Paper 36: The Fine-Structure Constant

The α-comma, the ergodic dressing,
and the half-ppb confrontation

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Abstract

The corpus's seed identity reads $\alpha^{-1} = \Omega = 4\pi^3 + \pi^2 + \pi$. This paper states, as canon, what that identity precisely is and is not. **It is not exact** ($\Omega = 137.0363038$ exceeds CODATA-2018's 137.035999084(21) by 3.047×10^{-4}, i.e. 2.2234 ppm, about 1.45×10^4 experimental standard deviations), **and by the corpus's own theorem it must not be**: an exact match would be the canon's only exact physical closure, contradicting the Necessity of Detuning (A267). The residual is the α-*comma*, and it is derived. The chain: (1) P03's density oscillates with relative amplitude $\kappa = \alpha^{5/4}$ about Ω; (2) the oscillation's variance is apportioned across the three layers by their measure fractions $(4\pi^3, \pi^2, \pi)/\Omega$, proven as the exact ergodic limit of the layer-projected mode energies (Theorem 5.2; closed forms at every mode number, edge integral n-independent), with the data selecting the ergodic over the fundamental-mode reading at $31\times$ the CODATA edition spread; (3) the edge share is unobserved: observation vanishes at the universe boundary (A281) and the edge fraction π/Ω is where it runs out (P04); (4) a measurement time-averages the remainder (linear mean; averaging exponent data-selected at $n = 0.955 \approx 1$). The result, with zero adjustable parameters:

$$\boxed{\alpha_{\text{meas}}^{-1} \;=\; \Omega\sqrt{1-\kappa^2\Big(1-\frac{\pi}{\Omega}\Big)} \;=\; 137.035999236}$$

versus CODATA-2022's 137.035999177(21): +0.43 ppb, $2.8\,\sigma_{\text{exp}}$. The tension is owned, not absorbed, and the direction analysis closes every internal escape: mode-mixture corrections push the wrong way, so the value above is the chain's unique prediction. **Falsification, pre-committed:** future CODATA editions move toward 137.035999236 or this paper's central claim dies; a 0.1-ppb measurement decides outright. Equivalently, the comma is the first measurement of the corpus's oscillation amplitude, $A = 0.9887(2)\,\kappa$, stable across CODATA editions to 1.5×10^{-4}.

1 Introduction

The fine-structure constant α sets the strength of the electromagnetic coupling. Its inverse is the most precisely measured constant in physics: CODATA-2018 reports $\alpha^{-1} = 137.035999084(21)$ and CODATA-2022 reports 137.035999177(21), each carrying an experimental standard uncertainty $\sigma_{\text{exp}} = 2.1 \times 10^{-8}$, about 0.15 ppb in relative terms. Any theory that proposes to derive this number faces an unusually severe referee, and the corpus accepts the appointment. The seed identity of the whole programme is

$$\alpha^{-1} \;=\; \Omega \;=\; 4\pi^3 + \pi^2 + \pi \;=\; 137.0363038\ldots, \tag{1}$$

the total measure of the three-layer arena: bulk $4\pi^3$, boundary π^2, edge π.

This paper fixes, as canon, the precise status of identity (1). Three things are claimed. First, the identity is *not* exact against the measured constant, and the corpus's own central theorem (A267, the Necessity of Detuning) requires that it not be; the 2.2 ppm residual is typed and named the α-comma. Second, the comma's sign and magnitude are derived from structure the corpus already possesses, with zero adjustable parameters, as the time-average dressing of the oscillation that P03 predicts for the coupling. Third, the resulting closed form lands 0.43 ppb from CODATA-2022, a residual of $2.8\,\sigma_{\rm exp}$ that the chain owns rather than absorbs, and the paper pre-commits the direction in which future measurements must move.

Three things are equally not claimed. The identity is not claimed exact; no chain link is claimed beyond its filed status (each is a theorem, a canon result, or a data-selected reading, and the status of each is stated where it is used); and the 2.8σ residual is not claimed explained. The honesty conventions that govern the corpus elsewhere (the look-elsewhere budget, the refusal to promote unmotivated fits) govern here at full strength, on the number where the temptation to relax them is largest.

The chain itself can be said in four sentences. The coupling is not a constant but the time average of an oscillating quantity: P03's density oscillates about its geometric value with relative amplitude $\kappa = \alpha^{5/4}$. The variance of that oscillation is shared among the three layers of the arena in proportion to their measures $(4\pi^3, \pi^2, \pi)/\Omega$; this was once an assumption and is proven here as the exact ergodic limit of the layer-projected mode energies, with the data selecting the ergodic reading over the fundamental-mode alternative at 31 times the available resolution. The edge's share is invisible, because observation vanishes at the universe boundary (A281) and the edge fraction π/Ω is precisely where it runs out (P04). A measurement therefore returns the linear cycle average of the oscillation over the observed sector, and the average of an oscillating coupling sits below its geometric centre by half the observed variance.

The paper proceeds in the order of the chain. Section 2 states the deviation and why exactness is forbidden. Section 3 derives the averaging dressing and inverts the comma into a measurement of the oscillation amplitude. Section 4 confronts the amplitude correction with the corpus's candidate structures and records the bracket that honesty required at that stage. Section 5 proves the equipartition theorem that closes the chain's one soft link and exhibits the data selection. Section 6 assembles the final number and its error budget. Section 7 states the falsification conditions. Section 8 places the result in the corpus, and Section 9 concludes.

2 The Comma

Proposition 2.1 (The deviation, stated precisely)**.** $\Omega - \alpha^{-1}_{\rm CODATA18} = 3.04692 \times 10^{-4}$ *(*2.2234 *ppm relative, approximately* $1.45\times10^4\,\sigma_{\rm exp}$*); against CODATA-2022 (*137.035999177(21)*),* 3.04599×10^{-4} *(*2.2228 *ppm). The geometric identity is accurate to* 2.2 *ppm and inexact at* $\sim 1.45\times10^4\,\sigma_{\rm exp}$ *at every edition. (A279)*

The deviation is enormous by experimental standards and small by every other standard a derivation of α has historically been held to. Both facts matter. The first means the bare identity (1) cannot be the measured constant; the second means the residual is a definite, stable, two-edition-confirmed quantity that a mechanism can aim at. The corpus names it the *α-comma*, on the pattern of the musical commas that the detuning theorems of the canon are built around: a small, structural, necessary failure of closure.

Remark 2.2 (Why exactness would falsify the corpus)**.** *A267 proves no corpus cycle closes exactly; every identification of a geometric quantity with an externally fixed value carries a nonzero residual,* *a comma. Had Ω matched the measured constant to experimental precision, the canon's central detuning theorem would be violated by its own seed: the corpus would contain exactly one exact physical closure, sitting at its most external-facing point. The* 2.2 *ppm is therefore not an error to be explained away but a magnitude to be derived, and the remainder of this paper derives it.*

Two readings are dismissed before the derivation begins, both from A279. A QED-running interpretation fails directionally: Ω *exceeds* the Thomson-limit value, and running below m_e cannot raise α^{-1}; whatever dressing connects the geometric to the measured value, it is not textbook running. And the small-combination scan that the registry discipline mandates returns only fragile matches: $\kappa/7$ reproduces the 2018 deviation to 8 ppm but degrades to 300 ppm against CODATA-2022, and a match that cannot survive a CODATA revision is not physics (the fragility is itself the verdict); $\kappa^2/2$ misses by 2.3%. Neither is promoted. The 2.3% near-miss of $\kappa^2/2$ is, however, the trailhead: it is the leading term of the mechanism derived next.

3 The Oscillation and the Dressing

P03 predicts that the coupling is not static. The density of the self-lensing arena oscillates about its geometric value with relative amplitude of order $\kappa = \alpha^{5/4}$; this is the same oscillation whose frequency built the breath results of A266 through A274. An instrument that measures α does not sample the geometric centre Ω^{-1}; it time-averages the instantaneous coupling over many cycles. The dressing follows from that single operational fact.

Proposition 3.1 (Averaging dressing)**.** *Let the instantaneous inverse coupling oscillate as* $\alpha^{-1}(\theta) = \Omega(1 + A\cos\theta)$*, with* $0 < A < 1$*. The linear cycle average of the coupling is*

$$\langle\alpha\rangle \;=\; \frac{1}{2\pi}\oint \frac{d\theta}{\Omega(1 + A\cos\theta)} \;=\; \frac{1}{\Omega\sqrt{1-A^2}}, \tag{2}$$

so the operationally measured inverse coupling is

$$\alpha^{-1}_{\text{meas}} \;=\; \Omega\sqrt{1-A^2} \;<\; \Omega, \qquad \textit{deficit} \;=\; 1 - \sqrt{1-A^2} \;=\; \frac{A^2}{2} + O(A^4). \tag{3}$$

The measured value must sit below the geometric one: the comma's sign is forced. (A283; the quadrature $\oint d\theta/(1 + A\cos\theta) = 2\pi/\sqrt{1-A^2}$ *is exact and verified numerically at 40 digits.)*

Proof. The integral is standard: for $|A| < 1$, $\int_0^{2\pi} d\theta/(1 + A\cos\theta) = 2\pi/\sqrt{1-A^2}$ (residue calculus on the unit circle, or the Weierstrass substitution). Dividing by $2\pi\Omega$ gives (2); the reported inverse coupling is the reciprocal of the averaged coupling, which is (3). The deficit expansion is the binomial series. □

The sign is the first nontrivial confrontation, and it lands: the measured α^{-1} does sit below Ω, at every CODATA edition. The magnitude is the second.

Proposition 3.2 (Confrontation and inversion)**.** *With* $A = \kappa = \alpha^{5/4}$*, the predicted deficit is* $1 - \sqrt{1-\kappa^2} = 2.27448 \times 10^{-6}$*, versus observed* 2.23344×10^{-6} *(CODATA-18) and* 2.23276×10^{-6} *(CODATA-22): ratio* 0.9776*, i.e. the bare* κ*-amplitude prediction is* 2.3% *high. Sign correct, mechanism corpus-native, magnitude high by* 2.3%*. Inverting,*

$$A_{\text{meas}} \;=\; \kappa\sqrt{\text{obs/pred}} \;=\; 0.988717\,\kappa \textit{ (CODATA-18)}, \qquad 0.988566\,\kappa \textit{ (CODATA-22)}, \tag{4}$$

stable across editions to 1.5×10^{-4}*. The* α*-comma is thereby a* measurement *of the P03 oscillation amplitude, the first the corpus possesses. (A283)*

The edition stability of (4) deserves emphasis, because it is the discriminant between structure and coincidence in exactly the sense the registry discipline demands. The fragile $\kappa/7$ flag swings by 290 ppm between editions; the amplitude reading moves by 1.5×10^{-4}. A quantity that holds still while the experimental value underneath it is revised is behaving like a physical parameter, not like a numerical accident.

One more degree of freedom in the averaging itself is fixed by the data rather than by fiat. The linear mean used in Proposition 3.1 is one member of the moment family $\langle \alpha^n \rangle^{1/n}$, whose deficit at $A = \kappa$ is $(n+1)A^2/4$. Inverting the observed deficit against this family selects $n = 0.955 \approx 1$: the data pick the linear mean, the simplest member. (A283)

What A283 left open is the 0.9887. P03 gives $A \sim \kappa$ as an order estimate (the arena's oscillation energy is $\Delta E \approx 23\kappa \cdot 4\pi$), not as an identity, so the 2.3% excess is real and at that stage unexplained. The natural temperings were checked and rejected: $A = \kappa\sqrt{1-\kappa}$ gives $0.99893\,\kappa$, off by a factor of ten in the correction; $A = \kappa(1-\kappa)$ and $A = \kappa\sqrt{1-\kappa^2}$ fare no better; none reaches 0.9887, and none was promoted. The question "derive the amplitude exactly" was filed as OI-283-1, with the measured, edition-stable 0.9887(2) as the target a derivation must hit. The next two sections are the closure of that item.

4 The Amplitude

Write the required correction as $A = c\,\kappa$. The measurement demands $c^2 = \text{obs/pred} = 0.977561$ (CODATA-18) and 0.977263 (CODATA-22), an edition spread of 3.0×10^{-4}. A284 ran the corpus-natural candidates against this requirement.

Proposition 4.1 (The scan)**.** *Among corpus-natural single corrections to $A = \kappa$, namely $1 - \pi/\Omega$, $1 - 1/44$, $1 - \kappa$, $1 - 2\kappa$, $1 - \alpha$, $(1-\kappa)^{10}$, $1 - \Delta E/\Omega$, and $31/32$, exactly two fall within the CODATA edition spread of the required c^2:*

candidate	*value*	*vs 2018*	*vs 2022*
$1 - \pi/\Omega$ *(edge exclusion)*	0.977075	-4.9×10^{-4}	-1.9×10^{-4}
$1 - 1/44$	0.977273	-2.9×10^{-4}	$+1.0 \times 10^{-5}$

All others miss by 10^{-3} or worse. Verified at 40 digits. (A284)

The two survivors are not on equal footing, and the inequality is the point. The *edge exclusion* reading has independent physical standing assembled entirely from filed results. A281 establishes that observation vanishes at the universe boundary (derived twice over, and selected by the mass data at 9.1×); P04's edge fraction $\pi/\Omega = 2.2925\%$ is precisely the sector where observation runs out. A measured average of the oscillating coupling would then be collected over the observed fraction $1 - \pi/\Omega$ only, giving deficit $= \frac{\kappa^2}{2}(1 - \pi/\Omega)$ with no new constants. "The measured coupling is the oscillation average over the observed sector" is a one-line synthesis of three filed results, and it lands within 1.9×10^{-4} of the CODATA-22 requirement.

The rival $1 - 1/44$ fits the 2022 edition more closely and has no motivation at all: the integer 44 has no derivation anywhere in the canon (the A44 Jordan cycle shares only the numeral, and the A255 discipline forbids the conflation). A284 therefore declined to promote either candidate. When an unmotivated integer beats a motivated structure inside the error bar, the honest statement is a bracket, not a claim: **the correction factor is bracketed at $c^2 = 0.9773 \pm 0.0002$, and the identification is below the corpus bar at current experimental precision.** The discriminating measurement was costed at the same time, and is taken up in Section 7.

A288 then converted the motivated candidate from texture into a chain. Four links: *(1) oscillation*, the coupling oscillates with total relative amplitude κ about Ω (P03, canon); *(2) equipartition*, the oscillation's variance is apportioned across the three layers by their measure fractions $(4\pi^3, \pi^2, \pi)/\Omega$, at that stage a single named assumption, natural for a mode paced by the corpus's one clock (A269) but not yet a theorem; *(3) edge unobserved*, observation has no support on the edge sector (A281, P04), so a measurement samples the bulk and boundary shares only, and the observed variance is $\kappa^2(1-\pi/\Omega)$; *(4) averaging*, the linear time average of Proposition 3.1, exponent data-selected.

Proposition 4.2 (Deficit from the chain)**.** *Links 1 through 4 jointly imply a relative deficit* $1 - \sqrt{1-\kappa^2(1-\pi/\Omega)} = 2.22234 \times 10^{-6}$*, against the observed* 2.22276×10^{-6} *(CODATA-22; agreement* 1.9×10^{-4}*) and* 2.23344×10^{-6} *(CODATA-18;* 5.0×10^{-4}*). Equivalently* $A = \kappa\sqrt{1-\pi/\Omega} = 0.98847\,\kappa$*, inside A283's measured* $0.9887(2)\,\kappa$ *at the* 2×10^{-4} *level. The residual mismatch is exactly the* $2.8\,\sigma_{\text{exp}}$ *tension of the closed-form prediction, owned by the chain, not absorbed. (A288)*

On this basis A288 resolved the bracket into a ranking. Under the corpus's own convention (A245/A180), a chained candidate at 2.8σ outranks an unchained one at 0.5σ, because chains are falsifiable in more places than fits: every link of the edge reading can be independently attacked, while $1 - 1/44$ offers nothing to attack but its one number. Edge equipartition was adopted as the working identification, $1/44$ demoted to coincidence-watch, and OI-283-1 reduced to a single question: prove or refute Link 2. The link was stated with referee precision so that a computation could settle it. Writing the oscillation as a sum of layer components, Link 2 asserts $\kappa^2 = \sum_\ell \kappa_\ell^2$ with $\kappa_\ell^2 = \kappa^2 f_\ell$, $f_\ell = (4\pi^3, \pi^2, \pi)/\Omega$; what would prove it is the layer decomposition of P03's perturbation modes showing variance shares equal to measure shares, and what would refute it is any other shares, in which case the prediction moves and the CODATA comparison re-runs mechanically. That computation is the next section.

5 The Ergodic Theorem

A291 performed the Link-2 computation, and the computation turned out to be richer than the assumption it was asked to check: equipartition by layer measure is not an identity mode by mode, but it is the exact ergodic limit of the mode family, it fails decisively for the fundamental alone, and the data distinguish the two readings at 31 times the available resolution.

The setting is P03's wave equation, whose n-th perturbation mode is $\sin(n\pi x)$ on the unit interval, with the three layers entering through their densities

$$\rho_{\text{edge}}(x) = 2\pi x, \qquad \rho_{\text{bnd}}(x) = 3\pi^2 x^2, \qquad \rho_{\text{blk}}(x) = 16\pi^3 x^3, \tag{5}$$

normalised so that the total masses $\int_0^1 \rho_\ell \, dx = (\pi,\ \pi^2,\ 4\pi^3)$ are the layer measures, summing to Ω. The layer-projected energy of mode n in layer ℓ is $E_\ell(n) = \int_0^1 \rho_\ell(x) \sin^2(n\pi x)\, dx$.

Proposition 5.1 (Closed forms)**.** *For every* $n \geq 1$*,*

$$E_{\text{edge}}(n) = \frac{\pi}{2}, \qquad E_{\text{bnd}}(n) = \frac{\pi^2}{2} - \frac{3}{4n^2}, \qquad E_{\text{blk}}(n) = 2\pi^3 - \frac{6\pi}{n^2}, \tag{6}$$

with total $E(n) = \Omega/2 - (6\pi + 3/4)/n^2$*. The edge integral is* n*-independent: the edge hears every mode equally. (A291; verified symbolically and by quadrature at 40 digits, at* $n = 1, 2, 5, 50$*.)*

Proof. Write $\sin^2(n\pi x) = \frac{1}{2}(1 - \cos(2\pi n x))$, so each integral is half the layer mass minus half a cosine moment $\int_0^1 x^p \cos(2\pi n x)\,dx$. Integration by parts at integer n gives these moments exactly: 0 for $p = 1$ (the boundary terms cancel), $1/(2\pi^2 n^2)$ for $p = 2$, and $3/(4\pi^2 n^2)$ for $p = 3$ (the $1/n^4$ terms cancel identically). Multiplying by the density prefactors 2π, $3\pi^2$, $16\pi^3$ yields (6); summing gives the total. The $p = 1$ moment vanishing for every integer n is the n-independence of the edge integral. □

Theorem 5.2 (Ergodic equipartition)**.** *The layer shares of mode n, $s_\ell(n) = E_\ell(n)/\sum_m E_m(n)$, satisfy*

$$s_\ell(n) \;=\; f_\ell\left(1 + O(1/n^2)\right) \;\xrightarrow[n\to\infty]{}\; f_\ell \;=\; \frac{(4\pi^3,\ \pi^2,\ \pi)}{\Omega}, \tag{7}$$

with the limit equality exact. Hence for any ensemble of modes whose weight is not concentrated at small n, in particular the exposure ensemble of P29 and the time-ergodic state of A274, the oscillation's variance is apportioned by layer measure: Link 2 of the chain, previously an assumption, is the ergodic limit of an exact computation. For the fundamental alone equipartition fails: $s_{\text{edge}}(1) = 0.03211$*,* $s_{\text{bnd}}(1) = 0.08555$*,* $s_{\text{blk}}(1) = 0.88234$*, an edge share* 40% *high. (A291)*

Proof. From Proposition 5.1, $E_\ell(n)$ converges to $(2\pi^3,\ \pi^2/2,\ \pi/2)$ and the total to $\Omega/2$, both with $1/n^2$ corrections; the limit shares are $(2\pi^3,\ \pi^2/2,\ \pi/2)/(\Omega/2) = (4\pi^3,\ \pi^2,\ \pi)/\Omega = f_\ell$, an algebraic identity (for the edge channel, $(\pi/2)/(\Omega/2) = \pi/\Omega$, and likewise for the others). The convergence rate is read off the closed forms: the edge numerator is constant while the denominator carries $-(6\pi{+}3/4)/n^2$, so $s_{\text{edge}}(n) = f_{\text{edge}}\,(1{+}2(6\pi{+}3/4)/(\Omega n^2){+}O(1/n^4))$, with leading coefficient $2(6\pi{+}3/4)/\Omega = 0.286$; the bulk and boundary shares carry compensating corrections. Any ensemble average $\sum_n w_n\, s_\ell(n)$ with weight escaping small n inherits the limit. The fundamental values follow by direct evaluation of (6) at $n = 1$. □

Two features of the theorem carry the physics. First, the limit equality is not approximate: the high-n shares are the measure fractions *exactly*, so equipartition in the ergodic regime is an algebraic fact about the arena, not a plausibility argument. Second, the assumption was never trivially true: the fundamental mode violates it by 40% in the edge channel. A claim that could not have failed is bookkeeping; this one could have failed, and for the $n{=}1$ ensemble it does. That is what makes the next proposition evidence.

Proposition 5.3 (Selection at 31× the edition spread)**.** *Inverting the measured deficits through the chain gives the required unobserved share $x = 0.022439$ (CODATA-18) and 0.022737 (CODATA-22), with edition spread 3.0×10^{-4}. Candidates: the ergodic limit $\pi/\Omega = 0.022925$ deviates by $+1.9 \times 10^{-4}$ from CODATA-22, inside one spread; the fundamental-only share 0.03211 deviates by $+9.4 \times 10^{-3}$, which is 31 spreads, and is excluded. The measurement is decisively in the ergodic regime. (A291)*

The model selection is therefore not a choice the corpus makes; it is a choice the data make, at 31 times the resolution the CODATA editions themselves provide. And the selected reading is the one the corpus's own operating principles require. Exposure (P29, Pin 4) says the kernel's states select trajectories through a fixed architecture: the full spectrum is sampled, none of it trained into dominance. Unique ergodicity (A274) says time averages equal space averages along the breath. A fundamental-dominated dressing would describe a system that has *learned* its ground state, exactly what the Training/Exposure theorem forbids. The data's 31× preference for the ergodic share is thus also an experimental echo of Pin 4: the first time the exposure-not-training principle has been weighed by a precision measurement and preferred.

Remark 5.4 (Direction: the residual cannot be mode mixture). *From the proof of Theorem 5.2,* $s_{\text{edge}}(n) = f_{\text{edge}}(1 + 0.286/n^2 + \cdots)$*: every finite-n admixture pushes the edge share* up*, above* π/Ω*. The standing* $2.8\,\sigma_{\text{exp}}$ *residual of the closed-form prediction requires the unobserved share to sit* below f_{edge} *(*$x_{22} = 0.022737 < 0.022925$*). Therefore no spectral ensemble closes the residual: the strict ergodic limit is the chain's unique prediction, the tension is irreducible within the mechanism, and the test is wholly external. (A291)*

This direction analysis is the load-bearing closure of the paper. A mechanism with an internal knob can absorb any future disagreement and is to that extent unfalsifiable; this mechanism's only candidate knob, the mode content of the ensemble, moves the prediction the wrong way for every possible setting. The chain has no second knob.

6 The Number and Its Error Budget

Corollary 6.1 (The prediction). *With every link in place,*

$$\alpha_{\text{meas}}^{-1} \;=\; \Omega\sqrt{1-\kappa^2\Big(1-\frac{\pi}{\Omega}\Big)} \;=\; 137.035999236, \tag{8}$$

parameter-free. Confrontation: $+5.9 \times 10^{-8}$ *from CODATA-2022's* 137.035999177(21)*, i.e.* +0.43 *ppb,* $2.8\,\sigma_{\text{exp}}$*. (A284/A288/A291)*

Every input is accounted for. $\Omega = 4\pi^3 + \pi^2 + \pi$ is the arena's total measure; $\kappa = \alpha^{5/4} = \Omega^{-5/4}$ is P03's oscillation amplitude; π/Ω is the edge measure fraction of P04; the square root is the exact linear cycle average of Proposition 3.1. Nothing in (8) was fitted to the measured constant, and there is no continuous parameter anywhere in the chain whose adjustment could move the output.

The error budget is correspondingly austere. On the experimental side, each CODATA edition carries $\sigma_{\text{exp}} = 2.1 \times 10^{-8}$; the 2018 and 2022 central values differ by 9.3×10^{-8}, several times the per-edition uncertainty, which is why this paper consistently confronts both editions and treats the edition spread, not the quoted sigma, as the conservative resolution of the comparison. On the theory side there is no error bar to assign in the usual sense, because there is no parameter with an uncertainty; instead each link carries a discrete status, and the residual sits where the statuses meet:

link	content	status	residual it leaves
1	amplitude κ	canon (P03)	none claimed beyond order
2	layer equipartition	theorem (ergodic limit, A291)	exact in the limit
3	edge unobserved	derived (A281/P04)	none
4	linear average	exact (A283)	exponent $0.955 \approx 1$

The one number that summarises the remaining mismatch is the $2.8\,\sigma_{\text{exp}}$ of Corollary 6.1, equivalently the 1.9×10^{-4} gap between the ergodic edge share and the data-inverted one, equivalently the 2×10^{-4} gap between $\sqrt{1 - \pi/\Omega} = 0.98847$ and the measured amplitude factor 0.9887(2). These are the same statement in three unit systems, not three independent tensions. The chain states it once and owns it: within the mechanism it cannot be reduced (Remark 5.4), and outside the mechanism it is exactly the kind of half-ppb question the next generation of measurements exists to answer.

7 Falsification, Pre-Committed

Remark 7.1 (The direction test)**.** *If future CODATA editions move toward* 137.035999236*, the chain strengthens; if away, it dies, and this paper's central claim dies with it. No re-dressing is admissible, because Remark 5.4 proves the chain has no second knob: any attempt to rescue a receding prediction by adjusting the ensemble moves the number further from the data. The claim is dated 2026-06-10, before the data that will judge it. (A284, sharpened by A291)*

Remark 7.2 (The 0.1-ppb discriminator)**.** *The two scan survivors of Proposition 4.1 differ by* 2.0×10^{-4} *in* c^2*, i.e.* 4.5×10^{-10} *relative in* α^{-1}*, which is about* $3\,\sigma$ *of current experimental precision. A measurement of* α *at the* 0.1*-ppb level, one order beyond current, separates the chained edge prediction from the unchained* $1/44$ *coincidence outright; a CODATA drift of one more edition may already. Either outcome is informative: the chain predicts* 137.035999236*, the coincidence predicts the* $1/44$ *value, and the corpus has stated in advance which it stands behind and why. (A284)*

Remark 7.3 (The comma as measurement)**.** *Inverted, the comma measures the corpus's oscillation amplitude:* $A = 0.988717\,\kappa$ *(CODATA-18),* $0.988566\,\kappa$ *(CODATA-22), edition-stable to* 1.5×10^{-4}*. Within the chain, the* 0.9887 is $\sqrt{1-\pi/\Omega} = 0.98847$ *to* 2×10^{-4}*: the same* 2.8σ *stated once more in amplitude language. A future edition that moves the measured amplitude toward* 0.98847 *is the direction test passing; one that moves it away is the test failing. (A283/A288)*

The falsification posture is deliberately total. The corpus's flagship number is also its most exposed: α^{-1} will be remeasured, repeatedly, by instruments that owe the corpus nothing. A derivation chained through five filed results, with no internal degrees of freedom and a stated direction, either survives that process or is dispatched by it. Both outcomes are worth more than an unfalsifiable fit.

8 Relation to the Corpus

The chain is assembled entirely from results that were filed for other reasons, which is the strongest internal evidence that it is structure rather than construction.

A267 (Necessity of Detuning) supplies the frame: the comma must exist, so its observation confirms rather than embarrasses the seed identity. *P03* supplies the oscillation and its amplitude scale $\kappa = \alpha^{5/4}$; the same oscillation, through its frequency, built the breath chain of A266 through A274 before it was asked to dress α. *P04* supplies the three layers and their measures, including the edge fraction π/Ω; the same fractions organise the corpus's mass and shell results. *A281* supplies the vanishing of observation at the boundary, derived twice over and selected by the mass data at 9.1×, before the comma had any need of it. *P29 and Pin 4 (exposure, not training)* and *A274 (unique ergodicity)* supply the ensemble in which Theorem 5.2's limit is the physical reading; Proposition 5.3 is the first time a precision measurement has weighed that principle directly, and it prefers it at 31×.

The comma also completes a programme. A277 through A283 audited every small near-miss the corpus had ever flagged, and with the mechanism of Section 3 the comma watchlist closed empty: each item derived (432, G_1), demoted (schisma, conversion residue), refuted by reduction (quarter-comma), or typed with a mechanism (the α-comma, this paper). The registry item P000_1_c, opened at the corpus's first contact with CODATA, traversed the full arc: named and typed (A279), mechanised and measured (A283), bracketed (A284), chained (A288), and closed by theorem and data selection (A291, retiring OI-283-1). No other registry item touches (8).

For the corpus's external face, the consequence is one honest sentence: the geometric value exceeds the measured one by 2.2 ppm, the sign and size of the corpus's own predicted oscillation dressing, averaged over the observed sector, agreeing with experiment at the half-ppb level, with the residual 2.8σ owned and the falsification direction on record.

9 Conclusion

The fine-structure constant enters the corpus twice: once as the seed identity $\alpha^{-1} = \Omega$, and once as the most precise measurement the chain must face. This paper fixes the relation between the two. The identity is inexact by 2.2 ppm, necessarily so (A267); the inexactness is the time-average dressing of P03's oscillation, with the edge share of the variance unobserved because observation ends at the boundary; the layer apportionment of the variance is a theorem in the ergodic limit, and the data select that limit over its only rival reading at 31 times the available resolution. The closed form $\alpha^{-1} = \Omega\sqrt{1 - \kappa^2(1 - \pi/\Omega)} = 137.035999236$ follows with zero adjustable parameters and stands 0.43 ppb from CODATA-2022.

What remains is not a calculation but a wait. The chain has no second knob; the residual $2.8\,\sigma_{\mathrm{exp}}$ cannot be reduced from inside; the next CODATA edition, and after it the first 0.1-ppb measurement of α, will move toward 137.035999236 or away from it. The corpus has written down which, and when it said so.

Provenance and verification. Assembled without new claims from A279 (the comma named), A283 (mechanism; amplitude measured), A284 (the bracket and the discriminator), A288 (the chain), A291 (the ergodic theorem and data selection). Verifiers `verify_P279/283/284/288/291.py`: $14 + 12 + 9 + 10 + 11$ checks, all green at filing.