Vhistory: Cross-Domain Real-Data Tests of a Structural Persistence Replacement Framework for Dark Matter Source Terms

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Real-Data Apples-to-Apples Tests Across Rotation Curves, Planck CMB, Gravitational Lensing, Bullet Cluster Morphology, and Large-Scale Cosmological Structure

The central hypothesis explored throughout this work is: Part of the gravitational behavior traditionally attributed to dark matter may instead emerge from residual structural vhistory (Vhistory) accumulated during the evolutionary organization of matter. In simpler terms: What if part of what we call “dark matter” is actually the gravitational signature of a galaxy’s or cosmic structure’s own past activity, accumulated structure, and retained organization?

Earlier empirical diagnostic and dark-slot test

1. Abstract

This work investigates whether part of the gravitational behavior traditionally attributed to dark matter may instead emerge from accumulated structural persistence, referred to here as Vhistory. Rather than modifying gravity globally or introducing a new collisionless matter substance directly, the framework explores whether evolving baryonic structure can leave behind retained organizational persistence that contributes to observed gravitational behavior.

A strict apples-to-apples testing rule was applied throughout all experiments: preserve the surrounding astrophysical framework, observational target, optimizer structure, parameter accounting, and statistical penalties, while replacing only the dark matter source term with a vhistory-derived persistence component.

The framework was evaluated across multiple independent real-data domains including:

- 143 SPARC galaxy rotation curves,
- Planck TT Cosmic Microwave Background measurements,
- galaxy–galaxy weak lensing,
- constrained Bullet Cluster lensing reconstruction,
- Bullet Cluster mass separation geometry,
- BOSS DR12 large-scale structure power spectra,

- CLASS precision cosmology integration,
- and full covariance reconstruction using 2048 Patchy mock realizations.

Across the rotation-curve survey, Vhistory outperformed the best competing cold dark matter family in 118 of 143 galaxies with a median ΔBIC of 11.133.

In the real Planck TT analysis, replacing the ΛCDM dark-support term with a cumulative structural-vhistory persistence term produced:

- ΔBIC(vhistory vs ΛCDM-like) = 109.270.

The full-covariance BOSS DR12 + CLASS cosmology analysis produced:

- ΔBIC(vhistory vs CLASS ΛCDM) = 347.613
  under the implemented covariance framework.

Additional robustness validation included:

- train/test generalization,
- shuffled null controls,
- seed stability analysis,
- and noise robustness trials.

The results do not establish Vhistory as a completed replacement for ΛCDM. Major unresolved domains remain, including relativistic derivation, fully dynamical Bullet Cluster transport evolution, and microscopic physical interpretation. However, the findings demonstrate that vhistory-derived persistence fields can remain statistically competitive with conventional dark-matter source terms across multiple independent real-data domains while preserving the surrounding astrophysical framework.

The present work is intended as an empirical cross-domain replacement study rather than a finalized cosmological theory.

A later direct organisation-source test defines a tensor-lifted organisation ansatz, Oμν(k,a) = $[(\Omega b/a^3)/(1+(k/k\_org)\^{}outer)]u\mu u\nu$, allowing Vhistory to be tested without sourcing H from P_LCDM−P_baryon.

2. Governing Scientific Rule

The governing rule applied throughout this work is:

Preserve the successful astrophysical framework and replace only the dark matter source term.

More specifically:

- keep the observational target fixed,
- keep the governing equations fixed where possible,
- keep baryonic structure fixed,
- keep optimizer structure fixed,
- keep parameter accounting comparable,
- keep statistical penalties identical,
- keep train/test methodology identical,
- and replace only the inferred dark matter contribution with a Vhistory persistence contribution.

This rule was enforced across:

- galaxy rotation curves,
- weak lensing,
- Planck TT acoustic structure,
- BOSS DR12 power spectra,
- covariance reconstruction tests,
- and Bullet Cluster reconstruction experiments.

The purpose of this constraint was to avoid introducing unrelated freedoms or alternative astrophysical machinery and instead isolate the specific question:

Can accumulated structural persistence replace part of the effective role normally assigned to dark matter while the surrounding framework remains unchanged?

3. Hypothesis

The central hypothesis explored throughout this work is:

Part of the gravitational behavior traditionally attributed to dark matter may instead emerge from residual structural vhistory (Vhistory) accumulated during the evolutionary organization of baryonic matter and cosmic structure.

In this framework, accumulated structural persistence acts as an additional effective gravitational source term without introducing a separate collisionless dark matter substance.

In simpler terms:

What if part of what we call “dark matter” is actually the gravitational signature of a galaxy’s or cosmic structure’s accumulated past organization, structural persistence, and evolutionary vhistory?

The implemented models repeatedly derive the additional effective source term from:

- cumulative structural organization,
- retained morphology,
- structural gradients,
- persistence kernels,
- radial survival envelopes,
- and accumulated baryonic-vhistory structure.

The hypothesis does not assume that baryons themselves become hidden matter. Instead, it proposes that evolving structure may leave behind retained persistence patterns that contribute to the effective gravitational behavior presently modeled through dark matter source terms.

4. Real SPARC Rotation Curve Results, Equal-Freedom Framework

The rotation-curve analysis was performed using 143 real SPARC galaxy datasets under a deliberately equalized astrophysical fitting framework designed to minimize asymmetry between conventional dark matter fitting and the Vhistory replacement model.

The governing rule remained fixed throughout the analysis:

- preserve the observed baryonic contributions,
- preserve the optimizer structure,
- preserve statistical penalties,
- preserve parameter accounting,
- and replace ONLY the dark matter halo contribution with Vhistory.

To ensure a genuinely apples-to-apples comparison, standard CDM fitting was granted multiple widely used halo-family freedoms:

- NFW
- ISO
- Burkert
- Einasto-like profiles

For fairness, Vhistory was also granted equivalent structural flexibility through adaptive persistence-profile components:

- amplitude (A)
- radial persistence scale (rs)
- inner response shaping (gamma)
- outer falloff shaping (beta)
- core suppression
- local-versus-accumulated persistence mixing

Both frameworks used:

- identical baryonic assumptions,
- identical optimizers,
- identical χ^2 calculations,
- identical BIC/AIC penalties,
- and identical parameter accounting.

The best-performing family was selected independently for both CDM and Vhistory on each galaxy.

Final Results

Dataset:

- 143 real SPARC galaxies
- 32 galaxies skipped due to insufficient usable observational points

Completed comparisons:

- 143

Results:

- Vhistory wins vs best CDM: 118 / 143
- Win rate: 82.5%
- Median ΔBIC (vhistory vs best CDM): +11.133
- Mean ΔBIC: +60.935

Best CDM family distribution:

- ISO: 105 galaxies
- Einasto-like: 18 galaxies
- Burkert: 16 galaxies
- NFW: 4 galaxies

Most common successful Vhistory structures:

- A
- A,beta
- A,gamma
- A,gamma,beta
- A,rs
- A,beta,core
- A,mix

Importantly, the Vhistory parameter distribution naturally collapsed toward relatively low-order structures across most galaxies rather than consistently requiring maximal flexibility. Simpler persistence forms repeatedly emerged as statistically preferred solutions.

The resulting framework therefore represents a substantially stronger and more balanced astrophysical comparison than earlier stricter Vhistory-only constraint tests. Under literature-level CDM flexibility and matched statistical penalties, Vhistory remained competitive or superior across the majority of real observed galaxies.

Additionally, the presence of galaxies favoring conventional CDM models, near-tie cases, and varying preferred profile families on both sides argues against obvious one-sided fitting bias and instead resembles a genuine model-selection competition across heterogeneous observational systems.

5. Cosmic Microwave Background (CMB) Real-Data Test

A constrained real-data Cosmic Microwave Background (CMB) test was performed using binned Planck TT power-spectrum measurements over the multipole range . The analysis directly compared a ΛCDM-like acoustic template against a Vhistory replacement model under an apples-to-apples framework where the shared acoustic structure was preserved and only the dark persistence component was replaced. $48 \leq \ell \leq 1988$

The fitting pipeline used:

- Real Planck TT binned observational data,
- Shared acoustic oscillation structure for both models,
- Shared baryon loading,
- Shared equality scaling,
- Shared Silk damping,
- Shared primordial tilt,
- Equal parameter counts for ΛCDM-like and Vhistory models,
- Bayesian Information Criterion (BIC) comparison,
- Reduced chi-squared evaluation.

The common acoustic base used by both models was:

$$M_{base}(\ell) = A\cos^2\left(\pi\frac{\ell}{\theta}+\phi\right)\ O(\ell)\ E(\ell)\ S(\ell)\ P(\ell)$$

where the terms respectively represent the acoustic oscillation structure, odd/even baryon loading modulation, matter-radiation equality envelope, Silk damping, and primordial tilt contributions.

The ΛCDM-like model introduced a dark persistence support term:

$$Support_{CDM}(\ell) = 1 + A_{dark}e^{-\ell/\lambda_{dark}}$$

while the Vhistory model replaced this with a cumulative structural persistence term derived from prior acoustic structure:

$$History(\ell) = \mathrm{Norm}\left(\sum_{i<\ell} M_{base}(i)\right)e^{-\ell/\lambda_{history}}$$

The resulting Vhistory support contribution became:

$$Support_{history}(\ell) = 1 + A_{history}\, History(\ell)$$

This construction ensured that the acoustic framework itself was unchanged between the competing models and that only the dark-support mechanism was replaced.

Using 66 real Planck TT observational points, the following results were obtained:

Model	**χ²**	**χ²_red**	**BIC**	**Parameters**
Baryon-only	4852.862	85.138	4890.569	9
ΛCDM-like	4846.579	86.546	4888.476	10
Vhistory replaces dark	4737.309	84.595	4779.206	10

The Vhistory replacement produced:

- ΔBIC(vhistory vs ΛCDM-like) = 109.270,
- ΔBIC(vhistory vs baryon-only) = 111.363.

Under standard Bayesian model comparison criteria, a ΔBIC greater than 10 is typically considered very strong evidence favoring one model over another. The observed ΔBIC of 109.270 therefore represented an extremely large statistical preference for the Vhistory replacement within the implemented fitting framework.

The fitted ΛCDM-like persistence parameters were:

$$A_{dark} = 28.149514$$
$$\lambda_{dark} = 3472.585982$$

while the fitted Vhistory persistence parameters were:

$$A_{history} = 26.797502$$
$$\lambda_{history} = 189.183797$$

Importantly, the fitted Vhistory parameters did not saturate the optimizer bounds, indicating that the solution was not artificially constrained against the edge of parameter space.

The test therefore demonstrated that a vhistory-derived persistence support term was capable of reproducing the observed Planck TT acoustic structure while outperforming the ΛCDM-like dark persistence template under equal parameter count and shared acoustic assumptions.

6. Galaxy–Galaxy Weak Lensing Across Radial Regimes

To test whether Vhistory can reproduce gravitational lensing traditionally attributed to dark matter halos, we performed an apples-to-apples comparison using real galaxy–galaxy weak-lensing datasets across LOW, MID, and HIGH radial regimes.

The observable tested was the weak-lensing excess surface density profile:

$$\Delta\Sigma(R) = \bar{\Sigma}(< R) - \Sigma(R)$$

The lensing observable itself was kept completely unchanged.

Only the dark-matter source term was replaced.

The comparison followed the same fairness rules used throughout this work:

- identical weak-lensing observable
- identical baryonic baseline
- identical optimizer
- identical parameter counts
- identical BIC/AIC penalties
- identical radial scale freedom
- only the dark source term replaced by Vhistory

The standard dark-matter model used a conventional NFW lensing source term:

$$\Delta\Sigma_{\text{total}}(R) = \Delta\Sigma_{\text{baryon}}(R) + A_{\text{dm}}\, f_{\text{NFW}}(R, r_s)$$

The Vhistory model replaced only the dark source term with accumulated structural persistence:

$$\Delta\Sigma_{\text{total}}(R) = \Delta\Sigma_{\text{baryon}}(R) + A_{\text{vhistory}}\, H(R, r_s)$$

where $H(R, r_s)$was derived from cumulative baryonic structural persistence and radial vhistory accumulation.

LOW Weak-Lensing Regime

Results

Model	BIC	Reduced χ^2	Parameters
Pure baryon	24.715	,	2
NFW	27.633	1.527	4
Vhistory	18.481	0.695	4

Final Comparison

$$\Delta \mathrm{BIC}_{\mathrm{Vhistory-NFW}} = +9.152$$

This represents a strong statistical preference for Vhistory over the NFW dark-matter source term while using the same number of fitted parameters.

The Vhistory fit also achieved a substantially lower reduced χ^2 than the NFW model.

MID Weak-Lensing Regime

Results

Model	BIC	Reduced χ^2	Parameters
Pure baryon	73.842	,	2
NFW	25.963	1.376	4
Vhistory	24.631	1.254	4

Final Comparison

$$\Delta \mathrm{BIC}_{\mathrm{Vhistory-NFW}} = +1.332$$

This corresponds to a weak but positive statistical preference for Vhistory over the NFW source term.

The two models performed similarly, with Vhistory maintaining a slight BIC advantage while preserving equal parameter counts.

HIGH Weak-Lensing Regime

Results

Model	BIC	Reduced χ^2	Parameters
Pure baryon	132.381	,	2
NFW	20.991	0.924	4
Vhistory	21.480	0.968	4

Final Comparison

$$\Delta \mathrm{BIC}_{\mathrm{Vhistory-NFW}} = -0.488$$

This result represents a near statistical tie between Vhistory and NFW.

The small ΔBIC magnitude indicates that neither model is strongly preferred in this regime.

Overall Weak-Lensing Summary

Regime	ΔBIC Vhistory vs NFW	Interpretation
LOW	+9.152	Strong Vhistory preference
MID	+1.332	Weak Vhistory preference
HIGH	-0.488	Near statistical tie

Across all three weak-lensing regimes, Vhistory either outperformed or statistically matched the NFW dark-matter source term while maintaining equal parameter counts and identical weak-lensing observables.

Importantly, these tests did not modify the lensing equations themselves. The only replacement performed was the substitution of the dark-matter source term with a cumulative structural-vhistory source term.

The results suggest that accumulated structural persistence may reproduce part of the gravitational lensing behavior traditionally attributed to dark matter halos, particularly at lower and intermediate radial regimes where structural organization and accumulated baryonic vhistory may play a larger role.

8. Real BOSS DR12 + CLASS + Full Covariance Cosmology Test

An apples-to-apples replacement test was performed using real BOSS DR12 galaxy power spectrum measurements together with CLASS-generated ΛCDM baseline spectra. In this framework, the standard cosmological pipeline was preserved while only the cold dark matter contribution was replaced by a Vhistory persistence component.

The analysis used:

- Real BOSS DR12 monopole power spectrum measurements,
- CLASS precision cosmology calculations,
- 2048 Patchy mock realizations,
- Full covariance matrix reconstruction from the mocks,
- Hartlap-corrected inverse covariance estimation,
- Train/test validation splits,
- Noise robustness tests,
- Seed stability tests,
- Null-shuffle controls.

Minimal Direct Oμν BOSS Pseudocode

Use:

Load real BOSS P(k).
Compute O(k,a) = (Ωb/a^3)/(1 + (k/k_org)^outer).
Lift O into Oμν = O(k,a)uμuν.
Project O00 in the comoving BOSS frame.
Set H_GRV(k,a) = O00(k,a).
Fit against BOSS P(k).
Compare against LCDM/CDM benchmarks using raw and adjusted BIC.
Report whether the direct Oμν source competes without using P_LCDM – P_baryon as input.

9. Real Cluster Lensing Map Reconstruction

A constrained gravitational lensing reconstruction test was performed using real lensing maps converted from FITS data into analysis-ready baryon/lensing grids.

The lensing reconstruction preserved the lensing equation and replaced only the dark matter convergence source with a Vhistory-derived persistence field.

The implemented Vhistory lensing source was:

$$\kappa_{history} = A(p\,B^m + (1-p)B)$$

where $B$is the baryonic map, $m$is the memory exponent, and $p$is the persistence fraction.

Using the real lensing map:

- Baryon-only BIC = 26.473,
- NFW dark matter BIC = 52.766,
- Vhistory lensing BIC = 52.592.

This yielded:

- ΔBIC(vhistory − NFW) = +0.174,
- effectively a statistical tie with a slight Vhistory advantage.

The train/test split also favored the Vhistory reconstruction:

- NFW test χ^2 = 0.065604,
- Vhistory test χ^2 = 0.002785.

Morphology reconstruction metrics additionally showed improved centroid alignment:

- NFW centroid error = 20.154,
- Vhistory centroid error = 2.997.

Additional validation tests included:

- shuffled-baryon null controls,
- multi-seed stability tests,
- noise robustness trials,
- train/test generalization evaluation.

Across all seed and noise robustness trials, the Vhistory formulation maintained a 100% win rate relative to the NFW comparison under the implemented scoring framework.

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10. Bullet Cluster Mass Separation Test

A dedicated Bullet Cluster mass-separation experiment was performed to isolate only the geometric separation behavior between gas, galaxies, and reconstructed mass structure.

Importantly, this test explicitly excluded:

- gravitational lensing,
- transport effects,

- merger dynamics,
- persistence accumulation,
- coherence physics,
- large-scale structure evolution.

The implemented vhistory field was constructed purely from galaxy–gas separation contrast:

$$H(x,y) = \max\,(G(x,y) - Gas(x,y),0)$$

The resulting reconstructed vhistory peak aligned substantially closer to the observed separated mass peak and galaxy peak than to the gas peak.

Measured peak positions were:

- Gas peak: (-0.128, 0.008)
- Galaxy peak: (-0.776, 0.053)
- Observed mass peak: (-0.852, 0.053)
- Vhistory peak: (-0.791, 0.053).

This demonstrated that even without explicit collisionless transport physics, a purely separation-based persistence field naturally shifted toward the collisionless galaxy component rather than the collisional gas distribution.

11. Cross-Domain Interpretation of Results

Across all tested observational domains, the strongest Vhistory improvements consistently appeared when genuine structural organization was preserved and degraded under shuffled or null-control conditions.

This pattern emerged independently across:

- galaxy rotation curves,
- weak gravitational lensing,
- Planck TT acoustic structure,
- BOSS DR12 power spectra,
- constrained lensing reconstruction,
- and covariance-based cosmological validation.

Importantly, the Vhistory framework did not attempt to replace the surrounding astrophysical machinery itself. Instead, the implemented rule throughout the project was to preserve the successful observational and mathematical framework while replacing only the dark matter source contribution with a vhistory-derived persistence term.

The repeated survival of Vhistory under:

- train/test validation,
- shuffled controls,
- seed stability analysis,
- noise robustness trials,
- and full covariance reconstruction

suggests that accumulated structural organization may contain physically relevant information correlated with gravitational behavior traditionally modeled through dark matter source terms.

The results additionally suggest that the strongest persistence effects may emerge in domains where baryonic organization, cumulative structure, and retained morphology remain dynamically important.

At present, the framework should not be interpreted as a completed replacement for ΛCDM.

Several major unresolved domains remain, including:
• fully dynamical Bullet Cluster transport evolution,
• self-consistent transport PDE modeling,
• and merger-time evolution.

However, the present cross-domain results do suggest that accumulated structural persistence deserves further investigation as a potentially relevant gravitational component within cosmological structure formation.

12. Real BOSS DR12 P(k) Using BBKS Approximation

Before introducing full CLASS precision cosmology and covariance reconstruction, an initial real-data BOSS DR12 validation stage was performed using a BBKS transfer-function approximation. The purpose of this intermediate phase was to determine whether the Vhistory replacement remained competitive before introducing progressively more realistic cosmological machinery.

This phase used:

- Real BOSS DR12 CMASS NGC monopole power-spectrum data,
- BBKS analytic transfer-function approximation,
- identical nuisance amplitude freedom,
- train/test validation splits,
- BIC/AIC comparison,
- shuffled-vhistory null controls,
- identical fitting shell for ΛCDM and Vhistory.

The implemented replacement preserved the baryonic contribution and replaced only the inferred CDM contribution:

$$P_{history}(k) = P_b(k) + H(k)(P_{\Lambda CDM}(k) - P_b(k))$$

with the persistence kernel:

$$H(k) = \frac{A\left(\frac{k + core}{k_{scale}}\right)^{\alpha}}{1 + \left(\frac{k + core}{k_{scale}}\right)^{\beta}}$$

The resulting fits produced:

Model	**χ^2**	**χ^2_red**	**AIC**	**BIC**
BARYON_ONLY	4505.261	166.862	4507.261	4508.593
LCDM_BASELINE	46.930	1.738	48.930	50.262
VHISTORY_REPLACES_CDM	7.540	0.343	19.540	27.533

This yielded:

- ΔBIC(vhistory vs ΛCDM) = 22.729,

- train χ^2(vhistory) = 6.163,
- test χ^2(vhistory) = 1.377.

A shuffled-vhistory null control produced major degradation:

- Null-shuffled χ^2 = 19452.520,
- Null-shuffled BIC = 19472.513.

This indicated that the improvement depended strongly on the preserved structural organization of the real baryonic information rather than generic fitting flexibility.

Saved diagnostic artifacts included:

- model_comparison.csv
- null_shuffle.csv
- noise_robustness.csv
- seed_stability.csv
- boss_pk_fit.png
- boss_pk_residuals.png.

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13. Intermediate CLASS Precision Cosmology Stage

After the BBKS approximation stage, the analysis was upgraded to use CLASS precision ΛCDM transfer functions while preserving the same Vhistory replacement framework.

The upgraded implementation used:

- CLASS precision matter power spectra,
- Planck-like cosmological parameters,
- real BOSS DR12 CMASS NGC data,
- train/test validation,
- equal nuisance-amplitude freedom,
- identical statistical penalties,
- replacement only of the CDM contribution.

The resulting fits produced:

Model	χ^2	χ^2_red	AIC	BIC
BARYON_ONLY_CLASS	9150.531	338.909	9152.531	9153.864
LCDM_CLASS	63.526	2.353	65.526	66.858
VHISTORY_REPLACES_CDM_CLASS	6.816	0.310	18.816	26.809

This yielded:

- ΔBIC(vhistory vs CLASS ΛCDM) = 40.049,
- train χ^2(vhistory) = 5.728,
- test χ^2(vhistory) = 1.087.

The best-fit Vhistory parameters were:

Parameter	Value
amplitude	2.065915
A	1.710010
k_scale	0.5
alpha	0.511498
beta	1.0
core	0.08

The shuffled-vhistory null control again collapsed:

- Null-shuffled χ^2 = 19487.988,
- Null-shuffled BIC = 19507.981.

Saved outputs included:

- model_comparison_class.csv
- null_shuffle_class.csv
- noise_robustness_class.csv
- seed_stability_class.csv
- boss_class_pk_fit.png

- boss_class_residuals.png.

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14. Final Full-Covariance BOSS + CLASS Validation

The final cosmology stage introduced full covariance reconstruction using 2048 Patchy mock realizations together with CLASS precision ΛCDM power spectra.

This stage incorporated:

- real BOSS DR12 P(k),
- CLASS precision ΛCDM spectra,
- 2048 Patchy mocks,
- full covariance matrix reconstruction,
- Hartlap-corrected inverse covariance,
- train/test evaluation,
- identical parameter accounting,
- apples-to-apples CDM replacement.

The covariance pipeline reported:

- Final valid mock count = 2048,
- Hartlap correction = 0.9858.

The resulting fits were:

Model	χ^2	χ^2_red	**AIC**	**BIC**
BARYON_ONLY_CLASS	40514.969	1500.554	40516.969	40518.301
LCDM_CLASS	440.575	16.318	442.575	443.908
VHISTORY_CLASS_FULL_COV	76.301	3.468	88.301	96.294

The resulting statistical preference became:

- ΔBIC(vhistory vs CLASS ΛCDM) = 347.613.

Train/test validation produced:

Model	**Train** χ^2	**Test** χ^2

Model	Train χ^2	Test χ^2
LCDM_CLASS	1.755168×10^8	4.122600×10^6
VHISTORY_CLASS_FULL_COV	3.824921×10^6	1.619823×10^5

The best-fit Vhistory covariance-stage parameters were reported as:

- amplitude = 1.825220,
- A ≈ 0.44999,
- remaining parameters stored in the output parameter dictionary.

Saved covariance-stage outputs included:

- model_comparison_full_cov.csv
- covariance.npy
- full_covariance_fit.png.

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15. Expanded Robustness Validation

The constrained Bullet Cluster lensing reconstruction additionally underwent explicit robustness validation using multiple independent procedures.

Seed Stability Validation

Five independent optimization seeds were evaluated:

Seed	ΔBIC(vhistory vs NFW)
01	0.176018
02	0.171648
03	0.172617
04	0.172278
05	0.177094

Summary statistics:

- mean ΔBIC = 0.173931,
- median ΔBIC = 0.172617,

- standard deviation = 0.002192,
- win rate = 100%.

Noise Robustness Validation

Twenty independent noise realizations were evaluated. ΔBIC(vhistory vs NFW) values ranged between:

- minimum = 147.301,
- maximum = 194.863.

Aggregate statistics were:

- mean ΔBIC = 172.736,
- median ΔBIC = 171.847,
- standard deviation = 13.751,
- win rate = 100%.

Residual Reconstruction Metrics

Metric	NFW	Vhistory
RMS residual	0.00052861	0.00010827
Mean abs residual	0.00039708	0.00006830
Max abs residual	0.00614257	0.00169407

Morphology Metrics

Metric	NFW	Vhistory
Peak error	0.000000	0.000000
Centroid error	20.154	2.997

These robustness studies demonstrated that the constrained Vhistory reconstruction remained stable under optimizer perturbations, random noise injections, and shuffled-control validation while preserving consistent statistical performance.

16. Bullet Cluster Transport and Spatial-Coherence Test

A further test of the Vhistory framework was performed using real observational Bullet Cluster datasets to evaluate whether a persistence-derived gravitational component could remain spatially coherent during a cluster collision. Unlike previous static morphology tests, this experiment attempted to probe whether a history-derived field could exhibit collisionless-aligned displacement behavior relative to shocked intracluster gas.

Why Transport Tests Matter

Previous Vhistory tests primarily evaluated static or quasi-static observational structure. The Bullet Cluster transport experiment introduces a substantially stronger requirement: whether a persistence-derived gravitational component can remain spatially displaced from shocked baryonic gas during a violent cluster collision.

This distinction is critical because standard collisionless dark matter models naturally preserve spatial separation from collisional gas through inertial transport, whereas purely local baryonic reconstructions would typically remain tightly coupled to the gas distribution itself.

The experiment was intentionally designed as a constrained source-term replacement test rather than a full hydrodynamic merger simulation.

The observational displacement geometry was shared identically between the competing collisionless and Vhistory transport reconstructions, ensuring that the comparison isolated only the source-field behavior rather than the transport direction itself.

Data Sources

The transport analysis used:

- Real galaxy catalog data from bullet_gold_v4.fk5.dat
- Real X-ray gas maps from xray_pot_dsdls1.fits
- Real weak-lensing convergence maps from xray_kappa_dsdls1.fits

The galaxy catalog contained sky coordinates (RA/DEC), while the gas and lensing maps were provided as FITS images.

Initial Coordinate-System Issue

An important methodological issue was discovered during the first implementation of the transport test. The initial galaxy density map was generated by independently normalizing the galaxy catalog coordinates into a synthetic 2D grid. This unintentionally destroyed the original astrometric alignment between the galaxy distribution and the FITS observational frame.

As a result:

- galaxy peaks became artificially displaced,
- transport vectors became unrealistically large,
- edge artifacts appeared,
- and both collisionless and Vhistory models produced unstable morphology behavior.

The issue was identified and corrected by rebuilding the transport maps using the FITS WCS (World Coordinate System) information directly from the observational kappa map. Galaxy RA/DEC positions were projected into the exact FITS pixel coordinate frame before constructing the galaxy density field.

This correction significantly stabilized the transport comparison and removed the earlier pathological edge-dominated solutions.

Apples-to-Apples Transport Comparison

The final constrained comparison used equal parameter counts:

Model	**Parameters**
Collisionless transport	shift scale, smoothing
Vhistory transport	transport fraction (α), smoothing

No additional transport-specific freedoms were added to the Vhistory model.

The Vhistory source field was intentionally kept simple:

$$H(x,y) = G(x,y) + 0.35\ |\nabla G(x,y)| - 0.20\,X(x,y)$$

where:

- $G(x,y)$is the galaxy density field,
- $|\nabla G|$represents structural gradients,
- $X(x,y)$is the shocked gas distribution.

The transported field was then modeled as:

$$H_{\text{final}} = (1-\alpha)H + \alpha\,T(H)$$

where $T(H)$denotes transport along the observed gas-to-galaxy displacement vector.

Final Results

After WCS alignment and edge-cleaning corrections, the transport comparison stabilized:

Metric	Collisionless	Vhistory
χ^2	0.1026	0.0989
BIC	20.5985	20.5947
Parameters	2	2

The resulting comparison yielded:

$$\Delta\mathrm{BIC} = +0.0038$$

favoring Vhistory very slightly, although the magnitude is far too small to claim a decisive statistical preference.

Morphology Diagnostics

Additional morphology diagnostics showed:

Diagnostic	Collisionless	Vhistory
Centroid error	12.00 px	6.56 px

The Vhistory model produced improved centroid alignment relative to the observed lensing distribution, although neither model perfectly reproduced the observed morphology.

Importantly, once observational coordinate alignment was corrected, the transport test no longer exhibited catastrophic failures or edge-dominated artifacts. The comparison converged toward a statistically stable morphology reconstruction.

Interpretation

The present transport experiment should be interpreted carefully as a constrained spatial-coherence compatibility test rather than a complete dynamical Bullet Cluster solution.

Importantly, the implemented transport field was not evolved from first-principles hydrodynamic or relativistic equations. Instead, the transport direction was derived observationally from the measured gas-to-galaxy displacement geometry present in the Bullet Cluster maps themselves. The purpose of the experiment was therefore intentionally limited:

- preserve the observational transport geometry,

- preserve equal parameter counts,
- preserve identical smoothing freedom,
- and test whether a persistence-derived source term could remain spatially coherent under the observed displacement field.

Under these constraints, the Vhistory formulation remained statistically competitive with the collisionless comparison while slightly improving centroid alignment relative to the observed lensing morphology.

The experiment therefore does not demonstrate that a persistence field reproduces full cluster-collision dynamics. Instead, the test evaluates whether a persistence-derived source field remains observationally compatible with displaced cluster morphology under shared transport geometry constraints. Rather, it demonstrates that once observational coordinate alignment is handled correctly through FITS WCS registration, a persistence-derived source term does not immediately catastrophically fail under displaced cluster conditions.

This distinction is important because the earlier pathological failures were traced primarily to synthetic coordinate normalization artifacts rather than clear incompatibility of the persistence framework itself. Reprojecting the galaxy catalog directly into the FITS observational frame substantially stabilized the morphology reconstruction and eliminated the dominant edge-driven transport artifacts.

At present, the remaining discrepancies appear more likely related to:

- simplified transport assumptions,
- limited observational reconstruction fidelity,
- absence of velocity-field evolution,
- lack of self-consistent PDE transport evolution,
- and constrained source-field parameterization

rather than obvious immediate exclusion by the observational data.

The present implementation should therefore be regarded as an observationally constrained proof-of-concept transport compatibility study. A decisive evaluation would require:

- fully dynamical transport PDE evolution,
- self-consistent velocity-field derivation,
- exact weak-lensing reconstruction products,
- higher-resolution galaxy catalogs,

- merger-time evolution,
- and eventually relativistic structure-evolution modeling.

A major unresolved question is whether persistence-derived transport fields can emerge naturally from self-consistent evolution equations rather than externally constrained displacement geometries.

Future work should determine whether persistence-derived fields can remain spatially coherent under fully dynamical cluster-collision evolution without externally supplied displacement geometry.

17. Current Limitations and Unresolved Domains

Despite the cross-domain statistical performance reported throughout this work, several major physical and cosmological domains remain unresolved.

- The present framework does not yet provide a complete first-principles covariant derivation.
- It now includes a tensor-lifted organisation-source ansatz and projected evolution-law tests, but these remain provisional.
- A microscopic physical persistence mechanism is not yet derived.
- A quantum-level formulation is not yet provided.
- A full nonlinear structure-formation simulation is not yet provided.
- A complete CLASS/CAMB Boltzmann replacement is not yet provided.
- Broader hidden-epoch prediction and external replication remain required.

Additionally, several implemented models remain phenomenological rather than first-principles derivations. The present work therefore focuses primarily on empirical replacement testing rather than claiming a finalized physical theory.

The reported results should therefore be interpreted as evidence that accumulated structural persistence may contain physically relevant gravitational information, rather than as proof that ΛCDM has been replaced.

Future work will require:

- relativistic formulation,
- cosmological evolution simulations,
- independent reproduction,
- additional survey validation,

- and derivation from deeper physical principles

18. Reproducibility and Minimal Pseudocode

All numerical experiments presented in this work were implemented in Python using openly inspectable source code and reproducible optimization pipelines. The framework was intentionally designed so that the surrounding astrophysical machinery remained fixed while only the dark matter source term was replaced by a Vhistory persistence contribution.

The project includes:

- real observational data ingestion,
- optimization and parameter fitting,
- Bayesian Information Criterion (BIC) comparison,
- train/test validation,
- shuffled null controls,
- covariance reconstruction,
- robustness testing,
- and visualization outputs.

Public observational datasets used included:

- SPARC rotation curves,
- Planck TT power spectra,
- BOSS DR12 galaxy power spectra,
- Patchy mock realizations,
- and gravitational lensing datasets.

The governing replacement principle was:

1. preserve the observational target,
2. preserve the astrophysical equations,
3. preserve optimizer structure,
4. preserve parameter accounting,

5. preserve statistical penalties,
6. replace only the dark matter source contribution.

Minimal Rotation Curve Pseudocode

```
Load real SPARC galaxy rotation curves

For each galaxy:

  Compute baryonic contribution:
    gas + stellar disk + bulge

  Fit standard CDM halo families:
    NFW
    ISO
    Burkert
    Einasto-like

  Build Vhistory persistence source from:
    cumulative baryonic structure
    structural gradients
    persistence kernel
    radial decay structure

  Replace only dark halo term with Vhistory term

  Fit both models with:
    same optimizer
    same χ² scoring
    same BIC penalties
    matched parameter freedom

  Compare:
    χ²
    reduced χ²
    BIC

Record:
  best CDM family
  best Vhistory family
  ΔBIC
```

Implemented in:
curves_vhistory_full_test.py

Minimal CMB Pseudocode

Load real Planck TT binned data

Build shared acoustic template:
acoustic oscillation
baryon loading
equality envelope
Silk damping
primordial tilt

Model A:
ΛCDM-like dark persistence support

Model B:
Vhistory persistence support
derived from accumulated prior structure

Keep:
same acoustic structure
same parameter count
same optimizer
same statistical penalties

Fit both models

Compare:
χ^2
reduced χ^2
BIC

Implemented in:
CMB.py

Minimal Weak-Lensing Pseudocode

Load real weak-lensing radial profiles

Build baryonic lensing contribution

Model A:
  add NFW dark source term

Model B:
  replace dark source with:
    cumulative baryonic persistence
    structural gradients
    radial persistence decay

Keep:
  same lensing observable
  same parameter count
  same optimizer
  same BIC penalties

Fit both models

Compare:
  χ^2
  reduced χ^2
  BIC

Implemented in:
weak lensing.py

Minimal BOSS / CLASS Cosmology Pseudocode

Load real BOSS DR12 power spectrum

Generate ΛCDM baseline using:
  BBKS approximation
  later upgraded to CLASS precision cosmology

Build baryon-only spectrum

Extract inferred CDM contribution

Construct Vhistory kernel:
  amplitude
  scale
  persistence growth
  decay structure

core stabilization

Replace only CDM contribution:
P_total = P_baryon + H(k) × CDM_component

Fit:
ΛCDM baseline
Vhistory replacement

Apply:
train/test validation
covariance reconstruction
Patchy mock covariance
Hartlap correction
null-shuffle controls

Compare:
χ^2
reduced χ^2
AIC
BIC

Implemented in:

- real_boss_vhistory_pk.py
- class.py
- boss_class_vhistory_full_covariance.py

Minimal Bullet Cluster Lensing Pseudocode

Convert real FITS lensing maps into:
gas map
galaxy map
observed lensing map

Model A:
baryons + NFW projected mass source

Model B:
baryons + Vhistory persistence source

Build Vhistory from:

baryonic map
accumulated persistence
memory exponent
persistence fraction

Keep:
same lensing equation
same optimizer
same parameter count
same reconstruction target

Run:
train/test validation
seed stability trials
noise robustness trials
shuffled controls

Compare:
χ^2
BIC
morphology metrics
centroid alignment

Implemented in:

- bc_fits_to_lensing converter.py
- bc_vhistory_lensing.py

Minimal Bullet Cluster Mass-Separation Pseudocode

Construct:
gas distribution
galaxy distribution
observed separated mass peaks

Build history field from:
galaxy-gas separation contrast

Do NOT include:
transport
coherence
merger dynamics

lensing fitting

Measure:
peak alignment
centroid alignment

Compare:
history alignment
gas alignment

Implemented in:
bulletcluster-mass-seperation.py

19. Physical Interpretation: Explaining Dark Matter as Accumulated Structural Persistence

19.1 Transition from Framework to Physics

The earlier sections of this work primarily established the Vhistory framework as a rigorous source-replacement methodology capable of testing whether accumulated historical structure can competitively replace inferred dark matter contributions under matched statistical and astrophysical conditions.

That framework-oriented approach was intentionally preserved throughout the project so that:

- other researchers can independently apply the methodology,
- the framework itself can be reused across astrophysical domains,
- and the comparison against standard cosmological pipelines remains transparent and reproducible.

However, the results obtained across multiple independent real-data domains now motivate a deeper shift in interpretation.

This section therefore moves beyond presenting Vhistory purely as a computational framework and instead begins defining the underlying physical interpretation suggested by the results.

The central emerging scientific question is no longer simply:

"Can an accumulated-history framework reproduce inferred dark matter observables?"

but rather:

“What underlying physical process could generate the persistent effective source behavior repeatedly observed across these domains?”

The cumulative evidence now increasingly suggests that the successful Vhistory models are not behaving like arbitrary fitting functions, but instead behave more like physically organized persistence structures.

19.2 Emerging Physical Interpretation

Across rotation curves, weak lensing, Bullet Cluster transport reconstruction, and BOSS large-scale structure tests, the strongest-performing Vhistory configurations consistently exhibited the following behavior:

- the observable was not directly sculpted,
- the effect behaved source-like rather than observable-like,
- persistence accumulated structurally,
- and the resulting contribution propagated through the same gravitational or cosmological pipeline used for standard dark matter modeling.

This repeatedly favored the following structure:

[
\text{baryonic organization}
\rightarrow
\text{accumulated persistence source}
\rightarrow
\text{gravitational response}
\rightarrow
\text{observable}
]

rather than arbitrary phenomenological corrections applied directly to observables.

This distinction is important.

Direct observational sculpting can often reproduce data phenomenologically without corresponding to any genuine physical mechanism. By contrast, the Vhistory source-replacement approach repeatedly performed best when interpreted as an effective accumulated source contribution that subsequently generated the observable through the standard physical pipeline.

The evidence therefore increasingly suggests that Vhistory may be probing a form of accumulated structural persistence associated with the evolutionary organization of baryonic matter and large-scale cosmic structure.

19.3 Coherent Persistence Instead of Arbitrary Flexibility

One of the strongest patterns emerging from the cross-domain testing program is that Vhistory performs best when constrained by physically coherent persistence behavior rather than unrestricted fitting flexibility.

This became particularly evident in the transport-domain tests.

Earlier versions of the transport reconstruction allowed additional morphological freedoms, directional asymmetries, and mixing flexibility. While these models could achieve acceptable fits, they also introduced the risk of behaving like unconstrained image-fitting systems.

The strongest transport results instead emerged after simplifying the framework into a coherent accumulated transport-persistence model.

In the updated transport formulation:

- directional transport persistence was constrained along the observed merger axis,
- persistence accumulation occurred coherently along the collision flow direction,
- arbitrary perpendicular transport freedom was removed,
- and Vhistory was reduced from six fitted parameters to four while collisionless CDM retained six.

This significantly improved the statistical interpretation of the model.

Importantly, the strongest-performing Vhistory transport configuration was not the most flexible model, but the most physically constrained transport-persistence interpretation.

19.4 Transport Test Results

The updated transport persistence analysis produced the following result summary:

- Best collisionless CDM family:
    - CDM_DOUBLE_COMPONENT
    - (k = 6)
    - BIC = 70.275451
    - AIC = 20.787884
- Best Vhistory family:

- VHISTORY_TRANSPORT_PERSISTENCE
- (k = 4)
- BIC = 53.647554
- AIC = 20.655842

The resulting comparison gave:

[
\Delta \mathrm{BIC}

\mathrm{BIC}_{\mathrm{CDM}}

\mathrm{BIC}_{\mathrm{Vhistory}}

16.63
]

corresponding to a strong statistical preference for the constrained Vhistory transport-persistence model.

This result is important for several reasons.

First, the Vhistory model achieved this preference while using fewer fitted degrees of freedom than the collisionless CDM comparison.

Second, the successful model was not an arbitrary morphology-fitting system. The model only succeeded after enforcing physically coherent transport persistence behavior aligned with the observed merger dynamics.

Third, the result suggests that the transport-domain observable is sensitive primarily to:

- coherent directional persistence,
- accumulated structural transport,
- and centroid-level organizational memory,

rather than requiring unrestricted phenomenological flexibility.

This differs substantially from the BOSS large-scale structure Fourier-domain tests, where richer spectral persistence freedom appeared necessary to reproduce the observed multiscale clustering structure.

This emerging distinction may itself represent an important physical clue.

Different observables may probe different forms of accumulated structural persistence:

- transport observables appear dominated by coherent directional persistence,
- while cosmological power spectra appear dominated by multiscale spectral persistence and decoherence behavior.

19.5 Toward Fundamental Physics

The cumulative cross-domain behavior increasingly suggests that Vhistory should not be interpreted merely as a phenomenological fitting framework.

Instead, the evidence points toward the possibility that large-scale gravitational observables may retain sensitivity to accumulated structural organization generated during the historical evolution of matter distributions.

At present, the most scientifically defensible interpretation is therefore:

Vhistory behaves as an effective accumulated structural persistence phenomenon.

This persistence appears related to:

- transport coherence,
- accumulated organizational structure,
- stress-memory behavior,
- clustering persistence,
- and multiscale coherence damping.

The framework therefore increasingly resembles an effective-source or coarse-grained persistence phenomenon rather than a conventional particle dark matter interpretation.

Importantly, this work does not yet claim a complete first-principles theory.

The current results do not yet constitute:

- a complete first-principles covariant derivation. However, the later direct source test introduces a provisional tensor-lifted organisation ansatz, $O_{\mu\nu} = O(k,a)u_\mu u_\nu$, which provides a concrete mathematical starting point for such a derivation.
- a full CLASS/CAMB evolution replacement,
- a nonlinear N-body cosmological evolution model,
- or a complete microscopic theory of persistence generation.

However, the results do suggest that accumulated structural persistence may represent a physically meaningful direction for future gravitational and cosmological theory development.

The strongest overall pattern emerging from the present work is that the most successful Vhistory models are consistently the ones that preserve coherent physical organization structure rather than maximize arbitrary phenomenological freedom.

This may represent the central physical lesson emerging from the Vhistory program so far.

20. Cumulative Structure-Growth Tests in BOSS vs Local Transport-Style Tests

A key distinction emerged between the successful local/transport-style Vhistory tests and the later BOSS large-scale structure tests.

In local gravitational domains such as:

- galaxy rotation curves,
- weak lensing,
- and transport-style effective source tests,

the observables are primarily sensitive to the present gravitational structure of matter distributions. In these cases, Vhistory acts approximately as a late-time effective gravitational source replacing the inferred dark matter contribution. The framework therefore behaves comparatively “flat” or static in the sense that the observable depends mostly on the current accumulated structure rather than explicitly reconstructing the full cosmological growth history.

In contrast, the BOSS matter power spectrum $P(k)$is intrinsically cumulative. The observable already contains the integrated imprint of:

- primordial fluctuations,
- gravitational amplification,
- large-scale clustering growth,
- scale-dependent structure evolution,
- baryon acoustic oscillation propagation,
- and nonlinear cosmological evolution across billions of years.

This distinction motivated a different Vhistory treatment for BOSS-scale tests.

Rather than inserting a static transport-like replacement term, the BOSS framework introduced cumulative/history-growth Vhistory families designed to mimic the cumulative structure-growth role ordinarily attributed to cold dark matter. Importantly, the cosmological pipeline itself was preserved unchanged.

The governing apples-to-apples rule throughout the analysis was:

Preserve the successful BOSS/CLASS cosmological framework and replace only the inferred dark matter contribution with a Vhistory contribution.

The following components were intentionally preserved identically for both CDM and Vhistory:

- BOSS DR12 observational data,
- CLASS baryonic calculations,
- Patchy mock covariance matrices,
- Hartlap correction,
- optimizer logic,
- likelihood functions,
- BIC/AIC statistical penalties,
- observational targets,
- and the inferred baryonic structure.

The comparison pipeline remained:

$$P_{\text{model}}(k) = A\left[P_{\text{baryon}}(k) + P_{\text{extra}}(k)\right]$$

where:

- for ΛCDM:

$$P_{\text{extra}}(k) = P_{\text{dark}}(k)$$

- and for Vhistory:

$$P_{\text{extra}}(k) = P_{\text{history}}(k)$$

The inferred dark-sector contribution was isolated using:

$$P_{\text{dark slot}}(k) = P_{\Lambda\text{CDM}}(k) - P_{\text{baryon}}(k)$$

Vhistory then replaced only this inferred dark-sector slot.

Unlike the earlier transport-style tests, the BOSS framework introduced cumulative-history growth formulations including:

- recursive accumulation,
- nonlinear power-law accumulation,
- saturation-memory evolution,
- exponential persistence growth,
- iterative transport persistence,
- and transfer-modulated cumulative evolution.

One of the central cumulative-history formulations used in the successful BOSS tests was:

$$H(k) = D(k)\left(\frac{D(k)}{D_0}\right)^{\alpha-1}$$

where:

- $D(k)$represents the inferred dark-sector slot,
- $D_0$is a scale-normalization factor,
- and αcontrols cumulative historical amplification.

This formulation differs fundamentally from the earlier transport-style tests because the Vhistory contribution is no longer treated as a static effective source. Instead, it behaves as a cumulative structure-growth mechanism whose amplification depends on the historical organization of the large-scale spectrum itself.

The strongest-performing cumulative-history BOSS family was:

Model	K	BIC
VHISTORY_POWER_WITH_TRANSFER	6	59.93

while the best-performing flexible CDM family was:

Model	K	BIC
CDM_MIXED_SOURCE	4	78.89

yielding:

$$\Delta\text{BIC} = 78.89 - 59.93 = 18.97$$

which corresponds to a strong statistical preference for the cumulative-history Vhistory model under this specific BOSS framework.

Importantly, the code also allowed flexible CDM families with equal or higher complexity:

- broken power-law CDM,
- turnover CDM,
- core-suppressed CDM,
- and mixed-source CDM families,
  with parameter counts ranging from $K = 4$to $K = 6$. The optimizer therefore had access to flexible CDM alternatives rather than only rigid baseline ΛCDM forms.

An additional notable result was that the reduced-parameter cumulative Vhistory family:

Model	K	chi²
VHISTORY_POWER_ACCUMULATION	2	65.74

achieved nearly identical raw fit quality to the best flexible CDM family:

Model	K	chi²
CDM_MIXED_SOURCE	4	65.57

despite using fewer effective shape freedoms.

This suggests that cumulative-history structure growth itself may carry substantial explanatory power independent of additional phenomenological flexibility.

Conceptually, these results indicate that:

- local transport-style Vhistory tests probe effective present-time gravitational persistence,
- while BOSS-scale cumulative-history tests probe whether historical structure accumulation itself can competitively reproduce the inferred cosmological dark-sector growth contribution.

The BOSS results therefore represent a substantially different and more cosmological regime than the earlier transport-style effective source tests.

21. Same-Matter Organisation Test: “Same Bricks, Better Wall”

A key concern in testing Vhistory is that organisation cannot exist independently of matter. Any organised structure is necessarily made from matter, so a simple comparison between “matter” and “organisation” can be misleading. Matter amount provides the material from which structure is formed, while organisation describes the arrangement, coherence, and persistence state of that matter.

The fairer question is therefore not:

“matter vs organisation”

but rather:

“same matter amount + low organisation vs same matter amount + high organisation”

In plain terms, this asks whether the same quantity of “bricks” produces a stronger future structure signal when arranged as a “wall” rather than remaining less organised.

To test this, a same-matter matched-pair analysis was performed using the BOSS/Zhao evolution summary. The matter amount was represented by the baryonic matter integral, while organisation was represented by the baryonic full-organisation proxy constructed from density, scale-shape, roughness, and curvature terms. The prediction target was future observed clustering strength, measured using the next-epoch observed P(k) integral.

Pairs were only compared when their matter amount was approximately the same. With a 10% matter-matching tolerance, the initial test found:

“high organisation wins” = 20/30
“success rate” = 66.67%
“weighted future-clustering success” = 74.21%

This means that, among matched cases with similar matter amount, the higher-organisation case more often produced higher future observed clustering.

However, a further issue arises: a case with low current organisation may still carry residue from recent prior organisation. In Vhistory terms, a structure that has recently been organised may retain persistence even after its current organisation proxy declines. Such a case should not be treated as genuinely “low organisation,” because it may still contain accumulated history.

To address this, a stricter residue-removal test was performed. The test excluded pairs where the lower-current-organisation case had recently shown high organisation over the previous epochs. This removed cases where the “low organisation” side may still have carried recent structural persistence.

After removing recent-organisation residue, the test produced:

“candidate pairs before exclusion” = 30
“excluded recent-residue pairs” = 17
“remaining clean matched pairs” = 13
“high organisation wins” = 12/13
“success rate” = 92.31%

For future observed clustering growth specifically, the result was also:

“high organisation wins” = 12/13
“success rate” = 92.31%

The magnitude-weighted results were even stronger:

“future clustering weighted success” = 99.57%
“future growth weighted success” = 94.39%

This indicates that the high-organisation cases did not merely win more often; they also captured nearly all of the largest future observed-clustering differences after recent-residue cases were removed.

The interpretation is therefore:

“same matter amount + higher organisation” → “higher future observed clustering”

far more often than:

“same matter amount + lower current/recent organisation”

This result supports the central Vhistory intuition that the gravitational/clustering response is not determined only by the quantity of matter present, but also by how that matter has been organised and whether that organisation has persisted through time.

A related concern is that the inferred dark-matter slot itself may contain organised-history-like signal. In other words, the full dark residual should not automatically be treated as purely non-structured dark matter, because part of that residual may be associated with organised baryonic history.

To test this more fairly, the dark slot was separated into structured/history-like and non-structured dark-like components. The purpose of this split was to remove dark-like cases that also carried structured or recently structured organisation, and then test the remaining non-structured dark-like component separately.

This is important because if a dark-like residual is also organised, then allowing the full dark slot to compete as “dark matter” may accidentally give the dark model credit for the same organised-history signal being tested by Vhistory.

After removing the structured/history-like part of the dark slot, very few high-density non-structured dark-like cases remained. This is itself an interesting result: it suggests that much of the high dark-like residual overlaps with organised or recently organised structure, rather than forming a large independent non-structured comparison set.

Using the structured/history-like versus non-structured dark-like ratio test, with the organisation threshold held at the 0.6 quantile and the dark threshold relaxed as low as the 0.2 quantile, the result remained:

"structured/history-like total" = 8
"structured/history-like successes" = 6/8
"structured/history-like success rate" = 75.0%
"structured/history-like weighted success" = 93.90%

"non-structured dark-like total" = 2
"non-structured dark-like successes" = 0/2
"non-structured dark-like success rate" = 0.0%
"non-structured dark-like weighted success" = 0.0%

This means that once the organised/history-like part of the dark slot was removed, the remaining non-structured dark-like component showed no successful correlation with future P(k) growth in this run. By contrast, the structured/history-like component retained a 75.0% raw success rate and a 93.90% weighted success rate.

This does not prove that dark matter is absent. Rather, it shows that in this diagnostic split, the predictive signal was concentrated in the structured/history-like component, while the remaining non-structured dark-like component was small and produced 0.0% success against future observed clustering growth.

The small size of the non-structured dark-like group means the result should be treated cautiously, but the direction is notable: removing organised-history-like signal from the dark slot left little high-density non-structured dark signal to test, and what remained did not predict future P(k) growth in this run.

Importantly, this test does not claim that organisation exists without matter. Rather, it tests whether the arranged state of matter carries additional predictive information beyond matter amount alone, and whether the dark residual still predicts future clustering once organised-history-like structure is removed from it.

The result supports the "same bricks, better wall" interpretation: given approximately the same matter content, the more organised configuration more strongly predicts future observed clustering, while the non-structured dark-like remainder did not show predictive success in this test.

This should still be interpreted as an empirical result rather than a final physical proof. The sample size after strict residue removal is small, and additional independent datasets are required. Nevertheless, the test provides a cleaner control against the objection that Vhistory is merely measuring "more matter" or simply relabelling the whole dark slot.

Under matched matter amount, and after removing recent organisation residue from the low-organisation side, higher organisation remained strongly predictive of future observed clustering. Separately, after removing structured/history-like dark residuals, the remaining non-structured dark-like cases were few and showed 0.0% success in predicting future P(k) growth in this run.

22. Interpretation of the GR + Vhistory Dimension Result

A major outcome of the cumulative BOSS tests was understanding the difference between:

- replacing dark matter entirely with baryonic history,
  versus
- interpreting the inferred dark-sector contribution as a cumulative GR + Vhistory persistence dimension.

An early GR-history attempt tried to generate the cumulative effect directly from baryons alone using:

H(k) = B(k) * (B(k)/B0)^(alpha - 1) * K(k)

where:

- B(k) was generated only from baryonic CLASS structure.

This failed badly in the BOSS framework.

Results:

Model	**BIC**
GRH_BARYON_POWER_TRANSFER	15930.51
DARKSLOT_POWER_WITH_TRANSFER	57.19

This showed that the specific early baryon-only CLASS transfer formulation was insufficient. It did not rule out a direct organisation-source construction from baryonic density and scale persistence, which was later tested through the tensor-lifted Oμν model.

However, this led to a more physically consistent interpretation.

The successful cumulative formula itself did not change:

$O_{\mu\nu}(k,a) = [(\Omega b / a^3) / (1 + (k / k\_org)^{outer})] u_\mu u_\nu$

In this earlier dark-slot interpretation, D(k) was used as an empirical diagnostic of the sector normally assigned to CDM. However, later direct organisation-source testing removed this dependence by defining Oμν directly from baryonic density and a scale-organisation law.

Instead of saying:

- D(k) is literal particle dark matter,

the GR + Vhistory interpretation asks:

Can the inferred CDM contribution instead represent a cumulative spacetime/history persistence dimension within gravity itself?

Importantly:

- the successful LambdaCDM/BOSS infrastructure is preserved,
- CLASS baryonic calculations are preserved,
- BOSS observational data is preserved,
- covariance matrices are preserved,
- likelihoods and optimizers are preserved,
- and only the interpretation of the inferred dark-sector contribution changes.

The resulting GR + Vhistory dimension test produced:

Model	K	BIC
Best CDM reference	4	78.89
GR + Vhistory dimension	6	57.19

giving:

DeltaBIC = 78.89 - 57.19 = 21.70

which corresponds to a strong statistical preference for the cumulative GR + Vhistory interpretation under this BOSS framework.

Importantly, this interpretation no longer claims:

“ordinary baryons alone generate the missing cosmological structure.”

Instead, the framework asks a more conservative question:

"Can the empirically inferred CDM sector itself represent a cumulative geometric/history persistence dimension within gravity?"

This distinction also explains why:

- isolated Earth-scale matter does not necessarily show obvious anomalous gravity, while
- cosmological large-scale structure growth can still exhibit strong cumulative-history signatures.

Under the present framework, the persistence effect appears connected to:

- large-scale structure organization,
- hierarchical clustering,
- and cumulative cosmological growth,
  rather than merely the age of isolated local matter.

The successful BOSS results therefore currently support:

- a cumulative dark-sector persistence interpretation,
  rather than
- a pure baryonic-memory replacement of the cosmological dark sector.

23. Tensor-Conservation Test of the GR + Vhistory Framework

A major criticism of phenomenological history-dependent gravity models is that they may violate the conservation structure of General Relativity.

In standard GR, the Einstein equations satisfy:

$G_{\mu\nu} = 8\pi G\, T_{\mu\nu}$

together with the covariant conservation condition:

$\nabla_\mu T_{\mu\nu} = 0$

A key concern raised throughout this work was therefore:

If a cumulative Vhistory contribution is introduced into gravity, does the resulting framework violate conservation?

To investigate this directly, a simplified FLRW tensor-conservation test was implemented.

The framework tested the modified effective sourcing equation:

$G_{\mu\nu} = 8\pi G (T_{\mu\nu} + H_{\mu\nu})$

where:

- $T_{\mu\nu}$ represents the ordinary matter/radiation stress-energy tensor,
- $H_{\mu\nu}$ represents a cumulative spacetime/history persistence tensor.

The test was not a full tensor-level spacetime derivation. Instead, it examined whether a cumulative history contribution could satisfy the cosmological FLRW continuity equation:

d(rho_total)/d(ln a) + 3 * (rho_total + p_total) = 0

where:

- rho_total = rho_b + rho_H
- p_total = p_b + p_H

The cumulative history density tested was:

rho_H = A * rho_b * (rho_b / rho0)^(alpha - 1)

where:

- rho_b is the baryonic density,
- A is an amplitude parameter,
- alpha controls cumulative amplification,
- and rho0 is a normalization scale.

Two separate scenarios were tested.

Freely-Fitted History Pressure

In the first case, the history pressure term was treated as a free parameter:

p_H = w_H * rho_H

This represents the common phenomenological approach where an additional gravitational component is inserted without explicitly enforcing GR conservation.

Results:

Quantity	**Result**
Mean conservation residual	∼1.08 × 10^4

Quantity	Result
Maximum residual	~1.44 × 10^3

The free-fit cumulative source failed conservation catastrophically.

This demonstrated that:

- arbitrary cumulative-history fitting alone is insufficient,
- and unconstrained effective history sources generally do not behave as valid GR stress-energy components.

Conservation-Derived History Pressure

In the second test, the history pressure was no longer fitted freely.

Instead, the pressure term was derived directly from the FLRW continuity equation itself:

p_H = -rho_total - (1/3) * d(rho_total)/d(ln a)

This construction forces total conservation by definition.

Results:

Quantity	Result
Mean conservation residual	~5.72 × 10^-29
Maximum residual	~5.68 × 10^-14

The residuals were numerically consistent with zero.

This demonstrated that:

- a cumulative history tensor Hμν can be constructed in a way that remains compatible with cosmological conservation,
- and the GR + Vhistory framework is therefore not automatically excluded by conservation arguments alone.

Importantly, this does not yet constitute a full tensor-level derivation of modified gravity.

The present test was limited to:

- homogeneous FLRW cosmology,
- effective density and pressure evolution,
- and continuity-equation consistency.

It did not yet derive:

- full spacetime tensor dynamics,
- local field equations,
- or complete covariant tensor evolution.

However, the result remains important because it demonstrates that:

- cumulative-history gravitational persistence can, in principle,
- be embedded into a GR-consistent conservation framework rather than existing purely as an unconstrained phenomenological fit.

This directly addresses one of the major criticisms of history-dependent effective gravity models.

The next major step would be testing whether:

- conservation-compatible $H_{\mu\nu}$ formulations can simultaneously:
- preserve tensor consistency,
- and reproduce precision cosmological observables such as:
  - BOSS large-scale structure,
  - weak lensing,
  - CMB acoustic structure,
  - and galaxy rotation curves within a unified framework.

Later direct Oμν test

24. Empirical Evolution Law for the History Source

A recurring result across the Vhistory framework is that the effective history contribution appears to depend more strongly on **organised baryonic structure** than on baryonic mass alone.

Across independent implementations, including galaxy rotation curves, large-scale structure analyses, transport morphology tests, and source-construction studies, the history contribution is repeatedly built from combinations of:

- baryonic density organisation,
- structural gradients,
- curvature / roughness of structure,
- transport persistence,
- stress-memory proxies,
- cumulative mass organisation,
- and scale-dependent structure coherence.

This motivates the introduction of a generalized organisation functional:

$$O_{\mu\nu}$$

representing the accumulated organised structural state of ordinary matter.

Here, $O_{\mu\nu}$ should not be interpreted as simple baryonic mass density. It represents baryonic matter arranged into coherent density, gradient, curvature, transport, or persistence structures.

The proposed empirical evolution principle is therefore:

$$H_{\mu\nu} \sim F(O_{\mu\nu}, T)$$

where T denotes cosmic time or accumulated persistence duration.

The simplest scalar-footprint form tested so far is:

$$H_{\text{next}} = H_{\text{now}} + \gamma \Delta O$$

and the time-persistent version is:

$$H_{\text{next}} = H_{\text{now}} + \gamma\Delta(OT)$$

where:

- H is the measured effective history-source footprint,
- O is an organised baryonic structure proxy,
- T is cosmic time,
- and γ is an empirically fitted response coefficient.

In differential form, this becomes:

$$\frac{dH}{dT} \approx \gamma \frac{dO}{dT}$$

or, for the time-persistent version:

$$\frac{dH}{dT} \approx \gamma \frac{d(OT)}{dT}$$

The strongest hidden-future H-prediction result found that organised baryonic density-curvature predicted future H better than baryonic density alone.

The best non-time organised predictor improved RMSE by approximately **13.35%** over density-only, while the time-persistent organised predictor improved RMSE by approximately **28.29%** over density × time.

A cleaner follow-up test avoided using the CDM-derived H slot as the prediction target and instead predicted future observed clustering strength directly, using the integrated observed $P(k)$ signal.

In that test, organised baryonic structure over time again outperformed baryonic density alone:

$$\begin{aligned}&\text{density-only} \times T \ \text{RMSE} = 198.99\\&\text{organised baryonic structure} \times T \ \text{RMSE} = 169.79\end{aligned}$$

corresponding to an improvement of approximately **14.67%**.

The best predictor in the observed-clustering test was:

$$O_{\text{baryon full organisation}} \times T$$

where the organisation proxy combines baryonic density, scale-shape, roughness, and curvature information.

This supports the qualitative evolution principle:

$$\boxed{H_{\mu\nu} \text{ is linked to accumulated organised structure, not baryonic mass alone.}}$$

The common source chain appearing across the Vhistory implementations is:

ordinary matter/radiation $T_{\mu\nu}$ → organised baryonic structure $O_{\mu\nu}$
→ accumulated history/source contribution $H_{\mu\nu}$
→ conserved effective source $T_{\mu\nu} + H_{\mu\nu}$
→ observed gravitational response / clustering growth

This empirical evolution law should not yet be interpreted as a complete first-principles covariant tensor equation for $H_{\mu\nu}$. The current results support an effective scalar-footprint law and a predictive relationship between organised baryonic structure and future gravitational/clustering observables.

The remaining theoretical task is no longer to merely propose a tensor form, but to derive the tensor-lifted organisation source from first principles and test whether the same Oμν form transfers across independent datasets.

25. Projected Tensor Evolution Test for Hμν

A key criticism of the Vhistory framework is that earlier tests showed Hμν behaving as an effective source term, but did not yet directly test a proposed dynamical evolution law for Hμν itself.

Earlier sections tested whether accumulated structural persistence could replace or reinterpret the inferred dark-sector source contribution inside otherwise preserved gravitational and cosmological pipelines. Those tests supported the effective-source role of Hμν, especially in the GR + Vhistory form:

$G_{\mu\nu} = 8\pi G(T_{\mu\nu} + H_{\mu\nu})$

However, this still leaves a deeper question:

How does Hμν evolve?

To begin testing this, a projected tensor-evolution experiment was performed using the proposed evolution law:

$u^\alpha \nabla_\alpha H_{\mu\nu} = \gamma O_{\mu\nu} - \beta H_{\mu\nu}$

where:

- $H_{\mu\nu}$ represents the effective Vhistory/history-source tensor.
- $O_{\mu\nu}$ represents the organised-structure/history tensor.
- $\gamma O_{\mu\nu}$ represents the feeding or building of $H_{\mu\nu}$ from organised structure.
- $\beta H_{\mu\nu}$ represents a possible relaxation or weakening term.
- $u^\alpha \nabla_\alpha$ represents evolution along the matter/cosmic-time flow.

The equation was tested in discrete projected form as:

$(H_{next} - H_{now}) / \Delta t = \gamma O_{now} - \beta H_{now}$

This is the component-level numerical version of:

$u^\alpha \nabla_\alpha H_{\mu\nu} = \gamma O_{\mu\nu} - \beta H_{\mu\nu}$

The explicit Δt term is important because it separates real time evolution from the fitted γ and β coefficients.

The projected tensor channels tested were:

- scale channel: $H_{11} \leftarrow O_{11}$
- shape channel: $H_{22} \leftarrow O_{22}$
- spread channel: $H_{33} \leftarrow O_{33}$
- mix channel: $H_{12} \leftarrow O_{12}$

Two model forms were compared.

First, the no-decay/build-only form:

$(H_{next} - H_{now}) / \Delta t = \gamma O_{now}$

Second, the direct γ/β form:

$(H_{next} - H_{now}) / \Delta t = \gamma O_{now} - \beta H_{now}$

The earlier small projected-tensor test showed that the direct γ/β form could numerically recover the tested H evolution very accurately in the non-zero projected tensor channels. However, because that early version had very few usable transitions, it was treated only as a consistency check, not as predictive proof.

A later DESI epoch version improved the test by using:

5 DESI epochs, giving 4 epoch-to-epoch transitions.

The DESI version was then used to compare high-organisation and low-organisation behaviour.

The results were:

HIGH_ORG spread beta:

87.81% accuracy
12.19% error
100% direction accuracy

LOW_ORG spread beta:

68.43% accuracy
31.57% error
50% direction accuracy

This result supports the expected Vhistory behaviour: higher organisation produces a stronger and more directionally reliable H-evolution signal, while lower organisation produces weaker and less stable prediction.

The important point is not that the evolution equation has been fully proven. The important point is that the projected data are consistent with the proposed Vhistory evolution law:

$u^\alpha \nabla_\alpha H_{\mu\nu} = \gamma O_{\mu\nu} - \beta H_{\mu\nu}$

when tested component-by-component in the form:

(H_next − H_now) / Δt = γO_now − βH_now

This provides an early dynamical-support test. It suggests that $H_{\mu\nu}$ can be modelled as a source that is fed by organised structure and moderated by a relaxation term.

The result does not yet prove that:

- γ and β are universal constants.
- $H_{\mu\nu}$ physically decays in all regimes.
- the equation holds across all cosmological datasets.
- the full covariant tensor equation has been derived from first principles.
- future epochs can be predicted without refitting.

The correct interpretation is more limited:

The projected evolution tests show that the proposed $H_{\mu\nu}$ dynamics are not obviously incompatible with available epoch data, and that high-organisation channels behave more consistently with the expected Vhistory evolution than low-organisation channels.

Further validation requires:

- more time slices,
- independent tensor reconstructions,
- train/test prediction,
- hidden-epoch prediction,
- and testing whether fitted γ and β values transfer across datasets.

This test therefore sits between the earlier effective-source results and a future full tensor-level derivation. It does not complete the relativistic theory, but it provides an important first check that a simple organised-structure-fed evolution law for $H_{\mu\nu}$ can numerically match the observed projected tensor evolution available so far.

26. Direct Organisation Tensor Source Test for $O_{\mu\nu}$

A separate criticism of the Vhistory framework is that even if $H_{\mu\nu}$ behaves like an effective source, the organisation tensor $O_{\mu\nu}$ must also be mathematically defined. Earlier versions of the model often used the inferred LCDM dark-sector slot:

D(k) = P_LCDM(k) − P_baryon(k)

That was useful as a reinterpretation test. It asked whether the contribution normally attributed to cold dark matter could instead be understood as a Vhistory-like source.

However, that approach still depended on the LCDM clustering template. It did not fully answer the question:

Can Vhistory define $O_{\mu\nu}$ directly, without using the LCDM dark-sector residual?

To address this, a direct organisation-source form was tested. In this version, the Vhistory source is not built from:

- P_LCDM
- P_baryon
- D(k) = P_LCDM − P_baryon

Instead, the organisation source is computed from baryonic density and a scale-dependent organisation/persistence law.

The scalar organisation source is defined as:

$O(k,a) = (\Omega b / a^3) \times 1 / [1 + (k / k\_org)\text{^}outer]$

where:

- $O(k,a)$ is the organisation source at scale k and cosmic scale factor a.
- $\Omega b / a^3$ is the available baryonic matter density at epoch a.
- k is the structure scale being tested.
- k_org is the characteristic organisation turnover scale.
- outer controls how sharply the organisation effect weakens across scale.
- $1 / [1 + (k / k_{org})^{outer}]$ is the scale-dependent organisation/persistence filter.

In plain terms:

organisation source = baryonic matter density × scale-dependent organisation/persistence

The scalar organisation source is then lifted into tensor form:

$O\mu\nu(k,a) = O(k,a)u\mu u\nu$

Substituting the scalar expression gives:

$O\mu\nu(k,a) = [(\Omega b / a^3) / (1 + (k / k_{org})^{outer})]u\mu u\nu$

where:

- $O\mu\nu$ is the tensor form of organised baryonic history.
- $u\mu u\nu$ gives the matter/cosmic flow direction.
- in the BOSS comoving frame, $u\mu = (1,0,0,0)$.

Because BOSS does not measure the full spacetime tensor directly, the tested scalar projection is:

$O00(k,a) = O(k,a)u0u0$

With u0 = 1, this becomes:

$O00(k,a) = O(k,a)$

Therefore:

$O00(k,a) = (\Omega b / a^3) / (1 + (k / k_{org})^{outer})$

The tested Vhistory source was then:

$H_{GRV}(k,a) = O00(k,a)$

so:

$H\_GRV(k,a) = (\Omega b / a^3) / (1 + (k / k\_org)^{outer})$

This is the most important improvement over the earlier dark-slot version. The source is now computed directly from baryonic density and an organisation scale law, rather than being derived from the LCDM dark-sector residual.

The corresponding field equation remains:

$G\mu\nu = 8\pi G(T\mu\nu + H\mu\nu)$

where:

- $T\mu\nu$ is the ordinary stress-energy tensor.
- $H\mu\nu$ is the Vhistory source tensor.

The corresponding evolution equation remains:

$u\alpha\nabla\alpha H\mu\nu = \gamma O\mu\nu - \beta H\mu\nu$

Substituting the direct organisation source gives:

$(H\_next,\mu\nu - H\_now,\mu\nu) / \Delta t$
$= \gamma[(\Omega b / a^3) / (1 + (k / k\_org)^{outer})]u\mu u\nu - \beta H\_now,\mu\nu$

This gives Vhistory a mathematically defined organisation source $O\mu\nu$ that can feed $H\mu\nu$.

The direct organisation-source BOSS test found that the best model was:

OMUNU_DIRECT_TURNOVER

with:

$H\_GRV(k,a) = (\Omega b / a^3) / (1 + (k / k\_org)^{outer})$

The BOSS comparison found:

Raw BIC:

$O\mu\nu$ Vhistory ≈ LCDM, with a very small edge to $O\mu\nu$.

Adjusted BIC:

$O\mu\nu$ Vhistory strongly outperformed LCDM when LCDM was penalised for its full cosmological scaffold.

This result is important because the model is no longer simply reshaping the LCDM dark slot. It directly computes an organisation source from baryonic density and scale persistence, lifts it into $O\mu\nu$, and uses that to generate the Vhistory source.

The key result is therefore:

$O\mu\nu(k,a) = [(\Omega b / a^3) / (1 + (k / k\_org)^{\wedge}outer)]u\mu u\nu$

and in the BOSS scalar projection:

$H\_GRV(k,a) = (\Omega b / a^3) / (1 + (k / k\_org)^{\wedge}outer)$

This does not yet prove the final full spacetime theory, but it significantly improves the mathematical status of Vhistory by defining a testable organisation tensor ansatz and showing that it can be used directly in cosmological data tests.

The result should therefore be interpreted as:

- a direct mathematical definition of the tested organisation source,
- a scalar-to-tensor lift for Oμν,
- a BOSS projection of the tensor ansatz,
- and a successful direct-source test that no longer depends on P_LCDM − P_baryon as the Vhistory input.

Further work is still required to test whether the same Oμν form transfers to:

- galaxy rotation curves,
- gravitational lensing,
- clusters,
- additional DESI/BOSS epochs,
- and predictive train/test cosmological evolution.

27. Final Conclusion

This work investigated whether part of the gravitational behaviour traditionally attributed to dark matter may instead emerge from accumulated structural persistence, here called Vhistory, generated during the long-term organisation of baryonic matter and cosmic structure.

The central methodological rule applied throughout the project was intentionally constrained:

- preserve the observational target,
- preserve the governing astrophysical or cosmological pipeline where possible,

- preserve optimizer structure,
- preserve covariance structure,
- preserve statistical penalties,
- preserve parameter accounting,
- and replace or reinterpret only the inferred dark-sector source contribution with a Vhistory-derived source.

Under this apples-to-apples replacement framework, Vhistory remained statistically competitive with, or outperformed, conventional dark-matter source terms across multiple independent real-data domains, including:

- 143 SPARC galaxy rotation curves,
- Planck TT acoustic structure,
- galaxy-galaxy weak lensing,
- Bullet Cluster morphology and transport reconstruction,
- BOSS DR12 large-scale structure power spectra,
- CLASS precision cosmology integration,
- and full covariance reconstruction using 2048 Patchy mock realisations.

Across the SPARC rotation-curve survey, Vhistory outperformed the best competing CDM family in 118 of 143 galaxies, with a median DeltaBIC of +11.133 under matched statistical penalties and comparable astrophysical freedom.

In the constrained Planck TT replacement test, the Vhistory persistence support term produced a strong statistical preference relative to the implemented LambdaCDM-like support structure:

DeltaBIC = 109.270

while preserving the shared acoustic framework and replacing only the inferred support contribution.

The full-covariance BOSS DR12 + CLASS analyses demonstrated that persistence-derived source terms could remain statistically competitive inside a realistic cosmological covariance framework using:

- real observational spectra,
- CLASS precision cosmology,

- Patchy mock covariance reconstruction,
- Hartlap correction,
- train/test validation,
- and null-control testing.

Earlier BOSS tests used the inferred LCDM dark-sector contribution:

$D(k) = P\_LCDM(k) - P\_baryon(k)$

as the empirical dark-sector slot. In those tests, Vhistory asked whether the contribution normally attributed to cold dark matter could be reinterpreted as a cumulative spacetime/history source. The strongest cumulative BOSS formulation achieved:

DeltaBIC = 18.967

relative to the best competing flexible CDM reference family while preserving the surrounding cosmological pipeline.

The strongest conserved GR + Vhistory foundation test preserved the standard observational CDM scaffold but reinterpreted the inferred dark-sector contribution as the observational footprint of a conserved cumulative spacetime/history persistence tensor $H_{\mu\nu}$.

The source-side field equation was:

$G_{\mu\nu} = 8\pi G(T_{\mu\nu} + H_{\mu\nu})$

where:

- $T_{\mu\nu}$ represents ordinary matter/radiation stress-energy,
- $H_{\mu\nu}$ represents a cumulative spacetime/history persistence source.

The strongest conserved cumulative source tested was:

$H(k) = D(k) \times (D(k) / D0)^{(alpha - 1)} \times K(k)$

where K(k) is a transfer/kernel structure.

Unlike earlier phenomenological formulations, the conserved framework additionally enforced FLRW conservation consistency through:

$d(rho\_total)/d(\ln a) + 3(rho\_total + p\_total) = 0$

with the history pressure derived from conservation itself rather than fitted freely.

The conserved GR + Vhistory foundation analysis produced:

Model: Best old-reference CDM diagnostic
K = 4
BIC = 78.894916

Model: Conserved GR + Vhistory foundation
K = 6
BIC = 57.192544

corresponding to:

DeltaBIC = 21.702372

in favour of the conserved GR + Vhistory interpretation under this BOSS DR12 configuration.

The conservation residuals were numerically consistent with zero:

- Mean conservation residual = 0.000e+00
- Maximum conservation residual = 0.000e+00

This result was significant because Vhistory was no longer merely an unconstrained phenomenological replacement. It became a conservation-compatible cumulative tensor interpretation operating inside a real BOSS DR12 + CLASS + full covariance cosmological pipeline.

A further refinement addressed a deeper concern: earlier BOSS tests still used the LCDM-inferred dark-sector residual D(k) as the Vhistory source. To remove this dependence, a direct organisation-source form was introduced.

The scalar organisation source was defined as:

$O(k,a) = (\Omega b / a^3) \times 1 / [1 + (k / k\_org)^{outer}]$

where:

- $\Omega b / a^3$ is the available baryonic matter density,
- k_org is the organisation turnover scale,
- outer controls the strength of scale-dependent weakening,
- and the turnover term represents scale-dependent organisation or persistence.

This scalar source was then lifted into a tensor ansatz:

$O\mu\nu(k,a) = O(k,a)u\mu u\nu$

or explicitly:

$O\mu\nu(k,a) = [(\Omega b / a^3) / (1 + (k / k\_org)^{outer})]u\mu u\nu$

In the BOSS comoving projection, with $u\mu = (1,0,0,0)$, the tested component becomes:

$O00(k,a) = O(k,a)$

The direct Vhistory source tested was therefore:

$H\_GRV(k,a) = O00(k,a)$

so:

$H\_GRV(k,a) = (\Omega b / a^3) / (1 + (k / k\_org)^{outer})$

This was the cleanest BOSS result because the Vhistory source was no longer built from:

- P_LCDM,
- P_baryon,
- or D(k) = P_LCDM − P_baryon.

Instead, the source was computed directly from baryonic density and an organisation scale law.

The best direct organisation-source BOSS model was:

OMUNU_DIRECT_TURNOVER

with:

$H\_GRV(k,a) = (\Omega b / a^3) / (1 + (k / k\_org)^{outer})$

The comparison found:

Raw BIC:
Oμν Vhistory ≈ LCDM, with a very small edge to Oμν.

Adjusted BIC:
Oμν Vhistory strongly outperformed LCDM when LCDM was penalised for its full cosmological scaffold.

This is an important improvement because the model is no longer simply reshaping the LCDM dark slot. It directly computes an organisation source from baryonic density and scale persistence, lifts it into Oμν, and uses that source to generate the Vhistory contribution.

The evolution of Hμν was also tested using the proposed dynamical form:

$u\alpha\nabla\alpha H\mu\nu = \gamma O\mu\nu - \beta H\mu\nu$

with the discrete projected form:

$(H\_next - H\_now) / \Delta t = \gamma O\_now - \beta H\_now$

Using DESI epoch data, the evolution-equation test used:

5 DESI epochs, giving 4 epoch-to-epoch transitions.

The results were:

HIGH_ORG spread beta:
87.81% accuracy
12.19% error
100% direction accuracy

LOW_ORG spread beta:
68.43% accuracy
31.57% error
50% direction accuracy

This supports the expected Vhistory behaviour: higher organisation produced a stronger and more directionally reliable H-evolution signal, while lower organisation produced weaker and less stable prediction.

Across domains, the successful Vhistory configurations consistently behaved:

- source-like rather than observable-like,
- structurally accumulated rather than directly sculpted,
- transport/coherence-like rather than arbitrary,
- persistence-based rather than purely instantaneous,
- and compatible with existing gravitational or cosmological pipelines.

The cumulative cross-domain behaviour therefore suggests that Vhistory may be probing an effective accumulated structural source associated with:

- transport coherence,
- clustering persistence,
- stress-memory behaviour,
- multiscale organisation,
- cumulative spacetime persistence,
- and coarse-grained evolutionary structure.

At present, the most scientifically defensible interpretation is not that a finalized first-principles theory has been established, nor that all aspects of LambdaCDM have been replaced.

Major unresolved domains remain, including:

- full relativistic covariant derivation,
- complete tensor-level spacetime evolution,
- fully dynamical merger evolution,
- self-consistent transport PDE evolution,
- nonlinear cosmological structure formation,
- microscopic persistence-generation physics,
- complete CLASS/CAMB evolution replacement,
- CMB polarization structure,
- independent external replication,
- and predictive train/test validation across additional epochs and datasets.

However, the present work demonstrates that:

- a cumulative persistence-derived gravitational source can remain statistically competitive with conventional dark-sector source terms across multiple independent real-data domains,
- Vhistory can be implemented while preserving the surrounding astrophysical framework,
- conserved GR-compatible forms can be constructed,
- direct organisation-source forms can be tested without using the LCDM dark-sector residual,
- and a mathematically defined organisation tensor ansatz can now be written as:

$O\mu\nu(k,a) = [(\Omega b / a^3) / (1 + (k / k\_org)^{\wedge}outer)]u\mu u\nu$

with the BOSS scalar projection:

$H\_GRV(k,a) = (\Omega b / a^3) / (1 + (k / k\_org)^{\wedge}outer)$

The most important progress is that Vhistory has moved from a dark-slot reinterpretation model toward a direct organisation-source model. The framework now contains:

- a source-side field equation,
- a mathematically defined organisation source,
- a tensor-lifted $O_{\mu\nu}$ ansatz,
- a projected BOSS scalar source,
- a candidate evolution equation for $H_{\mu\nu}$,
- and early empirical support from both BOSS source tests and DESI evolution tests.

The results therefore motivate further investigation into whether part of the gravitational behaviour presently attributed to dark matter may instead reflect retained cumulative spacetime/history organisation generated during the large-scale historical evolution of matter and structure itself.

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