Cosmic Acceleration from Finite Record Geometry

A Corrected Infrared-Closure Model of the Causal Ledger

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Abstract

We develop a record-theoretic model of late-time cosmic acceleration within the Void Energy-Regulated Space Framework (VERSF). Finite Distinguishability (FD), Irreversible Commitment (IC), and Law Invariance (LI) motivate an isotropic closure contribution defined on a stable committed-record algebra. Once a single infrared coherence length ξ is introduced, dimensional consistency permits an asymptotic scalar term $\Lambda\infty = 3/\xi^2$, while a minimal rational activation ansatz $F(\chi) = 1/(1 + \chi^n)$ suppresses the closure sector when committed matter channels are abundant and activates it as those channels become sparse. The sharpness exponent n is not derived by the axioms and must be constrained observationally.

This revision corrects the absolute-amplitude claim. For r_s = 150 Mpc, $3/r_s^2 = 1.40 \times 10^{-49}$ m^{-2}, which is approximately 1.26×10^3 times the observed cosmological scale $\Lambda\text{obs} \approx 1.11 \times 10^{-52}$ m^{-2}. Matching the observed asymptotic amplitude requires $\xi = \sqrt{(3/\Lambda\text{obs})} \approx 5.33$ Gpc, or $\xi/r_s \approx 35.5$; matching the present effective amplitude in the normalized n = 2 and n = 5 examples requires $\xi \approx 4.96$ Gpc and 5.28 Gpc respectively. The former $\xi = O(r_s)$ hypothesis is therefore falsified as an amplitude anchor.

The corrected model is presented in two logically distinct forms. In the normalized phenomenological form, the observed present density ratio fixes $\chi\infty$ and therefore calibrates the required ξ; this form tests the redshift dependence of the closure function but does not predict the dark-energy amplitude. In the amplitude-predictive form, ξ must be supplied by an independent microscopic or geometric derivation and the present density ratio must emerge as an output. No such derivation is claimed here. The internally exact relations for $\chi\infty$, wDE(z), ΩDE(z), and the Model 0 expansion stress test are retained, while the cosmological-constant and coincidence claims are restated at their defensible strength.

For the General Reader

Why is the universe speeding up? Observations show that the expansion of the universe is accelerating. In the standard cosmological model this is represented by a cosmological constant Λ, but quantum-field estimates of vacuum energy do not naturally reproduce its tiny observed value. This paper explores a different possibility: the acceleration term may be associated with the large-scale organization of irreversible physical records rather than with a sum of zero-point energies.

The central picture is a cosmic ledger. Stable structures—such as long-lived gravitationally bound overdensities—carry persistent correlations and therefore contribute committed records. As the universe evolves, the balance between matter-supported records and a large-scale closure capacity changes. The model represents that balance by a dimensionless occupancy variable χ. When χ is large, the closure contribution is suppressed; when χ is small, it approaches a constant.

The important correction is that the familiar 150 Mpc BAO ruler does not generate the observed acceleration amplitude through $3/\xi^2$. It produces a value more than one thousand times too large. The observed amplitude instead corresponds to a length of several gigaparsecs, comparable to a cosmological horizon scale. This revised paper therefore does not claim that early-universe acoustics explains the absolute size of dark energy.

What remains useful is a testable mathematical shape for how a closure contribution could turn on with cosmic dilution. That shape can be confronted with supernova, BAO, CMB-distance, and growth data. A successful fit would establish only the phenomenological viability of the activation law. A true explanation of the dark-energy amplitude would additionally require an independent derivation of the multi-gigaparsec coherence scale.

Contents

1. Foundational Axioms and Logical Scope

The VERSF framework begins from three principles governing distinguishable physical states and durable macroscopic records. These principles motivate the construction but do not, by themselves, determine a cosmological amplitude, a unique closure function, or an observationally viable expansion history. The revised presentation makes those logical boundaries explicit.

1.1 Finite Distinguishability (FD)

Axiom FD. Any two physical states s_1 and s_2 are operationally distinguishable only if their difference can be encoded in a finite sequence of committed distinctions.

FD asserts that physical distinctions cannot require infinite operational resolution. In the VERSF interpretation, the state space carries a granular distinguishability structure at sufficiently small scales. The continuum description of field theory is then an effective approximation rather than a claim that every mathematically distinct configuration is physically distinguishable.

Consequence used here. Macroscopic closure laws may depend only on operationally defined record variables, not on unresolvable microscopic labels. FD does not select the cosmic length ξ and does not fix the numerical coefficient in $\Lambda\infty \propto \xi^{-2}$.

1.2 Irreversible Commitment (IC)

Axiom IC. A distinction counts as a macroscopic record only when it has become operationally irreversible within the relevant causal domain—through decoherence, entropy production, stable amplification, or persistent gravitational binding.

Let $\mathcal{A}c$ denote the committed-record algebra: the set of observables associated with distinctions that remain stable under all physically available reversal operations in the domain. Uncommitted quantum alternatives do not supply independent macroscopic ledger channels merely by existing in superposition.

Cosmological use. The model treats persistent nonlinear overdensities as proxies for committed large-scale channels. This is a modeling choice that requires a concrete coarse-graining prescription. A halo mass function is one possible operational implementation; the axioms do not uniquely privilege it.

1.3 Law Invariance (LI)

Axiom LI. Macroscopic laws are invariant under relabelings of committed records that preserve their causal and relational structure.

At homogeneous and isotropic cosmological scales, LI motivates closure terms that are scalar and permutation-invariant. The resulting contribution may depend on a dimensionless occupancy statistic χ but not on the identity of any individual record. This is analogous in spirit to demanding that only relationally meaningful data enter the large-scale law.

1.4 What the axioms establish—and what they do not

The axioms motivate four structural requirements:

- The cosmological closure variable should be dimensionless and built from committed-record capacity.
- The closure contribution should be isotropic at the FRW background level.
- It should be suppressed when matter-supported channels are abundant and saturate when they are sparse.
- Any absolute cosmological amplitude must ultimately be tied to an independently justified physical scale.

They do not uniquely derive $F(\chi) = 1/(1 + \chi^n)$, the exponent n, the coherence scale ξ, the coefficient 3, the assumption of a smooth non-clustering closure sector, or the identification of committed records with a particular halo population. Those are explicit model hypotheses and are treated as such below.

2. Correlation Channels and the Occupancy Ratio

2.1 Operational definition of a correlation channel

A cosmological correlation channel is a causally connected, persistently nonlinear matter configuration whose internal correlations have become operationally committed and remain stable against Hubble dilution over a specified persistence interval. A practical proxy may require:

- a nonlinear overdensity exceeding a declared collapse or binding threshold;
- gravitational or other dynamical stabilization;
- persistence for a time of order H^{-1} or for another explicitly chosen record timescale; and
- a non-overcounting rule that defines when nearby structures are independent channels rather than parts of one connected record.

This definition is deliberately operational. It excludes generic linear fluctuations from the channel count, but it does not assume that every halo is one channel or that filaments and clusters can be counted without a graph-based independence criterion. The companion analysis must state the coarse-graining rule precisely.

2.2 Matter-supported correlation capacity

Let $\mathcal{C}\mathrm{m}(a)$ denote the effective capacity supplied by committed matter structures. At leading phenomenological order,

$$\mathcal{C}\mathrm{m}(\mathrm{a}) \propto \mathrm{fcoll}(\mathrm{a};\, \mathrm{Mmin})\ \rho\mathrm{m}(\mathrm{a}),$$

where fcoll is the fraction of matter contained in structures above an operational threshold Mmin. A standard proxy is

$$\mathrm{fcoll}(\mathrm{z};\, \mathrm{Mmin}) = \rho\mathrm{m}^{-1} \int[\mathrm{Mmin},\infty]\ \mathrm{M}\ (\mathrm{dn}/\mathrm{dM})(\mathrm{M,z})\ \mathrm{dM}.$$

This proxy is not a microscopic derivation of record capacity. It is a calculable bridge between the record premise and standard structure-formation statistics. Alternative proxies—such as connected-component counts, persistent-homology measures, or weighted halo graphs—could produce different redshift dependences and must be treated as distinct model realizations.

2.3 Asymptotic closure density

Using geometrized units c = 1 unless otherwise stated, define the asymptotic closure density by

$$\rho\Lambda,\infty = \Lambda\infty/(8\pi\mathrm{G}) = 3/(8\pi\mathrm{G}\ \xi^2).$$

The quantity ρΛ,∞ is the saturation density of the closure sector, not automatically the present dark-energy density. The present effective density is reduced by the activation function whenever χ(1) is nonzero.

2.4 Occupancy ratio and exact consistency relation

For the baseline model, define

$$\chi(\mathrm{a}) \equiv \rho\mathrm{m}(\mathrm{a})/\rho\Lambda,\infty = \chi\infty\ \mathrm{a}^{-3}, \quad \chi\infty \equiv \rho\mathrm{m},0/\rho\Lambda,\infty.$$

For the channel-consistent model, define

$$\chi(\mathrm{a}) \equiv [\mathrm{fcoll}(\mathrm{a})\ \rho\mathrm{m}(\mathrm{a})]/[\mathrm{fcoll}(1)\ \rho\Lambda,\infty] = \chi\infty\ \mathrm{a}^{-3}\ \mathrm{fcoll}(\mathrm{a})/\mathrm{fcoll}(1).$$

The normalization by fcoll(1) preserves χ(1) = χ∞. With ρDE(a) = ρΛ,∞/[1 + $\chi(a)^n$], the observable present density ratio is

$$\mathrm{r}_0 \equiv \rho\mathrm{m},0/\rho\mathrm{DE},0 = \chi\infty(1 + \chi\infty^{\mathrm{n}}).$$

This relation is exact within the model. For r_0 = 0.45, it gives χ∞ ≈ 0.3905 for n = 2 and χ∞ ≈ 0.4425 for n = 5. Rounded to the precision used in the original tables, these are 0.391 and 0.443.

2.5 Two formulations that must not be mixed

Formulation N — Normalized phenomenology

Input the observed present ratio r_0 and choose n. Solve $r_0 = \chi_\infty(1 + \chi_\infty^n)$.

The present dark-energy density then fixes $\rho_{\Lambda,\infty}$ and therefore ξ. The model predicts a redshift-dependent shape but not the absolute amplitude.

This is the formulation used by the dimensionless tables and the normalized E(z) stress test.

Formulation P — Amplitude-predictive theory

Derive ξ independently from the microscopic record geometry, then compute $\rho_{\Lambda,\infty}$.

Given the matter density and n, solve the model forward and predict r_0 rather than insert it.

The former proposal $\xi \approx r_s$ belongs to this formulation and fails the direct amplitude test by approximately three orders of magnitude.

Using an observed r_0 to fix χ_∞ while simultaneously claiming that $\xi \approx 150$ Mpc predicts the amplitude imposes two incompatible normalizations. The revised manuscript therefore keeps Formulations N and P separate throughout.

3. The Infrared Closure Term

3.1 Structural scaling from a single infrared length

Assume that the homogeneous closure sector is characterized by one infrared length ξ and contributes a scalar with dimensions of inverse length squared. Dimensional consistency then gives

$$\Lambda\infty = C/\xi^2.$$

The dimensionless coefficient C is not determined by FD, IC, or LI. Setting C = 3 is a convention that makes ξ equal to the de Sitter curvature radius when $\Lambda\infty$ is constant. With that convention,

$$\Lambda\infty = 3/\xi^2.$$

This is a structural parameterization, not a derivation of the observed numerical value. The physical content lies in an independent determination of ξ; without one, the amplitude remains a model parameter or a quantity inferred from observation.

3.2 Minimal rational activation ansatz

The activation function is required to be monotone decreasing, bounded, scale-free in χ, suppressed for $\chi \gg 1$, and saturated for $\chi \ll 1$. The adopted minimal rational family is

$$F(\chi) = 1/(1 + \chi^n), \quad n \geq 1.$$

This family satisfies the required limits, but it is not unique. Stretched exponentials, logistic forms in ln χ, and higher-order Padé functions are also admissible. The exponent n controls transition sharpness and must be constrained by data or derived from a microscopic channel-failure model.

3.3 Effective cosmological term

$$\Lambda\mathrm{eff}(a) = \Lambda\infty\, F(\chi(a)) = 3/[\xi^2(1 + \chi(a)^n)].$$

The limiting behavior is

- early dense regime, $\chi \to \infty$: $\Lambda\mathrm{eff} \to 0$;
- late sparse regime, $\chi \to 0$: $\Lambda\mathrm{eff} \to \Lambda\infty = 3/\xi^2$.

For $n \geq 2$ and $\chi \propto a^{-3}$ at high redshift, $\rho DE \propto a^{3n}$ and is strongly suppressed. This background-level result remains valid in the normalized model. It does not by itself establish perturbative stability, absence of non-adiabatic modes, or a consistent covariant action.

3.4 Model status of the closure sector

At this stage the closure contribution is an effective background component. A complete theory would require a covariant action or an equivalent set of field equations whose Bianchi identity, perturbations, stability conditions, and causal structure can be analyzed without imposing conservation by hand. The present paper confines its quantitative claims to the homogeneous background and to a smooth-sector working hypothesis for linear growth.

4. Coherence Scale and Absolute-Amplitude Audit

4.1 Direct evaluation of the former BAO identification

The previous version proposed $\xi = \kappa\, r_s$ with $r_s \approx 150$ Mpc and $\kappa = O(1)$. The direct SI conversion is

$$150\ \mathrm{Mpc} = 150 \times 3.0856776 \times 10^{22}\ \mathrm{m} = 4.62852 \times 10^{24}\ \mathrm{m}.$$

$$3/(150\ \mathrm{Mpc})^2 = 1.40035 \times 10^{-49}\ \mathrm{m}^{-2}.$$

Against $\Lambda obs = 1.11 \times 10^{-52}\ \mathrm{m}^{-2}$, the ratio is

$$[3/{r_s}^2]/\Lambda obs = 1.2616 \times 10^3.$$

The BAO-scale result is therefore approximately 1,262 times too large, not within 20 percent. The discrepancy is 3.10 decades in Λ and a factor of approximately 35.5 in length.

Quantity	Value	Implication
BAO ruler r_s	150 Mpc = 4.62852×10^{24} m	Input tested
$3/r_s^2$	1.40035×10^{-49} m^{-2}	Former claimed amplitude
Λobs	1.11×10^{-52} m^{-2}	Observed comparison scale
Amplitude ratio	1,261.6	BAO anchor overpredicts
√(3/Λobs)	5.33 Gpc	Required asymptotic length
√(3/Λobs)/r_s	35.5	Required κ for Λ∞ = Λobs

Table 1. Direct absolute-amplitude audit.

4.2 No-go proposition for an order-unity BAO calibration

Proposition 1. Under $\Lambda\infty = 3/\xi^2$ and $\xi = \kappa\, r_s$ with r_s = 150 Mpc, no κ of order unity can reproduce the observed cosmological amplitude.

$$\Lambda\infty/\Lambda\mathrm{obs} = 1261.6/\kappa^2.$$

Proof. Matching Λ∞ = Λobs requires κ = √1261.6 = 35.52. Even allowing κ between 0.7 and 1.3 leaves an overprediction between approximately 2.58×10^3 and 7.47×10^2. Therefore the discrepancy cannot be absorbed by drag-epoch conventions, sound-horizon definitions, or a modest geometric calibration. ■

At the previously stated κ ≈ 0.9, the overprediction would be approximately 1,558, not a 20 percent agreement.

4.3 Scale required in the normalized model

The present effective amplitude is $\Lambda\mathrm{eff},0 = \Lambda\infty/[1 + \chi\infty^n]$. If Λeff,0 is set equal to Λobs, then

$$\xi = \sqrt{\{3/[\Lambda\mathrm{obs}(1 + \chi\infty^n)]\}}.$$

Using r_0 = 0.45 and the exact χ∞ roots gives:

n	χ∞	F(χ∞)	Λ∞/Λobs	Required ξ	ξ/r_s
2	0.3905	0.8677	1.1521	4.96 Gpc	33.1
5	0.4425	0.9833	1.0170	5.28 Gpc	35.2

Table 2. Coherence length implied after normalizing the present effective density.

These values are close to the de Sitter radius because the present closure function is already near saturation, especially for n = 5. They are not close to the BAO sound horizon.

4.4 What may ξ represent?

The arithmetic constrains any viable interpretation of ξ. It must be a multi-gigaparsec effective length if the coefficient is fixed at 3. Several possibilities remain conceptually open, but none is derived here:

- an effective de Sitter or event-horizon scale, which reproduces the amplitude but risks circularity if defined from Λ itself;
- a renormalized record-correlation length generated by a nonlocal coarse-graining flow from much shorter microscopic or acoustic scales;
- an emergent connectivity length of the committed-record network rather than the size of an individual matter correlation feature; or

- a scale derived from a future covariant ledger action, boundary condition, or fixed-point calculation.

A legitimate derivation must calculate ξ without inserting Λobs or an equivalent late-time horizon measurement. Merely identifying ξ with √(3/Λobs) would restate the observed amplitude rather than explain it.

4.5 Cosmological-constant problem: corrected status

The record framework offers a different proposed source category for the acceleration term: closure of committed-record capacity rather than a direct sum of vacuum zero-point energies. That conceptual move may be useful, but it does not yet solve the quantitative cosmological-constant problem. The observed amplitude remains unexplained until ξ and the coefficient C are obtained from independent physics.

The strongest defensible statement is therefore: the framework parameterizes a non-vacuum closure contribution with the correct dimensional form and a testable activation history. It does not currently derive why the required infrared length is approximately five gigaparsecs.

4.6 Coincidence problem: corrected status

The crossover χ(a×) = 1 gives

$$\mathrm{a}\times = \chi\infty^{1/3}, \quad \mathrm{z}\times = \chi\infty^{-1/3} - 1.$$

For n = 2 and n = 5 with r_0 = 0.45 inserted, this yields z× ≈ 0.37 and z× ≈ 0.31. These values are algebraically correct. However, their proximity to the present epoch is not predicted from r_s. It follows because the observed present density ratio r_0 fixes χ∞ to a number of order unity.

The model therefore reorganizes the coincidence problem rather than resolves it. In Formulation N, the timing is inherited from observational normalization. In Formulation P, a genuine resolution would require an independent ξ and a predicted r_0 that naturally yields the observed crossover epoch.

4.7 Possible evolution or renormalization of ξ

A slowly evolving effective scale may be parameterized as

$$\xi(\mathrm{a}) = \xi_0[1 + \alpha \ln(\mathrm{a}/\mathrm{aref})], \quad |\alpha| \ll 1,$$

but this should not be introduced merely to repair the amplitude mismatch. The mismatch is already present at α = 0 and is too large for a perturbative correction. Any evolution law must follow from the record-network dynamics and must be tested jointly against distances, growth, and the present normalization.

5. Modified Friedmann Dynamics

5.1 Background equation

Treat the closure contribution as an effective smooth background component with

$$\rho\mathrm{DE}(\mathrm{a}) = [3/(8\pi\mathrm{G}\ \xi^2)] \cdot 1/[1 + \chi(\mathrm{a})^{\mathrm{n}}].$$

$$\mathrm{H}^2(\mathrm{a}) = (8\pi\mathrm{G}/3)[\rho\mathrm{m}(\mathrm{a}) + \rho\mathrm{DE}(\mathrm{a})]$$

for a spatially flat matter-plus-closure model. Radiation must be restored for early-universe calculations, and curvature, neutrino mass, and baryonic effects must be included in any precision likelihood analysis. The equation above is the late-time analytic core, not a complete Boltzmann implementation.

5.2 Effective equation of state

Defining wDE from the background continuity relation gives

$$\mathrm{wDE}(\mathrm{a}) \equiv -1 - (1/3)\ \mathrm{d} \ln \rho\mathrm{DE}/\mathrm{d} \ln \mathrm{a}.$$

For Model 0, $\chi = \chi\infty a^{-3}$, so

$$\mathrm{wDE}(a) = -1 + n\chi(a)^n/[1 + \chi(a)^n].$$

The limits are wDE → −1 for $\chi \ll 1$ and wDE → $n - 1$ for $\chi \gg 1$. The large early formal value does not imply a dynamically important stiff component because ρDE is simultaneously suppressed as a^{3n}. It also does not establish a microphysical sound speed: wDE is an effective background diagnostic until a perturbation theory is supplied.

For Model 1, the derivative acquires an additional contribution from d ln fcoll/d ln a. The Model 0 expression must therefore not be applied unchanged once the collapsed fraction is allowed to evolve.

5.3 Present normalization

In Formulation N, flatness and the measured present matter fraction set ΩDE,0 = 1 − Ωm,0. The dimensionless expansion function is

$$E^2(z) = \Omega m{,}0(1 + z)^3 + \Omega DE{,}0\ [\rho DE(z)/\rho DE{,}0],$$

$$\rho DE(z)/\rho DE{,}0 = [1 + \chi\infty^n]/[1 + \chi(z)^n].$$

This construction guarantees E(0) = 1 and removes the absolute amplitude from the shape test. It is therefore inappropriate to describe a good normalized fit as confirmation that ξ has been derived. The fit would constrain the activation history only.

5.4 Low-redshift constraint strategy

The primary constraints come from H(z), comoving angular-diameter distances, luminosity distances, and their integrals over $0 < z \lesssim 2$. Direct comparison of wDE(0) with a constant-w or CPL posterior is informative but not decisive because the closure model has a specific non-CPL redshift dependence. The correct test is a likelihood evaluation of the direct observables with all shared cosmological parameters treated consistently.

6. Observational Predictions and Stress Tests

6.1 Model 0 dimensionless predictions

For r_0 = 0.45, Model 0 gives the following internally consistent values. The table is retained because it tests the dimensionless machinery independently of the failed BAO amplitude anchor.

z	χ (n=2)	wDE (n=2)	ΩDE (n=2)	χ (n=5)	wDE (n=5)	ΩDE (n=5)
0.0	0.390	−0.735	0.690	0.442	−0.917	0.690
0.3	0.858	−0.152	0.402	0.972	+1.324	0.355
0.5	1.318	+0.269	0.217	1.493	+3.407	0.0736
1.0	3.124	+0.814	0.0289	3.540	+3.991	5.07×10^{-4}

Table 3. Model 0 closure history, rounded to three significant figures.

The n = 5 example exhibits a very sharp transition and a formally large positive wDE where the closure density is already small. It is included as a shape diagnostic, not as evidence of viability. A full distance fit may reject both examples.

6.2 Baseline expansion stress test

Holding Ωm,0 = 0.31, ΩDE,0 = 0.69, and H_0 fixed to the same reference values in Model 0 and ΛCDM isolates the shape difference. Define

$$\Delta\mathrm{E(z)} = [\mathrm{Emodel(z)} - \mathrm{E\Lambda CDM(z)}]/\mathrm{E\Lambda CDM(z)}.$$

z	χ (n=2)	ΔE (n=2)	χ (n=5)	ΔE (n=5)
0.1	0.520	−2.9%	0.589	−1.6%
0.3	0.858	−8.8%	0.972	−12.2%
0.5	1.318	−12.3%	1.493	−19.3%
0.7	1.918	−12.5%	2.174	−16.7%
1.0	3.124	−10.2%	3.540	−11.5%

Table 4. Fixed-parameter Model 0 deviation from a ΛCDM reference.

These are large departures. Model 0 should therefore be treated as a falsified or strongly disfavored baseline unless a refit of shared parameters produces an unexpectedly acceptable distance history. The purpose of retaining it is diagnostic: it exposes how strongly the activation law changes the background when the committed fraction is held constant.

6.3 Channel-consistent Model 1

Model 1 uses

$$\chi(\mathrm{z}) = \chi\infty(1+\mathrm{z})^3\ \mathrm{fcoll(z)/fcoll(0)}.$$

Because fcoll(z) < fcoll(0) at positive redshift, χ(z) is smaller than the constant-fcoll baseline at the same z. The closure contribution is therefore larger at intermediate redshift, which can raise H(z) relative to Model 0 and potentially reduce its negative ΔE deficit. This is the correct sign of the proposed moderation effect.

Whether the correction is large enough is a quantitative question. It must be computed self-consistently because the halo mass function and growth history depend on the modified background. Using a fixed ΛCDM fcoll(z) inside a substantially non-ΛCDM expansion would introduce circularity.

6.4 Relation to CMB and early dark energy

For $n \geq 2$, the normalized background closure density is strongly suppressed at recombination in the Model 0 scaling. This is encouraging but not sufficient for CMB consistency. A complete test must include radiation, baryons, neutrinos, recombination, the sound horizon, the angular-diameter distance to last scattering, the integrated Sachs–Wolfe effect, and closure-sector perturbations or a justified demonstration that they are negligible.

The BAO sound horizon remains essential as an observed standard ruler in the likelihood. What has been rejected is its identification with the amplitude-setting ξ, not its role in cosmological distance measurements.

6.5 Structure growth

Under the working assumption that the closure sector is smooth on sub-horizon scales and couples to matter only through the background, the linear matter equation retains the standard form

$$\delta m + 2H\, \delta m - 4\pi G \rho m\, \delta m = 0.$$

There is no additional fifth-force term in this approximation. Nevertheless, growth is not unchanged: the modified $H(z)$ alters the friction term and therefore the growth factor, $f\sigma_8$, and any effective growth index. A value $\gamma \approx 0.55$ may remain a useful ΛCDM reference, but it is not guaranteed by the absence of a fifth force and must be calculated for each fitted background.

6.6 Discriminating signatures

1. Transition shape. The closure function produces a characteristic sigmoid-like evolution in $\ln(1 + z)$, distinguishable from a constant Λ and generally not represented faithfully by a two-parameter CPL compression.
2. Amplitude-shape separation. In the normalized model, data test the shape independently of the origin of ξ. A future amplitude-predictive theory must reproduce both the present normalization and the fitted shape without inserting r_0.
3. No order-unity BAO amplitude tie. Any renewed proposal $\xi = \kappa r_s$ must explain a nontrivial renormalization $\kappa \approx$ 33–35, not a convention-level factor near unity.
4. Growth through the background. If the closure sector remains smooth, departures in $f\sigma_8$ arise through $H(z)$; any extra scale-dependent growth would signal closure perturbations or direct coupling.
5. Halo-threshold dependence. Model 1 predicts a calculable sensitivity to the operational record threshold Mmin. An acceptable fit that requires implausible or unstable Mmin values would count against the channel interpretation.

6.7 Viability and falsification criteria

The revised model is viable only if all of the following hold:

- A self-consistent Model 1 fit reproduces BAO, supernova, and CMB-distance observables without a material degradation relative to ΛCDM after accounting for parameter count.
- The required channel threshold and fcoll evolution are physically interpretable and robust to reasonable halo-mass-function choices.
- The inferred closure history does not produce unacceptable growth, ISW, lensing, or early-universe signatures.
- A covariant completion can support a smooth and stable closure sector, or its predicted perturbations remain compatible with data.
- Any claim of an absolute-amplitude derivation supplies an independent calculation of ξ near 5 Gpc without using Λobs or an equivalent late-time normalization.

Failure of the first four conditions falsifies the present phenomenological realization. Failure of the fifth leaves the normalized phenomenology potentially viable but means the cosmological-constant amplitude remains unexplained.

6.8 Interpretation of n

The exponent n controls how abruptly the closure sector activates as χ crosses unity. A broad transition may correspond heuristically to a wide distribution of channel-failure thresholds; a sharp transition may resemble network percolation. This interpretation is suggestive, not derived. A microscopic calculation should predict the distribution of stability thresholds and map it to F(χ), rather than selecting n from analogy alone.

7. Discussion, Model Status, and Companion Analysis

7.1 Results that survive the correction

- The occupancy relation $r_0 = \chi_\infty(1 + \chi_\infty^n)$ is internally exact within the chosen closure ansatz.
- The Model 0 expressions for F(χ), Λeff(a), wDE(a), ΩDE(z), and normalized E(z) follow algebraically from the stated definitions.
- For n ≥ 2, the normalized closure density is strongly suppressed at early times in the baseline scaling.
- The baseline model makes large, testable departures from ΛCDM and is therefore genuinely falsifiable.
- A channel-consistent extension based on fcoll provides a concrete, though non-unique, route to a more realistic occupancy history.

7.2 Claims withdrawn or reduced

- Withdrawn: ξ ≈ 150 Mpc gives Λ∞ within approximately 20 percent of observation.
- Withdrawn: κ ≈ 0.9 is a viable sound-horizon calibration.
- Withdrawn: early-universe acoustics presently explains the absolute dark-energy amplitude.
- Reduced: the framework offers a non-vacuum source hypothesis but does not solve the quantitative cosmological-constant problem.
- Reduced: the near-present crossover is reproduced after inserting r_0; it is not yet predicted from earlier-universe physics.
- Reduced: the smooth-sector approximation removes an explicit fifth force but does not guarantee ΛCDM-like growth.

7.3 Corrected model statement

Defensible central claim

Given an independently specified infrared coherence length ξ, the VERSF ledger model parameterizes an asymptotic closure amplitude $\Lambda_\infty = 3/\xi^2$ and a monotone activation history $F(\chi) = 1/(1 + \chi^n)$.

When normalized to the observed present density ratio, the model yields a definite redshift-dependent background that can be tested against distance and growth data.

The present work does not derive the required $\xi \approx 5$ Gpc and therefore does not claim an absolute prediction of the dark-energy amplitude.

7.4 Companion analysis plan

The companion analysis should be organized in two stages.

Stage I — normalized shape test.

1. Choose $\{H_0, \Omega_{m,0}, n, M_{min}\}$ and impose flatness or include curvature explicitly.

2. Solve $r_0 = \chi_\infty(1 + \chi_\infty^n)$ from the present density ratio at each parameter point.

3. Compute $f_{coll}(z; M_{min})$ using a halo mass function and growth history generated self-consistently from the same background.

4. Evaluate $E(z)$, $D_M(z)$, $D_H(z)$, supernova distance moduli, CMB compressed distances, growth, and lensing-sensitive quantities.

5. Compare the Bayesian evidence or information criteria with ΛCDM and report whether the additional structure is warranted.

Stage II — amplitude derivation test.

1. Propose a microscopic or geometric calculation of ξ that does not use Λ_{obs}, H_Λ, or the measured late-time horizon as an input.

2. Use the derived ξ to predict $\rho_{\Lambda,\infty}$ and then predict r_0 and the acceleration epoch.

3. Reject the amplitude mechanism if it does not reproduce the observed normalization within declared theoretical uncertainty.

The BAO ruler should enter Stage I through the observed distance ratios D_M/r_s and D_H/r_s. It should not be imposed as ξ unless a new derivation produces the required factor of approximately 33–35.

7.5 Conclusion

The amplitude correction changes the scientific status of the paper but does not erase its entire content. The record-theoretic closure picture still defines a coherent phenomenological family with an exact internal normalization relation and a sharply testable expansion history. What has failed is the claimed bridge from the 150 Mpc sound horizon to the observed cosmological amplitude.

The revised program is therefore clearer and stronger: first determine whether the closure shape survives precision cosmology; then seek an independent derivation of the required multi-gigaparsec coherence scale. Keeping those tasks separate prevents a phenomenological normalization from being mistaken for an amplitude prediction and turns the remaining open problem into a precise target.

Appendix A. Minimal Rational Ansatz

Assume $F(\chi)$ is rational, bounded on $\chi > 0$, monotone decreasing, satisfies $F(0) = 1$ and $F(\infty) = 0$, and introduces no additional dimensional scale. Let $F = P/Q$ with coprime polynomials. The limits require $P(0) = Q(0)$, $\deg P < \deg Q$, and a positive denominator on $\chi > 0$. The lowest-degree constant-numerator family is

$$F(\chi) = 1/(1 + \chi^n), \quad n > 0.$$

This establishes minimality within the declared rational class, not uniqueness among all admissible analytic functions. The observational analysis should therefore test whether conclusions are robust under nearby activation families.

Appendix B. Amplitude-Consistency Derivations

B.1 BAO-scale amplitude

$$r_s = 150\ \mathrm{Mpc} = 4.628516 \times 10^{24}\ \mathrm{m},$$

$$r_s^2 = 2.14232 \times 10^{49}\ \mathrm{m}^2,$$

$$3/r_s^2 = 1.40035 \times 10^{-49}\ \mathrm{m}^{-2}.$$

$$(3/r_s^2)/(1.11 \times 10^{-52}\ \mathrm{m}^{-2}) = 1.2616 \times 10^3.$$

B.2 Required scale

$$\xi\mathrm{obs} = \sqrt{[3/(1.11 \times 10^{-52}\ \mathrm{m}^{-2})]} = 1.6439 \times 10^{26}\ \mathrm{m} = 5.3278\ \mathrm{Gpc}.$$

$$\kappa\mathrm{obs} = \xi\mathrm{obs}/r_s = 35.5187.$$

B.3 Present-effective normalization

Because $\Lambda\mathrm{eff},0 = \Lambda\infty/(1 + \chi\infty^n)$, matching $\Lambda\mathrm{eff},0 = \Lambda\mathrm{obs}$ requires

$$\xi(n) = \sqrt{\{3/[\Lambda\mathrm{obs}(1 + \chi\infty^n)]\}}.$$

For $r_0 = 0.45$:

$$n = 2{:}\ \chi\infty = 0.390467\ldots,\ \xi = 4.9629\ \mathrm{Gpc},\ \kappa = 33.0859.$$

$$n = 5{:}\ \chi\infty = 0.442493\ldots,\ \xi = 5.2832\ \mathrm{Gpc},\ \kappa = 35.2212.$$

B.4 Incompatibility exposed through $\chi\infty$

If $\xi = 150$ Mpc were nevertheless imposed, then $\rho\Lambda,\infty$ would be approximately 1,262 times the observed dark-energy density. With the observed $r_0 \approx 0.45$, the density definition $\chi\infty = \rho m,0/\rho\Lambda,\infty$ would give $\chi\infty \approx 3.6 \times 10^{-4}$, not 0.39–0.44. At such a small $\chi\infty$, $F(\chi\infty) \approx 1$, so the activation function cannot suppress the amplitude by the required factor. This demonstrates that the original amplitude anchor and the dimensionless table normalization cannot hold simultaneously.

Appendix C. Holographic Bound as Interpretive Context

The Bekenstein–Hawking bound may provide qualitative context for a finite ledger capacity, but it is not used to determine $\chi\infty$ or ξ in this model. A microscopic bit count in a Hubble volume and a macroscopic committed-channel occupancy are different quantities. Identifying them without a coarse-graining map would conflate levels of description.

Any future holographic derivation must specify how microscopic boundary degrees of freedom project onto independent, persistent cosmological record channels and how that projection generates the effective multi-gigaparsec coherence scale. Until then, holography is interpretive motivation rather than quantitative support.

Appendix D. Channel-Consistent Occupancy from Halo Statistics

D.1 Collapsed-fraction proxy

$$\mathrm{fcoll}(z;\,\mathrm{Mmin}) = \rho m^{-1} \int[\mathrm{Mmin},\infty]\ M\ (dn/dM)(M,z)\ dM.$$

Mmin encodes the operational scale above which a structure is treated as a persistent committed channel. It is not automatically a fundamental constant. Robustness should be tested across Press–Schechter, Sheth–Tormen, simulation-calibrated mass functions, and alternative channel definitions.

D.2 Occupancy ratio

$$\chi(z) = \chi\infty(1+z)^3\ \mathrm{fcoll}(z)/\mathrm{fcoll}(0).$$

The same numerical grid and normalization procedure should be used for fcoll(z) and fcoll(0) to guarantee χ(0) = χ∞ without interpolation artifacts.

D.3 Self-consistency requirement

The mass function depends on the linear variance, growth factor, expansion history, and matter power spectrum. A self-consistent calculation must therefore iterate or jointly solve the background and structure statistics at each parameter point. Importing a fixed ΛCDM halo history is acceptable only as an explicitly labeled preliminary diagnostic.

D.4 Falsifiable consequence

At positive redshift, the normalized fcoll ratio generally lowers χ relative to Model 0 and increases the closure density, potentially bringing H(z) closer to ΛCDM. If no physically plausible channel prescription can reduce the Model 0 distance residuals to the observationally allowed level, the present closure ansatz is falsified.

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