on global constraints (periodicity, dimensionality), matching the RS emphasis on ledger-level universality.

3. **Coarse-graining intuition:** if an interaction is realized by a family of equivalent microconfigurations, then the effective coupling can scale like the reciprocal of the number (or measure) of those configurations, analogous to entropic factors in statistical mechanics.

However, mapping a particular symmetry count to a particular renormalized coupling requires more than analogy: it requires an explicit RS-to-QFT bridge that specifies how ledger channels correspond to renormalization schemes and how running effects appear. For this reason, this paper treats symmetry-count claims as benchmarks with explicit falsifiers, not as final mechanistic explanations.

10.3 Relation to standard frameworks: SM/ΛCDM as effective limits

RS is not intended to discard the Standard Model or ΛCDM; rather, it proposes that these frameworks are *effective limits* of a deeper discrete recognition dynamics. On this view:

- The Standard Model remains the correct low-energy effective theory for gauge interactions and particle content, but RS aims to reduce the number of externally supplied parameters by deriving couplings, mixings, and mass ratios from ledger geometry.

- ΛCDM remains the correct coarse-grained cosmological model for current data, but RS aims to explain why the inferred fractions (e.g. Ω_Λ) take the values they do, and why certain tensions (e.g. early/late H_0) might reflect distinct ledger regimes.

In particular, RS makes two pragmatic contributions even if one remains agnostic about the framework's ultimate correctness:

1. It offers a disciplined *prediction ledger* with explicit dependency accounting and falsifiers, which can be used to test any proposed parameter-reduction scheme.

2. It identifies a small number of high-leverage next targets (CKM/PMNS/CP, CMB/BBN) that would quickly distinguish genuine derivation structure from flexible pattern matching.

11 Conclusion

We have presented Recognition Science as a prediction ledger: a stand-alone, formally stated catalog of closed-form targets, together with conservative comparison protocols and explicit falsifiers. The A-tier results emphasize unusually simple rational/integer structures in dimensionless observables, including $\sin^2 \theta_W \approx 3/13$, $\alpha_s(M_Z) = 2/17$, $\Omega_\Lambda = 11/16 - \alpha/\pi$, and the benchmark $H_{\text{late}}/H_{\text{early}} = 13/12$. We also documented cross-domain extensions (biology, cognition, condensed matter) as Type E items, explicitly separating derived structure from proxy choices.

The primary scientific value of this paper is not the existence of coincidences, but the construction of a falsifiable workflow: each claim is stated explicitly, its dependencies are recorded, and its failure conditions are spelled out. The most important next step is to convert the falsification roadmap into prospective preregistered evaluations, focusing on high-leverage targets where post-hoc flexibility is minimal: CKM/PMNS structure and CP violation in particle physics, and shape-level CMB/BBN predictions in cosmology.

If RS is correct, these next targets should collapse toward simple closed forms with minimal degrees of freedom. If RS is not correct, the ledger provides a clear mechanism for failure: a small number of decisive out-of-sample tests will break the framework without ambiguity.

A   Appendix A: Preregistration Rules and Claim Taxonomy

This appendix formalizes the rules used to define, version, and interpret ledger claims in a way that minimizes leakage and look-elsewhere effects.

A.1   Claim taxonomy (Types P, C, E)

Definition 7 (Type P: Prediction). *A claim is **Type P** if it specifies a closed-form target x_{pred} for an observable x such that:*

1. *the specification contains no per-observable tunable parameter chosen after inspecting x_{obs};*

2. *all non-integer inputs are declared in advance as shared anchors (scheme conventions, global constants) and are not adjusted to optimize the match; and*

3. *the protocol defines the comparison dataset and metric/threshold prior to evaluation.*

Definition 8 (Type C: Consistency). *A claim is **Type C** if it is an identity or compatibility check within an established effective framework (e.g. a tree-level relation that holds given definitions), and therefore does not constitute independent empirical evidence.*

Definition 9 (Type E: Extension). *A claim is **Type E** if it maps RS motifs into another domain using a proxy that is not uniquely fixed by RS (e.g. a chosen scalar summary of a complex phenomenon). Type E items may be informative, but are not counted as confirmations unless promoted to Type P via a unique RS prescription.*

A.2   Preregistration rules

We treat preregistration as a versioned protocol. For each claim ID, the preregistration consists of a triple (Spec, Proto, Rec) as defined in Section 3.1. The governing rules are:

1. **R1 (ID stability).** Each claim has a stable identifier. If either the specification or protocol changes materially, the claim must be issued under a new identifier or explicit version suffix (e.g. C-004v2).

2. **R2 (Protocol completeness).** The protocol must declare: (i) the comparison dataset source and version, (ii) any scheme/scale conventions, (iii) the match metric, and (iv) the acceptance threshold.

3. **R3 (No leakage).** The observed value x_{obs} of the target may not be used to choose integers, exponents, tolerances, or proxy definitions that determine x_{pred}. Any dependence on external constants (e.g. α) must be explicitly declared as anchored.

4. **R4 (Report all attempts).** Any preregistered claim that is attempted must be reported, including failures and partials; selective reporting is disallowed.

5. **R5 (No p-values without a search model).** Numerical match quality may be reported as $\varepsilon_\%$ and/or n_σ, but not converted to p-values unless an explicit search distribution over formulas is stated (Appendix D).

A.3   No-leak dependency accounting

Each Type P claim must include an explicit dependency card (Section 3.2) that lists: allowed inputs, forbidden inputs, and the comparison convention. A claim is disallowed if its specification can be reinterpreted as "solve for the parameter from the observed value" (a common failure mode for ratios such as m_W/m_Z when θ_W is not independently predicted).

B   Appendix B: Reproducibility Instructions

This paper is mathematically stand-alone: all formal statements required to interpret the claims are included in the main text. This appendix provides *computational* instructions to reproduce the numerical evaluations and consistency checks used in the comparison tables.

B.1   Pinned reference version

The numerical evaluations reported in the A-tier tables correspond to a pinned reference state of the accompanying repository at commit hash:

$$23\mathrm{d}524\mathrm{f}29.$$

If the paper is distributed without the repository, the same evaluations can be reproduced by reimplementing the short computations described in the Results section (they are elementary).

B.2   Commands (example workflow)

The following is an example minimal workflow from a repository checkout:

```
# (1) Checkout pinned version
git checkout 23d524f29

# (2) Run A-tier validation scripts (all use Python stdlib)
python scripts/analysis/physics_electroweak_bosons.py
```

```
python scripts/analysis/physics_strong_coupling.py
python scripts/analysis/cosmo_dark_energy.py


# (3) Optional: run selected Type E extension checks
python scripts/analysis/bio_genetic_code.py
python scripts/analysis/bio_atp_energy.py
python scripts/analysis/neuro_attention_capacity.py
```

B.3   Artifact paths

The following machine-readable records (JSON) contain the numerical computations used in this paper:

- C-004 / electroweak benchmark suite: `artifacts/physics_electroweak_bosons.json`

- C-005 / strong coupling: `artifacts/physics_strong_coupling.json`

- A-009 and A-008 / dark energy and Hubble ratio checks: `artifacts/cosmo_dark_energy.json`

- B-010 / genetic code proxy checks: `artifacts/bio_genetic_code.json`

- B-013 / ATP proxy checks: `artifacts/bio_atp_energy.json`

- NS-007 / attention capacity proxy checks: `artifacts/neuro_attention_capacity.json`

These artifacts are not required to understand the claims; they provide a deterministic record of how the comparison metrics were computed.

B.4   Compiling this paper

The paper source is `papers/tex/RS_Prediction_Ledger.tex`. A standard LaTeX build is:

```
pdflatex RS_Prediction_Ledger.tex
pdflatex RS_Prediction_Ledger.tex    # second pass for references
```

C   Appendix C: Claim-Card Catalog

This appendix provides one "claim card" per ledger ID appearing in this paper. Each card records: the claim type, closed form (or proxy), key assumptions, dataset convention, and falsifier.

C.1   A-tier Type P claim cards

C-004 (Type P): Electroweak mixing benchmark

Claim. $\sin^2 \theta_W = 3/13$ (Eq. (5)), interpreted as a geometric benchmark in a declared scheme/scale.

Dataset. PDG electroweak summary values (PDG 2024), $\overline{\text{MS}}$ at M_Z.

Metric. Headline: $\varepsilon_\% < 1\%$; context: report n_σ if an uncertainty is used.

Falsifier. Persistent $\varepsilon_\% > 1\%$ in the declared scheme, or an RS correction model that predicts the wrong sign/magnitude residual.

Artifact. `artifacts/physics_electroweak_bosons.json`.

C-005 (Type P): Strong coupling

Claim. $\alpha_s(M_Z) = 2/17$ (Eq. (6)) in the declared scheme/scale.

Dataset. PDG world average for $\alpha_s(M_Z)$ (PDG 2024).

Metric. $n_\sigma < 1$ (primary), $\varepsilon_\%$ reported for intuition.

Falsifier. $|\alpha_s(M_Z)_{\mathrm{obs}} - 2/17| > 3\sigma$ robustly across independent determinations.

Artifact. `artifacts/physics_strong_coupling.json`.

A-009 (Type P): Dark energy fraction

Claim. $\Omega_\Lambda = 11/16 - \alpha/\pi$ (Eq. (7)); α treated as an anchored external constant in this paper.

Dataset. Planck 2018 baseline ΛCDM Ω_Λ.

Metric. $n_\sigma < 1$.

Falsifier. Future cosmological constraints place Ω_Λ outside a 3σ window around the prediction, or require a correction not of α/π form.

Artifact. `artifacts/cosmo_dark_energy.json`.

A-008 (Type P): Hubble-ratio benchmark

Claim. $H_{\mathrm{late}}/H_{\mathrm{early}} = 13/12$ (Eq. (8)) under a declared early/late convention.

Dataset. "Early": Planck 2018 ΛCDM H_0; "Late": SH0ES-style local ladder summary.

Metric. Headline: $\varepsilon_\% < 1\%$; optionally n_σ using propagated ratio uncertainty.

Falsifier. Under the preregistered convention, the observed ratio converges away from $13/12$ (e.g. toward 1) by more than 1%, or a redefinition of early/late is required post-hoc to preserve agreement.

Artifact. `artifacts/cosmo_dark_energy.json`.

C.2 Type C and Type E claim cards

EW-Cons (Type C): $m_W/m_Z = \cos\theta_W$

Claim. $m_W/m_Z = \cos\theta_W$ (Eq. (9)) given definitions (10)–(11).

Dataset. Not applicable (identity); used only for internal consistency.

Falsifier. Failure of the electroweak gauge structure (outside the scope of RS).

Artifact. Not applicable.

P-017 (Type E): Higgs mass patterns

Claim. "$125 \approx 5^3$ GeV" as a pattern; and RS-motivated coupling curvature $J''(\varphi) = 1/\varphi^3$.

Dataset. PDG Higgs mass summary.

Falsifier. Not applicable as Type P until RS fixes v and λ without importing m_H.

Artifact. `artifacts/physics_higgs_mass.json`.

B-010 (Type E): Genetic code redundancy proxy

Claim. $64/20 \approx 2\varphi$ with $\sim 1.1\%$ discrepancy (Eqs. (13)–(14)).

Dataset. Canonical genetic code mapping (64 codons, 20 amino acids).

Falsifier. Promotion to Type P requires an RS-derived objective and unique proxy; otherwise descriptive only.

Artifact. `artifacts/bio_genetic_code.json`.

B-013 (Type E): ATP energy proxy

Claim. $E_{\mathrm{ATP}}/\varphi^{-3}$ close to a low-complexity φ power (Eqs. (15)–(18)).

Dataset. Representative ATP hydrolysis free energy under standard biochemical conditions.

Falsifier. Promotion to Type P requires RS to fix the energy quantum and thermodynamic conditions.

Artifact. `artifacts/bio_atp_energy.json`.

NS-007 (Type E): Working-memory capacity proxy

Claim. $7 = 8 - 1$ "observer slot" framing plus theta–gamma nesting proxy (Eqs. (19)–(20)).

Dataset. Cognitive psychology capacity studies; representative oscillatory bands.

Falsifier. Robust evidence against cycle-based multiplexing constraints; or RS derivation implying a different capacity.

Artifact. `artifacts/neuro_attention_capacity.json`.

CM-010 (Type E): Curie-temperature ratio proxy

Claim. $T_C(\mathrm{Co})/T_C(\mathrm{Fe})$ close to $\varphi^{3/5}$ (Eq. (21)).

Dataset. Representative elemental Curie temperatures.

Falsifier. Promotion to Type P requires RS to fix material class and exponent without fit.

Artifact. `artifacts/condensed_ferromagnetism.json`.

CM-001 (Type E): HCP c/a proximity proxy

Claim. $\sqrt{8/3}$ is within $\sim 1\%$ of φ (Eq. (22)).

Dataset. Ideal packing geometry; empirical HCP values vary by material.

Falsifier. Promotion requires distributional prediction for empirical c/a deviations.

Artifact. Not applicable (geometric identity).

C.3 Preregistered future claim cards (specification pending)

The following IDs are preregistered as next high-leverage targets (Section 9.1). They are not yet assigned final closed forms in this paper; the preregistration commitment is that the closed forms and protocols will be stated *before* evaluation under the rules of Appendix A.2.

- P-022 (CKM), P-023 (PMNS), P-024 (CP),

- A-011 (CMB summary statistics), A-012 (BBN yields).

D Appendix D: Statistical Hygiene and Multiple Comparisons

This appendix expands the statistical interpretation policy introduced in Section 3.4. The central point is that "surprising" numerical agreement cannot be translated into rigorous significance statements without modeling the search process that generated the candidate formulas.

D.1 Why p-values are not reported

If one searches over a large family of candidate expressions (integers, rational combinations, φ-powers, etc.) until a match is found, the probability of finding a match at the "0.1%" level can be large even when the theory has no predictive content. Without an explicit prior over formulas and a documented search strategy, p-values are therefore misleading.

D.2 What is reported instead

We report:

- $\varepsilon_\%$ (relative error) as a scale-free descriptive measure;

- n_σ when the reference dataset supplies a stable uncertainty model;

- explicit falsifiers, which are more informative than retrospective significance claims.

D.3 Portfolio logic and out-of-sample priority

The evidential weight of the ledger is intended to come from:

1. a *portfolio* of independent Type P claims with minimal degrees of freedom, and

2. prospective out-of-sample predictions evaluated under preregistered protocols.

In this framing, the most important "statistical test" is forward performance on new, independent targets (Section 9.1), not the retrospective rarity of any single coincidence.

D.4   A practical error-control recommendation

If the ledger grows to many Type P claims with independent uncertainty models, then one can apply standard multiple-testing controls (e.g. family-wise error control or false discovery rate control), but only after the hypothesis space is frozen and the claims are evaluated prospectively. Until that stage, the conservative policy is to treat matches as motivating and falsifiers as decisive.