

6 – Dark Matter without Dark Matter

Geometric constraints on gravitational coupling

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Abstract

The anomalies attributed to dark matter: flat galactic rotation curves, excess cluster lensing, and elevated structure growth, have no direct particle explanation despite decades of searches. This note develops their reinterpretation under the Time-Symmetric Parity Constraint, a fixed algebraic condition on the spacetime metric that modifies gravitational coupling without new fields or degrees of freedom. The resulting correction is governed by a single bounded parameter, α_λ , which subtly but coherently strengthens curvature responses to baryonic matter.

Once α_λ is fixed, galactic rotation curves, cluster lensing, and structure growth follow as linked manifestations of the same structural effect. The

framework also predicts a mid-redshift hump in apparent acceleration: a small parity-induced clock skew along null geodesics, coupled to the entropy slope peaking near T^{tip} , yields the supernova residuals and BAO offsets otherwise attributed to dark energy. Thus, both dark matter and dark energy dissolve into one structural correction.

Current DESI measurements do not conflict with this interpretation. Forthcoming data from Euclid, LSST, and SKA will provide decisive tests. If falsified, the hypothesis is excluded. If confirmed, cosmic structure will be explained as a geometric consequence rather than evidence of hidden substance.

1. Introduction

The Λ CDM framework explains galactic rotation curves, cluster dynamics, and large-scale structure by postulating a cold dark matter component more than five times as abundant as baryons¹. This hypothesis has motivated extensive experimental and observational programmes, yet no dark matter particle has been securely identified, despite decades of increasingly sensitive searches for weakly interacting candidates such as WIMPs and axions.²

¹ F. Zwicky, *Die Rotverschiebung von extragalaktischen Nebeln*, Helv. Phys. Acta 6, 110 (1933). First identification of the missing-mass problem in galaxy clusters.

² LZ Collaboration, *Dark Matter Search Results from 4.2 Tonne-Years of Exposure of the LUX-ZEPLIN (LZ) Experiment*, Physical Review Letters 135, 011802 (2025). Reports the most sensitive LZ WIMP search from 4.2 tonne-years of exposure; no significant evidence for WIMP dark matter was found, and improved limits were placed on WIMP–nucleon interactions.

X. Bai et al. (HAYSTAC Collaboration), *Dark Matter Axion Search with HAYSTAC Phase II*, Physical Review Letters 134, 151006 (2025). Reports a sensitive search for galactic dark-matter axions over newly explored mass ranges; no statistically significant axion signal was observed, and new limits were placed on axion–photon coupling.

This sustained null result has prompted a range of alternative responses.³ Modified-gravity approaches, including MOND and its relativistic extensions such as TeVeS, alter the dynamical laws governing low-acceleration regimes, but often encounter theoretical instabilities or conflict with precision constraints. Observational tests using wide binaries have sharpened the debate: some analyses of Gaia data suggest deviations from Newton–Einstein gravity at ultra-low accelerations, while others find full consistency. The empirical situation remains unsettled, but the pressure to reinterpret the underlying anomalies continues to grow.

At the same time, recent work has begun to question whether these anomalies should be interpreted within a globally isotropic Friedmann–Lemaître–Robertson–Walker (FLRW) background at all. A recent Colloquium in Reviews of Modern Physics by Subir Sarkar *et al.* reviews evidence that the large-scale matter dipole exceeds the kinematic expectation of a perturbed FLRW universe at high statistical significance.⁴

While the dipole aligns in direction with that of the cosmic microwave background, its anomalous amplitude suggests either that matter and radiation do not share a common rest frame or that there exists an intrinsic large-scale anisotropy.

The implication is not the endorsement of a particular alternative model, but a weakening of the assumption that late-time cosmological observables must be interpreted within an exactly isotropic FLRW background. This opens space for approaches that act at the level of admissible geometry itself, rather than by introducing additional unseen components or modifying local dynamics.

This paper develops a different line. The Time-Symmetric Parity Constraint (TSPC) describes a fixed algebraic condition on the spacetime metric. It does not introduce new fields or degrees of freedom, but it narrows the class of admissible geometries. Its leading consequence is a small, structural correction to gravitational coupling, governed by a single bounded parameter α_λ . The constraint restricts only the Π -even sector of the metric; it does not impose pointwise relations on curvature or determine curvature invariants. This subtle shift strengthens curvature responses to baryonic matter.

Once expressed this way, the anomalies long attributed to a hidden mass component emerge naturally and in linked fashion. Spiral galaxies sustain flat outer rotation curves; cluster lensing and velocity dispersions are reproduced without invisible haloes, and structure growth is modestly elevated, consistent with the persistent S_8 tension.

³ Bertone & Hooper, *History of dark matter*, Rev. Mod. Phys. 90, 045002 (2018). Comprehensive review of dark matter searches and the absence of detection.

Milgrom, M., *Astrophysical Journal* 270, 365–370 (1983), introducing MOND;

Bekenstein, J. D., *Physical Review D* 70, 083509 (2004). Developed the relativistic extension TeVeS.

⁴ Subir Sarkar *et al.*, *The Cosmic Dipole Anomaly*, Reviews of Modern Physics 97, 041001 (2025).

Recent Gaia DR3 measurements have added important detail. Coquery and Blanchard report that the Milky Way’s rotation curve begins to decline beyond ≈ 15 kpc, falling below the circular-velocity plateau predicted by an NFW halo.⁵ Their analysis indicates that, even allowing for baryonic and anisotropy uncertainties, the decline cannot be reconciled with cosmological priors on halo concentration. Modified-gravity models such as MOND can fit the profile but require external-field prescriptions. Within TSPC the effect is interpreted as a small global strengthening of curvature coupling, applied uniformly, which can manifest as a mild decline without invoking a dark halo.

The mechanism by which the parity constraint enters galactic dynamics can be stated in advance of the formal expressions. TSPC introduces a fixed involutive tensor Π that acts as a projection operator on the spacetime metric, separating parity-even and parity-odd geometric sectors. Only the Π -even sector contributes to effective curvature response. The constraint is global and algebraic: Π is not a dynamical field, carries no energy-momentum, and does not introduce new degrees of freedom. Its role is to restrict the class of admissible metric configurations rather than to modify local equations of motion.

The magnitude of the resulting correction depends on the location of the geometry within the global entropic evolution of the universe. This evolution is *time-symmetric* about a single global tipping epoch, denoted T^{tip} , which represents the unique maximum of entropy and spatial extent separating two mirror temporal branches. Away from T^{tip} the parity projection induces a fractional suppression of curvature response, encoded in a dimensionless factor $\Pi(r)$ with $0 < \Pi \leq 1$. In galactic settings this factor varies slowly with radius and acts multiplicatively on the baryonic potential. The consequence is a uniform, scale-free strengthening of effective gravitational coupling relative to baryons alone, without invoking dark haloes or acceleration thresholds.

Parity-limited acceleration in an axisymmetric disc

The parity constraint modifies the relation between the baryonic potential and the effective curvature response. In linear, quasi-static conditions:

$$a_{\text{eff}}(r) = a_{\text{bar}}(r) \Pi(r) \quad \text{with} \quad 0 < \Pi(r) < 1$$

where $\Pi(r)$ is the parity-suppression factor determined by the local curvature phase relative to T^{tip} . This relation shifts the effective metric response while leaving baryonic dynamics unchanged.

Linearised field equations project to

$$\nabla \cdot [\Pi(r) \nabla \Phi_{\text{bar}}(r)] = 4\pi G \rho_{\text{bar}}(r)$$

Integrating in cylindrical symmetry gives

⁵ Coquery E, Blanchard A. 2025. *Cosmological implications of the Gaia Milky Way declining rotation curve*. Astronomy & Astrophysics. (accepted). DOI/ArXiv: see arXiv:2407.18846. Demonstrates, using Gaia DR3 data, that the Milky Way rotation curve declines at large radii, creating tension with standard NFW halo expectations under cosmological priors.

$$v_c^2(r) = r \frac{d\Phi_{\text{eff}}}{dr} = \Pi(r) \frac{G M_{\text{bar}}(< r)}{r}.$$

A minimal empirical parametrisation consistent with the Gaia profile is

$$\Pi(r) = [1 + \lambda \mathcal{E}(r)]^{-1}, \quad \mathcal{E}(r) \equiv \frac{1}{\Sigma_0} \frac{d \ln \Sigma_{\text{bar}}(r)}{d \ln r}, \quad 0 < \Pi \leq 1.$$

The empirical parametrisation captures the observed decline without appealing to additional matter components. The same correction also feeds into the expansion history, producing a slight elevation of $H(z)$ that contributes to the H_0 discrepancy between local and cosmological determinations. These apparently separate anomalies are unified as correlated outcomes of the same structural shift.

Modified Newtonian Dynamics (MOND) was originally introduced to account for galactic rotation curves, and later extended relativistically in TeVeS. A comprehensive review has set out both the empirical appeal and theoretical limitations of these models.⁶ Recent wide-binary studies using Gaia DR3 have brought the debate into sharp focus. Chae has reported, via Bayesian analysis of full 3D velocities, a $\sim 40\%$ excess in internal accelerations at $a \lesssim 10^{-9} \text{ m s}^{-2}$, interpreted as a MOND-like anomaly.⁷ Other pipelines, notably those by Banik and collaborators instead find consistency with Newton–Einstein gravity at high significance.⁸ The observational situation is unsettled, but it defines a decisive testing ground.

TSPC diverges from both positions. It introduces no acceleration threshold: the fractional strengthening of curvature coupling governed by α_λ applies scale-free across all regimes. If a MOND-like anomaly in wide binaries is robust, it would be read in TSPC as a local manifestation of the same structural shift that sustains rotation curves and cluster lensing. If binaries conform to Newton–Einstein dynamics, the null result serves to tighten the permissible bounds on α_λ . Either way, wide binaries provide a test now active and decisive.

The same mechanism accounts for late-time acceleration. Observed signals peak at intermediate redshift rather than increasing monotonically. Within TSPC this arises as a parity-induced clock skew: elapsed observer time differs from cosmic time along null geodesics, with the skew modulated by the entropy slope, which peaks at the tipping epoch T^{tip} . The outcome is a single broad hump in apparent acceleration, matching supernova residuals, BAO offsets, and cosmic-chronometer $H(z)$ profiles. Dark matter and dark energy are thereby reframed as two facets of one structural correction.

⁶ Famaey, B. & McGaugh, S., *Living Rev. Relativity* 15, 10 (2012). Review of MOND and its extensions.

⁷ K.-H. Chae, *Breakdown of the Newton–Einstein Standard Gravity at Low Acceleration in Internal Dynamics of Wide Binary Stars*, *Astrophys. J.* (2025). Reports MOND-like anomaly in Gaia wide binaries.

⁸ Banik, I *et al.*, *Mon. Not. R. Astron. Soc.* 523, 1773 (2023). Independent Gaia DR3 analysis finding wide binary dynamics consistent with Newton-Einstein gravity.

Gravitational waves fit naturally into this picture. They remain admissible solutions of general relativity within the parity-constrained manifold, their propagation unaltered but their effective coupling fractionally adjusted by the same parameter. This reinforces the deeper unity: time, gravity, and matter are interchangeable expressions of a single algebraic condition, and the global constraint cannot be shaken by local wave excitations.

Objects such as starless H I clouds (“RELHICs”) are sometimes presented as direct probes of dark matter.⁹ Their interpretation, however, depends entirely on assuming hydrostatic equilibrium within a dark halo. In the absence of independent dynamical or lensing constraints, such systems are equally compatible with non-halo confinement mechanisms and therefore do not constitute discriminating evidence.

The empirical situation is poised for resolution. DESI already hints at mild departures from a pure cold-dark-matter picture. Early Euclid lensing data are compatible with this interpretation within current uncertainties. LSST and SKA will test rotation curves, clustering, lensing, and acceleration with percent-level precision. Because all signatures flow from the same parameter, their correlation provides a sharp falsifiability test: either the anomalies attributed to the dark sector align as predicted, or the hypothesis fails.

The broader implication is that the “dark sector” represents an explainaway: a category introduced to patch anomalies. The TSPC approach dissolves it not by denying the data but by showing how these signatures arise from geometry alone. Constraint replaces content, exclusion replaces invention; and it is anticipated that it will be falsifiable.

Ultralight-field models such as those of Mirbabayi and collaborators exemplify this continuing elaboration of the standard paradigm. They achieve phenomenological success by multiplying the unseen content;¹⁰ TSPC seeks the same coherence by limiting the geometry instead. Both paths are testable, but only one is subtractive.

⁹ Anand, G., Benítez-Llambay, A., et al. (2025). *A Starless Reionization-Limited H I Cloud in the Local Universe*. The Astrophysical Journal Letters, 993, L55. <https://doi.org/10.3847/2041-8213/ad1f5c> Reports the discovery of a compact, starless neutral-hydrogen cloud (“Cloud-9”) and interprets it as a dark-matter-dominated relic halo under the assumption of hydrostatic equilibrium; the inferred dark matter content is model-dependent and not independently constrained by dynamics or lensing.

Benítez-Llambay, A., Navarro, J. F., et al. (2017). *The Origin of Reionization-Limited H I Clouds*. Monthly Notices of the Royal Astronomical Society, 465, 3913–3925. <https://doi.org/10.1093/mnras/stw3027> Introduces RELHICs as a theoretical Λ CDM population of low-mass haloes expected to retain neutral gas but fail to form stars following reionization.

¹⁰ Mirbabayi, M., Delos, M. S., & Amin, M. A. (2025). *Structure Formation with Warm White Noise: Effects of Finite Number Density and Velocity Dispersion in Particle and Wave Dark Matter*. arXiv:2503.20881 – An internal refinement of Λ CDM introducing ultralight fields with white-noise isocurvature to mitigate small-scale anomalies.

2. Algebraic Framework

TSPC modifies general relativity not by adding new dynamical content, but by reducing the freedom of its solution space. At its core lies a fixed algebraic condition on the spacetime metric. This condition requires the geometry to respect a built-in parity structure, narrowing the class of admissible metrics without introducing new fields, propagating modes, or energy–momentum contributions.

The condition is expressed through two objects. The first is a fixed symmetric parity tensor, which defines a reflection symmetry between opposing temporal directions. The second is a Lagrange multiplier field, which acts algebraically to impose the condition point by point. The multiplier is non-dynamical: it does not propagate, carry energy, or generate waves. Its role is structural, not causal¹¹.

The effect of this restriction is to modify curvature response to baryonic matter in a small but coherent way. Instead of introducing a new particle or field to account for anomalies, the framework strengthens curvature responses to the matter already present. The modification is governed by a single parameter, α_λ , which arises from the structure of the constraint and is sharply bounded by independent observations¹².

This subtle correction has far-reaching consequences. It enhances the effective strength of gravity just enough to sustain flat galactic rotation curves without dark haloes, to explain cluster lensing without hidden mass, and to modestly elevate the growth rate of structure. At larger scales, the same correction alters the expansion rate of the universe, producing a slight elevation in $H(z)$ and contributing to the observed H_0 discrepancy. These effects are not separate adjustments but linked manifestations of the same structural condition.

The correction is non-propagating and local. It alters no causal pathways, violates no conservation laws, and leaves the Bianchi identities intact. The familiar dynamical structure of general relativity is preserved, but the space of admissible solutions is narrowed. This narrowing is what unifies phenomena otherwise attributed to dark matter, dark energy, and late-time acceleration.

Because only one parameter governs all departures from the standard model, the framework is highly predictive. It cannot be tuned to fit one anomaly at the expense of another. Instead, it requires that galactic rotation, cluster lensing, structure growth, and expansion history all display correlated departures consistent with the same narrow range of α_λ . That correlation is the empirical strength of the framework but also its

¹¹ G. F. R. Ellis, *On the Philosophy of Cosmology*, Stud. Hist. Phil. Mod. Phys. 46, 5 (2014). Examination of structural versus dynamical approaches in cosmology.

¹² Boyle, Finn & Turok, *CPT-Symmetric Universe*, Phys. Rev. Lett. 121, 251301 (2018). Example of a symmetry-based cosmology; contrasts with TSPC's fixed algebraic condition.

vulnerability: any systematic mismatch across scales or probes would falsify the hypothesis outright.

The algebraic structure of TSPC can be expressed in five steps. These equations define how the parity tensor enforces symmetry on the metric, how the condition is built into the action, and how it alters the Einstein field equations.

1. Involution condition of the parity tensor

$$\Pi_\rho^\mu \Pi_\nu^\rho = \delta_\nu^\mu$$

Π acts as a reflection operator with eigenvalues ± 1 .

2. Constraint on the metric

$$g_{\mu\nu}(x) = \Pi_\mu^\alpha \Pi_\nu^\beta g_{\alpha\beta}(x)$$

The metric is invariant under the reflection defined by Π .

3. Modified Einstein–Hilbert action

$$S = \frac{1}{16\pi G} \int R \sqrt{-g} d^4x + \int \lambda^{\mu\nu} \left(g_{\mu\nu}(x) - \Pi_\mu^\alpha \Pi_\nu^\beta g_{\alpha\beta}(x) \right) \sqrt{-g} d^4x$$

$\lambda^{\mu\nu}$ is algebraic, not dynamical; it enforces the constraint pointwise without introducing new degrees of freedom.

4. Field equations with correction term

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

where $\Delta_{\mu\nu}$ enforces the constraint algebraically.

5. Effective gravitational coupling

$$G_{\text{eff}} = G(1 + \alpha_\lambda)$$

Single structural parameter with indicative bounds used throughout the suite:

$$\left| \frac{\Delta G}{G} \right| < 10^{-5} \quad (\text{solar system})$$

$$\alpha_\lambda \lesssim 10^{-6} \quad (\text{CMB lensing})$$

$$\alpha_\lambda \sim 10^{-2} \quad (\text{cosmological deviations})$$

The modification to gravitational coupling feeds directly into the standard cosmological observables. Because G_{eff} replaces G in the governing equations, all the familiar quantities – expansion rate, structure growth, and lensing strength – inherit the same fractional shift. This coherence is what ties together the phenomena otherwise attributed to dark matter and dark energy.

$$H(z) \propto \sqrt{G_{\text{eff}} \rho_{\text{baryon}}(z)}$$

Thus the Hubble expansion rate, the linear growth parameter, and the lensing convergence are not independent anomalies but correlated signatures of one structural parameter α_λ . The coherence across these observables provides the sharp falsifiability of the TSPC framework.

3. Cosmological Consequences

The algebraic correction introduced by TSPC alters gravitational interaction in a way that is subtle, coherent, and scale-independent. Because the effective coupling is fractionally strengthened, curvature responds more strongly to baryonic matter across all environments. What are conventionally treated as distinct anomalies therefore emerge as correlated consequences of one parameter.

3.1 *Galactic rotation curves.*

In standard dynamics, the visible mass of a spiral galaxy is insufficient to explain the flatness of its outer rotation curve.¹³ Under TSPC, a small, scale-independent fractional strengthening of curvature response to baryonic matter maintains orbital velocities at large radii, without requiring an unseen halo.¹⁴

3.2 *Cluster lensing and dynamics.*

Observed deflection of light by clusters, and the velocity dispersions of their galaxies, have long been taken as proof of hidden mass. Within the TSPC framework, the same fractional strengthening of curvature explains these signatures using baryons alone. The correction amplifies the effect of visible matter, bringing lensing and dynamics into alignment without an invisible halo¹⁵. Recent constrained-simulation work predicts that any dark-matter-annihilation origin of the GeV excess would produce a triaxial, halo-aligned morphology. Continued evidence that the γ -ray excess follows the bulge/bar therefore supports a baryonic or geometric interpretation consistent with TSPC.¹⁶

3.3 *Large-scale structure growth.*

Cosmological surveys reveal more rapid clustering than general relativity with baryons alone would predict. Λ CDM accounts for this by assuming gravitational dominance of cold dark matter. TSPC reproduces the elevation of the growth rate through the same structural correction. This naturally situates the framework

¹³ V. C. Rubin and W. K. Ford, *Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions*, *Astrophys. J.* 159, 379 (1970). Classic rotation-curve evidence for unseen mass.

¹⁴ Rubin, Ford & Thonnard, *Rotational properties of 21 Sc galaxies with a large range of luminosities and radii*, *Astrophys. J.* 238, 471 (1980). Landmark discovery of flat galactic rotation curves.

¹⁵ Zwicky, *On the masses of nebulae and of clusters of nebulae*, *Astrophys. J.* 86, 217 (1937). First identification of missing mass in clusters.

¹⁶ M. M. Muru et al., *Fermi-LAT Galactic Center Excess morphology of dark matter in simulations of the Milky Way galaxy*, *Phys. Rev. Lett.* (2025); arXiv: 2508.06314. Uses Hestia simulations to show the predicted triaxial morphology of a WIMP-origin excess.

within the current S_8 tension between low-redshift surveys and CMB-derived predictions¹⁷.

3.4 Expansion history and H_0 .

Because G_{eff} enters the Friedmann equation, the expansion rate is slightly raised relative to a pure baryonic model. This small elevation contributes to the persistent discrepancy between locally measured and cosmologically inferred values of the Hubble constant. In TSPC the H_0 tension is therefore not an additional anomaly but another expression of the same correction¹⁸.

3.5 Late-time acceleration.

The observed acceleration is not monotonic but peaks at intermediate redshifts. In TSPC this arises as a parity-induced clock skew: elapsed observer time along null geodesics is displaced relative to cosmic time, with the skew modulated by the entropy slope that peaks near the tipping epoch. The result is a broad hump in apparent acceleration, producing the supernova residuals, BAO offsets, and $H(z)$ profiles otherwise attributed to dark energy¹⁹.

3.6 Gravitational waves.

Propagating disturbances in curvature remain fully admissible solutions. Their programme is unchanged, but their effective coupling inherits the same fractional adjustment. In this way the parity constraint does not obstruct wave phenomena but places them within the same structural law as matter and time. Waves, matter, and gravity are interchangeable manifestations of the condition; none has the power to disturb the global symmetry it defines²⁰.

Together these consequences illustrate the explanatory economy of the framework. The anomalies that motivated the invention of dark matter and dark energy are reframed as correlated effects of a single algebraic correction. Rather than separate puzzles requiring separate hypotheses, they appear as linked expressions of one structural principle.

1. The algebraic correction expressed by G_{eff} propagates directly into the governing relations of cosmology. Once the single parameter α_λ is fixed, the

¹⁷ Heymans et al., *KiDS-1000 Cosmology: S_8 tension between weak lensing and CMB*, *Astron. Astrophys.* 646, A140 (2021). Survey evidence for the S_8 discrepancy.

¹⁸ Riess et al., *Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant*, *Astrophys. J.* 876, 85 (2019). Local H_0 determination, central to the tension with Planck.

¹⁹ Perlmutter et al., *Measurements of Omega and Lambda from 42 High-Redshift Supernovae*, *Astrophys. J.* 517, 565 (1999). Discovery paper for cosmic acceleration.

²⁰ Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), *Observation of Gravitational Waves from a Binary Black Hole Merger*, *Phys. Rev. Lett.* 116, 061102 (2016). First direct detection of gravitational waves, demonstrating their role in GR and their compatibility with the TSPC framework.

amplitudes of galactic, cluster, and cosmological anomalies follow without further tuning. What Λ CDM interprets as evidence for hidden matter or dark energy arises here as correlated signatures of one structural correction. Effective gravitational coupling:

$$G_{\text{eff}} = G(1 + \alpha_\lambda)$$

2. Modified Friedmann equation:

$$H(z) = \sqrt{\frac{8\pi G_{\text{eff}}}{3} \rho_{\text{baryon}}(z)}$$

3. Growth of structure:

$$f \sigma_8(z) \propto G_{\text{eff}}$$

4. Cluster lensing convergence:

$$\kappa(z) \propto G_{\text{eff}} \Sigma_{\text{baryon}}(z)$$

5. Galactic rotation curves (schematic):

$$v^2(r) \simeq \frac{G_{\text{eff}} M_{\text{baryon}}(r)}{r}$$

The flatness of outer rotation curves follows from the enhanced coupling, without requiring unseen mass haloes.

6. Parity-induced clock-skew:

$$\sigma(T) = \frac{1}{S(T)} \frac{dS}{dT}$$

Accumulated skew along null geodesics:

$$\Delta t_{\text{obs}}(z) \propto \alpha_\lambda \int \sigma(T) d\chi$$

This peaks near the entropy maximum at T^{tip} , producing the broad mid-redshift hump in apparent acceleration.

Equations (2)–(6) demonstrate the coherence of the framework: the same fractional correction governs expansion, growth, lensing, rotation curves, and acceleration. No additional fields or particles are invoked; the anomalies of the dark sector appear as consequences of geometry alone.

4. Observational Tests

The predictive strength of TSPC lies in its parsimony. A single structural parameter, α_λ , governs the amplitude of all departures from standard dynamics. It is not freely tunable. Its value must lie within a narrow band that is simultaneously consistent with precision tests in the solar system, with constraints from the cosmic microwave background, and with the modest but coherent anomalies observed in large-scale surveys.

At local scales, ephemerides and spacecraft tracking restrict fractional deviations in Newton’s constant to less than one part in 10^5 .²¹ At high redshift, reconstructions of CMB lensing constrain departures to less than one part in 10^6 .²² Yet at intermediate scales, the anomalies that motivated dark matter and dark energy all point towards a small but non-zero enhancement of order one per cent. Here, $\alpha_\lambda \sim 10^{-2}$ refers to the level of effective phenomenological deviations in galactic and mid-redshift observables, not to a uniform fractional shift in Newton’s constant across all regimes. The parameter α_λ controls a geometric response factor rather than a universal renormalisation of Newton’s constant; its observational imprint is therefore environment- and projection-dependent, despite being governed by a single bounded structural coefficient. The TSPC framework is therefore formulated to satisfy local and high-redshift constraints while allowing percent-level effective deviations at galactic and mid-redshift scales.

This coherence provides the framework with its empirical sharpness. Once α_λ is fixed, the following predictions follow without further adjustment:

4.1 Hubble expansion:

A slight elevation of $H(z)$ relative to the Λ CDM baseline, contributing to the H_0 discrepancy between local and cosmological determinations.

4.2 Structure growth:

A modest elevation of $f\sigma_8(z)$, aligned with the S_8 tension seen between low-redshift surveys and CMB-based extrapolations.

4.3 Weak lensing:

A small amplification of convergence in voids and low-mass haloes, consistent with emerging hints from DESI and Euclid.

4.4 Galactic and cluster dynamics:

Flat rotation curves and excess lensing explained without resort to non-baryonic haloes, the effects scaling coherently with the same parameter. Recent Gaia DR3 findings of a declining outer Galactic rotation curve offer an immediate test: TSPC reproduces the same trend without invoking a dark-matter halo.²³

4.5 Apparent acceleration:

A mid-redshift hump in the distance–redshift relation, produced by the parity-induced clock skew modulated by the entropy slope.

Because all of these are driven by the same structural adjustment, their correlation offers a decisive test. A mismatch across probes, for example an enhancement in lensing without a corresponding shift in structure growth, would falsify the hypothesis outright.

²¹ C. M. Will, *The Confrontation between General Relativity and Experiment*, Living Rev. Relativity 17, 4 (2014). Authoritative review of solar-system constraints on $\Delta G/G$.

²² Planck Collaboration, *Planck 2018 results. VIII. Gravitational lensing*, Astron. Astrophys. 641, A8 (2020). Tight CMB lensing constraints on gravitational coupling.

²³ Coquery & Blanchard (2025) *op. cit.*

Conversely, confirmation of the predicted correlated pattern would dissolve the dark-sector categories as explanatory constructs.

Current data remain consistent but inconclusive. DESI has already reported mild departures from the cold dark matter baseline, while Euclid's early imaging and lensing-validation data do not conflict with a structural interpretation. LSST and the SKA will deliver the decisive tests: percent-level accuracy in expansion, clustering, and lensing across a broad redshift range. If the predicted pattern emerges within the permitted range of α_λ , the framework will be supported. If not, it will be excluded.

The consequence is an unusually sharp empirical programme. Unlike particle candidates that can retreat indefinitely into higher energies, or scalar fields that can be reshaped to fit residuals, the TSPC framework has nowhere to hide. Its single parameter is already bracketed by independent tests. The task of observation is not to chase a moving target but to confirm or exclude a fixed pattern.

Large-scale observational programmes are now probing precisely this parameter window. DESI has already reported mild departures from the cold dark matter baseline. Euclid's early lensing data remain compatible with a structural interpretation. LSST and the SKA will extend coverage across redshift and scale at percent-level precision. Together, these surveys will provide decisive adjudication: if the correlated pattern of expansion, structure growth, lensing, and acceleration emerges within the permitted range of α_λ , the TSPC framework is supported; if not, it is excluded²⁴.

1. The single structural parameter α_λ is not a free fit but a tightly bounded quantity. Its permitted range is set by three independent domains: precision solar-system dynamics, CMB lensing, and cosmological anomalies. The same parameter must satisfy all three simultaneously. This defines a narrow falsifiable window.

Solar system bound:

$$\left| \frac{\Delta G}{G} \right| < 10^{-5} \quad (\text{planetary ephemerides and spacecraft tracking})$$

2. CMB lensing bound:

$$\alpha_\lambda \lesssim 10^{-6} \quad (\text{Planck and reconstruction analyses})$$

3. Cosmological deviations required:

$$\alpha_\lambda \sim 10^{-2} \quad (\text{galactic, cluster, and mid-}z \text{ cosmological effects})$$

4. Falsifiable window:

$$10^{-6} \lesssim \alpha_\lambda \lesssim 10^{-2}$$

²⁴ DESI Collaboration, *Overview of the DESI Experiment*, Astron. J. 161, 192 (2021). Laureijs et al., *Euclid Definition Study Report*, ESA/SRE(2011)12. LSST Science Collaboration, *LSST Science Book, Version 2.0*, arXiv:0912.0201. Braun et al., *Anticipated Performance of the Square Kilometre Array*, Proc. Sci. AASKA14, 174 (2015). – Authoritative descriptions of the four major surveys that will decide the hypothesis.

If α_λ lies outside this interval, the framework fails. If it lies within and the correlated pattern of expansion, growth, and lensing is confirmed, the dark-sector categories dissolve into geometry.

5. Concluding Remarks

The anomalies that motivated dark matter emerge in TSPC as linked consequences of a single algebraic correction to gravitational coupling: flat rotation curves, excess cluster lensing, and accelerated structure growth. No new particles or fields are invoked. The same parameter also accounts for the mid-redshift hump in apparent acceleration, unifying the signatures otherwise attributed separately to dark matter and dark energy.

The framework is sharp in both reach and risk. A single parameter, α_λ , lies in a narrow falsifiable window already bracketed by solar-system dynamics and CMB lensing. Its value cannot be tuned independently for different anomalies: either all effects align within the predicted range or the hypothesis fails.

The empirical path is immediate. DESI, Euclid, LSST, and the SKA will supply the percent-level accuracy needed to confirm or exclude the predicted pattern. If falsified, the proposal is discarded cleanly. If confirmed, the dark sector dissolves, and cosmic structure is reframed as a consequence of geometry rather than hidden substance.

Constraint replaces content; exclusion replaces invention.²⁵

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²⁵ Barbour, *The End of Time: The Next Revolution in Physics*, Oxford University Press (1999). Philosophical precedent for treating time and structure as consequences of constraint.

