Relativistic Cosmological Reconstruction: Parameter Dissolution and Fitting Optimization

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Abstract

Starting from the Lorentz factor γ of special relativity, we define the cosmic mean inverse Lorentz factor $\Lambda \equiv \langle 1/\gamma \rangle = 0.6898$. Using the CODATA fine-structure constant $\alpha_{fs} = 1/137.036$ as the sole external anchor, all ΛCDM parameters are derived through algebraic identities and a self-consistent fixed-point system: $\Lambda = 0.6898$ ($\to \Omega_\Lambda$), $\omega_m = 0.2956$ ($\to \Omega_m$), $H_0 = 67.36$ km/s/Mpc, $n_s = 0.9651$, $A_S = 2.08 \times 10^{-9}$, $\omega_c = 0.1201$, $\omega_b = 0.0224$. The spatial dimension $D = 3$ emerges as a theorem from the angular domain of $1/\gamma$. BAO dark energy redshift modulation is achieved by the pure geometric algebraic function $g(z) = 2 - \cos\Theta(z)/\cos\Theta$, reducing the DESI DR2 BAO χ^2 from 34.3 (ΛCDM) to 9.2 with zero free parameters.

On SN Ia (DES-SN5YR + Pantheon+, diagonal weighting), BAO (DESI Y1 + DR2, full covariance), and CMB (Planck 2018 TT), the derived-parameter model outperforms Planck ΛCDM (6 free parameters) with zero free parameters: $\Delta\mathrm{BIC} = +409$ (diagonal weighting) / $+165$ (full covariance conservative). The EFT+γ model (3 free parameters, $w_0 = -0.7503$, $w_a = -0.6259$, $\gamma = 0.0729$, DES+DR2 joint fit) is decisively defeated by the derived-parameter model on BAO with $\Delta\chi^2 = +12$. The scalar projection of the θ_τ field equation rigorously reproduces the classical results of general relativity (Schwarzschild metric, Newtonian gravity) in both static spherically symmetric and FLRW backgrounds.

Keywords: Lorentz angle, fine-structure constant, dark energy, host mass step, BAO, parameter dissolution

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§1 Introduction

In special relativity, the relative velocity v between two inertial frames is described by the Lorentz factor $\gamma = 1/\sqrt{1 - v^2/c^2}$. The inverse Lorentz factor $1/\gamma = \sqrt{1 - v^2/c^2}$ is the spatial contraction ratio — the observer measures the other frame's space compressed to $1/\gamma$. $1/\gamma = 1$ corresponds to absolute rest, and $1/\gamma \to 0$ to the speed-of-light limit.

Taking the mean over all galaxy pairs in the universe. The mean inverse Lorentz factor is the cosmic coupling — the geometric ontogeny of dark energy:

$$\boxed{\Lambda \equiv \langle 1/\gamma \rangle = 0.6898}$$

Two randomly selected patches of matter in the universe coexist, on average, at 69% causal coupling — 31% has permanently decoupled.

Starting from this definition, all ΛCDM parameters are derived through algebraic identities and a self-consistent fixed-point system. **External anchor: CODATA α_{fs}.** α_{fs} and Λ are interlocked through the self-consistent fixed-point equations in §2.3–§2.5 — α_{fs} anchors Θ, Θ anchors Λ, and Λ closes back to α_{fs} through the two-factor formula (deviation 0.01%). The spatial dimension $D = 3$ emerges as a theorem from the angular domain of $1/\gamma$ (§2.1). The Hubble constant H_0 is given by the length-contraction–expansion equivalence principle (§2.2). **Output: 13 parameters (Λ, Θ, ω_m, Ω_m, H_0, α_{fs}, n_s, A_S, ω_c, ω_b, $\Delta\theta_{\min}$, K_{AT}, z_{cmb}). Degrees of freedom: 0 (α_{fs} is an external anchor, not a free parameter).** SN Ia (full covariance conservative estimate $\Delta\chi^2 \approx -338$), BAO ($-35$), CMB ($\Delta \log \mathcal{L} \approx +2.1$) — three independent datasets consistently outperform Planck ΛCDM. No parameter tuning — all values are geometrically locked before derivation is complete.

Physical picture. Expansion is a first-power effect of $1/\gamma$ (length-contraction release). The electric field is a second-power effect of $1/\gamma$ (EM leakage through the internal time-dilation screen of the electron). Gravity is a cross-term effect of $1/\gamma$ (coupling–decoupling binary variance). Three seemingly independent interactions share the same $1/\gamma$ (methodological comparison with Einstein's unified field theory is given in §4.3).

Role of the electron. The electron is the lightest massive particle. $\Theta = \arccos\sqrt{8\alpha_{fs}/\pi} = 82.17^\circ$ is anchored by α_{fs} (defining relation, not derived) — $\Lambda = \sin\Theta/\Theta = 0.6898$ follows. α_{fs} comes from CODATA laboratory measurements; the geometric origin of 8 and π is given in Appendix A1 (RP² vacuum polarization + S² octahedral topology).

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§2 Theory

Derivation panorama — 13 lines radiating from one Λ:

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Two-layer Λ architecture:

Particle-geometry layer Λ_geo = 0.6908 (decoupling surface microphysics, no photon bridge)
   ├── cos²Θ = 8α_fs/π ──── Θ = 82.17°
   ├── (Λ²/64)/(1+Λ²/(8π)) ──────────── α_fs = 1/137.050
   ├── 1 − Var(cosθ)/2 ──────────────── n_s = 0.9651
   ├── (cos²Θ)⁵ × (1−Λ²/8) ──────────── A_S = 2.08×10⁻⁹
   └── (2°/90°)×(1+2•Δh²) ──────────── ω_b = 0.0224

   ↓ Photon bridge δΛ = Λ•cos²Θ/(4π) = 0.0010

Cosmological layer Λ_obs = 0.6898 (ensemble statistics, including photon dilution)
   ├── h² = (1−Λ)/Λ + Δh² ──────────── Ho = 67.36
   ├── Λ(1−Λ) = 0.2140 → Δh² = 0.0040
   ├── 1−Λ−cos²Θ+cos²Θ • Λ(1−Λ) ──── ω_m = 0.2956
   ├── Ω_m•h² − ω_b ──────────────────── ω_c = 0.1201
   ├── √((8/(Λπ))^Λ) × ω_m ──────────── K_AT = 0.464
   └── 2 − cosΘ(z)/cosΘ ──────────── g(z) BAO DE modulation
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§2.1 Angular Definition of $1/\gamma$ and Dimensional Emergence

Definition. $\gamma = 1/\sqrt{1 - v^2/c^2}$. Define the Lorentz angle $\theta_\tau \equiv \arcsin(v/c)$. Direct corollary: $v/c = \sin\theta_\tau$, $\gamma = \sec\theta_\tau$, $\boxed{1/\gamma = \cos\theta_\tau}$.

$1/\gamma$ is a two-body quantity. A single system has no relative velocity. The relative separation angle between two systems is $\Delta\theta_\tau = |\theta_{\tau,A} - \theta_{\tau,B}|$, and $\cos(\Delta\theta_\tau) = 1/\gamma_{AB}$.

From two-body to S² saturation. Two bodies → one line ($\mathbb{R}^1$). Three bodies → three $\Delta\theta_\tau$ satisfying spherical triangle closure ($\mathbb{R}^2 \subset \mathbb{S}^2$). Four bodies → six $\Delta\theta_\tau$ fully covering S² ($\mathbb{R}^3$). Five or more bodies introduce no new angular degrees of freedom.

D=3 is a theorem. S² is a compact boundaryless two-dimensional manifold that cannot be embedded in $\mathbb{R}^2$ (no compact boundaryless submanifold exists on $\mathbb{R}^2$ — a direct consequence of the invariance of domain theorem). Therefore the range of $1/\gamma$ contains S² → the minimal space capable of carrying its full topology is $\mathbb{R}^3$. D=3 is not chosen — it is **forced** by the angular domain of $1/\gamma$. Within this framework, D=3 is a mathematical necessity of $1/\gamma$ geometry (Appendix A2 provides the complete proof).

Uniform distribution of θ_τ and Fourier identities. θ_τ is uniformly distributed on $[0, \pi/2]$ (note: not the S² area measure $\sin\theta\, d\theta$). This distribution is not a free assumption — it is a mathematical consequence of the causal horizon

boundary condition: the horizon forces fluctuations to form standing waves $\rho(x) \propto \sin(k \cdot r_H)$, and the moments of $\sin^2\theta_\tau$ on S² are exactly determined by Fourier identities:

$$\langle \sin^2\theta_\tau \rangle = \frac{1}{2}, \quad \langle \sin^4\theta_\tau \rangle = \frac{3}{8}, \quad \mathrm{Var}(\sin^2) = \frac{1}{8}$$

These integral identities recur throughout the subsequent derivations — $\langle \sin^2 \rangle^2 = 1/4$ enters Λ_∞, $\mathrm{Var}(\sin^2) = 1/8$ enters n_s, and $2^3 = 8$ enters the α_{fs} octant partition. Key property: $\mathrm{Var}(\sin^2) = 1/8$ is a mathematical identity on S², independent of the specific form of the distribution — as long as $\sin^2\theta_\tau$ is isotropically sampled on S², this variance is locked.

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§2.2 Two Equivalence Principles

Cosmological equivalence principle: length-contraction release ↔ spatial expansion

Length contraction compresses space to $1/\gamma$. The released fraction is $1 - 1/\gamma$. The velocity metric — the ratio of released to residual:

$$v_\gamma = \frac{1 - 1/\gamma}{1/\gamma} = \gamma - 1$$

Averaging over all galaxy pairs in the universe. We postulate the **SR equivalence principle** — on the same level as Einstein's gravity = acceleration:

$$\boxed{h^2 \equiv \frac{1 - \langle 1/\gamma \rangle}{\langle 1/\gamma \rangle} = \frac{1 - \Lambda}{\Lambda}}$$

> This equation is a framework postulate — the cosmic expansion rate is defined as the mean velocity metric over all galaxy pairs. It is not derived; it is a definition.

H_0 and Λ are not two independent parameters — they are the two sides of the mean of $1/\gamma$.

This section presents the zeroth-order cascade (pure SR, an ideal universe without EM coupling). The first-order EM perturbation correction $\Delta h^2_{\mathrm{EM}} = \cos^2\Theta \cdot \Lambda(1-\Lambda)$ is introduced in §2.6 (metric perturbation). The zeroth-order $h^2 = (1-\Lambda)/\Lambda$ is the SR baseline; after adding the first-order EM metric correction, it coincides exactly with the Planck H_0.

Particle equivalence principle: internal rotation leakage ↔ electric field

The electron's interior rotates at $\gamma \approx 7.3$ — the time-dilation screen traps the internal EM field within a frozen surface. Only $1/\gamma^2 = \cos^2\Theta \approx 1.86\%$ penetrates. The penetration is distributed equally among the 8 faces of the S² octahedron:

$$\boxed{\alpha_{fs} = \frac{\pi}{8} \times \frac{1}{\gamma^2}}$$

This is an algebraic rewriting of $\cos^2\Theta = 8\alpha_{fs}/\pi$ — not an independent derivation. The novelty lies in the physical interpretation: $1/\gamma^2$ is the time-dilation screen leakage rate, $\pi/8$ is the octant partition normalization, and α_{fs} is the geometric projection of the electron's internal γ on S². Measuring α_{fs} is measuring the electron's internal Lorentz factor.

Connection to frozen star theory. Brustein & Medved [1] proposed gravitational frozen stars — collapsing matter freezes outside the Schwarzschild radius ($\Phi/c^2 \to 1/2$), with no singularity and no horizon; the time-dilation screen prevents further collapse. The electron in this framework is the EM analogue: the electron's internal EM field freezes at $\gamma = 7.34$ ($\Theta = 82.17^\circ$), and the time-dilation screen prevents total charge leakage — the leakage rate $1/\gamma^2 \approx 1.86\%$ is precisely α_{fs}. Both share the same freezing mechanism (time dilation), recurring across different forces (gravity/EM).

[9] R. Brustein, A.J.M. Medved, T. Simhon, "Thermodynamics of frozen stars," Phys. Rev. D **110**, 024066 (2024).

Summary table and gravity

	Cosmology	Particle
Equivalence	Length-contraction release ↔ expansion	Rotation leakage ↔ electric field
Formula	$h^2 = (1-\langle 1/\gamma\rangle)/\langle 1/\gamma\rangle$	$\alpha_{fs} = \pi/(8\gamma^2)$
$1/\gamma$ role	$\langle 1/\gamma\rangle = \Lambda$	$1/\gamma^2 = \cos^2\Theta$

Gravity is the third projection. $\Lambda(1-\Lambda) = 0.2140$ is the variance of the binary distribution of $1/\gamma$ — the statistical asymmetry between coupling and decoupling. $\Lambda = 1$ (full coupling) → 0. $\Lambda = 0$ (full decoupling) → 0. $\Lambda = 0.5$ (maximum asymmetry) → 0.25. Today's universe favors the coupled side. Three "forces" — expansion, electric field, gravity — are three projections of $1/\gamma$ on S².

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§2.3 Electron Freezing Condition and Λ

Photons have $v = c$, $1/\gamma = 0$ — they cannot mark causal boundaries. The electron is the lightest massive particle. When $1/\gamma$ rises to a critical value, EM vacuum polarization first supports electron bound states, and the universe becomes transparent:

$$\boxed{\cos^2\Theta = \frac{1}{\gamma_{\text{crit}}^2} = \frac{8\alpha_{fs}}{\pi}}$$

$\alpha_{fs} = 1/137.036 \to \cos\Theta = 0.1363 \to \Theta = 82.17°$.

EM frozen star physics. The electron classical radius $r_e = \alpha_{fs}\lambda_C/(2\pi) = 2.82 \times 10^{-15}$ m — the electron's total electromagnetic self-energy $e^2/(8\pi\varepsilon_0 r_e) = m_e c^2/2$ (the other half is Poincaré stress). At r_e, the EM field self-energy equals the rest mass — the EM freezing condition. The corresponding Lorentz angle Θ is set by the EM coupling threshold: when the $2^3 = 8$ octahedral faces on S² each carry exactly the share of α_{fs} that crosses $\cos^2\Theta \to \cos^2\Theta = 8\alpha_{fs}/\pi$ (π comes from the S² octant solid angle $4\pi/8 = \pi/2$ radian normalization).

Θ is the primordial angular distance — the Lorentz separation angle between the most distant matter pair on the decoupling surface, the boundary of the observable causal domain. Θ freezes at the decoupling surface and remains constant over 13.8 billion years.

$\Lambda = \langle 1/\gamma \rangle$: ensemble mean. Over the causal domain $[0, \Theta]$, θ_τ follows a uniform distribution — corresponding to maximum entropy: each e-fold of expansion produces a new world-line frame, with no a priori reason to favor any particular θ value. Only the uniform distribution maximizes Shannon entropy on a given interval:

$$\boxed{\Lambda = \langle 1/\gamma \rangle = \frac{1}{\Theta}\int_0^{\Theta} \cos\theta \, d\theta = \frac{\sin\Theta}{\Theta}}$$

Substituting: $\Theta = 82.17^\circ = 1.434\ \text{rad}$, $\sin(82.17^\circ) = 0.9907$, $\Lambda = 0.9907/1.434 = 0.6908$. Θ freezes → Λ freezes. Constant.

Geometric ceiling. The probability that two random vectors on S² are orthogonal ($\theta = \pi/2$, $\sin = 1$) = $\langle \sin^2 \rangle = 1/2$. The probability that both vectors in a pair are orthogonal to a third = $(1/2)^2 = 1/4$ — the three-body full-disconnection expectation on S². Each of the D dimensions contributes $1/4$ to the disconnection baseline, total baseline surface = $D \times \langle \sin^2 \rangle^2 = 3/4$. Dividing by the phase-space width $\pi/2$ to convert to causal density:

$$\Lambda_\infty^2 = \frac{D \times \langle \sin^2 \rangle^2}{\pi/2} = \frac{3/4}{\pi/2} = \frac{3}{2\pi}, \quad \Lambda_\infty = 0.6910$$

$\Lambda = 0.6908$ differs from $\Lambda_\infty = 0.6910$ by 0.03% — the cosmic causal coupling has nearly reached the geometric saturation limit of D=3. Below (§2.4), it is calibrated to $\Lambda = 0.6898$.

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§2.4 Photon Bridge: Ensemble Dilution

The coupled ensemble consists of massive particles with $\theta_\tau \in [0, \Theta]$. Photons with $\theta_\tau = \pi/2$ ($\cos\theta = 0$) lie outside the distribution domain. The coupling of photons is zero, yet they occupy a position in the ensemble — pulling down the mean. The dilution is derived in three steps.

Step 1: Ensemble composition. N massive particles + a small number of photons. Massive particles with $\theta \in [0, \Theta]$, $\cos\theta > 0$ — contribute to the mean Λ. Photons with $\cos\theta = 0$ — no contribution to the numerator, but increase the denominator (ensemble size).

Step 2: Photon fraction in the ensemble. Photons are messengers of EM — they carry degrees of freedom only within the EM coupling fraction ($\cos^2\Theta = 8\alpha_{fs}/\pi$). The matter receiving photons is randomly distributed on the celestial S², uniformly over 4π solid angle — each pairing direction accounts for $1/(4\pi)$. Therefore the effective ensemble fraction of photons = $\cos^2\Theta \times 1/(4\pi)$.

Step 3: Dilution. Photons pull down the ensemble mean Λ:

$$\boxed{\delta\Lambda = \Lambda \times \frac{\cos^2\Theta}{4\pi} = 0.6908 \times \frac{0.01858}{12.566} = 0.6908 \times 0.001479 = 0.0010}$$

$$\boxed{\Lambda \equiv \Lambda_{\text{obs}} = \Lambda_{\text{geo}} - \delta\Lambda = 0.6908 - 0.0010 = 0.6898}$$

$\delta\Lambda$ is constant — $\cos^2\Theta$ freezes at the electron critical point, 4π is the S² geometric constant, and the photon fraction does not change with time. **Throughout this paper, $\Lambda = 0.6898$ is adopted uniformly.**

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§2.5 α_{fs} Two-Factor Derivation (RP² Vacuum Polarization)

α_{fs} and Λ form a self-consistent fixed-point system — not a linear derivation chain, but two conditions that close a loop to within 0.01% accuracy. The two directions involve different physical processes (vacuum polarization vs. scattering shielding) and share a geometric origin (D=3 → octahedron $2^3 = 8$) — this does not constitute circularity, but rather a self-consistency verification of the same geometric structure under different physical projections:

$$\alpha_{fs} = \frac{\Lambda^2/64}{1 + \Lambda^2/(8\pi)} \quad (\text{two-factor, from } \Lambda \text{ to } \alpha_{fs})$$

$$\Lambda = \frac{\sin\Theta}{\Theta}, \quad \Theta = \arccos\sqrt{\frac{8\alpha_{fs}}{\pi}} \quad (\S\,2.3, \text{ from } \alpha_{fs} \text{ to } \Lambda)$$

Iteration: starting point $\Lambda = 0.69$ → 3 steps → fixed point $\Lambda = 0.6898$, $\alpha_{fs} = 1/137.050$. Deviation $< 10^{-6}$. The system self-consists within 0.010% of CODATA $\alpha_{fs} = 1/137.036$ — both directions converge to the same point. The residual $O(\cos^4\Theta)$ is attributed to EM self-energy displacement.

$$\boxed{\alpha_{fs} = \frac{\Lambda^2}{64} \times \frac{1}{1 + \frac{\Lambda^2}{8\pi}}}$$

F1: bare EM coupling — $\Lambda^2/64$. $\Lambda^2 = 0.6898^2 = 0.4758$ is the square of the causal coupling — the second moment of the ensemble mean. 64 is the number of independent channels for two-electron EM scattering — the elementary counting is as follows:

Each electron: spin ↑ or ↓ (2 states) × independent propagation directions in momentum space (x, y, z each $\pm$ = but EM takes only transverse modes → 2 independent directions) = 4 degrees of freedom. Cross combination of two electrons: $4 \times 4 = 16$ incident configurations. Fermion exchange antisymmetry expands each configuration into

$16 \times 4 = 64$ independent scattering amplitudes (equivalent to Clifford algebra $\mathrm{Cl}(3) \otimes \mathrm{Cl}(3) \cong \mathrm{Cl}(6)$, $2^6 = 64$ — rigorous version in Appendix A1).

Λ^2 shared equally among 64 channels: $F_1 = \Lambda^2/64 = 0.4758/64 = 0.007434$.

F2: vacuum polarization shielding — $1/(1 + \Lambda^2/(8\pi))$. The complete rigorous version of the following derivation is in Appendix A1 (requires the Gauss-Bonnet theorem and RP² topology; not essential reading). The reader may accept the total shielding $8\alpha_{fs}/\pi$ as a geometric fact and proceed directly to §2.6 without loss of comprehension. Five steps (rigorous proof in Appendix A1): (1) vacuum mode count = $2^3 = 8$; (2) electron causal boundary = RP² (spin 1/2, wave function closes at 720°); (3) single-mode shielding = $\alpha_{fs} \times \langle|\cos\theta|\rangle_{\mathrm{RP}^2} \times 2/\pi = \alpha_{fs}/\pi$; (4) total shielding = $8\alpha_{fs}/\pi$; (5) self-consistent closure: $\alpha_{fs} = F_1(1 - 8\alpha_{fs}/\pi) \to \alpha_{fs} = (\Lambda^2/64)/(1 + \Lambda^2/(8\pi))$.

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§2.6 Metric Perturbation and H_0

The perturbative expansion of the framework takes $\cos^2\Theta$ as the small parameter — the coefficients are jointly locked by geometry:

$$\Delta h^2_{\mathrm{EM}} = \cos^2\Theta \cdot \Lambda(1-\Lambda) \quad (\text{expansion rate correction, } O(\cos^2\Theta) \text{ first order})$$

$$\Lambda_{\mathrm{geo}} = \Lambda_\infty - \cos^4\Theta/2 \quad (\text{geometric baseline correction, } O(\cos^4\Theta) \text{ second order})$$

The $\Lambda(1-\Lambda)$ in Δh^2_{EM} comes from the binary variance of $1/\gamma$.

$\Lambda = 0.6898$ (coupling), $1 - \Lambda = 0.3102$ (decoupling). The product measures the variance of the binary distribution of $1/\gamma$ — the degree to which spacetime deviates from conformal flatness:

$$\boxed{\Lambda(1-\Lambda) = 0.2140}$$

It is not G — it does not determine how strong gravity is, but rather how much gravitational bending is available. G determines "how many kilograms," while $\Lambda(1-\Lambda)$ determines "the total allowance."

Projection of EM coupling onto metric perturbation:

$$\boxed{\Delta h^2_{\mathrm{EM}} = \cos^2\Theta \cdot \Lambda(1-\Lambda) = 0.0040}$$

$$\boxed{h^2 = \frac{1-\Lambda}{\Lambda} + \Delta h^2_{\mathrm{EM}}}$$

Substituting: $h^2 = 0.3102/0.6898 + 0.0040 = 0.4497 + 0.0040 = 0.4537$.

$$\boxed{H_0 = 100\sqrt{h^2} = 67.36\ \mathrm{km/s/Mpc}}$$

Planck $H_0 = 67.36 \pm 0.54$ — deviation 0σ.

$\delta\Lambda = 0.0010$ (§2.4) is the dilution effect of photons in the ensemble statistical domain (Λ domain). $\Delta h^2_{\mathrm{EM}} = 0.0040$ (this section) is the correction from the same batch of EM photons through metric perturbation in the expansion domain (h^2 domain). Both share the same source (EM coupling × S² geometry), but differ in domain and numerical value. Through the nonlinear mapping $h^2 = (1-\Lambda)/\Lambda$, the equivalent displacement of $\Delta h^2_{\mathrm{EM}} = 0.0040$ in the Λ domain is ~ 0.0022 — of the same order, same sign, and same physical origin as $\delta\Lambda = 0.0010$.

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§2.7 Gravitational Enhancement Factor

Geometric closure ratio — coupling baseline × arc domain / octahedral face count:

$$\Lambda \cdot \frac{\pi}{8} = 0.6898 \times 0.3927 = 0.2709$$

$\pi/8 = (\pi/2)/4$ — the causal range $\pi/2$ divided by 4 (number of S² octahedral faces per hemisphere). The value 0.271 means: the universe still has 27.1% of its causal potential unreleased.

Physical intuition. Imagine the causal potential as a reservoir. At the decoupling surface ($z = 1100$), the reservoir is full (100%). Today the water level has dropped to 27.1%. The less water remaining, the higher the "potential energy efficiency" of the remaining water — the same scoop of water can drive a larger turbine when the reservoir is nearly empty than when it is full. Gravitational enhancement factor:

$$\boxed{f = \left(\frac{8}{\Lambda\pi}\right)^{\Lambda} = \left(\frac{1}{0.2709}\right)^{0.6898} = 3.691^{0.6898} = 2.462}$$

$f = 2.46$ means that the gravitational output per unit causal potential today is 2.46 times that of a "full reservoir." SN Ia senses this enhancement through the cosmic expansion rate ($H \propto \sqrt{f}$), multiplied by the matter source strength ω_m:

$$\boxed{K_{AT} = \sqrt{f} \times \omega_m = \sqrt{2.462} \times 0.2956 = 1.569 \times 0.2956 = 0.4638}$$

K_{AT} is the projection of the gravitational enhancement factor in the SN Ia baseline correction.
$f = (8/(\Lambda\pi))^{\Lambda} = 2.462$ measures the amplification effect of causal potential scarcity on gravity — $\Lambda \cdot \pi/8 = 0.271$ (causal potential remaining fraction, coupling baseline × arc domain / octahedral face count). $K_{AT} = \sqrt{f} \times \omega_m$. Physical meaning: K_{AT} measures the modulation of the local expansion rate by the galaxy's S_{eff} — the larger S_{eff} (the more mature the structure), the closer the local expansion approaches the global benchmark.

MCMC independently constrains $K_{AT} \approx 0.47$ (posterior median), deviation 1.5%.

K_{AT} and decoupling surface closure. The $\omega_m = 0.2956$ in $K_{AT} = \sqrt{f} \times \omega_m$ already includes the photon bridge correction $\cos^2\Theta \cdot \Lambda(1-\Lambda) = 0.0040$. The decoupling surface closes exactly: $\omega_0 + \Lambda + \cos^2\Theta = 1.0000$. After decoupling, all parameters covary: ω_m dilutes as $(1+z)^3$, while Λ and $\cos^2\Theta$ remain constant.

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§2.8 Spectral Index, Baryon Density, and Dark Matter Density

Matter density. The decoupling surface closes geometrically — bare baseline $\omega_0 = 1 - \Lambda - \cos^2\Theta = 0.2916$. Cross-boundary photon reabsorption compensation $\cos^2\Theta \cdot \Lambda(1-\Lambda) = 0.0040$:

> **Notation statement:** In this framework, $\omega_m = 0.2956$ is the expandable matter fraction (excluding the EM-locked fraction $\cos^2\Theta$), entering the Friedmann equation directly. The standard notation $\omega_m \equiv \Omega_m h^2 \approx 0.143$ is not used in this paper. The total matter density is $\Omega_m = \omega_m + \cos^2\Theta = 0.3142$.

$$\boxed{\omega_m = 1 - \Lambda - \cos^2\Theta + \cos^2\Theta \cdot \Lambda(1-\Lambda)}$$

Term-by-term intuition: total budget $\mathbf{1}$ = $\mathbf{\Lambda}$ (dark energy / decoupling fraction) + $\mathbf{\cos^2\Theta}$ (pure EM locked fraction) + ω_0 (bare matter baseline). Correction term $+\mathbf{\cos^2\Theta\cdot\Lambda(1-\Lambda)}$: the projection of the EM coupling fraction ($\mathbf{\cos^2\Theta}$) onto the spacetime metric cross-term — $\mathbf{\Lambda=\langle 1/\gamma\rangle}$ is the mean spatial contraction, $\mathbf{(1-\Lambda)}$ is the mean time-dilation release, and their product is the variance of the $\mathbf{1/\gamma}$ distribution (spacetime asymmetry). EM-coupled matter acquires an additional gravitational potential well contribution on this asymmetric metric.

Substituting: $\omega_m = 1 - 0.6898 - 0.01858 + 0.01858 \times 0.2140 = 0.3102 - 0.01858 + 0.00397 = 0.2956$.

Total mass-energy closure including EM coupling: $\Omega_m = \omega_m + \cos^2\Theta = 0.3142$, $\Omega_m + \Lambda = 1.0040$ (implied curvature $\Omega_K = -0.0040$, deviating 2.5σ from the Planck central value, within 3σ). This deviation is an intrinsic effect of the photon bridge term.

Two-layer Λ architecture. n_s and A_S belong to the particle-geometry layer — decoupling surface microphysics, without photon bridge dilution. They use $\Lambda_{\rm geo} = \sin\Theta/\Theta = 0.6908$ (§2.3). The cosmological layer (H_0, ω_m, ω_c, K_{AT}) uses $\Lambda_{\rm obs} = 0.6898$ (including photon bridge, §2.4). The bridge between the two layers = $\delta\Lambda = 0.0010$.

Scalar spectral index n_s — variance of the $1/\gamma$ distribution. On the uniform θ_τ distribution $[0, \Theta]$, the variance of $\cos\theta_\tau$:

$$\mathrm{Var}(\cos\theta_\tau) = \langle\cos^2\theta_\tau\rangle - \langle\cos\theta_\tau\rangle^2$$

$$\langle\cos^2\theta_\tau\rangle = \frac{1}{2} + \frac{\sin(2\Theta)}{4\Theta}, \quad \langle\cos\theta_\tau\rangle = \frac{\sin\Theta}{\Theta} = \Lambda_{\rm geo}$$

Substituting $\Theta = 82.17^\circ$: $\langle\cos^2\rangle = 0.5471$, $\Lambda_{\rm geo}^2 = 0.4772$, $\mathrm{Var} = 0.0699$.

$$\boxed{n_s = 1 - \frac{\mathrm{Var}(\cos\theta_\tau)}{2} = 1 - \frac{0.0699}{2} = 0.9651}$$

Planck $n_s = 0.9649 \pm 0.0042$ — deviation 0.04σ. Pure geometric second moment, no tunable parameters.

Scalar amplitude A_S — duality with n_s. n_s and A_S are statistical descriptions of the same EM coupling process on two projection planes: n_s measures the inhomogeneity (variance) of the EM coupling distribution, while A_S measures the residual strength (endpoint decay) after EM coupling penetrates all geometric degrees of freedom.

Substituting $\cos^2\Theta = 8\alpha_{fs}/\pi$:

$$\boxed{A_S = \left(\frac{8}{\pi}\right)^5 \times \alpha_{fs}^5 \times \left(1 - \frac{\Lambda_{\text{geo}}^2}{8}\right)}$$

Substituting: $A_S = 107.1 \times (7.297 \times 10^{-3})^5 \times 0.9404 = 2.08 \times 10^{-9}$.

Planck $A_S = 2.10 \times 10^{-9}$ — deviation 0.5σ. The scalar amplitude is proportional to the fifth power of the fine-structure constant.

n_s-A_S duality: Both share $\Lambda^2/8$ — n_s uses it to erase the spectral slope, while A_S uses it to decay the spectral amplitude. Complementary usage:

$$n_s = 1 - \frac{\text{Var}(\cos\theta)}{2} \qquad (\text{variance to how much was erased})$$

$$A_S \propto \alpha_{fs}^5 \times (1 - \Lambda^2/8) \qquad (\text{endpoint}^5 \text{ to how much remains})$$

Exponent 5 = number of independent components of the S² quadrupole moment. On the S² sphere, the quadrupole spherical harmonics Y_{2m} at $l = 2$ have $2l + 1 = 5$ independent components ($m = -2, -1, 0, +1, +2$). Primordial density perturbations are the quadrupole deformation of the decoupling surface — each of the 5 independent deformation directions is attenuated by one factor of the EM endpoint $\cos^2\Theta$:

$$(\cos^2\Theta)^5 = \left(\frac{8\alpha_{fs}}{\pi}\right)^5$$

CMB power spectrum analysis is itself based on spherical harmonic decomposition — the 5 components of the quadrupole moment are standard knowledge. No channel counting is needed; the spherical harmonic language is sufficient.

Geometric origin of the n_s-A_S duality:

	Spatial side ( )	Temporal side ( )

S² geometric quantity	$8 = 2^D$ (octahedral face count)	$5 = 2l+1,\ l=2$ (quadrupole components)
Counting method	Discrete — angular partitioning of S²	Continuous — distortion modes of S²
Shared factor	$\Lambda^2/8$ (erases spectral slope)	$1-\Lambda^2/8$ (decays spectral amplitude)

The same S² causal topology. n_s reads the discrete face count; A_S reads the continuous distortion count. Complementary.

Baryon density ω_b. The geometric fraction of the EM boundary angular distance within the θ_τ range constitutes the base baryon density. $\Delta\theta_{\min} \approx 2.000°$ (exact value $1.9998°$, deviation 0.01%, marked with ≈). The baryonic fluid participates in bidirectional photon reabsorption:

$$\boxed{\omega_b = \frac{\Delta\theta_{\min}}{\pi/2} \times \left(1 + 2\cos^2\Theta \cdot \Lambda(1-\Lambda)\right) \approx \frac{2°}{90°} \times (1 + 2 \times 0.0040) = 0.02240}$$

BBN 0.0224 ± 0.0005 — central value agrees.

Dark matter density. Total mass-energy closure:

$$\boxed{\omega_c = \Omega_m \cdot h^2 - \omega_b = 0.3142 \times 0.4537 - 0.0224 = 0.1201}$$

Planck $\omega_c = 0.1200 \pm 0.0012$ — deviation 0.1σ.

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§2.9 Friedmann Equation and Full Parameter Table

Final form of all constants:

$$\boxed{\frac{H^2(z)}{H_0^2} = \omega_m(1+z)^3 + \Lambda}$$

$\omega_m = 0.2956$, $\Lambda = 0.6898$, $H_0 = 67.36$. Zero free parameters. Zero dynamical quantities.

> $\omega_m + \Lambda = 0.9854$ — the deficit 0.0146 is the photon bridge residual of $\cos^2\Theta$, already internalized into the h^2 derivation through Δh^2_{EM} (§2.5). The decoupling surface closes exactly: $\omega_0 + \Lambda + \cos^2\Theta = 1.0000$.

Decoupling surface closure: $\omega_0 + \Lambda + \cos^2\Theta = 0.2916 + 0.6898 + 0.0186 = 1.0000$. After decoupling, all parameters covary — ω_m dilutes as $(1+z)^3$, while Λ and $\cos^2\Theta$ remain constant.

All parameters are constants. Λ freezes at the electron critical point. Θ, $\cos^2\Theta$, ω_m, α_{fs}, H_0 are all algebraic functions of Λ — all locked at the decoupling surface. All parameters of the framework are determined at the moment of the electron critical point, with no subsequent dynamical evolution. The only quantity that changes in the Friedmann equation is $(1+z)^3$ — this is an effect of the time coordinate, not parameter evolution.

Full parameter derivation table. Each parameter is traced back to $\langle 1/\gamma \rangle = \Lambda = 0.6898$.

Fig. 4: Derived vs. observed values. Normalized comparison of derived values (red squares) and observed values (black circles, with error bars) for 8 key parameters.

Error propagation. External anchor $\alpha_{fs} = 1/137.036$ (CODATA, relative uncertainty 1.5×10^{-10}, negligible). The framework formula outputs $1/137.050$, with a residual of 0.010% from CODATA — attributed to uncomputed higher-order EM self-energy corrections $O(\cos^4\Theta)$. Using this residual as an upper bound on the theoretical uncertainty, we propagate to each parameter (propagation method: apply a 0.010% relative perturbation to α_{fs} and compute the absolute deviation of each parameter):

Parameter	Central value	Theoretical deviation	Observed error	Deviation/observed
Λ	0.6898	0.0010	0.0056	0.18
ω_m	0.2956	0.0010	0.0050	0.21
H_0	67.36	0.16	0.54	0.30
n_s	0.9651	0.0007	0.0042	0.17
A_S	2.08×10^{-9}	1.6×10^{-11}	2.9×10^{-11}	0.54
ω_b	0.02240	0.000007	0.0005	0.01
ω_c	0.1201	0.0011	0.0012	0.95

K_{AT}	0.4638	0.0015	0.010	0.15

The theoretical uncertainty of all parameters is smaller than the observational error (deviation/observed < 1). ω_c is the most sensitive (0.95) because $\omega_c = \Omega_m h^2 - \omega_b$ amplifies the indirect effect of α_{fs}.

Parameter	Derivation	Value	Observed	Deviation
Λ	$\sin\Theta/\Theta - \delta\Lambda$	0.6898	$\Omega_\Lambda = 0.6889 \pm 0.0056$	0.2σ
Θ	$\arccos\sqrt{8\alpha_{fs}/\pi}$	$82.17°$	—	—
ω_m	$1 - \Lambda - \cos^2\Theta + \cos^2\Theta \cdot \Lambda(1-\Lambda)$	0.2956	BAO ~ 0.302	$\sim 0.5\sigma$
Ω_m	$\omega_m + \cos^2\Theta$	0.3142	0.3153 ± 0.0074	0.1σ
H_0	$100\sqrt{(1-\Lambda)/\Lambda + \cos^2\Theta \cdot \Lambda(1-\Lambda)}$	67.36	67.36 ± 0.54	0σ
α_{fs}	$(\Lambda^2/64)/(1 + \Lambda^2/(8\pi))$	$1/137.050$	$1/137.036$	0.010%
n_s	$1 - \mathrm{Var}(\cos\theta_\tau)/2$	0.9651	0.9649 ± 0.0042	0.04σ
A_S	$(\cos^2\Theta)^5 \times (1 - \Lambda_{\text{geo}}^2/8)$	2.08×10^{-9}	2.10×10^{-9}	0.5σ
ω_c	$(\omega_m + \cos^2\Theta)h^2 - \omega_b$	0.1201	0.1200 ± 0.0012	0.1σ
ω_b	$(2°/90°)(1 + 2\cos^2\Theta \cdot \Lambda(1-\Lambda))$	0.02240	BBN 0.0224 ± 0.0005	0σ
$\Delta\theta_{\min}$	$16\alpha_{fs}/\pi - \alpha_{fs}(1-\Lambda)$	$\approx 2.000°$	—	—
K_{AT}	$\sqrt{(8/(\Lambda\pi))^\Lambda} \times \omega_m$	0.464	MCMC ~ 0.47	1.5%
z_{cmb}	$\cos^2\theta_\tau(z) = 8\alpha_{fs}/\pi$ inverted	~ 1086	1089.80	$\Delta z \approx 4$

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§3 Data Fitting

For the complete computational workflow, see the condensed version v2 §3–§4; only final results are given here. All SN data use diagonal weighting $w_i = 1/\sigma_i^2$ (see argument below), and BAO uses the full covariance matrix published by DESI.

Fig. 1: DES SN Ia Hubble residuals. DES residuals for three models (Planck LCDM, EFT+γ, v3 Symm), color-coded by host mass (blue: log M < 10, red: log M ≥ 10). Dashed lines are the weighted means of each mass group — the mass step decreases from −0.073 in LCDM to −0.033 in v3.

Fig. 2: Full dataset χ^2 comparison. χ^2 bar chart for three models across four datasets.

§3.1 SN Ia

Three-component host mass step model: $\delta\mu_i = K_{AT} S_{\text{eff,MW}}(z_i) + K_B(\log M_{h,i} - \log M_{h,\odot}) + K_C / z_{\text{form},i}$. $K_{AT} = 0.464$ (§2.7), $K_B = 0.007$ (stellar mass–halo mass relation SHMR, Behroozi et al. 2013), $K_C = -0.018$ (progenitor fast channel/slow channel ratio, Maoz et al. 2014, Childress et al. 2014). K_B and K_C are externally observationally anchored, not framework-derived — their values come from independent astrophysical measurements and are not counted in the framework's parameter tally.

M_B is eliminated through analytic marginalization: $\chi^2_{\text{SN}} = \sum w_i \Delta\mu_i^2 - (\sum w_i \Delta\mu_i)^2 / \sum w_i$.

Dataset	SNe	(Symm − Planck CDM, diagonal weighting)
DES-SN5YR	1820	−313
Pantheon+	1588	−65
Union3	2069	−313
Total	**5477**	**−691**

> Full covariance conservative estimate: $\Delta\chi^2 \approx -338$ (DES -251, Pantheon+ -64, Union3 -23). Full covariance pre-absorbs the B/C physical signal as systematic error, while diagonal weighting preserves the physical signal — this is an intentional choice, not an approximation compromise. Evidence: the Foundation subsample (173 SNe, no biasCor pre-correction) shows 72% signal amplification under full covariance, while Pantheon+ (with biasCor) shows 91% compression — opposite behavior rules out overfitting.

Why diagonal weighting was chosen. The full covariance matrix (STAT+SYS) contains the complete correlation structure of SN Ia systematics, but simultaneously pre-absorbs the physical signal of the three-component correction (B: mass metabolism, C: progenitor age) as "systematic error." Diagonal weighting $w_i = 1/\sigma_i^2$ preserves the individual characteristic signal of each SN (host mass, formation redshift, galactic S_{eff} integral), so that the $\Delta\chi^2$ of the three-component correction is not compressed by the covariance structure. This is not an approximation to the full

covariance — it is a choice of a different likelihood function to preserve the physical signal. The conservative result under full covariance ($\Delta\chi^2 \approx -338$) is reported as a lower bound.

§3.2 BAO and DE Redshift Modulation

DESI Y1 (12 points) + DR2 (13 points) full covariance.

Dataset	Planck CDM	EFT+ ( )	Symm ( )
DESI Y1	22.8	15.7	**12.9**
DESI DR2	34.3	21.1	**9.2**

BAO-only MCMC: $\omega_D = 0.302 \pm 0.013$, derived value 0.2956 deviates by 0.5σ.

DE redshift modulation: pure geometric algebraic form

The ratio D_M/r_s of the sound horizon r_s to the angular diameter distance $D_M(z)$ is sensitive to the redshift evolution of the dark energy density. v3 modulates the DE term using the redshift evolution of the Lorentz angle:

$$g(z) = 2 - \frac{\cos\Theta(z)}{\cos\Theta}$$

where $\Theta(z) = \frac{\pi}{2}\left(1 - \frac{1}{L(z)}\right)$, $L(z) = 1 + \frac{3}{2}\ln(1+z)$. $L(z)$ is obtained by direct integration from the matter-dominated solution of the Friedmann equation, $H \propto (1+z)^{3/2}$ (§2.2). This is a pure geometric algebraic function — independent of ODEs, independent of logistic equations.

$z = 0$: $\cos\Theta(0)/\cos\Theta = 1 \to g = 1$ (normalization)
$z > 0$: $\cos\Theta(z) < \cos\Theta$ (structure not yet saturated at high redshift) $\to g > 1$ (early DE stronger)

The DE term used for BAO: $\Lambda_{\rm DE}(z) = \Lambda \cdot g(z)$. The redshift evolution of $g(z)$ is shown in Fig. 3.

The necessity of this coupling is dictated by the data: $w = -1$ (ΛCDM, no coupling) yields BAO $\chi^2 = 34.3$ (DR2); the CPL parameterization $w(z) = w_0 + w_a z/(1+z)$ reduces it to 21.1 with 3 free parameters; the $g(z)$ coupling reduces it to 9.2 with zero free parameters. **CPL degenerates to a constant w model when $w_a = 0$** (the ΛCDM limit), at which point the BAO χ^2 rebounds to 34.3 — demonstrating that the CPL improvement comes entirely from the $w_a \neq 0$ redshift evolution, not from the w_0 offset. $g(z)$ provides the geometrically derived form of the same redshift evolution.

Parameter counting for $g(z)$. The functional form of $g(z)$ is not a free choice — $L(z)$ is uniquely determined by the Friedmann equation, and $\Theta(z)$ is mapped from $L(z)$. The essential difference between $g(z)$ and the CPL parameterization $w(z) = w_0 + w_a z/(1+z)$: the functional form of CPL is a phenomenological choice (linear expansion), while the functional form of $g(z)$ is constrained by Friedmann dynamics. "Zero free parameters" means: no continuous free parameters, no discrete functional-form selection — $g(z)$ is the unique output of the framework.

§3.3 CMB

Planck 2018 plik_lite TT + CAMB.

Model	
Planck ΛCDM	227.0
Symm (v3, $w = -1$)	222.7
$\Delta(-2\ln\mathcal{L})$	**−4.3** (corresponding to $\Delta\ln\mathcal{L} \approx +2.1$, positive = improvement)

> Note: Λ in the v3 framework is a constant, corresponding to a dark energy equation of state $w \equiv -1$ — formally equivalent to ΛCDM in the Friedmann formulation. The CMB improvement arises because the v3 parameter values ($H_0 = 67.36$, $\omega_m = 0.2956$) happen to fall in the high-density region of the Planck posterior. The v3 values $n_s = 0.9651$ and $A_S = 2.08 \times 10^{-9}$ show small deviations (~0.5σ each) from the Planck best fit, which is the reason the CMB $\Delta\log\mathcal{L}$ decreased from +2.8 in v2 to +2.1.

§3.4 Summary

Probe	(negative = improvement)
SN Ia (diagonal weighting)	-691

SN Ia (full covariance conservative)	-338
BAO (Y1+DR2, full covariance)	-35
CMB TT ($-2\Delta \ln \mathcal{L}$)	-4.3

The SN diagonal weighting result of −691 contains an approximation — under full covariance, it is conservatively reduced to approximately −338 (the reduction factor comes from the diagonal/off-diagonal decomposition of the full covariance matrix; see condensed version v2 §4 for details). All improvements originate from the natural coincidence of parameters with the data best-fit point — parameters were geometrically locked before the data were observed.

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§4 Discussion

§4.1 Constant Universe vs. Dynamical Dark Energy

Standard cosmology asks about $w(z)$ — $w = -1$ is the cosmological constant, $w \neq -1$ is dynamical dark energy. Planck+DESI+SN jointly constrain $w_0 = -0.997 \pm 0.061$.

The answer from this framework: dark energy does not introduce an equation of state. $\Lambda = \langle 1/\gamma \rangle = 0.6898$ is the statistical mean of the Lorentz factor ensemble — frozen at the electron critical point. Within this framework, Λ is a geometric quantity, not a dynamical variable — its value is locked by α_{fs} and $D = 3$ through algebraic identities.

Structural meaning of $w_a = -1$. The CPL parameterization $w(z) = w_0 + w_a z/(1+z)$ degenerates to a constant w (the ΛCDM limit) when $w_a = 0$. DESI+SN joint fitting yields $w_a = -0.626$ — significantly deviating from zero. However, the physical origin of w_a cannot be explained within the standard framework: it is a free parameter with no first-principles derivation. In this framework, the redshift evolution of $w(z)$ comes from the redshift evolution of the Lorentz angle — $g(z) = 2 - \cos\Theta(z)/\cos\Theta$ — whose functional form is uniquely determined by the matter-dominated solution of the Friedmann equation, introducing no free parameters. The deep meaning of $w_a = -1$ is that the "dynamics" of CPL is actually a coordinate reparameterization of the algebraic structure of the A field.

Current $w(z)$ precision ($\sim 6\%$) is far from sufficient to distinguish $w = -1$ from $w = -1 \pm O(\cos^2\Theta) \approx -1 \pm 0.02$. Next-generation probes (LSST, Roman, Euclid) are expected to push to $< 2\%$ — at which point the distinction between constant Λ and evolving $w(z)$ will become a falsifiable prediction.

The constant universe is a conclusion, not a gap. The framework does not contain dynamical relaxation — this is not an as-yet-unmodeled deficiency, but a physical finding: all parameters are locked at the electron critical moment on the decoupling surface, with no subsequent evolution. The change of $(1+z)^3$ in the Friedmann equation is a time-coordinate effect, not parameter evolution. If future data detect Λ evolving with z by more than $O(\cos^2\Theta) \sim 2\%$, the framework is falsified — this is precisely one of the framework's falsification paths (see §4.2 item 4 below).

Cosmic-scale dynamics degenerate to algebra. The predecessor version (v2) of this framework contained a complete dynamical system. v3 reveals that cosmic-scale dynamics (the Friedmann equation, $D(z)$ relaxation, $H(z)$ evolution) all degenerate into algebraic identities — independent of time coordinates, independent of ODE solving. The sole exception is the precise $A(z)$ computation for SN host galaxies: the logistic ODE $dA/dz = -A(1-A)/((1+z)E(z))$ is used for the S_{eff} integral of each individual SN — this is the only non-algebraic element in the framework. Everything else is closed-form:

Dynamical quantity	Algebraic substitute
$D(0)/\omega_m$	$\Lambda \cdot \pi/8 = 0.271$ (causal potential remaining)
$f(D_0)$	$(8/(\Lambda\pi))^{\Lambda} = 2.462$ (gravitational enhancement)
K_{AT}	$\sqrt{f} \times \omega_m = 0.464$ (SN baseline correction)
BAO DE modulation	$g(z) = 2 - \cos\Theta(z)/\cos\Theta$ (pure geometry)

Every dynamical quantity is proven to equal some algebraic function of Λ — the ODE numerical solutions of v2 and the algebraic closures of v3 agree to 6 significant figures. Dynamical variables ($D(z)$, $A(z)$, τ) are reparameterizations of algebraic identities in the time coordinate — the physical content is unchanged, the expression is more concise.

§4.2 Falsification Paths

The framework's strength is also its Achilles' heel: all values are exact.

1. **$H_0 = 67.36$.** If SH0ES $H_0 = 73.0$ is independently confirmed (after excluding K_{AT} systematics), the framework requires revision.

2. **$\alpha_{fs} = 1/137.050$.** Current residual 0.010%. If future measurements pin α_{fs} to within 0.015% and the deviation from $1/137.050$ exceeds that precision, the framework is excluded.

3. **$n_s = 0.9651$.** If the Simons Observatory excludes this value at ± 0.001, the framework is excluded.

4. **Constancy of Λ.** If BAO/SN detect $> 2\%$ redshift evolution, the framework is excluded.

§4.3 Relation to the Standard Model

ΛCDM describes the universe with 6 parameters. This framework derives those 6 parameters with 0 parameters. The two are equivalent in Friedmann form — differences are only $O(\cos^2\Theta)$. The framework does not replace GR — GR remains the correct theory for describing gravitational interactions. The framework answers the questions GR does not: why $\Omega_\Lambda \approx 0.69$? Why $H_0 \approx 67.4$? Why $\alpha_{fs} \approx 1/137$? The answer lies not in modifying gravity — but in reconceiving the geometric identity of $1/\gamma$.

§4.4 Open Questions

1. **Independent verification of the A_S exponent 5.** The geometric identity $5 = 2l + 1$ ($l = 2$ quadrupole component count) is established and self-consistent with CMB spherical harmonic analysis. Pending independent verification: whether primordial perturbations on the decoupling surface are strictly limited to quadrupole modes ($l = 2$), or whether higher-order multipole moments contribute corrections.

2. **α_{fs} residual of 0.010%.** Two-factor output $1/137.050$, CODATA $1/137.036$. EM self-energy calculations are expected to contribute corrections of order $O(\cos^4\Theta)$ — independent computation remains to be completed.

3. **Relation of $1/\gamma$ to quantum mechanics.** The RP² derivation uses spin 1/2 — this is a quantum mechanical input. Does $1/\gamma$ geometry emerge from quantum mechanics, or vice versa?

§4.5 Conclusion

Starting from a single definition $\Lambda = \langle 1/\gamma \rangle = 0.6898$, this paper derives all ΛCDM parameters through algebraic identities and a self-consistent fixed-point system. 13 output parameters, 0 degrees of freedom. SN Ia ($\Delta\chi^2 \approx -691$ diagonal / -338 full covariance conservative), BAO ($\Delta\chi^2 \approx -35$), CMB ($\Delta \log \mathcal{L} \approx +2.1$) — three independent datasets consistently outperform Planck ΛCDM.

The core finding of the framework is that cosmic-scale dynamics have entirely degenerated into the algebraic identities of v3. Λ freezes at the electron critical point, after which the universe undergoes no parameter evolution. The DE modulation of BAO is achieved by the pure geometric algebraic function $g(z) = 2 - \cos\Theta(z)/\cos\Theta$.

The framework's relation to GR: $\nabla^2(\cos^2\theta_\tau) = \kappa T$ is the scalar projection of the Einstein field equations in the θ_τ variable — rigorously reproducing the classical results of GR in both static spherically symmetric and FLRW

backgrounds (Appendix A3). The framework answers the questions GR does not — the numerical origins of Ω_Λ, H_0, α_{fs} — without modifying the dynamical structure of gravity itself.

Appendix A1: Complete Proof of RP² Vacuum Polarization

Step 1: Vacuum mode count = 8. D=3, $\pm$ direction per dimension, $2^3 = 8$. S² octant partition — 8 faces of a regular octahedron.

Step 2: Electron causal boundary = RP². Spin $\hbar/2$, wave function requires 720° closure. Domain is RP² = S²/$\sim$ (antipodal identification). $\chi(\mathrm{RP}^2) = 1$, $\chi(\mathrm{S}^2) = 2$.

Step 3: Single-mode shielding = α_{fs}/π. Hemisphere on RP² (same-direction coupling): $\langle|\cos\theta|\rangle_{\mathrm{RP}^2} = 1/2$.

Gauss-Bonnet normalization — in three steps:

(i) Total curvature integral on RP²: $\oint K dA(\mathrm{RP}^2) = 2\pi\chi(\mathrm{RP}^2) = 2\pi$ ($\chi = 1$).

(ii) Total curvature integral on S²: $\oint K dA(\mathrm{S}^2) = 2\pi\chi(\mathrm{S}^2) = 4\pi$ ($\chi = 2$).

(iii) Spin $1/2$ constrains the causal boundary to RP² — causal relations pair only within a half solid angle of 2π, while the full pairing in physical space (S²) distributes over 4π. Causal density normalization requires mapping the RP² flux back to S²: normalization factor = $\chi(\mathrm{S}^2)/\chi(\mathrm{RP}^2) \times 1/\pi = 2/\pi$ (where $1/\pi$ comes from the causal flux normalization per unit Euler characteristic).

Single-mode shielding = $\alpha_{fs} \times 1/2 \times 2/\pi = \alpha_{fs}/\pi$.

Step 4: Total shielding = $8\alpha_{fs}/\pi$. 8 independent modes.

Step 5: Self-consistent closure. $\alpha_{fs} = (\Lambda^2/64)(1 - 8\alpha_{fs}/\pi) \to \alpha_{fs} = (\Lambda^2/64)/(1 + \Lambda^2/(8\pi))$.

Note: The factor $24 = 3 \times 2^3$ happens to equal the ratio of QED vacuum polarization $\propto \alpha_{fs}/(3\pi)$ to this framework's $8\alpha_{fs}/\pi$ — a numerical coincidence, not a derived equivalence. The RP² argument stands independently and does not depend on the QED comparison.

A1.2 EM Boundary Angular Distance

Total two-electron EM coupling projected onto two-dimensional angular space: $16\alpha_{fs}/\pi$ (8 modes × 2 electrons). Shielded portion $\alpha_{fs}(1-\Lambda)$. Remaining effective angular distance:

$$\Delta\theta_{\min} = \frac{16\alpha_{fs}}{\pi} - \alpha_{fs}(1-\Lambda) \approx \frac{\pi}{90} \approx 2^\circ$$

Appendix A2: Emergence of D=3 from the Angular Domain of $1/\gamma$

Theorem. $D = 3$ is a topological necessity for the range of $1/\gamma$ to contain S².

Proof. Lemma 1: $1/\gamma = \cos\theta_\tau$, with directional components (θ, ϕ) taking any point on S². Lemmas 2–4: two bodies → line ($\mathbb{R}^1$), three bodies → surface (S² subset), four bodies → volume (S² saturation). Lemma 5: five bodies add no new dimension. Conclusion: S² is a compact boundaryless two-dimensional manifold that cannot be embedded in $\mathbb{R}^2$ (invariance of domain theorem); therefore the minimal space carrying its full topology is $\mathbb{R}^3$. $D = 3$ is forced by the geometry of $1/\gamma$.

Appendix A3: GR Scalar Projection of the θ_τ Field Equation

The scalar projection of the Einstein field equations $G_{\mu\nu} = \kappa T_{\mu\nu}$ in the θ_τ variable:

$$\nabla^2(\cos^2\theta_\tau) = -\frac{8\pi G}{c^4}\,T$$

This equation rigorously reproduces the classical results of GR under two boundary conditions:

Condition	Solution	Equivalent to
Vacuum spherical symmetry (T=0)	$\cos^2\theta_\tau = 1 - 2GM/rc^2$	Schwarzschild metric (including event horizon)

Point source M	$\cos^2\theta_\tau = 1 - 2GM/rc^2$	Newtonian gravity $g = -GM/r^2$ (exact)

The θ_τ derivation of gravitational potential and acceleration does not use the weak-field approximation:

$$\Phi = -\frac{c^2}{2}\sin^2\theta_\tau = -\frac{GM}{r}, \qquad g = -\frac{d\Phi}{dr} = c^2\sin\theta_\tau\cos\theta_\tau \cdot \frac{d\theta_\tau}{dr} = -\frac{GM}{r^2}$$

$\sin\theta_\tau \cdot \cos\theta_\tau$ cancels exactly in $d\theta_\tau/dr$. Newtonian gravity is an exact consequence of the θ_τ framework. The vacuum Einstein equation $R_{\mu\nu} = 0$ in static spherical symmetry collapses to $\nabla^2(\cos^2\theta_\tau) = 0$ — a Laplace equation.

Complete field equation for τ^μ. The fundamental variable is the timelike unit vector field τ^μ ($\tau^\mu\tau_\mu = -1$), with the spatial projection tensor $h_{\mu\nu} = g_{\mu\nu} + \tau_\mu\tau_\nu$. The Einstein equation $G_{\mu\nu} = \kappa T_{\mu\nu}$ decomposes into three projections in this variable:

$\tau^\mu\tau^\nu G_{\mu\nu} = \kappa\tau^\mu\tau^\nu T_{\mu\nu} \rightarrow \nabla^2(\cos^2\theta_\tau) = -\kappa\rho$ (scalar, covered in this paper)
$\tau^\mu h^\nu_\alpha G_{\mu\nu} = \kappa\tau^\mu h^\nu_\alpha T_{\mu\nu} \rightarrow$ momentum constraint (vector)
$h^\mu_\alpha h^\nu_\beta G_{\mu\nu} = \kappa h^\mu_\alpha h^\nu_\beta T_{\mu\nu} \rightarrow$ gravitational waves + lensing + E/B polarization (tensor)

The scalar projection yields all derivations in this paper for both the FLRW background and static spherical symmetry. The vector and tensor projections are direct rewrites of standard GR in the τ^μ variable — compatible with the tensor modes of GR. All observational tests in this paper (CMB TT, BAO, SN) fall within the scope of the scalar projection. The full tensor modes (gravitational waves, lensing) await future work.

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