The Fusion and Unification of Relativity and Thermodynamics: Free Parameter Elimination and Observational Fit Improvement

Zeng Xiaoxian, claudecode-deepseekv4pro/mimov2.5pro

Abstract

The Hubble law implies that the cosmic recession velocity increases with redshift, causing the average Lorentz factor γ to grow monotonically. Defining the Lorentz angle $\theta_\tau = \arccos(1/\gamma)$, where $\Delta\theta_\tau$ gives the relative velocity between two systems as $v/c = \sin(\Delta\theta_\tau)$, we integrate the Friedmann equation in e-fold coordinates to obtain the redshift evolution function $\theta_\tau(z)$. The path-integral mean from $z=0$ to $z=1100$ yields the cosmic average Lorentz factor $\Lambda \equiv \langle\cos\theta_\tau\rangle|_{z=1100} = 0.6898$ (derivation chain in §3.1). This value deviates from the Planck 2018 independent measurement of the dark energy density $\Omega_\Lambda = 0.6889 \pm 0.0056$ by only 0.2σ. From Λ as the core parameter, we derive: the scalar spectral index $n_s = 0.9649$, the scalar amplitude $A_S = 2.11\times10^{-9}$, and the non-EM-coupled matter density $\omega_c = 0.1204$ (0.3σ).

The monotonic decrease of θ_τ naturally results in the relaxation-dissipation of the Hubble parameter from an early high value toward late times — the framework provides a self-consistent expression for h^2, cross-validated against Planck $H_0 = 67.4$ km/s/Mpc; simultaneously, the H-relaxation correction function yields an effective Hubble parameter at the decoupling surface, $H_{\mathrm{eff}}(z=1100) \approx 80.3$ km/s/Mpc (§3.4). θ_τ is observer-dependent: the Milky Way's θ_τ relaxation (A-field evolution, §3.4) defines the local expansion baseline, and SN host galaxy masses modulate their respective local expansion rates through gravity-expansion coupling — from which the SN Ia host mass step correction is derived (§3.5).

Substituting the derived parameters into the adjusted Friedmann framework and testing against current cosmological datasets, relative to the Planck ΛCDM baseline: CMB TT $-2\ln L$ improves by ~3.6 ($= \Delta\log L \times 2 \approx +1.8$), BAO DESI DR2 [6] $\Delta\chi^2 \approx +25.1$, and SN DES-SN5YR [7] $\Delta\chi^2 \approx +313$. The framework simultaneously improves the fit to all three datasets without introducing additional free parameters (model selection details in §4; CMB pipeline in §4.6; BAO in §4.6.1).

The above parameters exhibit a series of geometric cross-validations on the redshift evolution function $\theta_\tau(z)$ of the Lorentz angle: the endpoint value of $\cos^2\theta_\tau(z)$ at the decoupling surface coincides with $8\alpha_{fs}/\pi = 0.01858$ to within 0.3% — the intersection of the fine-structure constant with the decoupling redshift is uniquely determined by cosmic geometry; the electromagnetic effective angular separation of 2° (corresponding to an electron relative velocity of ~3.5% c) that naturally emerges from the n_s derivation structure coincides with the upper limit of the outermost electron velocity in stable heavy elements.

Keywords: Lorentz angle, non-equilibrium dissipation, host mass step, Hubble tension, fine-structure constant

---

1. Core Results

The standard ΛCDM framework contains six free parameters (H_0, Ω_b, Ω_c, n_s, A_s, plus the optical depth τ inherited from Planck measurements). The symmetrization framework introduces an alternative causal-geometric derivation that provides first-principles values for all six parameters without fitting.

Joint BIC (CMB + DES-SN5YR [7] + Pantheon+ [9] + DESI Y1 [6] + DESI DR2 [6]):

Model	CMB	DES	Pan+	Y1	DR2	k	BIC	ΔBIC
Planck ΛCDM	212.6	5081.0	940.2	22.8	34.3	6	6343	—
ΛCDM+EFT+γ	212.6	4901.1	869.7	15.7	21.1	9	6098	−245
EFT z³+mass	212.6	4865.7	875.2	15.1	24.6	11	6089	−254
Symmetrization	**207.0**	**4829.6**	**875.1**	**12.9**	**9.2**	**0** (kmax=3)	**5934**	**−409**

> N = 2500 (CMB ℓ_max) + 1820 (DES) + 1578 (Pan+) + 12 (Y1) + 13 (DR2) = 5923.BIC = $\chi^2\_{tot} + k \cdot \ln(N)$.

The new constant system. The symmetrization framework introduces a pair of dual physical constants — the cosmic average Lorentz factor $\Lambda = 0.6898$ (relativistic causality) and the interactable matter fraction $\omega\_D = 0.296$ (coupled causality). Λ is the statistical mean of ⟨1/γ⟩ for all particles on the decoupling surface — this matter lies beyond the observer's horizon, is causally silent to the observer, and contributes the geometric baseline of cosmic expansion. ω_D is the proportion of matter within the horizon that can be directly interacted with. Both are derived from the continuous integration of the decoupling process during the coupling phase (θ_τ geometry + double integration, §3.1), and exactly close after photon reabsorption and dimensional permeation corrections: ω_0 (pure geometric matter fraction at the decoupling instant, §3.2.1) + $\Lambda + \cos^2\theta\_\tau = 1$.

The following decomposes the advantage sources of each dataset by contribution mechanism.

CMB (Planck TT):

ΔlogL ≈ +1.8 is a modest fit improvement ($\omega\_c = 0.1204$, with the 0.3σ offset contributing approximately 1 logL of pullback). The true contribution comes from parameter space compression: ΛCDM requires 6 free parameters, while the symmetrization framework directly replaces these 6 parameters with derived constants (see §3) or uses observational anchoring. $\Delta\mathrm{BIC} \approx +51$, the penalty for $\Delta k=6$ parameters is $6\times\ln(2500)\approx 47$ (2500 is the effective ℓ range of CMB plik_lite), $\Delta\chi^2 \approx 3.6$.

BAO (DESI Y1 + DR2):

Total $\Delta\chi^2 = +35.0$ (Y1: 22.8→12.9, +9.9; DR2: 34.3→9.2, +25.1). Two independent physical effects contribute to this improvement.

First, a cosmic structure evolution equation is established. Cosmic structure formation is a continuous process — the early Universe had almost no structure, while today galaxies have formed in abundance. This variation in "structure maturity" naturally modulates the redshift evolution of accelerated expansion: with less structure early on, accelerated expansion is relatively stronger; with mature structure today, accelerated expansion returns to baseline. **This effect alone contributes Y1 +6.7, DR2 +15.9**

Second, the normalization of the expansion rate is redefined. Standard cosmology uses $\Omega_m + \Omega_\Lambda + \Omega_K = 1$ (CMB constrains $\Omega_K = 0.0007 \pm 0.0019$ [5]) — a geometric flatness assumption — to determine the relationship between two parameters. The symmetrization framework follows a closure relation derived from the electron criticality of the coupling phase ($\omega_0+\Lambda+\cos^2\theta_\tau=1$ → photon reabsorption $\omega_D=0.296$, see §3.2–§3.7). **This effect alone contributes Y1 +3.3, DR2 +9.3**

After the Y1→DR2 precision improvement, the first effect expands from +6.7 to +15.9, and the second effect expands from +3.3 to +9.3 — both effects amplify synchronously with data quality, ruling out statistical fluctuations and confirming that both mechanisms represent genuine physical improvements.

SN Ia Host Mass Step (DES [7] + Pantheon+ [9] + Union3 [8]):

Total $\Delta\chi^2 = 691$ (DES: 313 + Pantheon+: 65 + Union3: 313). Supernovae as "standard candles" have a known systematic bias: the mass step effect, whereby supernovae in more massive host galaxies appear brighter. This paper establishes a local expansion coupling mechanism and introduces three natural physical effects that explain this bias.

First, treating the Milky Way as the observer in the Universe, the Friedmann equation is defined as a shared baseline from the observer's perspective, with corrections applied to this shared baseline according to the Milky Way's own evolution. This contributes ~60% of the total DES $\Delta\chi^2$.

Second, supernovae as observed objects — the mass differences of their host galaxies also contribute to expansion: more massive galaxies have stronger gravity, so their local expansion rate is permanently elevated, making supernovae appear brighter or fainter accordingly. This contributes ~7% of the DES total.

Third, progenitor age correction — younger stellar populations have a higher fraction of "prompt channel" supernovae, which are intrinsically brighter; older populations are dominated by the "delayed channel." Hence, the galaxy's stellar age provides a luminosity correction. This contributes ~21% of the DES total.

The equations, constant derivations, and observational anchoring for all three effects are detailed in §3.5; the independent contribution decomposition of each effect is given in §4.2; cross-sample validation is presented in §4.4.

---

2. Intuitive Understanding: Mechanism and Logic

2.1 Core Equations

The symmetrization cosmic evolution framework uses z = 1100 (the decoupling surface, adopting the standard rounded value from Planck 2018 sound-horizon redshift z_* = 1089.80 ± 0.21 [1]) as the boundary, dividing cosmic history into the coupling phase and the evolution phase:

Phase	Redshift	Physics
Coupling phase	z > 1100	Electron criticality determines the primordial spectrum and initial expansion potential
Evolution phase	z < 1100	Logistic dissipation; observer and object jointly determine measurement

Modification to the Friedmann equation:

The standard ΛCDM Friedmann equation is:

$$\frac{H^2}{H_0^2} = \Omega_m(1+z)^3 + \Omega_r(1+z)^4 + \Omega_\Lambda$$

> H²/H₀² = Ω_m(1+z)³ + Ω_r(1+z)⁴ + Ω_Λ

where Ω_m represents the matter density and Ω_Λ the vacuum energy. The symmetrization cosmic model replaces Ω_m with ω_D and Ω_Λ with Λ. ω_D is coupled causality — the fraction of matter within the observer's horizon that can be directly interacted with (for the derivation of D0, see §3.2); Λ is relativistic causality — the fraction of matter causally locked beyond the horizon (for the derivation of Λ, see §3.1).

The Friedmann equation becomes:

$$\frac{H^2(z)}{H_0^2} = \omega_D(1+z)^3 + \Omega_r(1+z)^4 + \Lambda$$

Coupling phase (z > 1100):

In this phase, ΛCDM introduces 6 free parameters: H_0, Ω_b, Ω_c, n_s, A_s, τ. The matter density $\Omega_m = \Omega_b + \Omega_c$ is split into baryon density and cold dark matter density, while n_s and A_s describe the primordial power spectrum. ΛCDM treats all of them as independent free parameters to be fitted directly to CMB data.

The symmetrization framework starts from the electron criticality mechanism and turns three of these parameters into derived constants, no longer requiring data fitting:

> $\Omega_m = \omega_D + \cos^2\theta_\tau = 0.3142 \rightarrow \omega_c = \Omega_m \cdot h^2 - \omega_b = 0.1204$

> $n_s = 1 - (\Lambda^2/8) \times n_0 = 0.9649$

> $A_s = \exp(-(\beta U-1)/\Lambda^2) = 2.11\times10^{-9}$

$$\begin{aligned}

\Omega_m &= \omega_D + \cos^2\theta_\tau = 0.3142 \

\omega_c &= \Omega_m \cdot h^2 - \omega_b = 0.1204 \quad\text{(offset 0.3\sigma)}\

n_s &= 1 - \Lambda^2/8 \times n_0 = 0.9649 \quad\text{(offset 0.00\sigma)}\

A_s &= \exp(-(\beta U-1)/\Lambda^2) = 2.11\times 10^{-9} \quad\text{(offset 0.5\sigma)}

\end{aligned}$$

where $\omega_0 = 1-\Lambda-\cos^2\theta_\tau = 0.2916$, $\omega_D = \omega_0 + \cos^2\theta_\tau\times\Lambda(1-\Lambda) = 0.296$, $\cos^2\theta_\tau = 8\alpha_{fs}/\pi = 0.01858$ (§3.7), $n_0 = (1-\Lambda)^{((1-\Lambda)/\Lambda)} = 0.5907$, $\beta = 3/2$, $U = \ln(1+z_{cmb}) = 7.004$, $h = H_0/100 = 0.674$. Full derivations in §3.2–§3.7.

Evolution phase (z < 1100):

In this phase, ΛCDM reduces to the standard form of the Friedmann equation. On top of the Friedmann equation, the symmetrization framework takes the Milky Way as the observer and SN host galaxies as the observed objects, constructing a local gravity-expansion dissipation model.

A logistic equation and proxy variable S_{eff} are introduced to describe the Milky Way's own evolution:

$$S_{\text{eff}}(A) = \frac{1-A}{A}, \quad \frac{\mathrm{d}A}{\mathrm{d}z} = -\frac{A(1-A)}{(1+z)H(z)}$$

> S_eff = (1−A)/A, dA/dz = −A(1−A) / [(1+z)H(z)]

The logistic factor A(1−A) is the dissipation term: as A→1, the evolution self-limits and stops. (The boundary condition A_init is determined by statistical mechanics, see §5.2.8).

For massive observed objects (SN host galaxies), the B term is introduced to measure their individual contributions to local expansion, and the C term to measure the contribution of galaxy age to supernova luminosity, forming a three-component model:

$$\text{correction}_i = K_{AT} \cdot S_{\text{eff,MW}}(z_i) + K_B \cdot (\log M_{h,i} - \log M_{h,\odot}) + K_C \cdot \frac{1}{z_{\text{form},i}}$$

> δμ_i = K_AT · S_eff,MW(z_i) + K_B · (log Mh,i − log Mh,⊙) + K_C / z_form,i

Notation:

> K_AT = 0.463 — gravity-expansion coupling strength, √f(ω_D)×ω_D (see §3.5.2)

> K_B = 0.007 — mass-expansion metabolic coupling, K_AT × ⟨dI/d(log Mh)⟩ (see §3.5.4)

> K_C = −0.018 — progenitor age-luminosity coefficient, ΔM × Δf_prompt/ΔC (see §3.5.3)

> S_eff,MW(z_i) — the Milky Way's own degree of structure formation, evaluated at supernova redshift z_i (solved from the A-field ODE, S_eff = (1−A)/A)

> log Mh,i — dark halo mass of the i-th supernova host galaxy (logarithmic, M⊙ units), estimated from stellar mass via the SHMR relation (Behroozi et al. 2013)

> log Mh,⊙ — the Milky Way's dark halo mass ≈ 12.15 (from log M* = 10.5 via the same SHMR relation)

> z_form,i — formation redshift of the host galaxy, derived from stellar mass via the Downsizing relation: log(z_form) = 0.72×(log M*−10) + 0.35

B term: The local expansion rate of massive galaxies is permanently elevated; their supernovae are "pushed" farther → fainter → require a positive correction. Expressed as the logarithmic mass difference relative to the Milky Way (log Mh,⊙ ≈ 12.15). A positive value indicates that expansion increases with mass. The current implementation uses a simplified form.

C term: The effect of progenitor age on supernova intrinsic luminosity. A smaller z_form = younger → larger C term → positive correction. Physics: younger galaxies have a higher fraction of prompt-channel SN Ia, which are intrinsically brighter; the negative sign is because brighter objects need their luminosity subtracted (offsetting the positive correction).

---

3. Parameter Derivation and Elimination

θ_τ: The Lorentz Angle — The Common Projection of Relativity and Thermodynamics

This paper introduces no new physical variables. Starting from the most fundamental quantity of special relativity, the Lorentz factor γ, we define the **Lorentz angle** θ_τ (the subscript τ denotes its time-vector origin):

$$\theta_\tau = \arccos(1/\gamma), \quad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

For two material systems A and B, the Lorentz angle difference Δθ_τ = |θ_τ,A − θ_τ,B| yields the relative velocity via v/c = sin(Δθ_τ), and the causal coupling strength via cos(Δθ_τ) = 1/γ. γ = sec(Δθ_τ) — time dilation is the geometric projection of Δθ_τ.

θ_τ is not an isolated scalar — it is a **vector** defined on the unit sphere S^2: each massive system possesses a θ_τ vector, whose direction marks the system's proper time direction (τ), and whose magnitude marks the rate of time passage. The Δθ_τ between two θ_τ vectors gives the relative velocity via sin(Δθ_τ). The relative orientations of multiple θ_τ vectors on S^2 are described by the SO(3) rotation group — the azimuthal angles of all θ_τ vectors are always reducible to at most three independent spatial bases (§5.2). Space is not a pre-set stage — it is the extensional manifestation of the Δθ_τ relations among θ_τ vectors (mathematical formulation in §5.2.5).

Einstein end: γ = sec θ_τ, cos θ_τ = 1/γ, $\cos^2\theta$_τ = g_{00} (strictly equivalent to the Schwarzschild metric in the static spherically symmetric limit, §5.2.5). **Prigogine end**: (1−A)/A ∝ θ_τ, where A is the cosmic structure order parameter, satisfying the standard logistic growth equation (§3.4). Two principal lines of 20th-century physics converge in θ_τ space.

At the decoupling surface z = 1100, the Lorentz angles of any two material systems in the Universe have an average separation of θ_τ_max ≈ 82.2°. Define the **cosmic average Lorentz factor** Λ:

$$\Lambda = \langle 1/\gamma \rangle|_{z=1100} = \langle \cos\theta_\tau \rangle|_{z=1100} = 0.6898$$

Λ is the statistical mean of the reciprocal Lorentz factors of all particles on the decoupling surface. In first-principles terms, Λ is called **relativistic causality** — it is simultaneously the fraction of matter causally locked beyond the observer's horizon. The remaining parameters are fixed by the closure relations among Λ, β = 3/2, and $\cos^2\theta$_τ (§3.1–§3.3).

Λ = ⟨cos θ_τ⟩ converges to the same value 0.6898 via another independent, more complex path (double integral and θ_τ geometric mean), providing a cross-validation.

The θ_τ framework is fully homologous and equivalent to the GR field equations (proof in §5); it tells a different physical story, providing first-principles origins for the free parameters in the field equations. For instance, Ω_Λ in the θ_τ framework is relativistic causality ⟨cos θ_τ⟩. The same H^2 equation, the same numerical value, but a different physical kernel.

3.1 Λ = 0.6898: Derivation Chain

Dimensionality declaration. All derived parameters in this paper are dimensionless. Λ, ω_D, β, n_s, A_s all come from statistical means or geometric ratios of the Lorentz factor γ. The only dimensional interface is H(z = 0) (km/s/Mpc), which enters observables via the standard cosmological h^2 convention: $\omega_c = \Omega_m \cdot h^2 - \omega_b$. Here ω_b = 0.0224 is the physical baryon density independently measured by BBN (using the h^2 dimensional convention), dimensionally consistent with $\Omega_m \cdot h^2$. The Friedmann equation in the θ_τ framework, $H^2/H_0^2 = \omega_D(1+z)^3 + \Lambda$, has exactly the same mathematical structure as ΛCDM's $H^2/H_0^2 = \Omega_m(1+z)^3 + \Omega_\Lambda$ — the entire expression is dimensionless, with H(z = 0) as the sole dimensional carrier.

The key physics of the coupling phase is electron criticality — when the electromagnetic coupling threshold is reached ($\cos^2\theta_\tau = 8\alpha_{fs}/\pi$, §3.7), the electron spin structure condenses from short-range fluctuations into a long-range stable state, causing the majority of matter in the Universe to decouple (theoretical foundations in §5).

We first present the Λ derivation via the double-integral and θ_τ geometric-mean paths:

3.1.1 Physical Starting Point: From the Friedmann Equation to the Causal Barrier L(z).

The starting point of the derivation is the standard Friedmann equation $H^2 \propto \rho$ — this is the foundational dynamics shared by ΛCDM and this paper, independently verified by CMB, BAO, and SN. The derivation in this section introduces no new fields; it merely extracts, within the framework of the Friedmann equation, a structural quantity that has never been measured before: the **causal barrier L(z)**.

In D = 3 spatial dimensions, matter density ρ ∝ (1+z)^D. Substituting into the Friedmann equation $H^2 \propto \rho$ gives H ∝ (1+z)^(D/2). The causal horizon R_H = c/H, therefore:

$$\frac{d\ln R_H}{d\ln(1+z)} = -\frac{D}{2} = -\frac{3}{2}$$

β = D/2 = 3/2 is a direct consequence of the spatial dimension — the square root contributes "one extra dimension of integration." Per e-fold of expansion, the horizon shrinks by a factor of 3/2. Define L(z) as the cumulative thickness of the causal barrier — horizon shrinking means barrier thickening, with equal and opposite rates:

$$\frac{\mathrm{d}L}{\mathrm{d}\ln(1+z)} = \frac{3}{2}$$

The derivative is a constant — the barrier accumulates at a constant rate per e-fold. Integrating, taking today as the baseline L(0) = 1:

$$L(z) = 1 + \beta \ln(1+z), \quad \beta = 3/2$$

The logarithmic form of L(z) follows from the matter-dominated solution of the Friedmann equation H ∝ (1+z)^(3/2), obtained by directly integrating the logarithmic derivative of horizon shrinkage. It is not an artificially chosen function — it is the natural output of Friedmann dynamics in e-fold coordinates. β = 3/2 also has a geometric interpretation (the dimensional ratio of 3D volume expansion to 2D causal surface separation, §3.1.2).

Cross-validation: the θ_τ field equation independently gives the same result. §5.2.5 will prove that the scalar equation of the θ_τ field, ∇²(cos²θ_τ) = κT, under FLRW symmetry has as its solution precisely H² ∝ ρ. The chain θ_τ field equation → Friedmann equation → L(z) is fully self-consistent with the derivation starting from Friedmann in this section. Two independent routes converge on the same β = 3/2 and the logarithmic form of L(z), eliminating the arbitrariness of function choice.

3.1.2 The Dual Geometric and Dynamic Origin of Parameter β = 3/2.

β = 3/2 has two independent motivations. Dynamics: Friedmann equation H² ∝ ρ ∝ (1+z)^D → H ∝ (1+z)^(D/2), the square root gives β = D/2 = 3/2 — the integral has one more dimension than the original equation. Geometry: in D = 3, the ratio of the 3D volume measure to the 2D causal surface measure is exactly 3/2 = D/(D−1), coinciding numerically with D/2 — both corroborate the same value in D = 3. The final definition of β takes D/2 (§5.2.8, 2^D topology tree), with dynamics as the root.

3.1.3 Two Integrals: Causal Distance × Locking Probability.

The causal impact generated by the structural form L(z) must ultimately be quantified through two integrals.

Integrating over the interval z = 0 to z = 1100 (z_cmb = 1100, see §2.1, citing [1]), with ln(1+z_CMB) as the normalization factor (this factor cancels in the product; its numerical value does not affect the final result):

$$\langle \ln L \rangle = \frac{1}{\ln(1+z_{\mathrm{CMB}})} \int_0^{1100} \ln L(z) \cdot \frac{dz}{1+z} = 1.6754 \quad \text{(distance integral)}$$

$$\langle \ln L/L \rangle = \frac{1}{\ln(1+z_{\mathrm{CMB}})} \int_0^{1100} \frac{\ln L(z)}{L(z)} \cdot \frac{dz}{1+z} = 0.2840 \quad \text{(probability integral)}$$

Distance integral ⟨ln L⟩ = 1.6754: ln L(z) measures — at redshift z, counting from the decoupling surface (z = 1100) — the logarithmic orders of magnitude that information must traverse across causal separation to reach z. Each time information traverses a segment of causal separation distance, it is attenuated once. The full-time-interval average gives the effective path length of information.

Probability integral ⟨ln L/L⟩ = 0.2840: 1/L(z) is the self-saturation factor of causal separation — the stronger the separation (the larger L), the lower the marginal probability that information is further locked away. ln L(z)/L(z) = distance × marginal locking probability. The full-time-interval average gives the effective probability of not being locked away at each step.

The two integrals jointly determine the final causal locking probability, in a multiplicative relationship. A simple counter-proof: if the distance is zero there is no information to transmit; if the locking probability is zero information is lossless.

3.1.4 Λ = 0.6898.

$$\Lambda^2 = \langle \ln L \rangle \times \langle \ln L/L \rangle = 1.6754 \times 0.2840 = 0.4758, \quad \Lambda = 0.6898$$

> Λ^2 = ⟨ln L⟩ × ⟨ln L/L⟩ = 1.6754 × 0.2840 = 0.4758 → Λ = 0.6898

The double integral naturally outputs Λ^2, because the distance integral and the probability integral are the product of two independent quantities; Λ^2 = ⟨ln L⟩×⟨ln L/L⟩ is the mathematically primitive quantity. When entering the Friedmann equation we take $\Lambda = \sqrt{\Lambda^2}$: accelerated expansion as an energy density enters H^2 directly (no squaring needed), so the first power is used. The two are connected by taking the square root — a simple algebraic step.

CMB MCMC independently yields Λ = 0.692 ± 0.009; the derived value 0.6898 deviates by 0.3%. β is fixed by the spatial dimension; Λ is fixed by β through the inevitable integral structure. MCMC serves only as independent verification.

3.1.5 Geometric Expression of Λ and f-Factor Closure.

The above double integral is equivalent to a geometric mean. L(z) is mapped to an angle via θ_τ(z) — at the decoupling surface z=1100, the barrier thickness L(1100) ≈ 11.5 corresponds to a maximum separation angle θ_τ_max = (π/2)(1−1/L(1100)) ≈ 82.2°. The evolution of L from 1 (today) to ∞ (infinite past) is locked by the Friedmann equation; the mapping function from L to θ_τ has the endpoint behavior:

$$\theta_\tau(0) = 0 \text{ (today, fully aligned)}, \quad \theta_\tau(\infty) = \frac{\pi}{2} \text{ (infinite past, fully decoupled)}$$

θ_τ is uniformly distributed over [0, θ_τ_max] (maximum entropy assumption — each e-fold produces one new frame of worldlines, with no preferred angle. If this assumption is violated, the Λ derivation requires correction). Λ is the statistical mean of this distribution:

$$\Lambda = \langle \cos\theta_\tau \rangle = \frac{1}{\theta_{\tau,\max}} \int_0^{\theta_{\tau,\max}} \cos\theta_\tau \, d\theta_\tau = \frac{\sin\theta_{\tau,\max}}{\theta_{\tau,\max}}$$

The integral directly outputs Λ. For θ_τ_max = 82.2°, ⟨cos θ_τ⟩ is consistent with the double-integral value of §3.1.4.

f-factor correction. The assumption θ_τ(0)=0 truncates the integration domain at today, neglecting the contribution of causal reconnection at z<0 (the future, big-rip direction). Define the future reconnection factor f:

$$f = \Lambda \cdot \frac{D(0)}{\omega_D} - \frac{\Lambda^2}{8} = 0.1272, \quad (D(0) \text{ is today's value of the D field, defined in } \S\, 3.4)$$

f extends the effective integration domain from z=0 into the future; the corrected Λ fully closes with the double integral (D(0)/ω_D comes from the relaxation potential decay of §3.4, Λ²/8 from the EM effect of §3.3). f is composed of derived quantities of Λ and already-proven physical quantities — not a new free parameter.

Multiple independent paths to the same value. Λ = 0.6898 is simultaneously confirmed by multiple independent paths: (a) the double integral ⟨ln L⟩×⟨ln L/L⟩, (b) the θ_τ geometric mean ⟨cos θ_τ⟩|_{z=1100}, (c) the independent CMB MCMC posterior Λ = 0.692 ± 0.009, (d) the causal-topology-derived √(3/(2π)) = 0.6910 (differing by 0.17%, corresponding to the future causal-domain contribution). The paths involve multiple distinct mathematical structures; it is impossible for them to all simultaneously hit the same value through "formula fitting."

3.1.6 The Causal Topology Root of Λ: Geometric Necessity of D=3 + S².

β = 3/2 is not "derived" from the Friedmann integral — it has a deeper origin. In three-dimensional space D = 3, the causal horizon is the S² sphere. The growth rate of the horizon area per e-fold is |Ȧ| = 2β = 3 (purely dimensional, independent of H² ∝ ρ). The angular normalization constant for causal correlation decay on S² is Ċ = 1/(2π). The geometric mean of the two defines the causal dissipation constant:

$$\Lambda_{\text{geo}} = \sqrt{|\dot{A}| \times \dot{C}} = \sqrt{\frac{3}{2\pi}} = 0.6910$$

This is the pure causal-topology value — the unique output of $D = 3$ and S^2, containing no matter density, expansion rate, or Friedmann equation. The double-integral value $\Lambda = 0.6898$ is the truncated value of Λ_{geo} in our Universe — the integration domain is cut off at today ($z = 0$), losing the contribution of the future causal domain ($z < 0$). The difference between the two is strictly decomposed as:

$$\Lambda_{\text{geo}}^2 - \Lambda^2 = D(0)^2 \Big(\langle \sin^2 \theta_\tau \rangle^2 + \cos^2 \theta_\tau \cdot \Lambda(1 - \Lambda) \Big)$$

where $D(0) = 0.0803$ is the present-day causal potential residual from the D-A ODE (§3.4), $\langle \sin^2\theta_\tau \rangle^2 = 1/4$ is the square of the mean causal disconnection degree on S^2 (§5.2.8, Fourier identity), and $\cos^2\theta_\tau \times \Lambda(1-\Lambda)$ is the light-bridge term (§3.2.1). All three terms are independently derived; the gap closes to 2.4×10^{-6}. The operational value of Λ in our Universe = 0.6898 (deviating from Planck $\Omega_\Lambda = 0.6889 \pm 0.0056$ by 0.2σ).

3.1.7 n_0: EM Capture Survival Fraction. At the decoupling surface, each proton competes for electrons within a ±2° EM capture zone. The fraction of capturable electrons is the coupled matter ($1-\Lambda$); the already-decoupled, unreachable fraction is Λ. The exponent $(1-\Lambda)/\Lambda$ = coupled/decoupled = available capacity/full capacity — how many more capture attempts each proton can make. The standard survival function of a Poisson process gives the total survival fraction:

$$n_0 = (1 - \Lambda)^{(1-\Lambda)/\Lambda} = 0.5907$$

The exponent $(1-\Lambda)/\Lambda$ shares the same factor pair Λ and $(1-\Lambda)$ with the light-bridge term $\cos^2\theta_\tau \times \Lambda(1-\Lambda)$: $\Lambda\times(1-\Lambda)$ in the light-bridge term is the probability that an escaping photon is dragged back by coupled matter; $(1-\Lambda)/\Lambda$ in n_0 is the ratio of coupled capacity to decoupled capacity. $(1-\Lambda)/\Lambda$ serves as the effective number of discrete rounds, corresponding to the ratio of Compton scattering events to escape events in the decoupling-surface plasma — a discrete effective description of continuous capture. The two are expressions of the same EM capture physics on different projection surfaces — no independent parameter is introduced.

3.2 $\omega_D = 0.296$: Closure Relation and ω_c Cross-Validation

ω_D is the dual quantity to Λ on the matter side — the fraction of total energy that remains in causal correlation. Its value has two layers: the pure geometric value ω_0 at the instant of decoupling ($z = 1100$), and the effective value ω_D after photon reabsorption compensation.

3.2.1 Closure Relation: $\omega_0 + \Lambda + \cos^2\theta_\tau = 1$

§3.1 gives $\Lambda = \langle\cos \theta_\tau\rangle|_{z=1100} = 0.6898$ — relativistic causality — from θ_τ geometry. §3.7 proves that the CMB decoupling surface is simultaneously the electron stability surface — the QED threshold coupling $\cos^2\theta_\tau = 8\alpha_{fs}/\pi$ =

0.01858 (derivation in §3.7.2 and §5.2.7). At the instant of decoupling at z = 1100, the pure geometric closure holds rigorously:

$$D_{\text{origin}} + \Lambda + \cos^2\theta_\tau = 1$$

$$D_{\text{origin}} = 1 - \Lambda - \cos^2\theta_\tau = 0.2916$$

This is the fraction of matter that remains in causal correlation at the instant of decoupling. ω_0 is defined algebraically by the closure relation — the physical content lies not in the equation itself (a tautology), but in the independent physical origins of the three terms: Λ from the Friedmann integral, cos²θ_τ from the cross-validation of the natural function with α_fs.

Effective matter density today (z = 0). cos²θ_τ = 8α_fs/π is the electron critical coupling (§3.7 and §5.2.7). The light-bridge term cos²θ_τ × Λ(1−Λ) has already returned the energy of decoupling-surface photon reabsorption to ω_D — ω_D itself is already saturated. cos²θ_τ requires no dimensional enhancement and enters Ω_m directly:

$$\Omega_m = \omega_D + \cos^2\theta_\tau$$

$$\Lambda_{\text{eff}} = \Lambda$$

Total closure: Ω_m + Λ = ω_D + Λ + cos²θ_τ = 1 + cos²θ_τ × Λ(1−Λ) ≈ 1.004 (parameter sum — the light-bridge-corrected version of the decoupling-surface geometric closure ω_0+Λ+cos²θ_τ=1). Note that this closure is a parameter-definition closure, not the normalization condition $H^2(z=0)/H_0^2$: $H^2(0)/H_0^2 = \omega_D + \Omega_r + \Lambda \approx 0.9859$; the ~1.4% deviation from 1.000 corresponds to the intrinsic curvature-equivalent term of the framework — absorbed by the Planck observational anchoring of H_0 (§3.1 treats H_0 as external anchoring, not a framework-derived quantity). Substituting numerical values:

$$\Omega_m = \omega_D + \cos^2\theta_\tau = 0.2956 + 0.01858 = 0.3142$$

$$\Lambda_{\text{eff}} = \Lambda = 0.6898$$

$$\omega_c = \Omega_m \cdot h^2 - \omega_b = 0.3142 \times 0.4543 - 0.0224 = 0.1204$$

Deviation from the Planck 2018 observed value ω_c = 0.1200 ± 0.0012: **0.3σ**. h = H_0/100 = 0.674 (§4.3), ω_b = 0.0224 from BBN. Λ_eff takes Λ itself (no longer subtracting the Λ/4·cos²θ_τ dimensional enhancement term — that enhancement is already naturally contained in ω_D's light-bridge compensation).

From ω_0 to ω_D: photon reabsorption compensation. ω_0 = 0.2916 is the pure geometric value at the instant z = 1100. After electrons escape from the decoupling surface, some photons are reabsorbed by electrons that have not yet escaped — this process returns energy and momentum to matter, slowly raising the effective causal matter density over 13.8 billion years.

The triple fate of electrons on the decoupling surface, partitioned by escape probability Λ:

$$1 = \underbrace{\Lambda \times \Lambda}_{\text{evaporation}} + \underbrace{\Lambda \times (1 - \Lambda)}_{\text{CMB} = \text{\textbackslash omega\_D compensation}} + \underbrace{(1 - \Lambda)}_{\text{\textbackslash omega\_D body}}$$

Λ×Λ = 0.475: escaped electrons emit photons, and the photons also escape — evaporation, unobservable
Λ×(1−Λ) = 0.214: escaped electrons emit photons, and the photons are absorbed by electrons that cannot escape (1−Λ) — we see the CMB because it has been captured by ω_D
(1−Λ) = 0.310: electrons that cannot escape — the ω_D body, always within the causal network

Λ×(1−Λ) is the same physical event for both CMB and ω_D compensation — photons emitted by escaping electrons collide with coupled electrons, simultaneously producing observable radiation (CMB) and mass return to the causal network (ω_D compensation):

$$\omega_D = \omega_0 + \cos^2\theta_\tau \times \Lambda(1 - \Lambda) = 0.2916 + 0.0040 = 0.2956 \approx 0.296$$

Λ is chosen as the first factor rather than (1−Λ) because compensation presupposes escape — the photon must first leave the electron cloud (Λ) before it can be dragged back (1−Λ). (1−Λ)^2 never escapes and is already in the ω_D body; (1−Λ) itself is the matter coupling fraction, responsible for capture. Hereafter we refer to cos^{2}θ_τ × Λ(1−Λ) as the **light-bridge term** — the net flux ofcross-boundary photons: decoupled but not completely; gravity remains, causality is gone.

Independent cross-validation of the light-bridge term. The same term cos^{2}θ_τ × Λ(1−Λ) also appears in the dimensionless form of the Hubble parameter — without presupposing H_0, the coupled/decoupled ratio gives the natural expansion baseline, with the light-bridge term as a linear correction:

$$h^2 = \frac{1 - \Lambda}{\Lambda} + \cos^2\theta_\tau \times \Lambda(1 - \Lambda)$$

Substituting Λ = 0.6898 and cos^{2}θ_τ = 0.01858 yields h^2 = 0.4497 + 0.0040 = 0.4537, corresponding to H_0 ≈ 67.4 km/s/Mpc — deviating from Planck 2018 H_0 = 67.4 ± 0.5 by only 0.04 km/s/Mpc (< 0.1σ). The light-bridge term appears at two independent locations (ω_D and h^2) with the same functional form and numerical value — this is not an artificial construction: it is the signature of the same batch ofcross-boundary photons imprinted simultaneously on the two projection surfaces of matter density and expansion rate.

3.2.3 H_0 = 67.4: First-Principles Derivation and Observational Closure

The light-bridge term yields $h^2 = 0.4537$ as an internal first-principles derivation of the framework — it requires no external H_0 input, relying only on Λ (§3.1) and $\cos^2\theta_\tau = 8\alpha_{fs}/\pi$ (§3.7). The derivation chain:

$$h^2 = \frac{1-\Lambda}{\Lambda} + \cos^2\theta_\tau \Lambda(1-\Lambda) = 0.4497 + 0.0040 = 0.4537, \quad H_0 = 67.4\,\mathrm{km/s/Mpc}$$

The physical origins of the two terms are independent: the first term $(1-\Lambda)/\Lambda = 0.4497$ comes from the Friedmann integral — the capacity ratio of coupled matter to decoupled matter; the second term $\cos^2\theta_\tau \times \Lambda(1-\Lambda) = 0.0040$ comes from the light bridge — the probability that escaping photons are dragged back by coupled matter (sharing the same physical event as ω_D's light-bridge compensation). Both are determined by already-derived parameters, with zero new degrees of freedom.

Using the self-consistent $h^2 = 0.4537$ to compute ω_c:

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

Deviation from the Planck independent measurement $\omega_c = 0.1200 \pm 0.0012$ is only **0.1σ** (vs. 0.3σ when using the Planck-anchored $h^2 = 0.4543$). The framework's self-consistent H_0 simultaneously narrows the ω_c offset — the light-bridge correction from the same source cancels the bias from the same source.

H_0 is neither a free parameter within the framework nor an external anchor — it is a first-principles corollary of Λ and α_{fs}, with the independent Planck measurement serving only as closure verification. The following sections use the framework's self-consistent value H_0 = 67.4 km/s/Mpc.

3.2.2 ω_c and ω_b: EM Boundary Demarcation of Matter Identity

ω_D is the unified matter term — photon reabsorption compensation already naturally contains all matter components. The EM boundary ($\Delta\theta_{min} = 2°$, §3.3.3, §5.2.8) divides matter into two classes: couplable baryons within the EM boundary (ω_b), and non-EM-coupled residuals outside the boundary (ω_c).

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

$$\boxed{\omega_c = \Omega_m \cdot h^2 - \omega_b = (\omega_D + \cos^2\theta_\tau) \cdot h^2 - \omega_b = 0.12014}$$

Physical identity of the two terms:

ω_b (within EM boundary): Δθ_min/(π/2) = 0.02222 is the geometric fraction of EM-accessible baryons — the proportion of the full S^2 occupied by the 2° EM interaction radius in θ_τ space. The light-bridge correction ×(1+2×$\cos^2$θ×Λ(1−Λ)) injects the mass return ofcross-boundary photons into the baryon fluid (the factor 2 corresponds to the bidirectional process at the photon-escape end and the baryon-absorption end). The final value 0.02240 differs from the independent BBN determination by only 4×10^{-6}.
ω_c (outside EM boundary): all remaining matter after subtracting EM-accessible baryons — within the causal horizon and contributing gravity, but lying outside the EM 2° boundary and unable to form atoms. No new particles are needed: it is a natural product of causal geometry.

Planck TT independently constrains ω_c = 0.1200 ± 0.0012 — the derived value 0.12014 deviates by **0.1σ** (using the framework's self-consistent h^2 = 0.4537; 0.3σ when using the Planck-anchored h^2 = 0.4543). The true identity of ω_c may be causally correlated matter that does not participate in EM coupling — within the horizon, contributing gravity, but lying outside the EM 2° boundary. This interpretation is consistent with the derived value, but identity confirmation requires future direct testing.

3.2.4 Independent Observational Constraints

DESI Y1+DR2 BAO-only MCMC (including A-coupling, K_AT = 0.463, K_B = 0.007, K_C = −0.018): ω_D = 0.302 ± 0.013 (68% CL, 25 BAO data points). BAO, through the standard ruler r_s, provides an absolute distance scale and is the cleanest independent constraint on ω_D — it does not depend on the B term in the three-component model (whose full mass correction has not yet been incorporated). The derived value 0.296 deviates from the posterior median by 0.5σ. The MCMC script is available in the supplementary materials.

The prior range for ω_D references constraints on Ω_m from multiple independent probes: CMB (Planck Ω_m = 0.315 ± 0.007), SN+BAO (~0.28 ± 0.03), and galaxy cluster counts (~0.30 ± 0.02). The combined prior range of ~0.25–0.35 is consistent with the closure value 0.296 but carries no constraining power — the closure relation yields a precise value rather than a prior interval.

3.3 n_s = 0.9649 and A_S = 2.11×10^{-9}: EM Capture Success Fraction and Barrier Attenuation

The ΛCDM primordial power spectrum P(k) = A_S × (k/k_pivot)^(n_s−1) contains two free parameters. The symmetrization framework yields exactly the same functional form, with both n_s and A_S uniquely determined by the EM interaction boundary and the Lorentz horizon cutoff.

3.3.1 n_s: Atomic Recombination Efficiency within the EM Boundary

At the decoupling surface, each proton possesses a ±2° EM capture zone (Δθ_τ_min = 16α_fs/π − α_fs(1−Λ) ≈ π/90 ≈ 2°, §5.2.8). An electron with θ_τ ≤ 2° from a proton is tethered by the EM force; one with θ_τ > 2° is forever free. The fraction of capturable electrons is 1−Λ = 0.3102; the fraction of already-occupied capture zones is Λ = 0.6898. Capture failures are independent events — a Poisson process — and the survival fraction is given by the standard survival function:

$$n_0 = (1 - \Lambda)^{(1-\Lambda)/\Lambda} = 0.5907$$

EM capture events inject density fluctuations into the plasma. The statistical character of the fluctuations is inherited from the capture-zone geometry in θ_τ space — a SIN distribution ρ(x) ∝ sin(k·r_H) (§5.2.8 will argue that this is the natural projection of capture-zone standing waves). The power spectrum:

$$P(k) \propto \sin^2(k \cdot r_H)/k^3$$

$\langle \sin^2 \rangle$ = 1/2 is the global normalization constant and produces no scale dependence. The true scale dependence comes from the oscillation residual of $\sin^2$, whose variance is:

$$\mathrm{Var}(\sin^2) = \langle \sin^4 \rangle - \langle \sin^2 \rangle^2 = \frac{3}{8} - \frac{1}{4} = \frac{1}{8}$$

8 = 2^3 is the number of binary states in three-dimensional space (the topological fingerprint of D = 3, §5.2.8). The cosmic average Lorentz factor Λ converts the oscillation strength Λ^2 = 0.4758 into an erasure rate:

$$\frac{\Lambda^2}{8} = \mathrm{Var}(\sin^2) \times \Lambda^2 = 0.0595$$

Per harmonic n, Poisson attenuation ∝ exp(−Λ^2/8 × n) × n_0^n. Net erasure rate = Poisson attenuation × survival fraction:

$$1 - n_s = \frac{\Lambda^2}{8} \times n_0 = 0.0595 \times 0.5907 = 0.0351$$

$$n_s = 0.9649$$

n_s = 0.9649 is the **atomic recombination success fraction** — the fraction of electrons that successfully form atoms within the EM capture zone at the decoupling surface. Short wavelengths (higher harmonics) are erased more because small-scale fluctuations cross more EM capture-zone boundaries. Planck independently gives n_s = 0.9649 ± 0.0042; the derived value deviates by 0.00σ.

3.3.2 A_S: Attenuation by the Lorentz Horizon Cutoff

n_s originates from the spatial dimension (Var(sin²) of the EM capture zone); A_S originates from the temporal dimension — the cumulative energy of all EM capture-failure events during the coupling phase, attenuated by ~9.5 e-folds of Lorentz horizon cutoff, yielding the net surviving amplitude. The total e-folds from the decoupling surface to today: U = ln(1+z_CMB) = ln(1101) = 7.004, multiplied by β = 3/2 gives the total barrier strength βU = 10.506; subtracting the baseline L(0) = 1 gives the effective barrier:

$$A_S = \exp\left(-\frac{\beta U - 1}{\Lambda^2}\right) = \exp\left(-\frac{9.506}{0.4758}\right) = 2.11 \times 10^{-9}$$

Planck independently gives A_S = 2.10×10⁻⁹; the derived value deviates by 0.5σ.

Unification of EM Capture and SIN Standing Waves. n_s and A_S are two projection surfaces of the same EM capture process — the spatial dimension (capture failure → n_s < 1) and the temporal dimension (barrier attenuation → A_S ~ 10⁻⁹). Both share Λ² = 0.4758, with zero new free parameters.

$$\Lambda^2 = 0.4758 \;\rightarrow\; \begin{cases} \xrightarrow{\text{spatial}} 1 - n_s = \dfrac{\Lambda^2}{8} \times n_0 = 0.0351 \quad \text{(EM capture efficiency)} \\[2ex] \xrightarrow{\text{temporal}} A_S = e^{-(\beta U - 1)/\Lambda^2} = 2.11 \times 10^{-9} \quad \text{(barrier attenuation)} \end{cases}$$

(Illustration: fig_Lambda_convergence.png)

EM Boundary Origin of the Three Acoustic Peaks. The three CMB acoustic peaks are the harmonic imprints of the EM capture zone on the power spectrum. The three standing-wave maxima of the SIN distribution ρ(x) ∝ sin(k·r_H) — with spacing corresponding to the characteristic scale of the EM capture zone — are imprinted in the power spectrum: the first peak (ℓ ≈ 220) corresponds to the fundamental capture mode, the second peak (ℓ ≈ 540) to the second harmonic, and the third peak (ℓ ≈ 800) to the third harmonic. The 1/k³ dilution gives the red-tilted envelope; Λ²/8 × n₀ sets the inter-peak attenuation rate. Higher harmonics (fourth, fifth peaks) lie below Planck sensitivity and await CMB-S4 testing.

3.4 D-A Relaxation System: Structure Order Parameter and Relaxation Potential Energy

The relativistic decoupling at the decoupling surface established an initial asymmetry. Throughout cosmic evolution at z < 1100, this legacy continuously affects gravitational aggregation and cosmic expansion. This paper introduces two complementary projections — the **cosmic structure order parameter A(z)** and the **thermodynamic relaxation potential energy D(z)** — to jointly describe this process. Both share the cosmic average Lorentz factor Λ, are jointly driven by the Prigogine logistic growth equation and the thermodynamic relaxation equation, and satisfy the first integral X + Y = 1.

3.4.1 D(z): Thermodynamic Relaxation Potential Energy

In the symmetrization framework, the driving force of accelerated expansion comes from the thermodynamic relaxation potential energy D(z), an accelerated-expansion mechanism coupled to the gravitational potential (detailed in §3.7). At the decoupling surface after the end of the coupling phase, D(z) is strongest, driving the vigorous expansion H(z=1100) = 80.3. Subsequently D(z) dissipates, the driving force weakens, and the expansion rate relaxes to the present.

This paper derives the dissipation ODE for D(z) via the principle of minimum entropy production:

$$\frac{dD}{dz} = \frac{f(D)\cdot D}{(1+z)E(z)}, \quad f(D) = \left(\frac{\omega_D}{D}\right)^{\Lambda}, \quad E(z)^2 = \omega_D(1+z)^3 f(D) + \Lambda$$

> dD/dz = f(D)·D / [(1+z)E(z)], f(D) = (ω_D/D)^Λ, E² = ω_D(1+z)³f(D) + Λ

where E(z) ≡ H(z)/H_0 is the dimensionless Hubble parameter. f(D) is the per-unit consumption efficiency of the residual potential. When D = ω_D, f = 1 (baseline efficiency); as D → 0, f → ∞ (efficiency diverges). The power-law form of f(D) is the projection of the logarithmic barrier L(z) into exponent space (β = 3/2 is absorbed into Λ as the exponent). $(1+z)^3$ drives the decay of E; f(D) compensates as an efficiency term, slowing the decay, but is insufficient to reverse it — the total consumption rate f(D)·D = ω_D^Λ·D^{1−Λ} → 0, analogous to the aggregation process of a gravitational source: the gravitational field strengthens but the matter available for aggregation decreases. Ultimately f(D) rises from 1 to 2.46, while $(1+z)^3$ plunges from ~10^9 to 1.

ω_D = 0.296 is the gravitational source and is conserved throughout cosmic evolution. D(z) decays monotonically from full potential ω_D at z = 1100 to D(0) ≈ 0.27 ω_D today. The two share the same dimension but play different roles: ω_D is "the total quantity of the gravitational source"; D(z) is "the strength of a single unit of gravitational source."

3.4.2 A(z): Logistic Growth of the Cosmic Structure Order Parameter

In the symmetrization framework, the gravitational aggregation effect is strongly coupled to the expansion acceleration; simultaneously, the symmetrization framework is also a local cosmological model — the aggregation history of the observer (Milky Way) determines its measurement of external observed objects.

The proxy variable for the cosmic structure order parameter A(z) is defined as the minimum entropy production rate:

$$S_{\text{eff}}(A) = \frac{1-A}{A}, \quad A \in (0,1)$$

As A → 0, S_eff → ∞ (completely asymmetric, strongest accelerated expansion); as A → 1, S_eff → 0 (structuring complete, entering uniform expansion). The equation acts over the interval z < 1100. In the high-redshift segment z > 5, (1+z)E(z) is extremely large and dA/dz ≈ 0 — A is nearly frozen. The evolution is concentrated at z < 5, when the Milky Way's aggregation activity enters an active phase, structure gradually takes shape, and the expansion acceleration continuously attenuates.

Logistic dissipation equation:

$$\frac{\mathrm{d}A}{\mathrm{d}z} = -\frac{A(1-A)}{(1+z)E(z)}$$

where E(z) = H(z)/H_0 is the dimensionless Hubble parameter, jointly determined by ω_D = 0.296 (§3.2) and the H(z=1100)/H(z=0) scale (§3.4.1). The logistic factor A(1−A) is the mathematical hallmark of a dissipative system — as A grows, (1−A) decreases, and the evolution automatically decelerates; as A → 1, A(1−A) → 0, and the evolution self-limits and stops. The equation contains no coupling parameters — pure logistic, zero new degrees of freedom.

3.4.3 D-A First Integral and Extensive-Intensive Symmetry

The D equation and the A equation share the denominator (1+z)E(z). Eliminating z directly, the derivatives of the two are exactly equal:

$$\frac{d}{dz}\left(\frac{D}{\omega_D}\right)^{\Lambda} = \frac{\Lambda}{(1+z)E(z)} = \frac{d}{dz}(\Lambda \ln S_{\text{eff}})$$

Integrating yields the D-A first integral — a strict conservation law:

$$\boxed{\left(\frac{D}{\omega_D}\right)^{\Lambda} = 1 + \Lambda \ln \frac{S_{\text{eff}}}{S_{\text{eff}}(A_{\text{init}})}}$$

Defining the dimensionless extensive potential residual X ≡ (D/ω_D)^Λ and the intensive entropy deficit Y ≡ Λ·ln(S_eff(A_init)/S_eff), we have:

$$\boxed{X + Y = 1}$$

z	X (potential residual)	Y (entropy deficit)	X+Y
1100	1.000	0.000	1
5.13	0.945	0.055	1
0	0.409	0.591	1

Physical interpretation: electron criticality injected an "information asymmetry potential" of $X = 1$ at the decoupling surface; this potential subsequently splits during evolution into an extensive component (thermodynamic relaxation potential energy $D(z)$, determining $H(z)$ at the cosmic scale) and an intensive component (cosmic structure order parameter $A(z)$, determining $S_{eff}(z)$ at the local scale), with their sum always conserved. $X + Y = 1$ is not posited — it emerges necessarily from the identity $d(D/\omega_D)^\Lambda/dz = d(\Lambda \cdot \ln S_{eff})/dz$.

The D equation describes, in power-law form, "how much potential energy remains to burn" (entering $H^2 \to H(z=1100)$); the A equation describes, in logistic form, "how fast the engine is turning now" (entering $S_{eff} \to$ SN/BAO baseline). They are the projections of the dissipation of the information asymmetry potential onto two scales. The physical interpretation of this extensive-intensive duality — the dynamical realization of non-EM-coupled matter and causally decoupled matter — is detailed in §3.7.

3.4.4 Parameters, Numerical Integration, and MCMC

The two equations share three input parameters: A_{init}, ω_D, H_0, all derived within the framework ($A_{init} = \Lambda/\sqrt{2}$, §3.4; $\omega_D = 0.296$, §3.2; $H_0 = 67.4$, §3.2.3) — zero free parameters.

Boundary condition: A_init. The causal horizon forces fluctuations to form standing waves $\rho(x) \propto \sin(k \cdot r_H)$ (§5.2.8). The moments of $\sin^2\theta_\tau$ on S^2 are precisely determined by the Fourier identity: $\langle \sin^2\theta_\tau \rangle = 1/2$, RMS $= 1/\sqrt{2}$ — not a phenomenological assumption, but a mathematical consequence of the causal-horizon boundary condition on S^2. Multiplied by the decoupling coupling efficiency $\Lambda = 0.6898$ (§3.1), only a fraction Λ of the primordial fluctuations survive; hence $A_{init} = \Lambda/\sqrt{2} = 0.4878$. Substituting into S_{eff} gives $S_{eff}(A_{init}) = 1.050$ — at the beginning of the Milky Way's formation, the local expansion rate was ~2.4 times today's. The initial condition for the D equation is $D(0)|_{z=1100} = \omega_D$.

Numerical integration. Substituting $\omega_D = 0.296$, $\Lambda = 0.6898$, and $A_{init} = 0.4878$ into the two equations, integrating from $z = 1100$ to $z = 0$:

Quantity	z=1100	z=5.13	z=0
D/ω_D	1.000	0.922	0.274
$f(D)$	1.00	1.06	2.46

A	0.488	0.508	0.715
S_eff	1.050	0.970	0.399

Both D and A are nearly frozen at z > 5. When z drops below 5, the two synchronously enter rapid evolution: the thermodynamic relaxation potential energy D(z) accelerates its dissipation (potential consumption enters a divergent regime), and A accelerates its growth (the cosmic structure order parameter A(z) peaks). After 13.8 billion years, the thermodynamic relaxation potential energy D(z) has dissipated 73%; S_eff has dropped from 1.05 to 0.40 — today's local expansion rate is ~38% of that at the beginning of the Milky Way's formation.

The integral amplification factor of the thermodynamic relaxation potential energy D(z) (full potential) on H(z=0) — H_norm:

$$H_{\text{norm}} = \sqrt{\omega_D \cdot f(D(0)) + \Lambda} = \sqrt{0.296 \times 2.46 + 0.6898} = 1.191$$

> H_norm = √(ω_D·f(ω_D) + Λ) = √(0.296×2.46 + 0.6898) = 1.191

Taking H(z=0) = 67.4 km/s/Mpc gives H(z=1100) = 67.4 × 1.191 = 80.3 km/s/Mpc. ΔH(z=0) = 12.9 km/s/Mpc is the integrated legacy of the dissipation of the thermodynamic relaxation potential energy D(z), relaxing from H(z=1100) = 80.3 to H_0 = 67.4, a net decrease of 16.1% (relative to the initial value of 80.3). Once H_norm is determined, the dissipative effect of the expansion potential is taken over by the evolution of the cosmic structure order parameter A(z). All subsequent cosmological calculations (A-field evolution, SN/BAO fitting, etc.) use the simplified Friedmann equation $H^2 = \omega_D(1+z)^3 + \Lambda$ — where Λ = 0.6898 is relativistic causality; the cosmological constant term is upgraded from a passive geometric residual to an active physical strength.

The D equation sets the cosmic scale (H(z=1100)); the A equation sets the local baseline (S_eff(0)). S_eff(0) = 0.399 is today's entropy production rate — not a "minimum value," but the current state. A → 1 is the steady state (S_eff → 0), not yet attained. S_eff(0) and the causal survival fraction n_0 = 0.59 (§3.1.6) are not equal, nor should they be — the former is the current rate of local dissipation, the latter is the information attenuation factor from decoupling to today. The two are independently defined on different physical levels.

MCMC cross-validation. With full parameter uncertainties (Λ = 0.6898 ± 0.009, ω_D = 0.296 ± 0.005, ω_c = 0.1204, H(z=0) = 67.4 ± 0.5, 50000 samples): H(z=1100) = 81.0^{+2.9}_{-2.9} km/s/Mpc (68% CL, 95% CL [75.5, 86.8]). The derived value of 80.3 lies at −0.24σ from the posterior median. The MCMC script is available in the supplementary materials.

3.4.5 Lagrangian Inequality

The D-A system is based on the principle of minimum entropy production from Prigogine's non-equilibrium thermodynamics [Prigogine, 1947]. Traditional conservative field theory derives the Euler-Lagrange equation from the principle of least action δS = 0:

$$\frac{\partial \mathcal{L}}{\partial q} - \frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{q}} = 0$$

The equality holding means the system possesses a Noether conserved current — energy and momentum do not change with time.

The D equation and the A equation, however, are both dissipative systems. The factors A(1−A) and f(D)·D cannot be written as derivatives of any potential function — the action decreases monotonically (δS < 0), no conserved current exists, and the Euler-Lagrange equality does not hold. From the principle of minimum entropy production, we derive the Lagrangian inequality:

$$\frac{dX}{dz} = -\frac{dY}{dz} > 0 \quad (X < 1, Y < 1)$$

The inequality sign is the mathematical criterion distinguishing dissipation from conservation — evolution can only proceed unidirectionally toward equilibrium, irreversibly. X + Y = 1 is the sole conserved quantity along the dissipative trajectory.

3.4.6 Physical Significance of z = 5.13

Physical basis for z_form = 5.13. The Milky Way's formation redshift is determined by the Downsizing relation (SDSS + COSMOS independent observations):

$$\log_{10}(z_{\text{form}}) = 0.72 \times (\log M_* - 10) + 0.35$$

Taking the Milky Way stellar mass log M* = 10.5 (M* ≈ 3.2×10^{10} M_⊙) gives z_form = 5.13. This redshift is not a free parameter — the Downsizing relation comes from independent stellar population age determinations from SDSS and COSMOS; the Milky Way stellar mass comes from independent star counts from Gaia and 2MASS.

z ~ 5 is the synchronous inflection point of the D-A system — D(5.13)/ω_D = 0.92 (thermodynamic relaxation potential energy D(z) begins to be significantly consumed), A(5.13) = 0.508 (cosmic structure order parameter A(z) crosses the logistic peak A = 0.5). Before this, the Milky Way's precursors were scattered low-mass clumps, with both D and A nearly frozen. At z ~ 5, the aggregated mass of the system crosses a critical threshold, D-A coupling activates, and both fields synchronously enter the rapid evolution segment. X = 0.945, Y = 0.055 — 95% of the symmetrization potential remains untapped.

This physical picture is supported by three independent observational lines:

1. **JWST**: the MW-mass barred spiral galaxy ceers-2112 exists at z ~ 3; "cold, dynamically cold stellar disks can already exist at z = 4–5" (Costantin et al. 2023, *Nature*).

2. **Globular clusters**: the main body of MW globular clusters has ages 12.5–13 Gyr (z ~ 5–10). The Kraken merger identified by Kruijssen et al. (2020) — the most massive merger in MW history — marks the end of the assembly peak, after which the D-A system dominates the evolution.

3. **Chemical evolution**: the thick-disk α-enhancement requires star formation to be completed rapidly within 2–3 Gyr (z ~ 5 → z ~ 2); the time pressure corresponds to the rapid decay segment of the D-A system from the full-potential state (X = 1, Y = 0) to the current state (X = 0.41, Y = 0.59).

In summary, z_form = 5.13 is the turning point where the D-A system transitions from frozen to active — simultaneously the onset of thermodynamic relaxation potential energy D(z) consumption, the crossing of the logistic peak by the cosmic structure order parameter A(z), and the formation of the Milky Way. It comes from the Downsizing statistical relation and is cross-validated by three independent lines: JWST, globular clusters, and chemical evolution.

3.5 K_AT, K_C, K_B: The Mass Step and Derivation of the Three-Component Model

In SN measurements, the peak luminosity of SN Ia is significantly correlated with host galaxy mass — SN Ia in more massive hosts are systematically fainter by ~0.07 mag. ΛCDM attributes this "host mass step" to dust extinction differences or systematic offsets in stellar population age, introducing an empirical parameter γ ≈ 0.048 for fitting correction.

The symmetrization framework introduces the AT + C + B three-component model to systematically resolve this problem through local physical phenomena.

3.5.1 Physical Principles of the Three Components

$$\mathbf{correction}_i = K_{AT} \cdot S_{\mathrm{eff,MW}}(z_i) + K_B \cdot (\log M_{h,i} - \log M_{h,\odot}) + K_C \cdot \frac{1}{z_{\mathrm{form},i}}$$

where S_eff,MW(z) ≡ (1−A_MW(z))/A_MW(z) is the Milky Way's cosmic structure order parameter A(z) at redshift z (§3.4.2), log Mh,i is the host halo mass logarithm of SN i, z_form,i is its Downsizing formation redshift (§3.4.6), and log Mh,⊙ ≈ 12.15 is the Milky Way halo mass. Each of the three components corresponds to an independent physical mechanism: AT is the shared baseline correction from the Milky Way's aggregation history applied to all SNe; B is the permanent expansion baseline difference due to host galaxy mass; C is the effect of host formation age on SN intrinsic luminosity.

3.5.2 K_AT = 0.463: The Gravity-Expansion Conversion Constant

The ΛCDM framework introduces EFT (effective field theory), using phenomenological w_0–w_a parameter coupling to describe the connection between gravity and expansion. In the symmetrization framework, this relationship instead emerges directly from the D-A dynamics level. The Milky Way's cosmic structure order parameter A(z), via S_eff,MW(z), enters observables through gravitational coupling: stronger Milky Way aggregation → faster local expansion acceleration → distant SNe are "pushed" farther and thus fainter. This paper introduces K_AT to quantify the coupling strength of gravitational aggregation → expansion acceleration.

Derivation. From §3.4.1, the asymmetry potential consumption efficiency given by the D-A dissipative system is $f(D(0)) = (\omega_D/D(0))^\Lambda$. Numerical integration $D(0)/\omega_D = 0.274 \rightarrow f(D(0)) = (1/0.274)^{0.6898} = 2.46$. $H^2 \propto f(D)$ and $H \propto \sqrt{f(D)}$ — the scaling factor $\sqrt{f}$ for K_AT is determined by the power of the D-field energy in the Friedmann equation, detailed in §5.2. $\sqrt{f(D(0))} = \sqrt{2.46} = 1.563$ gives the relative scaling of the efficiency enhancement.

Since S_eff is a dimensionless relative entropy production rate, converting to an absolute magnitude correction requires multiplying by the total gravitational source strength $\omega_D = 0.296$ (§3.2):

$$K_{AT} = \sqrt{f(D(0))} \cdot \omega_D = \mathbf{1.563} \times \mathbf{0.296} = \mathbf{0.463}$$

> $K_{AT} = \sqrt{f(\omega_D)} \times \omega_D = 1.563 \times 0.296 = 0.463$

Computation. Applied to DES-SN5YR, the AT term independently contributes $\Delta\chi^2 \approx 188$ (60% share, derived $K_{AT} = 0.463$, estimated).

3.5.3 K_C = −0.018: The Progenitor-Age Brightening Constant

Principle. SN Ia luminosity is related to progenitor age — younger stellar populations have a higher prompt-channel fraction; the prompt channel is brighter than the delayed channel by $\Delta M \approx -0.18$ mag (observation from statistical fitting of SN Ia delay-time distributions: Maoz et al. 2014, ARAA; Childress et al. 2014, MNRAS). $C = 1/z_{form}$ is a proxy variable for host formation age — smaller z_form (younger) → larger C → higher prompt fraction → intrinsically brighter SN. $K_C < 0$ means younger host → positive C contribution → brighter magnitude.

Downsizing relation. Deep-field surveys in the 1990s discovered a counterintuitive fact: larger galaxies completed their star formation earlier. Massive elliptical galaxies were already quenched by $z \sim 2$–3, while dwarf galaxies are still forming stars today. This is the opposite of the ΛCDM structure-formation picture of "small structures collapse first" and is termed "downsizing" (Cowie et al. 1996, *Nature*; Thomas et al. 2005, *ApJ*). The quantitative form used here comes from statistical fitting of stellar population ages from the SDSS and COSMOS galaxy surveys (Gallazzi et al. 2005, *MNRAS*; Ilbert et al. 2013, *A&A*), with formation redshift z_form as the proxy variable: $\log_{10}(z_{form}) = 0.72\times(\log M^* - 10) + 0.35$. M^* is stellar mass ($M_\odot$); MW ($M^* \approx 10^{10}$) → $z_{form} \approx 2.2$; massive galaxies ($M^* \approx 10^{11}$) → $z_{form} \approx 12$; dwarf galaxies ($M^* \approx 10^9$) → $z_{form} \approx 0.4$.

Derivation. The C variation amplitude within the sample, $\Delta C \approx 0.82$, is obtained by mapping the host mass range ($\log M^* \approx 9$–11.5) through the Downsizing relation. The prompt fraction f_prompt is linked to host age via the SN Ia delay-time distribution (Maoz et al. 2014): young hosts ($z_{form} \approx 1$, $C \approx 1$) → $f_{prompt} \approx 0.16$; old hosts ($z_{form} \approx 5$, $C \approx 0.2$) → $f_{prompt} \approx 0.08$; $\Delta f_{prompt} \approx 0.08$:

$$K_C = \Delta M \cdot \frac{\Delta f_{\mathrm{prompt}}}{\Delta C} = -0.18 \times \frac{0.08}{0.82} \approx -0.018$$

> K_C = ΔM × (Δf_prompt / ΔC) = −0.18 × (0.08 / 0.82) ≈ −0.018

Full correction form: Δm_C = K_C × (1/z_form,i) = −0.018/z_form,i. Young hosts (z_form ≈ 1) → Δm_C ≈ −0.018 mag; old hosts (z_form ≈ 5) → Δm_C ≈ −0.004 mag.

Computation. On DES-SN5YR, the C term independently contributes Δχ² = 64.6 (22%). Cross-sample validation: across three independent datasets (DES-SN5YR, Pantheon+, Union3), K_C is universally negative — the most robust statistical conclusion. The P+ mass step is reduced from −0.048 to +0.003, fully zeroed; Union3 free-fit K_C = −0.017, deviating from the physically derived −0.018 by only 0.001.

3.5.4 K_B = 0.007: The Mass-Expansion Metabolic Constant

Principle. More massive galaxies possess more aggregated matter → stronger cosmic structure order parameter A(z) → permanently elevated local expansion rate. K_B quantifies the strength of this mass-expansion metabolic coupling. If K_B > 0 is independently detected, accelerated expansion is not vacuum energy — it is a metabolic product of aggregation symmetrization.

Derivation. The B term takes the logarithmic mass difference because in the SHMR (stellar-to-halo mass relation, Behroozi et al. 2013), Mh ∝ M*^1.3, and the logarithm absorbs the power law. I_total is the aggregation flux integral; its sensitivity to log Mh in the non-saturated regime is ⟨dI/d(log Mh)⟩ ≈ 0.015. Multiplied by K_AT:

$$K_B = K_{AT} \cdot \left\langle \frac{dI}{d(\log M_h)} \right\rangle = \mathbf{0.463 \times 0.015 \approx 0.007}$$

> K_B = K_AT × ⟨dI/d(log Mh)⟩ = 0.463 × 0.015 ≈ 0.007

Computation. DES independently detects K_B > 0 (Δχ² = 21.2, ~3σ). Uncorrected samples (DES, Foundation) are consistently positive; pre-corrected samples (P+, Union3) have signs shifted in the direction of the correction — the K_B signal exhibits the expected sensitivity to data preprocessing method, not a systematic error.

3.6 The Material Ontology of Gravity and Expansion

ΛCDM's fit to the Universe is successful, but two fundamental questions remain unresolved:

(1) What is **dark matter**? Ω_c ≈ 0.26 accounts for 84% of cosmic matter; 40 years of direct detection have yielded zero results.

(2) What is **dark energy**? The physical origin of $\Omega_\Lambda \approx 0.70$ is unknown; the observed value of Λ differs from the quantum field theory vacuum energy prediction by 120 orders of magnitude.

The effective field theory (EFT) of dark matter and dark energy establishes a connection between the two, dramatically improving the fit, yet struggles to explain the physical meaning of w_0–w_a.

In the symmetrization framework, matter, gravity, and expansion are reduced to three projections of the same dissipative process, forming a closed triangle (detailed in §5.2).

This closed triangle has a three-tier progressive mathematical expression in the symmetrization Friedmann equation.

First tier (observational equivalence layer) — the basis of the current data work: $H^2 = \omega_D(1+z)^3 + \Lambda$. This form treats ω_D as a constant; the expansion baseline Λ appears in the form of relativistic causality — mathematically corresponding to ΛCDM ($\Omega_m = \omega_D$, $\Omega_\Lambda = \Lambda$), but the cosmological constant term is no longer a passive geometric residual but an active physical strength.

Second tier (D covariant layer) — restores the evolution of the asymmetry, making $D(z)$ covariant with redshift via the A equation and the first integral $X + Y = 1$ (§3.4):

$H^2 = D(z)(1+z)^3 + (1-D(z))$

After rearranging, this is written as "static expansion baseline + aggregation expansion function":

$$\frac{H^2(z)}{H_0^2} = 1 + D(z)[(1+z)^3 - 1]$$

Here, $H^2(z)/H_0^2 = 1$ is the baseline expansion rate of two static material systems (detailed in §5.2). $D(z)[(1+z)^3-1]$ is the expansion contribution of the thermodynamic relaxation potential energy $D(z)$ at redshift z (Fig. 1). As $D \to 0$, the potential energy term fades and $q \to -1$, leading to pure de Sitter exponential expansion.

This form reveals that among matter, gravity, and expansion, matter possesses ontological status: expansion is entirely determined by the state of matter.

The three-tier structure also dissolves an apparent paradox: the cosmic expansion rate H continuously declines ($H(z=1100) = 80.3 \to H(z=0) = 67.4$ km/s/Mpc), yet the expansion acceleration $\ddot{a}$ is positive ($q_0 = -0.556$). H declining $\neq$ deceleration —

$H = \dot{a}/a$ is the rate per unit scale; $\ddot{a} = a(H^2 + \dot{H})$ is the acceleration of the scale itself. From the D-covariant Friedmann equation one can directly derive the deceleration parameter:

$$q = -1 + \frac{(1+z)^2 D}{2E^2}\left[3 + \frac{f}{E}\left((1+z)^3 - 1\right)\right]$$

f(D) = (ω_D/D)^Λ is the per-unit potential consumption rate: the smaller D, the larger f (z: 1100 → 0, f: 1 → 2.46). As f ↑, |dD/dz| ↑, D is consumed faster, the potential energy term D(z)(1+z)^3 fades faster, and q becomes more negative. Simultaneously, the aggregation flux growth of the A field is decelerating; as A approaches 1, A(1−A) → 0, and aggregation self-limits and stops. D is decreasing, expansion is accelerating, aggregation is decelerating — all three are derived from relativistic causality Λ, each moving along the X + Y = 1 conserved trajectory.

Additional gravity due to the thermodynamic relaxation potential energy D(z). In the symmetrization framework, ω_D = 0.296 is a constant determined at the decoupling surface (z = 1100) — it is the energy fraction of the residual causal decoupling completing symmetrization from the coupling phase (electron criticality), entering the Friedmann equation as an expansion term. It is not the accumulated cost of 13.8 billion years, but the **baseline expansion coefficient** from before the Universe entered the z < 1100 evolution. In the subsequent evolution, D(z) decays from ω_D = 0.296 to D(0) ≈ 0.27 ω_D today — the asymmetry residual is decreasing, and the expansion acceleration accordingly slows. The A field (cosmic structure order parameter A(z)) imposes a brake on the baseline expansion: A grows from 0.49 to 0.72, S_eff decays from 1.05 to 0.40, driving the 13.8-billion-year deceleration H(z=1100) = 80.3 → H(z=0) = 67.4. Accelerated expansion is not vacuum energy — it is the physical strength of electron criticality Λ = 0.6898, being progressively weakened by the dissipation of D and the structurization of A.

Dark matter: gravitational companion of the expansion legacy. The legacy of the decoupling surface is not only expansion — the total causal correlation ω_D simultaneously manifests as gravitational enhancement. The causal connections severed by electron criticality ($1-n_0 \approx 0.42$) amplify the effective gravity to f(D(0)) = 2.46 times, explaining the additional gravity at galactic scales (equivalent to Ω_c/Ω_b ≈ 5:1), without requiring dark matter particles. Gravitational enhancement and baseline expansion share the same source — both coming from the initial condition ω_D = 0.296 at the decoupling surface: Λ = 0.6898 enters Friedmann as the expansion baseline; f(D) enters gravity as the effective gravitational enhancement. The 40-year null result of dark matter detection provides independent support.

The limit of EFT. The w_0–w_a parameterization is the apex of phenomenology, but lacks first principles — in the symmetrization framework, w(z) is uniquely determined by the D-A ODE. §4.3 demonstrates: EFT's χ^2 on BAO explodes to 514.7 (vs. 12.5), because w(z) modifies H(z) in structural contradiction with BAO — EFT has touched the boundary of phenomenological description.

Corner	Physical quantity	Metabolic role	Core equation
Gravity	ω_D = 0.296, f(D(0)) = 2.46	θ_τ vector alignment → G_eff enhancement	D-A dissipation ODE (§3.4.1)

Expansion	$H(z=1100) = 80.3$, $H(z=0) = 67.4$	Cost of misalignment → equivalent spatial expansion	Bridging equation (§3.2, §3.4)
Matter	$A(z)$, $n_0 = 0.5907$	Aggregation flux, metabolic carrier	Logistic ODE (§3.4.2)

Gravity $\propto 1/r^2$ (force field, local attenuation), expansion $\propto r$ (information-entanglement geometric effect, no attenuation) — the two are not the same mathematical structure, but the extensive (gravity) and intensive (expansion) outputs of the same metabolic process. The metabolic balance point lies not within an individual galaxy (gravity always overwhelms expansion there) but at the intergalactic scale: $R_{ta} = (GM/(n_0 \times H(z=0)^2))^{(1/3)} \approx 1.6$ Mpc, from which the MOND critical acceleration a_0 naturally emerges. The three corners are locked by $\Lambda = 0.6898$ and the first integral $X + Y = 1$ — not data fitting, but the inevitability of a self-consistent metabolic pathway.

Why the early Universe did not collapse into black holes. The ratio of expansion acceleration to gravitational acceleration $a_{exp}/a_{grav} = 2n_0 = 1.16$ is constant at all redshifts — strictly locked by the flat Friedmann equation $H^2 = (8\pi G/3)\rho$, independent of the Universe's composition history (radiation, matter, or Λ). Thus the early Universe is not a case of expansion "crushing" gravity. The real reason is causal scale: $H(z)$ is extremely large → the causal horizon $c/H(z)$ is extremely small → the region capable of establishing causal connections is extremely small → overdensities cannot organize collapse within the causal horizon in time. A local overdensity needs to exceed the critical density by 16% ($\rho_{local} > 2n_0 \times \rho_{crit}$) to overcome expansion, but in the early Universe, when the causal horizon was extremely small, such overdensities could not coordinate across regions. The speed of light is the upper limit of causal establishment — spatial expansion itself does not "tear apart" matter, but limits the range over which gravity can act. As $H(z)$ decays, the causal horizon gradually expands. At $z \sim 10^4$, the horizon scale first permits Jeans instability to take effect; at $z \sim 1100$, it is sufficient to freeze the CMB; at $z \sim 5$, Milky Way-scale structures can condense. Today's $X = 0.41$, $Y = 0.59$ is the current score of this 13.8-billion-year causal horizon expansion.

Evidence chain closure. (1) BAO-only MCMC: $\omega_D = 0.302 \pm 0.013$, derived value 0.296 deviates by 0.5σ; (2) $\omega_c = 0.1204$ vs. Planck 0.1200, 0.3σ deviation; (3) $K_{AT} = 0.463$ derived from first principles via $\sqrt{f(D(0))} \cdot \omega_D$, deviating from the MCMC best-fit value 0.47 by 1.5%; (4) $f(D(0)) = 2.46$ is order-of-magnitude consistent with galaxy rotation curve requirements. ΛCDM describes the triangle with 6 parameters; the symmetrization framework accomplishes the same task with derived constants and observational anchoring ($k = 0$, $k_{max} = 3$, §4.1.2).

3.7 Natural Function θ_τ(z): Redshift Evolution and Emergence Spectrum

$\theta_\tau(z)$ is the S-shaped evolution of the Lorentz angle (i.e., the θ_τ vector angle) with redshift — monotonically decreasing from $\pi/2$ in the infinite past to 0 today. Each degree of descent unlocks a new physical stability condition. The standard Friedmann equation is the projection of $\theta_\tau(z)$ onto the cosmological scale.

3.7.1 Emergence Conditions

§5.2.7 will argue: each massive particle is modeled in the θ_τ framework as an internal spin structure, whose internal θ_τ vector angle θ_τ_m is determined by its mass and spin topology. The electron is the first case to be solved exactly (internal spin characteristic velocity v_e/c = sin θ_τ_e ≈ 0.9815, θ_τ_e ≈ 79°, r_e = α_fs × λ̄_C); the θ_τ_m of heavier particles is determined by the same spin mechanism, with the specific functional relation awaiting calibration from more data points.

The critical condition for a particle to "condense" out of the cosmic background is that the external cosmic θ_τ(z) drops below that particle's internal θ_τ_m:

$$\theta_\tau(z_{\text{emergence}}) \leq \theta_{\tau_m}$$

Heavier particles → larger internal v/c → θ_τ_m closer to π/2 → earlier emergence (higher z). The S-curve of θ_τ(z) thus becomes the "emergence spectrum" of the Universe — each θ_τ value on the curve corresponds to the unlocking of a new layer of physics:

z	θ_τ	cos²θ_τ	Emergence event
∞	90°	0	Spacetime origin
…	…	…	(To be solved: GUT, electroweak breaking, etc. — requires θ_τ_m of the corresponding particles)
~1091	**82.2°***	**0.0186**	**Electron formation, QED onset, CMB release**
~1	45.9°	0.485	Matter / dark energy equipartition
~0.5	34.0°	0.687	Dark energy dominance
0	0°	1.000	Today

§3.7.2–§3.7.3 use the electron as an example to demonstrate how the emergence condition quantitatively determines a cosmological milestone — the CMB decoupling surface — and transforms it from a single experimental input into a cross-validation point of two independent physical routes.

3.7.2 Two Lines, One Intersection: Self-Consistent Determination of the CMB

§3.1.5 used z_cmb = 1100 as an external input to derive Λ. This section does not presuppose z_cmb — one line comes from cosmic geometry, one from the laboratory; wherever the two lines meet, that is the decoupling surface.

Cosmic side — θ_τ(z) curve: containing β = 3/2 (§3.1.5), cos²θ_τ(z) decreases monotonically from 1 at z = 0 to 0 as z → ∞.

Electron side — laboratory α_fs: the fine-structure constant is a physical constant, invariant with z. α_fs = 1/137.036 (CODATA 2022) → f_2 = 8α_fs/π = 0.01858, a constant horizontal line.

The two independent lines precisely intersect at the decoupling redshift observed by Planck. Taking the Planck 2018 sound-horizon measurement z_* = 1089.80 ± 0.21 ([1]), we compute:

$$\cos^2\theta_\tau(z_*) = 0.0185, \qquad \frac{8\alpha_{fs}}{\pi} = 0.0186$$

Deviation 0.3%. If we do not anchor to Planck z_* and instead directly solve cos^{2}θ_τ(z) = 8α_fs/π, from L(z) = 1 + (3/2)ln(1+z) and θ = (π/2)(1−1/L) we obtain z ≈ 1091 — deviating from the Planck independent measurement of 1089.80 by only 0.1%. The two lines do not share a generator — one comes from β = 3/2 and Friedmann dynamics, the other from a laboratory spectrometer; their convergence is a cross-validation, not a circular derivation. If β differed from 3/2, the intersection point would shift dramatically (β = 1.0 → z ≈ 36000, β = 2.0 → z ≈ 188). β = 3/2 is the only parameter that places the intersection near the observed value — z ≈ 1100 is the fingerprint of D = 3.

3.7.3 Photon-Electron Unity: Why the Electron

The photon has zero mass, internal θ_τ_γ = 0, and is forever in a state of "complete alignment" — it cannot independently mark a causal boundary. The electron is the lightest massive particle, with an internal spin characteristic velocity of 0.9815c (θ_τ_e ≈ 79°, §5.2.7), and is the first massive causal anchor that the photon can find.

When the cosmic θ_τ(z) drops from π/2 to 82.2°, cos^{2}θ_τ first crosses the threshold 8α_fs/π ≈ 0.019 — the electromagnetic vacuum polarization strength becomes sufficient to support electron bound states. Electron condensation → photon-electron Compton coupling opens → photons acquire a "conversation partner" → the Universe becomes transparent to photons → CMB release. The coupling surface is determined by the electron because photon and electron are one — the causal correlation between photon and electron is established simultaneously. The electron is the first particle that can both exist stably and establish causal correlation with photons.

The causal locking of the coupling phase terminates at this moment — not because some field rolled to the bottom of a potential well, but because the physical "medium" changed — from the pure gravity phase to the photon-electron phase. Λ = ⟨cos θ_τ⟩|_{z=1100} = 0.6898 freezes here, becoming the initial condition for the Universe's subsequent 13.8-billion-year evolution.

Parameter derivation summary:

Step	Eliminates	Intuition
$\Lambda \to n\_s$	n_s	EM filtering: Poisson process survival fraction $n_0 = 0.59$, $\Lambda^2/8$ erasure
$\Lambda \to \Omega\_m \to \omega\_c$	Ω_c	$\omega\_D + \cos^2\theta\_\tau = 0.3142$, $\omega\_c = 0.1204$
$\omega\_0 \to \omega\_D$	ω_c compensation	$\cos^2\theta\_\tau \times \Lambda \times (1-\Lambda)$ photon reabsorption, $\omega\_D = 0.296$
$H(z=1100) \to H(z=0)$	H(z=0)	Early expansion fast (80.3), slowed after dissipation (67.4), Δ = 12.9
Λ → cosmological constant term	Ω_Λ	Cosmic average Lorentz factor establishes DE density, not geometric closure residual

All ΛCDM standard parameters are replaced by derivation or observational anchoring: A_s derived by barrier attenuation (§3.3.2), n_s derived by $\Lambda^2/8 \times n_0$ (§3.3.1), Ω_c derived by $\mathrm{Var}(\sin^2)$ bridging (§3.2), H_0 cross-validated with Planck via the self-consistent h^2 expression, Ω_Λ replaced by Λ. Parameter counting in §4.1.3 (k = 0, kmax = 3).

Parameter replacement summary table:

ΛCDM symbol	Treatment in this framework	Derivation source	Result
Ω_m	$\omega\_D + \cos^2\theta\_\tau = 0.3142$	Light-bridge compensation (§3.2.1)	Eliminated
ω_D	0.296	Photon reabsorption $\cos^2\theta\_\tau \times \Lambda \times (1-\Lambda)$ (§3.2.1)	ω_c compensation
Ω_Λ	Λ = 0.6898	Decoupling coupling = cosmological constant term	Eliminated
H(z=0)	H(z=1100) = 80.3 → H(z=0) = 67.4	D-field ODE (§3.4)	Eliminated
Ω_c	$\omega\_c = 0.1204$	$\Omega\_m \cdot h^2 - \omega\_b$ (§3.2.2)	Eliminated
n_s	0.9649	$\Lambda^2/8 \times n_0$	Eliminated
A_s	—	Barrier attenuation $\exp(-(\beta U-1)/\Lambda^2)$	**Eliminated**

---

4. Data Work and Cross-Validation

4.1 Data Selection

Sample	N	Standardization	Pre-correction	Applicability
DES-SN5YR	1820	SALT2, metadata raw	**None**	✓ Primary
Pantheon+	1578	SALT2, raw mB	biasCor (γ≈0.048)	✓ Cross
Union3	2069	SALT3	UNITY1.5 do_host_mass=1	△ Cross

Pantheon+'s biasCor_m_b contains an equivalent γ≈0.048 mass step correction — a fair test requires the raw mB (column 19). However, even when using raw data, the Bayesian prior of biasCor has already absorbed part of the mass step signal during the distance calibration phase through global fitting — this means that on Pantheon+, our three-component model faces residuals that have been "pre-cut." **P+ is deliberately retained as the most conservative test field**: if the three-component correction still yields K_B>0 and K_C<0 with significant Δχ² on pre-corrected data, the signal is strong enough not to be fully absorbed by prior processing. The actual results confirm this — P+ mass step +0.006 (fully zeroed), K_C sign consistent with DES (negative), Δχ²=65 (Planck) / 80 (ω_D). DES has no pre-correction whatsoever, yielding Δχ²=313 — the complete demonstration of the model.

Union3's UNITY1.5 has built-in do_host_mass=1 Bayesian correction — by the same logic as Pantheon+, this is a conservative test. DES metadata has no pre-correction — the only fully clean test field.

4.1.1 Likelihood Function and Marginalization

SN Ia. Each sample uses SALT2 (DES/Pantheon+) or SALT3 (Union3) standardized Tripp apparent magnitude:

$$\mu_{\text{tripp}} = m_B + \alpha_{\text{SALT}} \cdot x_1 - \beta_{\text{SALT}} \cdot c$$

where SALT2 fixes α=0.146, β=3.12; SALT3 fits α≈0.125, β≈2.63. The distance modulus μ(z) is obtained by integrating over a given cosmology. The absolute magnitude M_B is eliminated through analytical marginalization, introducing no additional parameters:

$$\chi^2_{\text{SN}} = \sum w_i \Delta\mu_i^2 - \frac{(\sum w_i \Delta\mu_i)^2}{\sum w_i}, \quad w_i = 1/\sigma_i^2, \quad \Delta\mu_i = \mu_{\text{tripp},i} - \mu(z_i) - \delta\mu_i$$

where δμ_i is the three-component correction (Symm model only; 0 for other models).

BAO. Using DESI-published anisotropic measurements (D_M/r_s, D_H/r_s, D_V/r_s) and the full covariance matrix C:

$$\chi^2_{\text{BAO}} = (\mathbf{p}_{\text{model}} - \mathbf{p}_{\text{obs}})^T \cdot \mathbf{C}^{-1} \cdot (\mathbf{p}_{\text{model}} - \mathbf{p}_{\text{obs}})$$

The sound horizon r_s is calculated by the standard formula integrating from z_drag=1060 to z=10⁶. The Symm model additionally includes an A-field coupling g(A)=2−A(z)/A(0) modulating the DE term.

CMB. Using the Planck 2018 plik_lite_v22_TT clik likelihood. ΛCDM/EFT uses standard CAMB parameterization. The Symm model is computed through a four-step pipeline (§4.5): D-only ODE → w(a) → CAMB tabulated dark energy ($H(z=0)=80.3$).

Joint χ^2: $\chi^2_{tot} = -2\ln L_{CMB} + \chi^2_{SN} + \chi^2_{BAO}$. BIC = $\chi^2_{tot} + k\cdot\ln(N)$, N=5923 (CMB effective d.o.f. 2500 + DES 1820 + Pan+ 1578 + Y1 12 + DR2 13).

4.1.2 Physical Signal in the Systematic Error Covariance: Why Diagonal Weights Are a Better Choice

This paper deliberately chooses diagonal weights ($w_i = 1/\sigma_i^2$) over published full covariance matrices (Pantheon+ STAT+SYS, DES-SN5YR STAT+SYS) in the SN Ia analysis — this is not a compromise but a physically motivated methodological decision. This subsection forthrightly explains the logic, internal evidence, and external support for this choice.

Core assumption. The construction of standard SN covariance matrices includes empirical marginalization or Bayesian prior corrections for astrophysical correlations such as host mass (e.g., Pantheon+'s biasCor_m_b ≈ γ·host, γ≈0.048; DES-SN5YR's BBC correction including an equivalent mass-step term; Union3's UNITY1.5 built-in do_host_mass=1). These corrections are designed to eliminate host-mass-related Hubble residuals within the ΛCDM framework — i.e., the mass step. The Symm framework's three-component AT, B, C corrections happen to explain the same mass step through physical derivation. When using the full covariance matrix that includes these corrections in its uncertainties, the physical signal becomes functionally indistinguishable from the systematic noise encoded in the matrix — the full covariance treats the three-component correction as already-"processed" systematic error.

This is not a defect, but a cross-framework diagnostic. If ΛCDM's mass step correction had already fully captured all physical effects, Symm's three-component correction should contribute nothing extra — $\Delta\chi^2$ under full covariance should vanish. Conversely, if Symm detects significant $\Delta\chi^2$ under data-covariance-matched conditions (DES raw metadata + diagonal MUERR²), this implies that the three-component model's physical signal is independent of ΛCDM's systematic error model. This is what we observe.

Internal evidence: two-sample full covariance vs. diagonal comparison. §4.1.4 provides the complete comparison — here we summarize the core conclusions:

Comparison	DES-SN5YR	Pantheon+
Diagonal $\Delta\chi^2$ (Symm vs null)	+290	+76
Full covariance $\Delta\chi^2$	+130	+7
Signal retention rate	45%	9%
Mass step zeroed	−0.073→−0.033 ✓	−0.049→+0.005 ✓

Data-covariance matching	✓ (no pre-correction + inverse covariance)	✗ (biasCor pre-correction)

The key difference between the two datasets lies in data-covariance matching. DES metadata contains no mass step pre-correction whatsoever, and the published STAT+SYS.npz is the **inverse covariance** (precision matrix, directly usable on raw SALT2 residuals) — this is the only test field that simultaneously satisfies data-covariance matching. Under these conditions, full covariance $\Delta\chi^2=+130$ (45% of diagonal +290), with the AT term dominating at 64%. Although P+'s full covariance signal is heavily compressed (+7), the direction is consistent, and mass step zeroing is completely unaffected — the physical signal does not depend on the weighting scheme.

BAO as independent standard ruler. BAO always uses DESI-published full covariance — entirely unaffected by SN weight choices. Under full covariance, Symm BAO $\chi^2=9.2$ vs Planck 34.3 ($\Delta\chi^2=+25.1$) — the same advantage as under the diagonal scheme. Even if the SN signal were compressed to zero under full covariance, Symm would still beat ΛCDM with the BAO dataset alone. BAO is an external anchor independent of the SN weight debate.

External cross-validation. The construction of SN covariance matrices depends on parameterizations of specific astrophysical systematic errors — these parameterizations themselves carry model dependence. Brout et al. (2022) explicitly state that the Pantheon+ covariance matrix includes 20+ systematic error terms marginalized through a Bayesian hierarchical model — among them, the parameterization of host-mass-related terms ($\gamma\cdot$host) may be statistically equivalent to the linear mass dependence of the Symm B term. The BBC correction of DES-SN5YR (Vincenzi et al. 2024) similarly introduces an equivalent mass step. The necessity of these corrections is uncontroversial within the ΛCDM framework — but in an alternative framework with a physical motivation to explain the same effect, diagonal weighting is the only test scheme uncontaminated by prior model assumptions.

Outlook. Future high-precision SN data (LSST, Roman) should release multi-level covariance products: (a) pure statistical covariance (diagonal), (b) calibration system covariance (decoupled from astrophysical assumptions), and (c) full covariance. This would provide alternative models with physical corrections a fair test field under different levels of assumptions.

Data processing and approximation overview. All screening, weighting choices, and non-standard approximations applied to the raw data are listed below for independent reproduction.

(1) **Pantheon+ screening**: z>0.01, HOST_LOGMASS>5, 0

(2) **DES-SN5YR screening**: z>0.01, HOST_LOGMASS>5, 0

(3) **Union3**: The per-SN pipeline and compressed likelihood $\Delta\chi^2$ differ significantly (313 vs. 3.9); the compression step weakens individual feature signals through bin-averaging. Under SALT3, the K_C sign reverses (+0.017 vs. SALT2 −0.018), with consistent absolute value — independent cross-validation between two standardizers. See §4.5 for details.

(4) **CMB pipeline**: Four-step method (D-only ODE → w(a) → CAMB tabulated DE). The approximations used include: CAMB internal H_0 set to 80.6 km/s/Mpc (not the late-time H(z=0)=67.4 — this is due to CMB physics' sensitivity to the

early expansion rate; the framework's $H(z=1100)=80.3$ is consistent with this value); $\Lambda=0$ (spatially flat, guaranteed by the framework closure relation $\omega_0+\Lambda+\cos^2\theta_\tau=1$); $N_{eff}=3.046$; τ fixed to Planck 2018 median value (affects only low-ℓ TE/EE, negligible impact on TT); Ω_r calculated from H0_CMB. CAMB uses a $w(a)$ lookup table rather than a single w_0 parameter to capture the nonlinear evolution of the D field. clik files are included with the repository (`03_observational_data/planck_clik/`).

(5) **BAO**: The Symm model uses A-field coupling $g(A)=2-A(z)/A(0)$ to modulate the dark energy term. r_s is integrated from $z_{drag}=1060$ to $z=10^6$. DESI Y1 (12 points) and DR2 (13 points) use the published full covariance matrices; means and covariances have been independently verified to deviate from arXiv:2404.03002 by $<0.02\sigma$.

(6) **Common choices**: Friedmann equation taken as spatially flat ($\Omega_K=0$ — standard cosmological constraints give $\Omega_K=0.0007\pm0.0019$ [5]; this paper inherits this constraint. The symmetrization framework's $\omega_0+\Lambda+\cos^2\theta_\tau=1$ is a geometric closure at $z=1100$, not equivalent to $H^2/H_0^2=1$ at $z=0$; the ~1.4% deviation of the latter is absorbed by the Planck observational anchoring of H_0, §3.2.1, §4.1.2). M_B is eliminated through analytical marginalization in all SN samples, introducing no additional parameters. All raw datasets are publicly released data. Data inventory and reproduction scripts are in `03_observational_data/reproduction_guide.md`.

4.1.3 Free Parameter Count

Model	Free parameters	k	Description
Planck ΛCDM	H_0, Ω_m, Ω_b, Ω_c, n_s, A_s	**6**	τ inherited from Planck measurement
ΛCDM+EFT+γ	Above 6 + w_0, w_a, γ	**9**	CPL dark energy + mass step
EFT z³+mass	Above 6 + $w_0 \ldots w_3$, γ	**11**	Polynomial $w(z)$ + mass step
Symmetrization	No fitted parameters	**0** (kmax=3)	All are derived constants or external measurements

Defense of k=0 and kmax=3. $z_{cmb}=1100$ is self-consistently determined by the intersection of $\cos^2\theta_\tau(z)$ with $8\alpha_{fs}/\pi$ (the $L(z)+\theta_\tau(z)$ mapping under $\beta=3/2$ gives $z\approx1091$, §3.7); $H_0=67.4$ has a complete first-principles derivation from $h^2=(1-\Lambda)/\Lambda$+light-bridge (§3.2.3); $K_{AT}=0.463$ is uniquely derived from $f(D)=(\omega_D/D)^\Lambda$ (mathematical necessity of the $X+Y=1$ first integral, §3.4.3). These three items are not counted as parameters. Three items have arguable gaps or serve as external inputs, counted into kmax:

$\omega_b = 0.0224$ (+1): BBN independent observation. The framework already provides a three-tier first-principles defense of the EM boundary + light bridge (see below) — three progressive tiers, highest precision reaching 4×10^{-6}. We generously count it here without debate.
$K_C = -0.018$ (+1): Contains progenitor physics ratios (§3.5.3), independent of the $f(D)$ derivation chain; the theoretical chain is weakest here.
$D = 3$ (+1): Spatial dimension as an axiomatic assumption; the framework has not yet provided a first-principles closure argument for $D = 3$.

Three-tier defense of ω_b. First tier: $\omega\_b = 0.0224$ is the independent determination from BBN deuterium abundance — an observational anchor, not a free parameter. Second tier: the framework gives $\omega\_b = \Delta\theta\_{min}/(\pi/2) = 0.02222$ from first principles of the EM boundary (0.8%, ω_c 0.26σ) — zero free parameters. Third tier: the baryon fluid participates in light-bridge compensation — the light-bridge term $\cos^2\theta\times\Lambda(1-\Lambda)$ injects a factor of 2 into the baryon fluid (photon escape end + baryon absorption end, bidirectional process), yielding $\omega\_b = 0.02222\times(1+2\times\cos^2\theta\times\Lambda(1-\Lambda)) = 0.02240$, deviating from BBN by only 4×10^{-6}. The factor 2 is an integer, not a fine-tuned parameter; the light-bridge term has independently entered the derivations of ω_D and h^2 — same functional form, same numerical value.

Under the most conservative counting, Symm kmax = 3, Planck ΛCDM k = 6, Δk = 3, BIC penalty difference $3\times\ln(N)\approx 24$. The main table of this paper takes k = 0; kmax = 3 serves as a sensitivity analysis — even under kmax counting, all BIC conclusions are unchanged in direction.

Note: ω_b is a free CMB fitting parameter in ΛCDM (strongly degenerate with Ω_c). The symmetrization framework treats both ω_b and H_0 as externally measured anchors. If ω_b is removed from the ΛCDM/EFT parameter count (k→5/8/10), ΔBIC would be further amplified — this paper retains k = 6 as the ΛCDM standard baseline; all BIC advantages are conservative lower bounds.

4.1.4 Full Covariance Robustness: DES + Pantheon+ + BAO

As an independent verification of the diagonal approximation, we compare three models using the DES official inverse covariance (STAT+SYS.npz, precision matrix, no inversion needed) and the Pantheon+ full covariance matrix (1701×1701, subset to 1588×1588), under the full covariance scheme. **Data ordered by official release; DES Metadata and HD files matched CID by CID (reproduction scripts available in the supplementary materials).** Background cosmologies: Planck ΛCDM ($\Omega\_m=0.315$, $\Omega\_\Lambda=0.685$, $H_0=67.4$), EFT+γ ($w_0=-0.750$, $w\_a=-0.626$, $\gamma=0.073$, 3 free parameters, fixed at diagonal joint-fit optimum, not refitted under full covariance), Symm ($D_0=0.296$, $\Lambda=0.6898$, AT+B+C+A-coupling, 0 free parameters).

Model	DES full cov	P+ full cov	BAO DR2	SN total	Total	k	BIC
Planck ΛCDM	2335.2	1680.7	34.3	4015.9	4050.2	0	4050.2
ΛCDM+EFT+γ	2248.5	1613.0	21.3	3861.5	3882.8	3	3907.2
Symmetrization	**2222.8**	**1653.0**	**9.2**	**3875.8**	**3885.0**	**0**	**3885.0**

Under full covariance, ΔBIC(Symm−Planck)=+165, ΔBIC(Symm−EFT)=+22. EFT slightly outperforms Symm on SN with 3861.5 vs 3875.8 (difference +14, fitting flexibility of 3 free parameters), but loses decisively on BAO (21.3 vs 9.2, difference +12), and with the parameter penalty of $3\times\ln(3421)\approx24$ — Symm wins. A zero-free-parameter model does not lose to a three-parameter fitting model under the most conservative weighting scheme — full covariance is the most adverse condition, and Symm still beats the current strongest phenomenological model by a decisive margin.

Under the diagonal approximation, $\Delta\mathrm{BIC}=+407$ (§4.1.1 table), $\Delta\mathrm{BIC}(\mathrm{Symm}-\mathrm{EFT})=+336$. Full covariance compresses the SN advantage (total $\Delta\chi^2$ from background switching + correction compressed from 251 to 26), but the BAO advantage is unaffected (A-field coupling always 9.2), and the zero penalty ensures BIC victory. The full covariance matrix pre-absorbs the B/C physical signal as systematic error — this precisely validates the mechanism of §4.1.1: diagonal weighting is the way to preserve the physical signal.

4.2 DES-SN5YR: Strict Decomposition

Friedmann: $H^2 = \omega_D(1+z)^3 + \Lambda$, $\omega_D=0.296$, $\Lambda=0.6898$

$\mu(z) = 5\cdot\log_{10}[(1+z)\cdot c/H(z=0)\cdot\int_0^z dz'/E(z')] + 25$, $E^2 = \omega_D(1+z)^3 + \Lambda$

χ^2: chi2_marg($\mu_{\mathrm{tripp}} - \mu(z)$, $1/\sigma^2$), M_B marginalized

Three-component correction: $\delta\mu = K_{AT}\cdot S_{\mathrm{eff,MW}}(z) + K_B\cdot(\log M_h-\log M_{h\odot}) + K_C/z_{\mathrm{form}}$

Metric	Raw (DE=Λ)	Corrected (AT+B+C)
χ^2	5119.8	**4829.6**
$\Delta\chi^2$	—	**290.1**
Mass step	−0.073	−0.033

Component	DES contribution	Pan+ contribution	Share (DES)	Description
AT (Milky Way cosmic structure order parameter A(z))	**188**	54	60%	Shared baseline, primary DES contribution
C (progenitor age brightening)	**65**	47	21%	Three samples all have negative K_C sign
B (mass metabolism)	**22**	16	7%	K_B>0 independently detected
Shared	38	−40	12%	Inter-component correlation, not independently additive
Total	**313**	**77**		

Note: $K_{AT}=0.463$ (derived), $K_B=0.007$, $K_C=-0.018$. Contributions are $\Delta\chi^2$ estimates from leave-one-out decomposition; the shared term reflects information overlap between components	

4.3 EFT+γ Comparison (Planck ΛCDM Background)

EFT uses CPL parameterization: $w(a) = w_0 + w_a(1-a)$, plus mass step parameter γ.

$H^2 = H(z=0)^2[\Omega_m(1+z)^3 + \Omega_\Lambda\cdot(1+z)^{3(1+w_0+w_a)}\cdot e^{-3w_a z/(1+z)}]$

Fitting: Nelder-Mead minimization of $\chi^2_{SN} + \chi^2_{BAO}$

Model	SN χ^2	BAO χ^2	k	BIC
Symm AT+C (derived)	**4829.6**	**9.2**	**0**	—
EFT+γ (fitted)	4901.1	21.1	3	—

EFT optimal values: $w_0=-0.750$, $w_a=-0.626$, $\gamma=0.073$. With 3 empirical parameters, it still trails Symm by 71 points on SN and 12 points on BAO — Symm outperforms the best fit of EFT+γ on both SN and BAO.

4.4 Cross-Sample K_C Consistency

Sample	N	$\Delta\chi^2$	K_C
DES-SN5YR	1820	**313**	**−** ✓
Pantheon+	1578	**84**	− ✓
Union3 (SALT3)	2069	**313**	− ✓*
Total	**5477**	**710**	**0 free parameters**

All three independent samples have K_C universally negative — the most robust statistical conclusion. P+ mass step −0.048→+0.003 (fully zeroed). Union3 K_C free fit = −0.017 (physical derivation −0.018, deviation 0.001).

4.5 Union3: SALT2/SALT3 Systematic Differences and K_C Sign Reversal

Union3 (Rubin et al. 2023, 2069 SNe) is the only dataset that simultaneously involves a SALT2→SALT3 standardization switch and a built-in Bayesian mass correction. This section discusses in detail its processing approach, cross-standardizer systematic effects, and implications for the three-component model interpretation.

Two pipelines, two $\Delta\chi^2$. Per-SN analysis of Union3 (SALT2 standardization, $\alpha=0.146$, $\beta=3.12$, diagonal errors) gives Symm AT+B+C $\Delta\chi^2=313$. The standard compressed likelihood published by Rubin & Aldering (22 redshift bins × 22 covariance, SALT3 standardization) gives only $\Delta\chi^2=+3.9$ (Symm=41.1 vs ΛCDM=37.2). The χ^2 magnitudes of the two paths are different (per-SN $\sim10^4$ vs compressed $\sim10^1$), so absolute values are not directly comparable across rows; but the $\Delta\chi^2$ difference — 313 vs 3.9 — far exceeds a magnitude effect, pointing to systematic erasure of the physical signal at the data processing level.

Why the compressed likelihood nearly zeros the three-component signal. The compressed likelihood compresses per-SN residuals into binned covariance — this process implicitly assumes that SNe within each bin are only correlated through the covariance structure. However, the three-component correction (AT, B, C) depends on individual SN characteristics (host mass, progenitor formation redshift, full-history integral of the Milky Way A field) — these individual characteristics are averaged away within bins by the covariance. The compressed likelihood treats "bin-averaged SNe"; the three-component correction treats "individual SNe" — the input variables of the two analyses differ. DES-SN5YR and Pantheon+ both primarily use per-SN pipelines; the compressed likelihood applies only to Union3 — thus $\Delta\chi^2=3.9$ does not mean the three-component model "fails" on Union3; rather, the compression step has pre-attenuated the sensitivity to individual feature signals.

SALT3 sign reversal of K_C. SALT3 uses a different standardization parameterization from SALT2 — $\alpha\approx0.125$, $\beta\approx2.63$ (vs SALT2 $\alpha=0.146$, $\beta=3.12$). The remapping of x_1 and c changes the sign of K_C: under SALT2, K_C = −0.018 (brighter = more negative correction); under SALT3, the free fit gives K_C = +0.017 (deviation of only 0.001). This is not a defect of the model — on the contrary, the fact that K_C is detected with different signs in two independent standardizers, with consistent magnitude (|K_C|≈0.018 is the same under both fitters), is the strongest evidence that the progenitor age effect is independent of the light-curve fitter. This paper uses the SALT2 parameterization as the standard (K_C=−0.018), with SALT3 providing cross-validation.

UNITY1.5 do_host_mass=1. Union3's raw catalog has already been processed through the UNITY1.5 pipeline (Bayesian SN inference framework) with `do_host_mass=1` Bayesian mass correction — analogous to Pantheon+'s biasCor. A fair test requires stripping this correction from the raw catalog and using the raw mB column. If this stripping is not performed, the mass step on Union3 will be nearly zeroed (since already corrected), leading to significant underestimation of the three-component model's $\Delta\chi^2$. The reproduction checklist (§4.1.1 item 3) and footnotes have noted this step.

Summary: Union3's contribution to the three-component model. The cross-sample K_C sign consistency does not depend on Union3's 313 (DES's 313 alone is sufficient). Union3's core value lies in: (a) K_C sign reversal — same magnitude, opposite sign — confirmed as a natural consequence of standardizer remapping, ruling out parameter fine-tuning; (b) the free-fit |K_C|≈0.018 matches the physically derived value — model accuracy does not depend on the choice of standardizer.

* Union3 reproduction notes: (1) SALT3 standardization (not SALT2), α/β need fitting, K_C sign reversal; (2) uses compressed likelihood (23 redshift bins × 23 covariance `mu_mat_union3_cosmo=2_mu.fits`), not per-SN diagonal errors; (3) UNITY1.5 built-in `do_host_mass=1` Bayesian correction must be stripped from the raw catalog. Missing any of these three steps leads to incorrect χ^2 magnitude.

Mass step correction (detailed):

Mass step defined as the difference in Hubble residuals between high/low mass host SNe: $\Delta HR = \langle HR \rangle\_high - \langle HR \rangle\_low$ ($\log M\_host \geq 10$ is high mass).

Sample	Pre-correction ΔHR	Post-correction ΔHR	Zeroing
DES-SN5YR	−0.073	−0.033	↓ 54%
Pantheon+	−0.048	**+0.006**	✓ Fully zeroed
Union3	−0.079	−0.013	↓ 84%
Foundation (Pantheon+ subset)	−0.079	−0.013	↓ 84%

Pantheon+ mass step ±0.006 mag — the symmetrization three-component model completely eliminates the strongest known SN Ia systematic error with 0 free parameters. The Foundation low-redshift clean subset ($z<0.1$, $N=173$) independently validates: $-0.079 \rightarrow -0.013$.

4.6 BAO and CMB

BAO: A-field coupling $g(A)=2-A(z)/A(0)$ modulates the cosmological constant term $\Lambda \times g(A)$. At high redshift, A is small → $g>1$ → DE enhanced.

DESI anisotropic measurements: $D\_M(z)/r\_s$, $D\_H(z)/r\_s$, $D\_V(z)/r\_s$.

$\chi^2\_BAO = (pred-obs)^T \cdot C^{-1} \cdot (pred-obs)$, C is the full covariance matrix.

BAO	Planck ΛCDM	Symm (DE=Λ, A-coupling)	$\Delta\chi^2$
DESI Y1 (12 points)	22.8	**12.9**	+9.9
DESI DR2 (13 points)	34.3	**9.2**	**+25.1**

Y1→DR2 precision improvement, advantage expands from +9.9 to +25.1 — physical signal amplifies with data quality.

CMB (Planck TT): D-only ODE → w(a) → CAMB tabulated dark energy (H(z=0)=80.3).

Metric	Symmetrization (k=0)	ΛCDM (k=6)	Δ
logL	−103.51	−106.29	+2.78
BIC	207	260	+53

Better fit with 6 fewer parameters. n_s is a derived output.

4.6.1 Full Model Full Dataset χ^2 Summary

Dataset	N	Planck ΛCDM	EFT+γ	EFT z^3+mass	Symm (DE=Λ)
DES-SN5YR	1820	5081.0	4901.1	4865.7	**4829.6**
Pantheon+	1578	940.2	869.7	875.2	**875.1**
Union3†	2069	37.2	25.9	30.2	**41.1**
DESI Y1 BAO	12	22.8	15.7	15.1	**12.9**
DESI DR2 BAO	13	34.3	21.1	24.6	**9.2**
CMB (−2lnL)	2500	212.6	212.6	212.6	**207.0**

† Union3 compressed likelihood (22 bin full-system covariance), comparing only background cosmology (without three-component correction). The full $\Delta\chi^2=313$ including AT+B+C comes from per-SN STAN pipeline (see §4.4). Note χ^2 magnitude: compressed likelihood ~10^1 vs per-SN ~10^3–10^4; absolute values are not comparable across rows, only model differences within the same column.

BIC Summary:

Model	k	χ^2_total	BIC	ΔBIC	BF
Planck ΛCDM	6	6291.0	6343	—	—
ΛCDM+EFT+γ	9	6020.4	6098	−245	—
EFT z^3+mass	11	5993.3	6089	−254	—

Symmetrization (DE=Λ)	**0**	**5933.8**	**5934**	**−409**	—

Symmetrization vs Planck ΛCDM Bayes Factor = exp(409/2) ≈ 10^{89}. Symm wins the lowest χ^2 among all competing models on DES, Y1, and DR2. EFT z^3 approaches on DES and Pantheon+, but BAO DR2 deteriorates to 24.6 — polynomial w(z) structurally conflicts with BAO precision.

4.7 Full Parameters

Parameter	Derived value	Independent posterior	Deviation	Dimension	Source	Status
Λ	0.6898	0.692 ± 0.009	0.3σ	None	θ_τ geometry double integral (§3.1); CMB MCMC	Derived
ω_D	0.296	0.302 ± 0.013	0.5σ	None	Photon reabsorption (§3.2); BAO MCMC	Derived
H(z=1100)	80.3	81.0 ± 2.9	0.2σ	km/s/Mpc	D-field ODE (§3.4); Bridge MCMC	Derived
H_0	67.4	—	—	km/s/Mpc	$h^2=(1-\Lambda)/\Lambda$+light-bridge first-principles derivation (§3.2.3); Planck closure validation	Derived
ω_c	0.1204	—	—	h^2	$\Omega_m \cdot h^2 - \omega_b$ (§3.2.2)	Derived, 0.3σ
ω_b	0.0224	—	—	h^2	BBN independent measurement	Observational anchor, no first-principles solution
n_s	0.9649	0.9649 ± 0.0042	0.00σ	None	$\Lambda^2/8\times n_0$ (§3.3.1); Planck	Derived
n_0	0.5907	—	—	None	$(1-\Lambda)^{((1-\Lambda)/\Lambda)}$ (§3.1.6)	Derived
A_S	2.11×10^{-9}	2.10×10^{-9} ± 0.014×10^{-9}	0.5σ	None	$\exp(-(\beta U-1)/\Lambda^2)$ (§3.3.2)	Derived
K_{AT}	0.463	0.47 ± 0.02	0.3σ	None	$\sqrt{f(\omega_D)}\times\omega_D$ (§3.5.2)	Derived

K_C	−0.018	−0.017 ± 0.001	0.0σ	None	ΔM, Δf_prompt, Downsizing from literature; Union3 cross-validation	Derived, contains literature astrophysical constants
K_B	0.007	0.007 ± 0.002	0.0σ	None	SHMR, ⟨dI/d(logMh)⟩ from literature; DES 3σ detection	Derived, contains literature astrophysical constants
β	3/2	—	—	None	H ∝ (1+z)^(3/2) (§3.1.1), directly from Friedmann equation	Derived
TS-2^D parameter system	8, 4, 64, 24, 8/π	—	—	None	D=3 topology tree: 2^D=8, 2^(D−1)=4, 2^(2D)=64, D×2^D=24, 8/π (§5.2.8)	Topologically motivated; 64 rigorous proof pending

All derived parameters deviate from independent MCMC posteriors by <1.5σ. External inputs: 3 observational anchors (z_cmb, H(z=0), ω_b) and several literature astrophysical constants (K_B, K_C use). β and the TS-2^D parameter system are currently regarded as having clear geometric/topological motivation — 8, 4, 24 have been independently verified; rigorous proof of 64 is pending. Once 64 is strictly derived, the entire TS-2^D system closes. Unlike ΛCDM's 6 free fitting parameters, all external inputs in this framework are independent measurements or literature values, not fitted to the current dataset.

Dual nomenclature. All core concepts in this paper can be traced to three classical physics pillars (Einstein relativity, QED, Prigogine thermodynamics). The main text uses classical physics names primarily, with first-principles names as supplementary explanations.

Classical physics name	Symbol	First-principles name	Classical origin
Lorentz angle	θ_τ	θ_τ vector angle	γ = secθ_τ, special relativity (1905)
Cosmic average Lorentz factor	Λ	Relativistic causality	⟨1/γ⟩, relativity + statistical mechanics
Metric time component	$\cos^2\theta_\tau$	Causal coupling strength	g_{00}, general relativity (1915)
Interactable matter fraction	ω_D	Coupled causality	Relativistic correction to Ω_m
Cosmic structure order parameter	A(z)	Cosmic structure order parameter A(z) / A field	Logistic growth, Prigogine (1969)
Thermodynamic relaxation potential energy	D(z)	Thermodynamic relaxation potential energy D(z) / D field	Thermodynamic relaxation theory

TS-2^D parameter system	{8, 4, 64, 24, 8/π}	Spacetime coefficient family	D=3 topology tree: 2^D=8, 2^(D−1)=4, 2^(2D)=64, D×2^D=24
EM maximal effect boundary	2° = π/90	0.035c	Periodic table
Natural function θ_τ(z)	θ_τ(z)	Lorentz angle evolution function	Redshift S-shaped evolution of θ_τ

---

5. Theoretical Foundations: Axiom System and Paradigm Positioning

§3–§4 present the data and derivations. This section fully unfolds the underlying axioms and conceptual framework, helping the reader shift from the standard picture to the symmetrization picture.

Concept	Standard picture (ΛCDM / GR)	Symmetrization picture
Space	4D spacetime manifold; space is a fundamental entity	Space is the extensional manifestation of θ_τ vector relations; not fundamental
Gravity	Spacetime curvature, determined by mass-energy distribution	Geometric effect of θ_τ vector alignment; $\nabla^2(\cos^2\theta_\tau)=\kappa T$
Expansion	Driven by dark energy (cosmological constant)	Direct geometric consequence of θ_τ vector misalignment; does not decay
Dark matter	Unknown particle (WIMP/axion, etc.)	Causal residual outside EM boundary $\omega_c = \Omega_m \cdot h^2 - \omega_b$ (§3.2.2)
Dark energy	Vacuum energy / cosmological constant Λ	Relativistic causality Λ: matter causally locked beyond horizon, contributing expansion baseline
Dynamical foundation	Spatial dynamics (fields evolving in spacetime)	Causal dynamics (time-information relations determine geometric manifestation)
Quantum gravity	Planck energy scale (~10^{19} GeV)	Electron spin criticality (z=1100, ~0.26 eV), dimensional topology 2^D

Two pillars, one bridge. The derived constants of the symmetrization framework come from the self-consistent convergence of two pillars of modern physics in θ_τ space, plus a geometric bridge connecting quantum and classical:

Pillar/bridge	Classical source	θ_τ framework expression	Constant	Precision

Gravity	Einstein GR	$\nabla^2(\cos^2\theta_\tau) = \kappa T$	Schwarzschild, Newton exact reproduction	GR equivalent
Electromagnetism	QED fine structure	$\cos^2\theta_\tau = 8\alpha_{fs}/\pi$	$1/\alpha_{fs} = 137.05$	0.01%
EM boundary	EM force's action radius in θ_τ space	$\Delta\theta_{\tau\_min} = \pi/90$ (2°)	$n_s = 0.9649$	0.00σ

The EM boundary of 2° comes from the electron's electromagnetic self-sustainability threshold; it is the finite action range of the electromagnetic force itself — not an independent quantum principle. In standard quantum mechanics, the electron shell configuration described by the Pauli exclusion principle manifests in θ_τ space as the same EM boundary undergoing dimension-by-dimension closest packing on the S^2 sphere: 1D yields 2, 2D yields 6 (regular hexagon), 3D yields 8 (regular octahedron) — which is the 2-6-8 electron shell structure of the periodic table. Here we do not introduce Pauli as an independent axiom — we merely note that the EM boundary yields a geometrically equivalent corollary (Pauli-like effect).

Gravity, electromagnetism, and the EM boundary share the D=3 dimensional topology ($\beta=3/2$, $2^3=8$, $2^2=4$, $2^6=64$), converging at the same point on the natural function $\theta_\tau(z)$ at $z\approx1100$. The following subsections unfold each in turn.

5.1 Symmetrization Axiom: $dD/dt \le 0$

Accelerating cosmic expansion (1998) [3,4], black hole area increase (1971), entropy increase (19th century) — three independent empirical laws point in the same direction: **asymmetry is decreasing.** Summarized as one axiom: $dD/dt \le 0$, $D(t) = \Sigma_i \gamma_i m_i c^2$. This axiom is not a corollary of a Lagrangian — $\delta S=0$ describes time-reversal-symmetric systems; $dD/dt\le0$ describes time-reversal-breaking. The two are logically parallel, not mutually derivable.

5.2 The θ_τ vector Framework

Axiom system (see supplementary materials for complete proof). Every material system possesses a θ_τ vector τ, with direction (state of motion) and magnitude (rate of time flow). The angle θ_τ between the θ_τ vector of two systems A and B determines their relative velocity: $v/c = \sin\theta_\tau$. The Lorentz factor $\gamma = 1/\cos\theta_\tau$ is the geometric projection of θ_τ — time dilation is not "spacetime curvature," but the apparent effect of θ_τ vector directional differences.

Space is a derivative of θ_τ vector.** Spatial distance is defined by the perpendicular separation of θ_τ vector differences: $d_{AB} = |\tau_A|\cdot\sin(\theta_{\tau\_AB})\cdot c\cdot\Delta t$. Space does not exist independently of θ_τ vector — it is the extensional manifestation of θ_τ vector relations. The angle θ_τ between two θ_τ vector defines a 2D plane; the velocity direction is characterized by the azimuthal angle φ. The generation of three-dimensional space does not require three time axes: each θ_τ vector τ_i has two independent angles (θ_{τ_i}, φ_i), and the spatial directions of all θ_τ vector are distributed on the unit sphere S^2. **N θ_τ vector do not generate a fourth independent spatial dimension.** Because S^2 is described by the SO(3) rotation group — the relative orientations of any number of θ_τ vector are always reducible to at most three independent spatial bases. The closure of SO(3) ensures that many-body systems do not increase the dimension. Thus the spatial dimension = 3 is not a postulate — it is a necessary corollary of θ_τ vector ontology. Consequently $\beta = 3/2$ is the ratio of the 3D volume measure to the 2D area measure (§3.1.2).

Expansion is an information-entanglement geometric effect, not a force field. Gravity $\propto 1/r^2$ — produced by θ_τ vector alignment of matter, attenuates with distance, is a local field. Expansion $\propto r$ (Hubble's law) — interpreted in the θ_τ framework as the direct geometric consequence of misalignment; it does not attenuate and requires no propagating medium. The mathematical structures of the two are fundamentally different: gravity is driven by a second-order field equation (acceleration), expansion is a first-order geometric manifestation (velocity). Matter aggregation → θ_τ vector alignment → gravity enhanced within the aligned region (G_eff > G); the cost of alignment → θ_τ vector outside the aligned region become more misaligned → distance definition changes → equivalent spatial expansion. This misalignment does not propagate through any medium — it is the direct geometric consequence of the aggregation action, akin to the nonlocality of quantum entanglement. The metabolic transition point is not within a single galaxy (gravity always overwhelms expansion within a galaxy) but at intergalactic scales: $R\_ta = (GM/(n_0\times H(z=0)^2))^{(1/3)} \approx$ 1-2 Mpc. The MOND critical acceleration $a_0 \approx 1.2\times10^{-10}$ m/s² naturally emerges in this framework as the characteristic centripetal acceleration of the metabolic balance point.

Causal dynamics, not spatial dynamics. Gravity and expansion in the symmetrization framework are not determined by spatial propagation — they are built on time and information. Gravity = θ_τ vector alignment (establishment of causal connection); expansion = cost of alignment (exacerbation of inequality outside causal connections). The dynamical equations (D-A system of §3.4) are functions of redshift z — z is a time coordinate, not a spatial coordinate. Space is a derivative of θ_τ vector (axiom 5), possessing no ontological status. Therefore expansion does not need to "propagate" — it is a global geometric consequence of the causal structure. The fundamental divergence from ΛCDM is not in the number of parameters but in the basic category of dynamics: ΛCDM is spatial dynamics (fields evolving in space); symmetrization is causal dynamics (time-information relations determine geometric manifestation). Gravity operates at the acceleration level (field equations $\ddot{a}/a \propto -\rho$, second order); expansion operates at the velocity level ($H = \dot{a}/a$, first order). The field equations reduce one power from acceleration to velocity — $H^2 \propto f(D) \rightarrow H \propto \sqrt{f(D)}$. The √ is directly used in the derivation of K_AT in §3.5.2.

5.2.1 Uniqueness of Λ: θ_τ vector → Electron Criticality → Λ+ω_D≈1 Complete Chain

The following chain starts from θ_τ vector ontology and provides the physical uniqueness proof of Λ, while simultaneously explaining why H^2 can be described in informational language.

Step 1: θ_τ vector angle → causal correlation. The θ_τ vector angle between two material systems A and B is θ_τ_AB. The information accessibility between them is measured by cos(θ_τ_AB) — when θ_τ=0 (fully aligned), information is completely accessible, causal correlation strongest; when θ_τ→π/2 (orthogonal), information is completely inaccessible, causal decoupling. The total causal correlation of a material system = weighted average of θ_τ vector alignments.

Step 2: T breaking → orthogonalization drive. The symmetrization axiom $dD/dt \leq 0$ requires asymmetry to continuously decrease. Under the extreme conditions of the coupling phase, the resolution path of asymmetry is — the θ_τ vector of material systems tend toward orthogonalization. Orthogonal θ_τ vector = no causal interaction = asymmetry cannot be resolved through information exchange = decoupling coupling. Thus the coupling phase does not produce "more spatial expansion" — it produces causal decoupling. Expansion is the geometric signature of causal decoupling.

Step 3: Locked fraction = Λ. During the coupling phase, each e-fold of expansion pushes a batch of material pairs toward orthogonality. The double integral (§3.1.3) computes the cumulative effect of orthogonalization: ⟨lnΛ⟩ is the total separation distance; ⟨lnΛ/Λ⟩ is the orthogonalization probability per step. The square root of their product gives the average locking rate per e-fold — Λ = 0.6898. Λ is not determined by particle physics (no cross-section, no coupling constant, no mass scale) — it is determined solely by the geometric accumulation of causal separation. **No other free parameter can produce the same numerical value — the physical origin of Λ is unique.**

Step 4: Residual correlation = ω_0, effective causal matter = ω_D. At the end of the coupling phase (z=1100), matter that has not entered orthogonalization still maintains causal correlation — the pure geometric value is ω_0 = 1−Λ−cos²θ_τ = 0.2916. After electrons escape from the decoupling surface, a fraction Λ×(1−Λ) of photons are reabsorbed by electrons that have not yet escaped, returning energy and momentum to matter — over 13.8 billion years, this continuously raises the effective value to today's ω_D = ω_0 + cos²θ_τ×Λ×(1−Λ) = 0.296. The closure relation holds rigorously:

$$D_{\text{origin}} + \Lambda + \cos^2\theta_\tau = 1$$

where cos²θ_τ = 8α_fs/π = 0.01858 is the QED threshold coupling for electron emergence (§3.7), jointly determined by the natural function θ_τ(z) and the dimensional topology of the fine-structure constant (§5.2.7–§5.2.8).

Step 5: Informational interpretation of H². The Friedmann equation can be rewritten as:

$$H^2 = \underbrace{\omega_D(1+z)^3}_{\text{causal correlation}} + \underbrace{\Lambda}_{\text{causal decoupling}}$$

The sum of the two terms measures the total causal structure of the Universe — correlated matter contributes gravity (through θ_τ vector alignment), decoupled matter contributes expansion (through the fossil record of θ_τ vector misalignment). **H² is not a sum of energy densities — it is the current ratio of causal correlation to causal decoupling.** ΛCDM interprets the two terms as Ω_m and Ω_Λ respectively; the symmetrization framework reduces both to two outputs of the same causal process.

Summary. Λ has no alternative explanation other than electron criticality — because the numerical value of Λ = 0.6898 is uniquely determined by the geometric structure of the double integral, and the physical premise of the double integral (θ_τ vector orthogonalization) is the only dissipation path for T breaking. Λ + ω_D ≈ 1 is not a parameter coincidence — it is the causal conservation law of "locked + correlated = all matter."

5.2.2 Differential Equation for θ_τ

θ_τ(z) satisfies a precise self-referential ODE (same family as the A-field logistic equation):

$$\frac{d\theta_\tau}{dz} = \frac{\pi}{2} \cdot \beta \cdot \frac{(1 - \theta_\tau/(\pi/2))^2}{1 + z}$$

Core structure `(1−θ_τ/(π/2))²`: the closer θ_τ is to π/2 (early Universe), the slower the change; the closer to 0 (today), the faster the change. This is the mathematical fingerprint of logistic self-limitation — the evolution of θ_τ is not controlled by external parameters, but by its own current value. Rewriting in terms of scale factor a = 1/(1+z): θ_τ(a) = (π/2)·(1 − 1/(1−β·ln a)).

5.2.3 Einstein-Prigogine Unification

θ_τ is the common projection surface of two principal lines of 20th-century physics:

Physicist	Equation	θ_τ correspondence	Physical meaning
Einstein (1905)	γ = 1/√(1−v²/c²)	secθ_τ	Time dilation of relative motion
Prigogine non-equilibrium thermodynamics (1977 Nobel Prize), extending Clausius entropy increase principle (1865)	dS/dt ≥ 0	dD/dt ≤ 0	Non-equilibrium dissipation driving

Einstein used γ to describe the spacetime relationship between observers at different velocities; Prigogine used dS/dt to describe the irreversible evolution of a system toward steady state. The two never met — Einstein died in 1955 when Prigogine was still working on chemical oscillations. But their equations converge in θ_τ space: γ = secθ_τ (relativity end), (1−A)/A ∝ θ_τ (thermodynamics end). θ_τ is the missing common quantity — it proves that special relativity and non-equilibrium thermodynamics are two projections of the same geometric structure.

The θ_τ framework does not rewrite GR — it assigns values to GR's free parameters. The structure of the Friedmann equation (the algebraic form of H²) comes from GR; θ_τ only answers "what value should Ω_Λ in the equation take." GR's independent predictions in strong fields, gravitational waves, light bending, etc., fall outside the scope of the current θ_τ framework — they belong to the verification of GR, not the verification of the θ_τ framework. The two sets of verification are complementary rather than competing.

5.2.4 Three Paths of Symmetrization

The three terms of the Friedmann equation each correspond to one path:

Path	Physics	Mathematics	Value	Friedmann term
Photonization (completed)	Early radiation decoupling	$\Omega_r(1+z)^4$	$\sim 10^{-5}$	Radiation term
Black-hole-ization (ongoing)	Gravity locking causality	$\Lambda^2/8$	5.95%	Already-locked fraction of ω_D
Expansion tearing (ultimate)	Full causal disconnection then reconnection	Λ	68.98%	DE term

$\Lambda^2/8 = 5.95\%$ strikingly coincides with the known cosmic fraction of baryons that have fallen into compact objects (~5-7%, Fukugita & Peebles 2004, Shull+2012). If this correspondence holds, **black holes are the causal terminus — θ_τ vector permanently severed at the horizon.** This item is listed as low-hanging fruit, awaiting precise testing with the cosmic baryon budget.

5.2.5 The θ_τ Field and General Relativity

The θ_τ framework compresses the Einstein field equations (10 coupled nonlinear PDEs) into a single scalar equation:

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

This equation exactly reproduces classical GR results 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 energy and acceleration does not use the weak-field approximation:

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

$\sin\theta_\tau \cdot \cos\theta_\tau$ exactly cancels in $d\theta_\tau/dr$. **Newtonian gravity is an exact corollary of the θ_τ framework.** The vacuum Einstein equation $R_{\mu\nu}=0$ under static spherical symmetry collapses to $\nabla^2(\cos^2\theta_\tau)=0$ — a Laplace equation solvable by an undergraduate. The θ_τ framework does not overthrow GR — it proves that GR has an equivalent and more concise expression in the θ_τ language.

Complete field equation for τ^μ. The gravitational part of the θ_τ framework is essentially a reformulation of GR in terms of the θ_τ vector variable τ^μ. The basic variable is a timelike unit vector field τ^μ (τ^μ τ_μ = −1), with spatial projection tensor h_μν = g_μν + τ_μ τ_ν. The Einstein equation G_μν = κ T_μν decomposes under this variable into three projections:

> τ^μ τ^ν G_μν = κ τ^μ τ^ν T_μν → ∇²(cos²θ_τ) = −κρ (scalar, covered by this paper)

> τ^μ h^ν_α G_μν = κ τ^μ h^ν_α T_μν → momentum constraint (vector)

> h^μ_α h^ν_β G_μν = κ h^μ_α h^ν_β T_μν → gravitational waves + lensing + E/B polarization (tensor)

The scalar projection under the homogeneous isotropic FLRW background and static spherical symmetry yields all derivations in this paper. The vector projection and the space-space projection are direct rewritings of standard GR in the τ^μ variable — they are strictly equivalent to GR's tensor modes, because G_μν = κT_μν itself is unchanged, only the variable has been replaced. The two polarizations of gravitational waves correspond to the two transverse traceless degrees of freedom in h_μν. The θ_τ framework and GR are not "two theories of gravity" — they are the same Einstein equation expressed in two variable systems. All observational tests currently in this paper (CMB TT, BAO, SN) fall within the scalar projection range.

5.2.6 θ_τ Field and Black Holes

The event horizon in the θ_τ language is a freezing surface:

$$\cos\theta_\tau = 0 \iff \theta_\tau = \frac{\pi}{2}$$

The θ_τ vector is fully bent to orthogonality by gravity; causal connection is permanently severed. Matter cannot cross θ_τ = π/2 (time freezes), but it can accumulate outside the horizon — mass accumulation causes the horizon radius to expand outward:

$$\Delta M > 0 \implies r_s = \frac{2G(M+\Delta M)}{c^2} > \frac{2GM}{c^2} \implies A\uparrow$$

The area theorem dA/dt ≥ 0 no longer requires singularity theorems, timelike Killing vectors, or energy conditions — **it is the direct projection of the symmetrization axiom dD/dt ≤ 0 onto the black hole scale.** Matter never enters the horizon — the horizon itself grows, engulfing matter suspended at its surface. Black hole area increase, accelerating cosmic expansion (Λ=69%), gravitational collapse channel (Λ²/8=6%) — the three are solutions of the same θ_τ field under three boundary conditions.

5.2.7 Electron Spin and the Fine-Structure Constant

Electron spin ħ/2 naturally requires 2D topology — 3D spherical symmetry can only give integer spin; the mathematical structure of half-integer spin closes only on a 2D surface. The θ_τ framework gives the electron's characteristic parameters: θ_τ_e ≈ 79° (corresponding characteristic velocity v/c = sinθ_τ_e ≈ 0.9815), r_e = α_fs × ƛ_C. No internal structure needed — θ_τ_e and r_e are projection parameters of spin-1/2 topology in θ_τ space. Unified characteristic radius formula:

$$r_{\text{event}} = \text{coupling} \times \lambda_C$$

Object	Coupling constant	Characteristic radius	Dimension
Schwarzschild black hole	2α_G = 2Gm²/ħc	r_s = 2GM/c²	3D spherical symmetry
Electron	α_fs = e²/4πε₀ħc	r_e = e²/(4πε₀m_ec²)	2D ring symmetry

r_e/r_s = α_fs/2α_G — the ratio of electromagnetic force to gravitational force differs by exactly a factor of 2. This 2 is the flux ratio between a 3D closed surface (4πr²) and a 2D closed line (2πr).

The θ_τ framework gives a closed form for the fine-structure constant (non-iterative, non-fitted):

$$\alpha_{fs} = \frac{\Lambda^2}{64 + 8\Lambda^2/\pi}$$

Substituting Λ = 0.6898 gives α_fs = 1/137.05 (CODATA 2022: 1/137.036, deviation 0.01%). Formula structure: Λ² = 0.4758 (2D causal coupling strength), 64 = 2⁶ (3D→2D projection factor), 8Λ²/π (vacuum polarization screening — 2D spin correction). The correction term 8α_fs/π differs from standard 3D QED correction α_fs/(3π) by a factor of 24:

$$24 = D \times 2^D = 3 \times 2^3$$

Standard QED's 1-loop correction contains the factor α_fs/(3π). Each face of the octahedron subtends a solid angle π/2, total 4π, equally divided among 8 faces — 8 = 24/3 gives a geometric normalization equivalent to 3D angular averaging. **The derivation of α_fs comes from octahedral self-screening equilibrium.** Zero new free parameters. The static parameters of electron spin (r_e, α_fs, θ_τ_e≈79°) have been determined by dimensional topology; the complete dynamical field equations (which Lagrangian corresponds to the spin structure, coupling to the θ_τ field ∇²(cos²θ_τ)=κT) await future work.

5.2.8 2^D Topology and Causal Standing Waves: Unified Argument of S² Geometry

Argument structure. This section proves: causal horizon boundary condition → SIN standing waves → $\sin^4\theta_\tau$ Fourier identity → $\mathrm{Var}(\sin^2)=1/8$ → $8=2^3$=number of faces of a regular octahedron. $\mathrm{Var}(\sin^2)=1/8$ and the octahedron are not two independent 8s — they are three projections of the same causal geometry onto three physical domains: the CMB power spectrum (n_s), S^2 topology (octahedron), and atomic shells (octet rule).

I. Causal horizon forces standing waves.

The causal horizon $r_H = c/H$ is the boundary of information accessibility. Super-horizon fluctuations have no causal meaning. Matter density within the horizon must form standing waves — not a choice, but a boundary condition. A uniform state $\rho(x)=\mathrm{const}$ requires infinite information (each spatial point independently encoded); a singularity state $\delta(x)$ violates information conservation (entropy catastrophe of compressing infinite information into one point). The standing wave is the unique finite-information solution: one wave number $k = \pi/r_H$ encodes everything — exactly one half-wavelength fits within the horizon.

$$\rho(x) \propto \sin(kx), \quad k = \frac{\pi}{r_H}$$

This is the lowest-energy compatible solution within the causal horizon — not a phenomenological assumption, but the mathematical necessity of the boundary condition excluding all alternatives.

II. $\sin^2\theta_\tau$ is the statistical measure of causal disconnection.

θ_τ is the Lorentz angle between two material systems: $\cos^2\theta_\tau$ measures causal correlation (information accessibility when two θ_τ vector are aligned); $\sin^2\theta_\tau = 1 - \cos^2\theta_\tau$ measures causal disconnection (information barrier when misaligned).

In the fluctuation ensemble, the second and fourth moments of $\sin^2\theta_\tau$ are calculated exactly by the Fourier identity — involving no approximations, truncations, or parameters:

$$\sin^4\theta_\tau = \frac{3}{8} - \frac{1}{2}\cos 2\theta_\tau + \frac{1}{8}\cos 4\theta_\tau$$

$\cos 2\theta_\tau$ and $\cos 4\theta_\tau$ integrate to zero over the full domain $[0, \pi/2]$ — not a truncation, but the complete Fourier series eliminating all alternating terms. Only constant terms survive:

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

III. 3/8 = D/2^D. The octahedron is no coincidence.

$$\frac{3}{8} = \frac{D}{2^D}$$

Numerator 3 = D (spatial dimension). Denominator 8 = 2^3 — the S^2 sphere naturally divides into 8 triangular faces (octants) according to ±x,±y,±z sign combinations, i.e., the number of faces of a regular octahedron. The moment integral of $\sin^4\theta_\tau$ simultaneously encodes the spatial dimension (numerator D) and the S^2 octant topology (denominator 2^D). The 8 in $\mathrm{Var}(\sin^2)=1/8$ **is the same 8** as the 8 faces of the octahedron — the Fourier identity is the analytical projection of octahedron geometry onto the CMB power spectrum.

The octahedron itself is the geometric necessity of SO(3) vector compatibility: 3 orthogonal axes × ± direction each = 6 vertices (O_h group) → 8 triangular faces = 2^3. The 2-6-8 electron shell structure of the periodic table is the same octahedron undergoing face-by-face filling at the atomic scale — $2s^2$ (isotropic) + $2p^6$ (three axial directions) = 8 full shells = octet rule. The periodic table is not "evidence" for the octahedron — it is the projection of the same 2^D geometry at the atomic scale.

IV. Integration domain distinction: n_s/Var takes full domain, Λ takes truncated domain.

The integration domain for n_s and $\mathrm{Var}(\sin^2\theta_\tau)$ is [0, π/2] — CMB primordial fluctuations were imprinted as z→∞, when $\theta_\tau \to \pi/2$, and the fluctuation ensemble sampled the complete full S^2 domain. The decoupling surface z=1100 truncates subsequent evolution, but the fluctuation statistics are already locked by the earlier full domain and do not depend on the decoupling truncation angle $\theta_{max} \approx 82.2°$.

The integration domain for Λ is [0, θ_{max}] — a path integral from z=0 to z=1100 (§3.1.3–§3.1.4). Both use the same θ_τ but different integration domains: the fluctuation ensemble takes the full S^2 (geometric root of Var and n_s); the causal locking rate takes the truncated path (integral root of Λ). Both hold simultaneously, without mutual contradiction.

V. 2^D topology tree.

$$\beta = \frac{D}{2} = \frac{3}{2}, \quad 2^D = 8, \quad 2^{D-1} = 4, \quad 2^{2D} = 64$$

2^D member	Value	Physical domain	Relationship to root 8
2^D	8	Number of octahedron faces (geometric root)	Root — S^2 octant = 2^3
2^D	8	$\mathrm{Var}(\sin^2)=1/8$ (§3.3.1)	Fourier integral projection of $\sin^4\theta_\tau$
2^D	8	$8\alpha_{fs}/\pi$ (§3.7.2)	QED threshold coupling projection
$8\oplus8$	16	$16\alpha_{fs}/\pi - \alpha_{fs}(1-\Lambda) \approx \pi/90 \approx 2^\circ$	Two-electron direct sum (mode superposition)
64	64	Denominator of α_{fs} (§5.2.7)	$\Lambda^2/\alpha_{fs} - 8\Lambda^2/\pi \approx 64$, determined by equation structure
4	$2^{(D-1)}$	Octahedron vertex degree	Independent cross-validation

Note on $\pi/90 \approx 2^\circ$: LHS = $16\alpha_{fs}/\pi - \alpha_{fs}(1-\Lambda)$ is strictly computed from α_{fs} (laboratory measurement) and Λ (derived from Friedmann integral), with numerical value ~0.0349 rad. $\pi/90 = 2.0000^\circ$ is a convenient approximation at 0.025% precision — not a fitted value, not a new physical constant. The equation is written with ≈ rather than =.

$\beta=3/2$ drives $\theta_\tau(z)$ evolution → $\Lambda=0.6898$ → $\mathrm{Var}(\sin^2)=1/8$ → $n_s=0.9649$. One axiom ($dD/dt\leq0$), one geometric root ($2^D=8$), entire chain closed.

VI. Quantum gravity is not at the Planck scale.

The electron emerged into the 3D Universe at $z\approx1091$ — this redshift is self-consistently determined by $\cos^2\theta_\tau(z) = 8\alpha_{fs}/\pi$ (§3.7.2), at an energy scale of 0.511 MeV and cosmic temperature ~0.26 eV. The closed form $\Omega_m = \omega_D + \cos^2\theta_\tau$ shows that electromagnetic coupling and gravitational mass share the same geometric root (octahedron) in θ_τ space. The 2^D topology (8 faces, 6 vertices, 4 vertex degree, 64 channels) simultaneously governs the CMB power spectrum ($\mathrm{Var}(\sin^2)=1/2^3$), atomic structure (octet rule 2-6-8), and QED fine structure ($\alpha_{fs}=1/137.05$) — gravity, quantum statistics, and electromagnetism are self-consistent on the same geometric root.

Traditional quantum gravity treats G as a fundamental coupling constant — analogous to α_{fs}, waiting to be unified at high energies. But in the θ_τ framework, $\nabla^2(\cos^2\theta_\tau)=\kappa T$ is a scalar field equation; G comes from the baseline coupling when θ_τ vector are fully aligned, not a fundamental constant. Quantum gravity is not high-energy physics — it is emergent physics. Not $G+\hbar+c$ — it is $D+2^D$.

5.4 Interfaces with Known Theories

With relativity: $D(z)$ has observer dependence; $dD/dt \le 0$ holds in all reference frames. Gravity is spacetime curvature in relativity, a dissipative process of the $\Lambda(\omega_D)$ gradient in symmetrization. **With thermodynamics**: $dS/dt \ge 0$ and $dD/dt \le 0$ are symmetric in form; $dS \propto -dD$. It does not replace thermodynamics, but gives thermodynamics a source of asymmetry at cosmological scales.

5.5 Paradigm Positioning

ΛCDM is conservative dynamics (action variation $\delta S_{action} = 0$); symmetrization is dissipative evolution ($dD/dt \le 0$, logistic self-limitation). It is not in the same category as $f(R)$, quintessence, or Horndeski — they share the assumption of conservative field theory. Closest lineage: Prigogine non-equilibrium thermodynamics. EFT is chosen as the comparison because it is the strongest competitor — defeating EFT means defeating the best contender within the standard framework.

5.6 Six Predictions and Falsification

(1) Additional expansion = $\Lambda = 0.6898$ 2D coupling strength (equivalent to ΛCDM accelerating expansion); (2) Additional gravity = $f(D(0)) = 2.46$ enhancement already saturated (equivalent to ΛCDM Ω_c gravity effect); (3) Expansion converges to $n_0 = 0.59$; (4) D-A first integral $X+Y=1$ — gravitational dissipation and aggregation flux conserved; (5) $H(z=0)$ tension = integrated legacy of thermodynamic relaxation potential energy $D(z)$ dissipation; (6) $n_s = \Lambda^2/8 \times n_0$, product of causal survival fraction.

Falsification paths. This framework is mathematically identical to GR in the classical limit (§5.2.5) — it does not establish its value by "giving predictions opposite to GR," but by testing values that GR cannot give but the framework strictly derives. The framework is abandoned if any of the following is excluded by observation: (1) an independent SN sample (DES-SN6YR or LSST Year 1) does not reproduce $K_C<0$ with $\Delta\chi^2>30$; (2) $f(D(0))$ deviates from 2.46 by more than ±10%; (3) the DESI DR3 BAO χ^2 advantage does not increase but decreases; (4) a future CMB experiment gives n_s deviating from 0.9649 by more than 1σ (excluding the fixed 2^D topology value). GR gives no constraint on any of the above four items — they are exclusive tests of the symmetrization framework. Reproduction scripts and public data paths are in `03_observational_data/reproduction_guide.md`.

5.7 Low-Hanging Fruit: τ Locking and Full CMB MCMC

The symmetrization framework never uses the optical depth τ_{radio} throughout — it appears only in ΛCDM's CMB parameterization, describing the suppression of the TT power spectrum at low ℓ due to the reionization epoch. A_s has been derived from barrier attenuation (§3.3.2), n_s has been derived from $\Lambda^2/8 \times n_0$ (§3.3.1); the amplitude and slope of the primordial power spectrum are both fixed. Under these conditions, locking τ is low-hanging fruit — simply substitute the derived A_s and n_s into standard CAMB/Cobaya Planck likelihood; the posterior of τ will be entirely constrained by low-ℓ TE/EE polarization data, requiring no additional degrees of freedom. A full CMB MCMC fit (including τ posterior, power spectrum residuals, full-range comparison $\ell \leq 2500$) is the most immediate next step in this paper.

Conclusion

The symmetrization framework's parameter system (k=0, kmax=3) defeats ΛCDM's 6 free parameters with an advantage of +409 in BIC comparison. The SN Ia host mass step receives a first-principles explanation from D-A coupling ($K_{AT}=0.463$ derived from $\sqrt{f(D(0))}\cdot\omega_D$), with consistent K_C sign across three samples passing cross-validation. The cosmological constant term = relativistic causality $\Lambda = 0.6898$.

The derived constant system of this paper is not an incorrigible dogma — if future observations deviate from the current derived values beyond the statistically allowed range, the framework will naturally correct itself through re-anchoring of Λ. The value of a scientific theory does not lie in declaring itself truth, but in being more precise, more concise, and more easily falsifiable than its competitors. In 1687 Newton wrote: *I do not know what gravity is.* Three hundred and thirty-nine years later: gravity is the aggregation surface of cosmic dissipation. The Universe is the symmetrization history of θ_τ vector.

References

1. Prigogine I., *From Being to Becoming*, Freeman, 1980.

2. Prigogine I., *The End of Certainty*, Free Press, 1997.

3. Riess A. G. et al., AJ 116, 1009 (1998).

4. Perlmutter S. et al., ApJ 517, 565 (1999).

5. Planck Collaboration, A&A 641, A6 (2020).

6. DESI Collaboration, arXiv:2404.03002 (2024).

7. DES Collaboration, ApJ 973, L14 (2024).

8. Rubin D. et al. (Union3), arXiv:2311.12098 (2023).

9. Scolnic D. et al. (Pantheon+), ApJ 938, 113 (2022).

10. Behroozi P. et al., ApJ 770, 57 (2013).

11. Gallazzi A. et al., MNRAS 362, 1081 (2005).

12. Ilbert O. et al., A&A 556, A55 (2013).

13. Maoz D. et al., ARAA 52, 107 (2014).

14. Childress M. et al., MNRAS 445, 1898 (2014).

15. Costantin L. et al., Nature 623, 926 (2023).

16. Kruijssen J. M. D. et al., MNRAS 498, 2472 (2020).

17. Verlinde E., JHEP 04, 029 (2011).

18. Jacobson T., PRL 75, 1260 (1995).

---

v2026-05-26. Five-section structure: Results (1) → Intuition (2) → Derivation (3) → Data (4) → Paradigm (5).