From Chaos to Coherent Gravity

The SCT Formalism That Solves The Dark Matter Problem

DR JM NIPOK N.J.I.T.
https://orcid.org/0009-0006-3940-4450

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ABSTRACT

Context and Motivation. The dark matter problem comprises three independent observational requirements: the seeding of cosmic structure from near-uniform plasma, the gravitational lensing excess at cluster scales, and the persistence of flat rotation curves beyond visible galactic disks. Paper 4 of this series resolved the structure-seeding requirement through the collision cascade angular momentum inheritance relation J = mu_eff (b x v_rel). This paper addresses the lensing excess and, through the validated Milky Way convergence test, provides the strongest current observational anchor for the galactic-scale framework.

The Particle Dark Matter Null Result. LUX-ZEPLIN (417 live days, arXiv:2410.17036) excludes WIMPs across their entire preferred mass range after achieving a sensitivity improvement of three million times over prior experiments. LHC Run 3 (2022 to 2025) excludes gluinos beyond 2.4 TeV and electroweak-inos beyond 1 TeV. JWST observations of galaxies at z > 10 reveal a 4 to 16 sigma excess of massive early galaxies above LCDM structure formation predictions.

The New Mathematical Result: v_cross = sigma_v [PHYSICALLY MOTIVATED]. We establish the physical reasoning that v_cross = sigma_v from the tidal decorrelation of galaxy velocities in the isothermal sphere potential. The argument uses eight steps grounded in linearized general relativity and the virial theorem. A rigorous proof via orbit-averaging is deferred to the companion numerical paper (Paper 15).

The Virialized Fixed Point: A* = 1/f_b = 5.970 [DERIVED]. The virialized coherence amplification factor A* = 1 + N_eff x e^-1 = 1/f_b_cosmic = 5.970 +/- 0.21 is derived from three independently measured physical constants with zero free parameters: e (mathematics), f_b = 0.1675 +/- 0.006 (Big Bang nucleosynthesis and CMB acoustic peak ratios, Planck 2018 and PDG 2023), and the virial theorem (Newtonian gravity). The effective coherent galaxy count N_eff = e x (1/f_b - 1) = 13.51 is the unique algebraic consequence of self-consistency. Note: A* = 1/f_b is derived from the theory's self-consistency condition with f_b as a measured input parameter from BBN, analogous to how LCDM takes Omega_m as a measured parameter.

The Milky Way Convergence Test. Two completely independent measurements of the Milky Way baryonic mass agree within 1.2 percent. Route A: Lian+2025 direct stellar census gives M_baryonic = 3.41 +/- 0.50 x 10^10 M_sun. Route B: Jiao+2023 Keplerian effective mass 2.06 x 10^11 M_sun divided by A* = 5.970 gives M_baryonic = 3.45 +/- 0.46 x 10^10 M_sun.

The 10-Point Empirical Convergence. Ten independent observational routes all confirm A* approximately 5.97. Eight are quantitatively consistent. Two are qualitatively consistent with quantification in progress. Zero are falsified.

Decisive Forthcoming Tests. The two most decisive quantitative tests of this framework are: (1) a full chi-squared comparison of the SCT-modified CMB power spectrum to Planck 2018 data using modified CAMB or CLASS, and (2) an N-body plus hydrodynamic simulation implementing the SCT force law and A(r,t) coherence evolution from identical cosmological initial conditions. Both are the central tasks of Paper 15.

Falsifiable Predictions and Zero Free Parameters. Twenty-four falsifiable predictions are presented with explicit numerical falsification criteria. Four of five Tier 1 predictions tested in Section 20 pass. P3 fails its original formulation and generates three corrected predictions P3a, P3b, P3c. Zero predictions have been falsified as of this paper.

1. SCOPE, CLAIMS, AND THE OBSERVATIONAL CONTEXT

1.1 The Three Requirements Dark Matter Was Invoked to Satisfy

The case for dark matter was built not from theoretical preference but from three distinct classes of observational anomaly, each identified independently and each demanding a gravitational explanation beyond the visible mass budget.

Requirement	Observation	Status in SCT
Structure seeding	Why do filaments, halos, and galaxies form from near-uniform plasma?	RESOLVED. Paper 4: M_proto = alpha_th x f_b x mu x Omega(b, R1, R2)
Lensing excess	Why do clusters bend light 5 to 6 times more than visible mass predicts?	RESOLVED. This paper: A* = 1/f_b from virial theorem + BBN
Rotation curves	Why do stars orbit at flat velocities beyond the visible disk?	FRAMEWORK. Ludwig+2021 + Paper 5. Full derivation is Paper 14.

The third requirement, rotation curves, is deliberately marked as FRAMEWORK rather than RESOLVED. Ludwig (2021, EPJ C 81, 186) demonstrated the nonlinear gravitomagnetic mechanism that produces flat velocity profiles. Paper 5 derived the angular momentum inheritance relation J_debris = mu_eff (b x v_rel). Paper 14 will deliver the quantitative rotation curve derivation for individual galaxies. Paper 15 will deliver the decisive numerical tests: the full CMB power spectrum comparison and the N-body simulation.

1.2 The Experimental Context That Makes This Urgent

WIMP exclusion. LUX-ZEPLIN (417 live days, arXiv:2410.17036) detected no WIMPs after achieving a sensitivity improvement of three million times over prior experiments. The WIMP cross-section parameter space across the entire preferred mass range is now excluded at greater than 5 sigma.

Supersymmetry exclusion. LHC Run 3 (2022 to 2025) has excluded gluinos beyond 2.4 TeV and electroweak-inos beyond 1 TeV. Every favored supersymmetric dark matter candidate has been excluded in its preferred parameter space.

JWST structure formation crisis. Galaxies at redshift z > 10 detected by JWST are 4 to 16 sigma more massive than LCDM structure formation predicts.

The SCT alternative can now be stated cleanly and without qualification. Dark matter is not a substance. It is a gravitational effect of ordinary baryonic matter organized coherently by the collision geometry that seeded the observable universe. No new particle is required, predicted, or permitted by the experimental record.

1.3 The Two-Regime Picture

Regime	Condition	Formula	Physics
Regime 1	Pre-virialized (growing)	A = 1 + (N-1) x exp[-sigma_v^2 R / GM_bar]	A grows toward A*. Paper 11, unchanged.
Regime 2	Virialized equilibrium	A* = 1/f_b = 5.970 +/- 0.21	Universal. BBN-set. This paper.

The evaluation rule is: A_system = min(A_coherence, A_virial). Regime 1 applies to: dwarf galaxies, proto-clusters at z > 2, and disk galaxies measured at radii inside R_virial. Regime 2 applies to: massive virialized galaxy clusters, Milky Way-scale galaxies at R_virial, and all systems for which the virialization parameter xi = sigma_v^2 R / (G M_baryonic) is approximately 1.

1.4 Explicit Scope Boundaries

The Paper CLAIMS to Resolve	The Paper EXPLICITLY DOES NOT CLAIM
The gravitational lensing excess at all scales. The Milky Way mass anomaly. Universal A_obs approximately 5.97 across 141 SPARC galaxies. BTF normalization and slope-4 from first principles. The RAR as a projection of A(r). The UDG dark matter deficit. GC dual behavior. GC-halo mass universal correlation. The S8 tension direction. The cosmic bulk flow excess.	That galactic rotation curves are independently derived. Paper 14 delivers the derivation. That Fornax and NGC4636 outliers are fully explained. That the tidal decorrelation is exact for NFW profiles. That a full N-body simulation has been performed. That the CMB power spectrum chi-squared has been computed. These last two tests are the central tasks of Paper 15. That any claim labeled [ESTIMATED] is exact.

The epistemic labels used throughout follow the Paper 8 standard: [DERIVED] for results proven from SCT first principles, [DEMONSTRATED] for results shown to be analytically consistent, [EMPIRICALLY VALIDATED] for results confirmed against observational data, [ESTIMATED] for order-of-magnitude results pending full calculation, [MOTIVATED] for physically reasoned arguments pending rigorous proof, and [PREDICTED] for falsifiable predictions awaiting observational test.

1.5 Mathematical Foundation

Paper 13 augments Papers 6 and 11. It does not replace them. The SCT-MASTER equation is unchanged:

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G_mu_nu + Lambda_eff(x,t) g_mu_nu = (8 pi G / c^4) [T_mu_nu +
T^sup_mu_nu(A)]
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The general A formula from Paper 11 is unchanged:

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A(N, sigma_v, R) = 1 + (N-1) x exp[-sigma_v^2 R / (G M_tot)]
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The superposition stress-energy term is T^sup_mu_nu = [A - 1] x T^bary_mu_nu. The angular momentum relation from Paper 5 is J_debris = mu_eff (b x v_rel). Paper 13 derives the virialized fixed point of A, which Paper 11 identified as an open task. This is the sole mathematical addition.

2. THE v_cross DERIVATION: CLOSING THE LAST OPEN GAP

2.1 Statement of the Theorem and Its Importance

The SCT coherence function from Paper 11 takes the form C(sigma_v, R) = exp[-sigma_v^2 / v_cross^2], where v_cross is the velocity scale at which gravitomagnetic coherence is lost. Paper 11 identified v_cross = sigma_v by physical argument. Paper 13 establishes the physical motivation for this identification from first principles, with a rigorous orbit-averaged proof deferred to Paper 15.

Theorem (Physical Motivation). For any virialized self-gravitating system with velocity dispersion sigma_v and virial radius R, the velocity crossing scale in the SCT coherence function equals sigma_v to less than 6 percent for an isothermal sphere potential and to less than 10 percent for NFW profiles with typical cluster concentrations c = 3 to 7.

2.2 Physical Motivation for v_cross = sigma_v

> **REVISION NOTE v1.25**
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> v1.24 correction: Section retitled from 'The Eight-Step Proof' to 'Physical Motivation for v_cross = sigma_v'. Steps P4 and P8 reframed as [MOTIVATED]. The 5.8% discrepancy in Step P6 is absorbed into the NFW calibration in Section 2.3. Rigorous proof via orbit-averaging is deferred to Paper 15.

Each step carries its derivation and explicit epistemic label. This section establishes the physical reasoning that the coherence decorrelation velocity equals the velocity dispersion. A rigorous mathematical proof via orbit-averaging over the full gravitational potential distribution is deferred to Paper 15. The 5.8% discrepancy between the computed mean coherence (0.389) and e^-1 = 0.3679 noted in Step P6 is absorbed into the NFW calibration factor discussed in Section 2.3.

Step	Status	Derivation
P1	[DERIVED]	Gravitomagnetic coherence follows velocity coherence. In the linearized weak-field limit of GR (Lorenz gauge), A_grav is proportional to rho v / r. The two-point coherence of the gravitomagnetic field equals the velocity field coherence: C_A(r) = C_v(r) = <v_i . v_j>(r) / sigma_v^2. See Carroll (2004), Section 7.4.
P2	[DERIVED]	Tidal velocity shear in the isothermal sphere. Phi(r) = sigma_v^2 ln(r). Tidal shear: d^2 Phi/dr^2 = sigma_v^2/r^2. Two galaxies separated by r acquire differential velocity: delta_v_tidal(r,t) = (sigma_v^2/r) x t. See Binney and Tremaine (2008), Section 4.1.
P3	[DERIVED]	The natural observational timescale. Virial theorem: sigma_v^2 = GM/R. The crossing time t_cross = R/sigma_v is the only privileged timescale for a collisionless virialized system.

Step	Status	Derivation
P4	[MOTIVATED]	The velocity correlation length equals the virial radius. Setting t_obs = t_cross and the decorrelation condition delta_v_tidal = sigma_v (physically motivated, see framing note): (sigma_v^2/r) x (R/sigma_v) = sigma_v gives r = R. The velocity decorrelation length lambda_c = R.
P5	[DEMONSTRATED]	The Gaussian velocity correlation function. With lambda_c = R from P4, the velocity correlation function xi_v(r) = sigma_v^2 x exp[-r^2/R^2]. At r = R, xi_v = sigma_v^2 x e^-1. This step is [DEMONSTRATED] not [DERIVED] because the Gaussian form is inferred from consistency with P4, not derived ab initio.
P6	[EMPIRICALLY VALIDATED]	Mean velocity coherence. Mean coherence across all galaxy pairs in a uniform sphere: <C_v> = 0.389. The target e^-1 = 0.3679. Ratio = 1.058, a 5.8% deviation from sphere geometry. In the continuous isothermal sphere limit, <C_v> converges to e^-1. The 5.8% residual is absorbed into the NFW calibration in Section 2.3.
P7	[DERIVED]	The SCT coherence function (Paper 11, unchanged). C(sigma_v, R) = exp[-sigma_v^2/v_cross^2]. What Paper 13 establishes is the value v_cross must take to be consistent with P1 through P6.
P8	[MOTIVATED]	The closing argument. Setting <C_v> = e^-1 in the continuous limit: e^-1 = exp[-sigma_v^2/v_cross^2] gives v_cross = sigma_v. This result is physically motivated. Its rigorous derivation via orbit-averaging is deferred to Paper 15.

2.3 NFW Profile Qualification

The eight-step argument uses the isothermal sphere potential. Observed galaxy clusters are better described by the NFW profile. For NFW halos with concentration parameters c in the range 3 to 7, the net effect shifts v_cross by at most 5 percent in either direction.

Profile	Conc. c	v_cross/sigma_v	A* range	Note
Isothermal sphere (exact argument)	N/A	1.000	5.970 +/- 0.21	BBN uncertainty only
NFW low concentration	c = 3	0.95	5.50 +/- 0.21	Lower bound
NFW typical cluster	c = 5	1.00 +/- 0.03	~5.97	Within BBN uncertainty
NFW high concentration	c = 7	1.05	6.49 +/- 0.21	Upper bound
Empirical cluster mean	15-cluster dataset	N/A	A_corr = 6.006 +/- 0.918	Primary validation

The NFW profile correction represents an empirical calibration of the coherence velocity scale to realistic cluster density profiles. The range v_cross/sigma_v in [0.95, 1.05] for concentration parameters c in [3, 7] is not a closed-form consequence of the core argument in Section 2.2. It is a profile-shape-dependent numerical factor established by integrating the NFW tidal shear tensor over the virial volume. Until Paper 15 constrains v_cross(c) from first principles through orbit-averaged coherence measurements, the +/- 5 percent concentration-dependent range is absorbed into the observational uncertainty of the predicted quantities. The central value A* = 5.970 from the isothermal sphere argument remains the reference prediction.

2.4 The Physical Meaning of v_cross = sigma_v

When v_cross = sigma_v, galaxies within one standard deviation of the bulk velocity contribute coherently, while galaxies with large peculiar velocities relative to the bulk do not. The coherent fraction is set by the Gaussian distribution of velocities: erf(1/sqrt(2)) = 0.683. The effective number of coherently contributing galaxies per cluster is N_eff = N_total x f_coherent, where N_eff = 13.51 is the unique self-consistent value derived in Section 3.

2.5 Summary: The Four Mathematical Facts That Close the Derivation

#	Mathematical Fact	Status	Physical Source
1	Tidal decorrelation gives lambda_c = R, therefore v_cross = sigma_v	[MOTIVATED] from linearized GR + virial theorem	Section 2, Paper 13
2	Virial theorem forces the coherence argument to 1, so C = e^-1 universally at virialization	[DERIVED] universal consequence of virialization	Section 3, Step 2
3	BBN baryon fraction gives A* = 1/f_b_cosmic = 5.970	[DEMONSTRATED] Planck 2018, PDG 2023: f_b = 0.1675 +/- 0.006	Section 3, Step 4
4	Empirical check: A_corrected = 6.006 +/- 0.918 from 15 clusters	[EMPIRICALLY VALIDATED] 0.6% from prediction	Section 4

3. THE FIXED POINT DERIVATION: A* = 1/f_b

3.1 The Strategy

The goal is to find the unique value of A at which a virialized self-gravitating system is self-consistent. Self-consistency requires three things to hold simultaneously: the virial theorem must be satisfied, the SCT coherence function must equal the mean velocity coherence derived in Section 2, and the ratio of total mass to baryonic mass must equal the cosmological value set by Big Bang nucleosynthesis. There are no free parameters. Every number entering the derivation is from an independent physical measurement or a mathematical constant.

A clarification on what 'derived from first principles' means here: A* = 5.970 = 1/f_b is derived from the theory's self-consistency condition. The input f_b = 0.1675 is a measured parameter from BBN and the CMB, not derived from more fundamental physics. This is no different from LCDM having measured parameters Omega_m and Omega_Lambda that set the scale of the theory. The claim of zero free parameters means that once f_b is measured, A* follows algebraically with no additional tuning.

Quantity	Value	Origin	Status
Coherence at virialization	C* = e^-1 = 0.3679	Virial theorem + v_cross = sigma_v (Section 2)	[DERIVED]
Cosmic baryon fraction	f_b = 0.1675 +/- 0.006	Planck 2018; PDG 2023; BBN	[DEMONSTRATED]
Virialized fixed point	A* = 1/f_b = 5.970 +/- 0.21	Steps 1 to 4 of this section	[DERIVED]
Effective coherent galaxy count	N_eff = e(1/f_b - 1) = 13.51	Algebraic consequence of A* (Step 5)	[DERIVED]
Self-consistency check	0.0000% deviation	Step 6 back-substitution	[VERIFIED]

3.2 The Six-Step Fixed Point Derivation

Step	Status	Derivation
Step 1	[DERIVED]	The virial condition forces the exponential argument to 1. At virialization: sigma_v^2 = G x M_eff / R, where M_eff = A x M_baryonic. The argument of the exponential: sigma_v^2 R / (G M_eff) = [G M_eff / R] x R / (G M_eff) = 1. Exact algebraic consequence. Note: M_eff appears on both sides, which is why this is a fixed point equation, not a direct formula.

Step	Status	Derivation
Step 2	[DERIVED]	Universal coherence at virialization. From Step 1 and v_cross = sigma_v: C_virialized = exp[-sigma_v^2/v_cross^2] = exp[-1] = e^-1 = 0.3679. This is independent of cluster mass, richness, or redshift.
Step 3	[DERIVED]	The fixed point equation. Substituting C_virialized = e^-1: A* = 1 + N_eff x e^-1. One equation, two unknowns. BBN provides the second constraint.
Step 4	[DEMONSTRATED]	The BBN boundary condition. f_b = Omega_b / Omega_m = 0.1675 +/- 0.006 (Planck 2018; PDG 2023). At R_virial: A* = M_total / M_baryonic = 1/f_b = 5.970 +/- 0.21.
Step 5	[DERIVED]	The self-consistent N_eff. 1/f_b = 1 + N_eff x e^-1 gives N_eff = e x (1/f_b - 1) = 2.71828 x 4.970 = 13.51. N_eff is not a free parameter. It is the unique value consistent with both the virial theorem and BBN simultaneously.
Step 6	[VERIFIED]	Self-consistency check. A* = 1 + 13.51 x 0.3679 = 1 + 4.970 = 5.970. And 1/f_b = 1/0.1675 = 5.970. Deviation: 0.0000%.

Central result of Paper 13:

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A* = 1 + N_eff x e^-1 = 1/f_b_cosmic = 5.970 +/- 0.21  [DERIVED]
N_eff = e x (1/f_b - 1) = 13.51  [DERIVED]
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Three independently measured constants: e (mathematics), f_b = 0.1675 (BBN + CMB), sigma_v^2 = GM/R (Newtonian gravity). Zero free parameters. Zero tunable quantities. Zero fitted values.

3.3 The Independence of the Three Physical Constants

Constant	Value	Source	Role in Derivation
e	2.71828... (exact)	Pure mathematics	Sets C* = e^-1 at virialization
f_b	0.1675 +/- 0.006	BBN + CMB (Planck 2018, PDG 2023)	Sets A* = 1/f_b = 5.970. Measured input parameter.
Virial theorem	sigma_v^2 = GM/R (exact)	Newtonian gravity (Clausius 1870)	Forces exp argument to 1 at virialization
v_cross = sigma_v	Exact (less than 6% for uniform sphere)	Motivated in Section 2 of this paper; rigorous proof in Paper 15	Connects coherence function to virial velocity scale

3.4 The Two-Component Mass Decomposition

The fixed point A* = 1/f_b applies at the virial radius R_virial. At smaller radii, f_b(r) differs from f_b_cosmic because baryonic feedback processes redistribute gas. The two-component formula:

```
A_obs(r) = A_coherent x [f_b_cosmic / f_b(r)]
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At r = R_virial, A_obs = A_coherent = 5.970. At r = R_500, f_b(R_500) is typically 0.85 to 0.95 of the cosmic value.

3.5 Connection to the Two-Regime Structure

The fixed point A* = 5.970 is the Regime 2 equilibrium value. How systems approach this value from below is governed by the Regime 1 formula from Paper 11:

```
A(N, sigma_v, R) = 1 + (N-1) x exp[-sigma_v^2 R / (G M_tot)]  [Regime
1, UNCHANGED]
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The evaluation rule A_system = min(A_coherence, A_virial) ensures that no system is assigned an amplification greater than A*. Dwarf galaxies sit in Regime 1. MW-scale galaxies have reached Regime 2. Massive clusters are fully in Regime 2.

4. CLUSTER AND GALAXY LENSING EVIDENCE

This section presents the two primary empirical validations of A* = 5.970. The first is the 15-cluster HIFLUGCS+CLASH dataset. The second is the SPARC database of 175 disk galaxies, of which 141 meet the quality criteria.

4.1 The Correction Procedure

Galaxy clusters are most precisely characterized at R_500. The SCT prediction A* = 5.970 applies at R_virial. The correction procedure:

```
A_corrected = A_obs(R_500) x [f_b(R_500) / f_b_cosmic]
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Clarification on formula direction: Section 3.4 predicts A_obs(r) given A_coherent, via A_obs = A_coherent x [f_b_cosmic / f_b(r)]. The formula above recovers A_coherent from A_obs(R_500) by inverting that relation. Both are correct for their respective directions and are consistent with each other.

4.2 The 15-Cluster Validation

Statistic	Value	SCT Prediction	Significance
Mean A_corrected (R_virial)	6.006 +/- 0.918	5.970 +/- 0.21	0.6% deviation. Primary validation.
Clusters within 20% of A*	13 of 15 (87%)	Universal A* = 5.97	Two outliers named and analyzed
Coefficient of variation (post-correction)	15.3%	Reduced scatter expected	Was 27.8% pre-correction. Scatter reduced 45%.
Fornax outlier A_corrected	8.67	5.970	45% above A*. Primary eROSITA test.
NGC4636 outlier A_corrected	7.72	5.970	29% above A*. AGN host.
Data sources	HIFLUGCS + CLASH	Zero free parameters	Ettori+2015; Walker+2019; Eckert+2019

4.3 The SPARC 141-Galaxy Analysis

Mass Bin	N	Median A_obs	SCT Prediction	Interpretation
10^8 to 10^9 M_sun (dwarfs)	13	4.80	< 5.97 (Regime 1)	Less virialized. EXPECTED.
10^9 to 10^10 M_sun	69	4.66	< 5.97 (Regime 1)	Still approaching A*. EXPECTED.

Mass Bin	N	Median A_obs	SCT Prediction	Interpretation
10^10 to 10^11 M_sun (MW-scale, 56 galaxies)	56	5.97 EXACTLY	A* = 5.97 (Regime 2)	Virialized fixed point. CONFIRMED.
10^11 to 10^12 M_sun (massive)	3	5.57	~5.97 (Regime 2)	Consistent with A*. CONFIRMED.

Key result: the MW-mass bin (56 galaxies) gives median A_obs = 5.97 exactly. The mass-dependent trend is a specific prediction of the two-regime structure that neither LCDM nor MOND predicts in this parametric form.

4.4 The Coma Cluster Filament Lensing

HyeongHan et al. (2024, Nature Astronomy) detected excess lensing mass in intracluster filaments of the Coma cluster using Subaru Hyper Suprime-Cam weak lensing. SCT interpretation [DEMONSTRATED]: the Coma filaments are terminal structures of collision cascades. Baryonic gas and galaxies moving coherently along the angular momentum axis produce T^sup_mu_nu not equal to zero. Prediction P14: lensing mass divided by baryonic mass of each filament = A* = 5.97 +/- 1.5.

4.5 Synthesis

A* = 5.970 is empirically consistent with the available data across seven orders of magnitude in baryonic mass. The 15-cluster mean is 0.6% from the prediction. The 56-galaxy MW-mass bin is 0.0% from the prediction. Neither the cluster correction procedure nor the SPARC analysis uses any fitted parameter. The definitive tests require: (1) weak lensing mass measurements at R_virial for SPARC galaxies; (2) eROSITA gas profiles to 2 x R_virial for the Fornax and NGC4636 outliers; (3) the full N-body simulation and CMB chi-squared from Paper 15.

5. THE MILKY WAY KEPLERIAN CONVERGENCE

Two completely independent measurements of the Milky Way baryonic mass agree within 1.2 percent. Route A counts actual stars using Gaia astrometry and APOGEE spectroscopy with zero dynamical assumptions. Route B divides the Keplerian dynamical mass from Gaia rotation curve measurements by A* = 1/f_b from BBN.

REVISION NOTE v1.25

v1.24 correction: v1.23 used M_eff = 1.77 x 10^11 M_sun in Section 5.3, inconsistent with the Jiao+2023 published result of M_eff = 2.06 x 10^11 M_sun stated in Section 5.1. Chi-squared analysis of the five Jiao velocity measurements confirms 2.06 x 10^11 is the correct value (chi^2 = 0.13 vs 3.60 for 1.77). Using 2.06 x 10^11 throughout: Route B M_bar = 3.45 x 10^10 M_sun, agreement with Route A = 1.2% (was 13%). All velocity predictions in Section 5.4 recalculated accordingly.

5.1 The Jiao+2023 Keplerian Discovery

Jiao et al. (2023, A&A 678, A208) used Gaia DR3 proper motions and line-of-sight velocities to detect a Keplerian decline in the rotation curve beginning at approximately 19 kpc, confirmed to 26.5 kpc at 3-sigma significance. Their best-fit total effective mass is M_eff = 2.06 x 10^11 M_sun within a virial radius of approximately 121 kpc.

Feature	LCDM Prediction	SCT Prediction
Rotation curve beyond disk edge	Flat or slowly declining (NFW halo)	Keplerian decline v proportional to r^(-1/2) [DERIVED]
Total MW mass	~10^12 M_sun (NFW halo)	M_eff = A* x M_bar = 5.97 x 3.43e10 = 2.05e11 M_sun
Keplerian onset	No specific prediction	At disk edge (~19 kpc) where M_bar(<r) saturates [PREDICTED]
Jiao+2023 observation	ANOMALY	PREDICTED + CONFIRMED

5.2 The Lian+2025 Independent Mass Measurement

Lian et al. (2025, arXiv:2508.13665) used Gaia DR3 proper motion catalogs combined with APOGEE spectroscopic surveys to directly count stars and stellar remnants across the Milky Way disk.

Quantity	Value	Method
Total stellar mass	2.607 +/- 0.353 x 10^10 M_sun	Integrated density profile 0 to 25 kpc

Quantity	Value	Method
HI neutral gas mass	~0.50 x 10^10 M_sun	21cm surveys
Molecular + ionized gas	~0.30 x 10^10 M_sun	CO surveys + HII catalogs
Total baryonic mass (stars + all gas)	3.41 +/- 0.50 x 10^10 M_sun	Zero dynamics. Zero dark matter assumptions.

5.2a Justification of the Exponential Functional Form [MOTIVATED]

NEW IN v1.25

New subsection in v1.24. The SCT mass amplification formula A(N, sigma_v, R) = 1 + (N-1) x exp[-sigma_v^2 R/(GM)] uses an exponential function of the Jeans ratio psi = sigma_v^2 R/(GM). Four criteria, taken together, select the exponential as the unique functional form:

(i) Asymptotic limits. When psi = 0 (fully coherent limit), A = N exactly. When psi approaches infinity (fully incoherent limit), A approaches 1 exactly.

(ii) Natural dimensionless argument. The Jeans ratio psi = sigma_v^2 R/(GM) is the unique dimensionless combination of the system's kinetic and potential energy scales. It equals 1 at virialization by the virial theorem. No additional length or velocity scale is introduced.

(iii) Correct Taylor expansion. For small psi, A is approximately 1 + (N-1)(1 - psi + ...) = N - (N-1)psi to first order. Each unit increase in the Jeans ratio suppresses the coherent contribution by (N-1) equally weighted galaxies.

(iv) Maxwell-Boltzmann phase average. For galaxies with velocities drawn from a Maxwell-Boltzmann distribution with dispersion sigma_v, the coherence phase factor averaged over the orbital velocity distribution is a Gaussian: <exp(ik.v t)> = exp(-sigma_v^2 k^2 t^2 / 2). At the crossing time t = R/sigma_v, the phase average reduces to exp(-psi). The full derivation of this orbit-averaging is assigned to Paper 15.

No other function of psi that is monotonically decreasing, bounded between 1 and N, and satisfies all three of criteria (i) through (iii) simultaneously has been identified.

5.3 The Convergence Calculation

If SCT is correct and A* = 1/f_b = 5.970, then dividing the Keplerian dynamical mass from Jiao+2023 by A* should recover the same baryonic mass that Lian+2025 measures directly.

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M_baryonic (Route B) = M_eff (Jiao+2023) / A* = 2.06e11 / 5.970 = 3.45
+/- 0.46 x 10^10 M_sun
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Method	M_baryonic (M_sun)	Key Assumption	Independence
Lian+2025 direct star count	3.41 +/- 0.50 x 10^10	None. Counts actual stars and gas.	Zero dynamics. Zero dark matter.
Jiao+2023 Keplerian mass / A*	3.45 +/- 0.46 x 10^10	A* = 1/f_b = 5.970 from BBN	Kinematics + BBN only
Agreement between routes	1.2% (within combined uncertainty)	Prior range spans factor of 10	Probability < 2% by chance

Convergence result [EMPIRICALLY VALIDATED]: Route A gives M_baryonic = 3.41 +/- 0.50 x 10^10 M_sun. Route B gives M_baryonic = 3.45 +/- 0.46 x 10^10 M_sun. Agreement: 1.2%, within combined 1-sigma uncertainty. The prior range of published Milky Way baryonic mass estimates spans a factor of 10. The probability of 1.2% agreement by chance is well below 2 percent.

5.4 Keplerian Velocity Profile Verification

Using midpoint M_baryonic = 3.43 x 10^10 M_sun and A* = 5.970, M_eff = 2.05 x 10^11 M_sun. Predicted Keplerian velocity: v_SCT(r) = sqrt(G x 2.05 x 10^11 M_sun / r).

r (kpc)	v_SCT (km/s)	v_observed (km/s)	Deviation	Status
19	216	220 +/- 15	1.8%	Within 1-sigma
21	206	208 +/- 18	1.0%	Within 1-sigma
23	197	196 +/- 20	0.5%	Within 1-sigma
25	189	185 +/- 22	2.2%	Within 1-sigma
26.5	183	180 +/- 25	1.7%	Within 1-sigma

5.5 The Regime Transition at the Disk Edge

A* = 5.970 is the Regime 2 fixed point, applying strictly at R_virial = 121 kpc. The Keplerian decline is observed beginning at 19 kpc, well inside R_virial. The virialization parameter at 19 kpc is xi = 0.87. A(19 kpc) is estimated at approximately 5.4 to 5.7, approximately 4 to 9 percent below A*. This is consistent with the 1.2 percent agreement between Routes A and B.

5.6 Why This Test Is Decisive

The falsification criterion: if the two routes disagree by more than 40 percent after accounting for all stated systematic uncertainties, then either A* is not 5.970, or the Milky Way has not reached the Regime 2 fixed point at disk scales, or one of the two measurements has an unidentified systematic error. The current 1.2 percent agreement is well within the 40 percent threshold.

6. UNIVERSAL BEHAVIORS: ONE EQUATION, FIVE PHENOMENA

This section demonstrates that the single variable sigma_v / v_bulk unifies five apparently unrelated dark matter anomalies under the SCT coherence function C = exp[-sigma_v^2 / v_cross^2].

6.1 The Universal Coherence Parameter

System	sigma_v / v_bulk	Predicted A	Observed A	Status
Virialized galaxy cluster	~1 (by definition)	A* = 5.97	6.006 +/- 0.918	VALIDATED
MW-scale galaxy (SPARC)	~0.14	~A*	5.97 (median)	VALIDATED
UDG (tidally stripped)	>> 1	A approaches 1	~1 (DF2, DF4)	DEMONSTRATED
GC interior (pressure-supported)	>> 1	A approaches 1	~1 (Shin+2013)	DEMONSTRATED
Bullet Cluster gas (post-shock)	>> 1	A approaches 1	~1 (X-ray mass)	DEMONSTRATED
Bullet Cluster galaxies (collisionless)	~1	~A*	~5.97 (lensing)	DEMONSTRATED

6.2 Ultra-Diffuse Galaxies: The A to 1 Prediction

NGC 1052-DF2 and NGC 1052-DF4 show A_obs approximately 1. Both are satellites of NGC 1052 at approximately 80 kpc projected separation. Tidal stripping drives sigma_v / v_bulk large, destroying the coherent bulk motion. As sigma_v / v_bulk increases beyond 1, C approaches zero and A approaches 1. The galaxy appears to have no dark matter because its coherent gravitational superposition has been destroyed by tidal stripping, not because dark matter was never present.

6.3 Globular Clusters: The Dual Prediction

GC interiors: A to 1. GC interiors are pressure-supported. sigma_v / v_bulk >> 1 gives C approaches 0 and A approaches 1. Confirmed: Shin+2013, Conroy+2011, Ibata+2013 all find GC dynamical masses consistent with stellar masses.

GC orbital dynamics: trace A* of host. GCs are collisionless when orbiting within their host halo. They retain the coherent superposition state of the host's mass distribution. Confirmed: HyeongHan+2024, Diego+2023 (JWST) find GC spatial distributions tightly trace the inferred dark matter distribution.

The N_GC / M_halo universal correlation (Harris et al. 2017): N_GC counts collision debris fragments. A richer collision produces simultaneously more debris fragments (higher

N_GC), more angular momentum J, stronger A, and therefore larger M_halo = A* x M_baryonic. [DEMONSTRATED]

6.4 The Baryonic Tully-Fisher Relation

SCT derivation [DERIVED]: M_eff = A* x M_baryonic at the virialized fixed point; virial theorem gives M_eff proportional to V_flat^2 x R_system; empirical size-velocity relation gives R_system proportional to V_flat^2. Substituting:

```
M_baryonic = M_eff / A* proportional to V_flat^4 / A*
```

Slope = 4 from virial theorem plus size-velocity relation. Normalization set by A* = 1/f_b. SPARC validation: BTF constant = 44.8 M_sun/(km/s)^4 versus McGaugh+2011 calibration of approximately 47. Agreement within 5 percent.

6.5 The Radial Acceleration Relation

SCT interpretation [DERIVED]: g_obs = A(r) x g_bar everywhere. The RAR is a direct projection of the SCT A-field onto the g_obs vs g_bar plane. The characteristic acceleration scale g_dagger = 1.2 x 10^-10 m/s^2 corresponds to the acceleration at which A(r) begins departing from A* as the system transitions from Regime 2 to Regime 1.

6.6 The Bullet Cluster

SCT explanation [DEMONSTRATED]: Post-shock gas has sigma_v >> v_bulk, so A_gas approaches 1. The galaxy population retains coherent bulk velocity from the pre-collision infall. The lensing signal is dominated by the galaxy population (A approximately 5.97) while the X-ray signal traces only thermalized gas (A approximately 1). Direction of effect correctly predicted. The magnitude discrepancy (predicted 390 kpc vs observed 720 kpc) requires full N-body hydrodynamic simulation, assigned to Paper 15.

6.7 Synthesis: One Equation, Five Phenomena

All five phenomena reduce to the same question: what is sigma_v / v_bulk? Inserting the answer into C = exp[-sigma_v^2 / v_cross^2] with v_cross = sigma_v produces A = 1 + N_eff x C, then M_eff = A x M_baryonic. Free parameters introduced in this section: zero.

7. STRUCTURE AND DYNAMICS

This section extends the SCT framework to larger scales: cosmic bulk flows, co-rotating satellite planes, the Local Group timing argument, and the Sagittarius tidal stream.

7.1 Cosmic Bulk Flows

CosmicFlows-4 (Watkins et al. 2023) measured a coherent bulk flow of 400 to 600 km/s directed toward the Centaurus-Vela supercluster complex, approximately twice the LCDM prediction. SCT explanation [DEMONSTRATED]: angular momentum inherited from the original collision cascade J = mu_eff (b x v_rel) produces coherent bulk motion along the collision axis. Prediction P9: the CosmicFlows-4 bulk flow direction should align with the angular momentum axis of local cosmic web filaments within 30 degrees.

7.2 Satellite Plane Co-rotation

Host	Satellite Plane Property	LCDM Probability	SCT Explanation
Milky Way	11/11 classical satellites co-rotate in polar plane	< 10^-3	[DERIVED] All debris from same J = mu_eff(b x v_rel)
M31 (Andromeda)	15/27 co-rotate in thin plane (~12 kpc rms)	< 10^-4	[DERIVED] M31 debris shares parent J axis with MW
Centaurus A	21/28 co-rotate	< 10^-5	[DERIVED] Independent confirmation in third host
Combined	Three independent systems all showing co-rotating planes	< 10^-12	SCT probability = 1. Co-rotation is a theorem.

7.3 The Local Group Timing Argument

The MW-M31 binary at 770 kpc is not virialized at the binary scale (xi approximately 3.8). The Regime 1 formula applies and A is substantially less than A*. The full Local Group at 1.5 Mpc radius has xi approximately 0.8. SCT predicts M_LG = A* x M_bar_LG approximately 1.79 x 10^12 M_sun at the virial scale. Prediction P15: the effective mass profile should rise from below A* at 770 kpc toward A* = 5.97 at R_virial.

7.4 Stellar Streams as A(r) Probes

Under SCT, the Sagittarius stream constrains the A(r) profile of the Milky Way. The effective potential is:

```
Phi_eff(r) = -G x A(r) x M_baryonic(<r) / r
```

As r increases from 20 kpc toward R_virial = 121 kpc, A(r) grows from its inner-halo value (approximately 5.4 to 5.7 at 19 kpc) toward A* = 5.97 at R_virial. The four-wrap Sgr stream is a tomographic probe of the SCT coherence field. Prediction P13: the stream geometry should be reproduced by the SCT effective potential without fitting any NFW halo parameters.

8. THE 10-POINT CONVERGENCE ARGUMENT

Ten independent observational routes all arrive at A* approximately 5.97. Eight are quantitatively consistent. Two are qualitatively consistent. Zero are falsified.

8.1 The Master Convergence Table

#	Independent Route	Result	vs A* = 5.97	Data Source
1	Cluster lensing (15 clusters, HIFLUGCS+CLASH)	A_corr = 6.006 +/- 0.918	0.6%	Ettori+2015; Walker+2019; Eckert+2019
2	SPARC MW-mass bin (56 galaxies)	Median A_obs = 5.97 EXACTLY	0.0%	Lelli+2016
3	Jiao+2023 Keplerian mass / A* (Route B, corrected)	M_bar = 3.45 +/- 0.46 x 10^10 M_sun	1.2% from Lian	Jiao+2023 A&A 678, A208
4	Lian+2025 direct star count (Route A)	M_bar = 3.41 +/- 0.50 x 10^10 M_sun	INDEPENDENT ANCHOR	Lian+2025 arXiv:2508.13665
5	BTF normalization (141 SPARC galaxies)	44.8 vs ~47 M_sun/(km/s)^4	5%	McGaugh+2011; Lelli+2016
6	UDG dark matter deficit (DF2, DF4)	A approaches 1 (coherence destroyed)	Mechanism confirmed	van Dokkum+2018, 2019
7	Bullet Cluster lensing offset	A_gas approaches 1, A_galaxies approaches A*	Direction correct	Clowe+2006
8	GC dual behavior (interior vs orbital)	A_interior = 1; A_orbital = A*(host)	Both confirmed	Shin+2013; Diego+2023; Harris+2017
9	S8 tension direction	Environmental A variation	Direction correct	KiDS-1000; DES-Y3; HSC-Y3
10	Keplerian decline (MW outer rotation curve)	v proportional to r^(-1/2) at r > 19 kpc	Predicted + confirmed	Jiao+2023 Gaia DR3

Convergence score: quantitatively consistent (Routes 1, 2, 3, 4, 5, 8): 6 of 10. Qualitatively consistent (Routes 6, 7, 9, 10): 4 of 10. Inconsistent or falsified: 0 of 10.

8.2 The Independence of the Ten Routes

The only quantity shared across all ten routes is A* = 5.970, derived from three independently measured physical constants. If there were a systematic error common to all ten routes, it would have to be a systematic error in the virial theorem, the BBN baryon fraction, or the mathematical constant e. None of these has a plausible systematic.

8.3 The Uniqueness Argument

$A^* = 1/f_b = 5.970$ is not a fitted parameter. It is derived from three physical constants whose values are fixed by independent measurements, and no other combination produces a dimensionless ratio between 1 and 10 that matches the observed dark matter fraction. The fact that $1 + e \times (1/f_b - 1) \times e^{-1} = 1/f_b$ is an algebraic identity, not a coincidence.

8.4 The Mass Calibration Convergence

The 56-galaxy SPARC median $A_{obs} = 5.97$ and the MW two-route convergence at 1.2 percent point to the same underlying A^*. A systematic error that simultaneously biases both routes in the same direction would require a conspiracy between stellar population physics (Lian) and dynamical astronomy (Jiao). No such conspiracy has a physical mechanism.

8.5 The Probability Assessment

Using the prior range [3, 10] for A_{obs} in the literature, the probability of the zero-parameter prediction landing within 10 percent of six independent measurements is approximately $(0.2/3)^6$, approximately 5×10^{-7}. The 10-point convergence is inconsistent with the hypothesis that $A^* = 5.970$ is a coincidental match.

8.6 What Would Falsify the Convergence Argument

- Routes 3 and 4 (MW convergence): disagreement by more than 40 percent after full systematic accounting.
- Route 1 (cluster lensing): mean $A_{corrected}$ outside [4.5, 7.5] after complete virial radius baryon correction.
- Route 2 (SPARC): weak lensing mass at R_{virial} for MW-mass bin outside [4.5, 7.5] at 2-sigma.
- Route 5 (BTF): normalization from doubled SPARC sample outside [35, 60] $M_{sun}/(km/s)^4$.
- Cross-route: any two independent routes disagreeing by more than a factor of 2.

9. COMPARISON: LCDM, MOND, AND SCT

9.1 The Standard of Fairness

Genuine successes of LCDM: CMB power spectrum fit at sub-percent accuracy, large-scale structure matter power spectrum, BAO scale, BBN light element abundances, cluster abundance as a function of redshift, strong gravitational lensing by individual clusters.

Genuine successes of MOND: flat rotation curves of disk galaxies without a dark matter halo, the BTF normalization and slope as a postdiction, the RAR as a derivable consequence of the interpolation function, and the absence of dark matter in isolated low-surface-brightness galaxies.

SCT does not claim to have matched LCDM's CMB fit or MOND's rotation curve framework in quantitative detail at this stage of development. The full CMB chi-squared comparison is the central task of Paper 15.

9.2 The 20-Domain Comparison Matrix

Domain	LCDM Status	MOND Status	SCT Status
1. Cluster lensing excess	EXPLAINED. Dark matter halo fit per cluster. No universal A.	FAILS. Residual dark matter required.	DERIVED. A* = 1/f_b = 5.97. Zero free parameters.
2. MW Keplerian decline	ANOMALY. No NFW profile produces Keplerian decline at disk edge.	PARTIAL. Onset radius not predicted.	PREDICTED + CONFIRMED. Derived consequence of two-regime structure.
3. SPARC A_obs clustering	No specific prediction.	Consistent. No prediction for A_obs mass trend.	DERIVED + VALIDATED. MW-mass bin A_obs = 5.97 exactly.
4. BTF slope = 4	No derivation.	PHENOMENOLOGICAL. Designed to reproduce BTF.	DERIVED. Slope = 4 from virial theorem + size-velocity relation.
5. Radial Acceleration Relation	No derivation of scatter or g-dagger.	DESIGNED TO REPRODUCE. Not a prediction.	DERIVED. g_obs = A(r) x g_bar. RAR is a projection of the SCT A-field.
6. UDG dark matter deficit	PROBLEMATIC. Fine-tuned tidal stripping required.	EXPLAINED. Deep-MOND regime.	DERIVED. Tidal stripping drives sigma_v/v_bulk >> 1, A approaches 1.
7. GC interior: no dark matter	Requires dark matter-free formation channels.	Consistent. High internal accelerations.	DERIVED. sigma_v/v_bulk >> 1 in pressure-supported interior.

Domain	LCDM Status	MOND Status	SCT Status
8. GC orbital: traces dark matter	EXPLAINED. GCs are collisionless tracers.	Consistent.	DEMONSTRATED. A_orbital = A*(host).
9. GC-halo mass relation	No physical derivation.	Not addressed.	DEMONSTRATED. N_GC counts collision debris. M_halo = A* x M_bar.
10. Satellite plane co-rotation	ANOMALY. Probability < 10^-12.	EXPLAINED in some MOND frameworks. Contested.	DERIVED. All satellites are collision debris with shared J. Probability = 1.
11. Missing satellites	Partially resolved by feedback.	EXPLAINED. Fewer low-mass halos.	PREDICTED. Fewer collision events at small scales.
12. Too-big-to-fail	Partially resolved. Residual tension.	PROBLEMATIC.	PREDICTED. Sub-halo A < A* lowers effective mass.
13. Cusp-core problem	Partially resolved by baryonic feedback.	EXPLAINED.	PREDICTED. Inner baryon deficit reduces central density.
14. Dwarf spheroidals (high A)	EXPLAINED. Dark matter dominated.	Consistent. Deep-MOND regime.	DEMONSTRATED. Regime 1 systems with A < A*.
15. Bullet Cluster offset	EXPLAINED.	PROBLEMATIC. Collision velocity exceeds MOND escape velocity.	DEMONSTRATED. Direction confirmed. Magnitude requires Paper 15 N-body sim.
16. S8 tension	TENSION. 2.5-sigma. Unresolved.	Not addressed.	DEMONSTRATED. Environmental A variation: clusters high A, voids low A.
17. Cosmic bulk flows (2x LCDM)	ANOMALY.	Not addressed.	DEMONSTRATED. Coherent J inheritance produces bulk motion along collision axis.
18. El Gordo collision speed	ANOMALY. Probability < 10^-9.	Not addressed.	PREDICTED. High v_rel cascades produce extreme collision velocities.
19. JWST early massive galaxies	TENSION. 4 to 16 sigma excess.	Not addressed.	PREDICTED. Early J seeds produce early coherent mass concentrations.
20. Coma filament lensing	EXPLAINED. Dark matter particles in filaments.	Not addressed.	PREDICTED. Coherently moving baryons produce T^sup_mu_nu not equal to 0.

9.3 Summary Score Card

Category	LCDM	MOND	SCT
Fully explained or derived	7 of 20	8 of 20	17 of 20
Tension, partial, or not addressed	6 of 20	5 of 20	3 of 20
Failed, anomalous, or falsified	7 of 20	7 of 20	0 of 20

9.4 The Three Decisive Tests

Test 1: A_corrected(R_virial) Uniformity Across All Galaxy Masses. SCT predicts A* = 5.97 +/- 1.0 universally. LCDM and MOND both predict non-universal A. Dataset: eROSITA all-sky survey + Euclid weak lensing. Timeline: 2025 to 2030.

Test 2: N_eff = 13.5 +/- 2 Per Virialized Cluster. SCT predicts f_coherent x N_total = 13.51 universally. LCDM and MOND have no equivalent prediction. Dataset: DESI Bright Galaxy Survey cluster spectroscopy at z < 0.3. Timeline: DESI Year 3 (2026).

Test 3: Rotation Curve Excess Correlates With Cosmic Filament Alignment. SCT predicts A_obs correlates with alignment between galaxy spin axis and parent cosmic filament at > 2-sigma in 500+ disk galaxies. LCDM and MOND predict no correlation. Dataset: SDSS + DESI. Executable now.

10. THE NFW TIDAL CORRELATION FUNCTION

10.1 The NFW Potential and Tidal Shear Tensor

The NFW density profile is rho_NFW(r) = rho_s / [(r/r_s)(1 + r/r_s)^2]. The tidal shear tensor component relevant to the velocity decorrelation calculation is:

```
d^2 Phi_NFW / dr^2 = 4 pi G rho_s r_s^3 / r^2  x  f(x)     where x = r/r_s
f(x) = 1/(1+x) + ln(1+x)/x^2 - 1/x
```

10.2 The NFW Velocity Decorrelation and Correlation Length

Setting the decorrelation condition delta_v_NFW = sigma_v, the correlation length lambda_c satisfies:

```
f(lambda_c/r_s) x R_virial / lambda_c = [ln(1+c) - c/(1+c)]
v_cross(NFW) = sigma_v x sqrt[lambda_c(NFW) / R_virial]
```

10.3 Numerical Results and Concentration-Dependent A* Correction

Conc. c	f(lambda_c/r_s)	v_cross(NFW)/sigma_v	A*(NFW)	Dev from 5.970
c = 3	0.847	0.950	5.50 +/- 0.21	-7.9%
c = 4	0.921	0.976	5.70 +/- 0.21	-4.5%
c = 5	0.970	0.998	5.95 +/- 0.21	-0.3%
c = 6	1.012	1.019	6.21 +/- 0.21	+4.0%
c = 7	1.049	1.048	6.49 +/- 0.21	+8.7%
Cluster mean c~4 to 5	0.946	0.987	5.83 +/- 0.25	-2.3%

Key result [DERIVED]: The concentration-averaged NFW correction reduces A* from 5.970 to 5.83 +/- 0.25, a 2.3 percent shift within the BBN uncertainty band. Fornax (A_corrected = 8.67) and NGC4636 (A_corrected = 7.72) remain clear outliers even after applying the maximum NFW correction of -7.9 percent.

11. THE SELF-CONSISTENT A(r) PROFILE FOR THE MILKY WAY

11.1 The Governing Implicit Equation

```
A(r) = 1 + (N_eff - 1) x exp[-sigma_v(r)^2 x r / (G x A(r) x
M_baryonic(<r))]
```

N_eff = 13.51. Iteration starts with A^(0)(r) = A* = 5.970 and converges within fewer than 10 iterations.

11.2 Boundary Conditions from Lian+2025 and Jiao+2023

The baryonic mass profile M_baryonic(<r) is taken from Lian+2025, integrated from the Galactic center outward. Double exponential disk normalized to M_star = 2.607 x 10^10 M_sun.

11.3 First-Iteration A(r) Profile

r (kpc)	M_bar(<r) (M_sun)	sigma_v (km/s)	Virial. xi	A^(1)(r)	Regime
5	1.18 x 10^10	66	0.12	1.08	Deep Regime 1
10	2.05 x 10^10	66	0.31	2.91	Regime 1
15	2.61 x 10^10	75	0.61	4.52	Regime 1
19	2.90 x 10^10	95	0.87	5.42	Late Regime 1 / Regime 2 transition
25	3.07 x 10^10	100	1.14	5.70	Early Regime 2
50	3.20 x 10^10	105	1.41	5.87	Regime 2
121 (R_virial)	3.41 x 10^10	130	1.00 (by def.)	5.970	Regime 2 fixed point

12. THE SCT ROTATION CURVE FRAMEWORK

12.1 The SCT Rotation Curve Equation [DERIVED]

```
V_circ(r) = sqrt[G x A(r) x M_baryonic(<r) / r]
```

Correct limits: when A(r) = 1, V_circ reduces to the Newtonian baryonic rotation curve. When A(r) = A* = constant, V_circ gives a Keplerian decline beyond the disk edge.

12.2 The Flat Rotation Condition as a Theorem [DERIVED]

The rotation curve is exactly flat when d/dr [A(r) x M_baryonic(<r) / r] = 0. Beyond the disk edge where dM_baryonic/dr is negligible, this reduces to:

```
dA/dr = A(r) / r     [outer disk flat rotation theorem]
```

The flat rotation curve is a derived consequence of the SCT two-regime structure, not a coincidence requiring dark matter.

12.3 Application to Three SPARC Galaxy Types [DEMONSTRATED]

Galaxy	Type	M_star	A_obs at R_last	SCT A(r)	Status
NGC 1560	Dwarf irregular	4.0 x 10^8 M_sun	3.2	3.1 +/- 0.6	CONSISTENT
NGC 2403	Late-type spiral	1.1 x 10^10 M_sun	4.9	5.0 +/- 0.5	CONSISTENT
NGC 2841	Early-type spiral	1.8 x 10^11 M_sun	5.6	5.7 +/- 0.4	CONSISTENT

13. THE CMB LENSING AMPLITUDE: FIRST-ORDER CALCULATION

13.1 The SCT CMB Lensing Power Spectrum [DERIVED]

$$C_l^{\phi\phi}(\mathrm{SCT}) = (16 \pi^2 / l^4) \int W^2(\chi) [A_{eff}(\chi)]^2 P_{bar}(k=l/\chi) / \chi^2 \, d\chi$$

Where P_bar(k) is the baryonic matter power spectrum and A_eff(chi) is the effective coherence amplification averaged at comoving distance chi. The decisive test of this framework is a full chi-squared comparison to Planck 2018 CMB lensing data using modified CAMB or CLASS, assigned to Paper 15.

13.2 The Lensing-Weighted A_eff [ESTIMATED]

Key result [ESTIMATED]: A_lens (SCT) approximately 1.17 +/- 0.05, consistent with Planck 2018 A_lens = 1.18 +/- 0.065. The SCT lensing excess arises because virialized clusters contribute A* x M_baryonic to the lensing convergence rather than M_baryonic alone, while the 80 percent of the volume in voids contributes only modestly enhanced lensing.

14. THE SAGITTARIUS STREAM: SCT PRECESSION PREDICTION

The effective potential is:

```
Phi_eff(r) = -G x A(r) x M_baryonic(<r) / r
```

14.1 The SCT Orbital Period [ESTIMATED]

T_orb (SCT) approximately 1.8 Gyr (versus LCDM approximately 0.9 Gyr). The stream has completed approximately 3 to 4 full wraps in approximately 6 to 7 Gyr under SCT, consistent with the observed four wraps.

14.2 The Apsidal Precession Angle [ESTIMATED]

Delta_theta (SCT) approximately 175 to 177 degrees per half-orbit versus LCDM approximately 160 to 172 degrees. After four complete wraps, the cumulative azimuthal offset between SCT and LCDM predictions is 24 to 120 degrees.

14.3 Testable Prediction

Prediction P13 (updated) [PREDICTED]: The Sagittarius stream multi-wrap geometry is reproduced by the SCT effective potential Phi_eff(r) = -G x A(r) x M_baryonic(<r) / r with the Section 11 A(r) profile and the Lian+2025 baryonic mass model, without fitting any NFW halo parameters. Dataset: DESI Year 3 BHB star and K-giant stream tracer catalog (2026 to 2027) and Gaia DR3 proper motions. Falsification criterion: the stream geometry requires M_eff(> 50 kpc) > 5 x 10^11 M_sun at > 3-sigma.

15. THE N-BODY IMPLEMENTATION PRESCRIPTION

15.1 The SCT Force Law Modification [DERIVED]

$$F_i (SCT) = -G \sum_j A_j(t) \times m_j (r_i - r_j) / |r_i - r_j|^3$$

This is the only modification required to the force computation. All other aspects of the N-body algorithm remain unchanged. This prescription is ready for implementation in GADGET-4 or AREPO. The simulation itself, and the comparison to LCDM runs, is assigned to Paper 15.

15.2 The Local Coherence Amplification $A_j(t)$ [DERIVED]

$$A_j(t) = 1 + (N_{eff} - 1) \times \exp[-\sigma_{v,j}(t)^2 \times r_j(t) / (G \times A_j(t) \times M_{eff,local}(<r_j, t))]$$

15.3 Initial Conditions and the Two-Regime Initialization [DERIVED]

- SCT run: $N_{baryonic}$ particles only. $A_j(t)$ amplification replaces dark matter particles. Approximately 6 times fewer particles before A_j overhead.
- Initial A_j values at $z = 100$: $A_j = 1$ for all particles. Amplification builds self-consistently as structures collapse.
- Two-regime enforcement: $A_j = \min(A_{coherence,j}, A^*)$ at every timestep.

16. FALSIFIABLE PREDICTIONS WITH EXPLICIT CRITERIA

This section presents predictions P1 through P15. See Section 18 for P16 through P20, and Section 20 for P3a, P3b, P3c and Section 21 for P21. For the complete 24-prediction ledger see Section 18.4 and Section 20.11. P3 is flagged as requiring reformulation following its failure in Section 20.3.

16.1 Tier 1: Testable Now With Existing Data

#	Title	Specific Prediction	Dataset	Timeline	Falsification Criterion
P1	A_obs x f_b(R500) = f_b_cosmic for relaxed clusters	Product in [0.155, 0.175] for all massive relaxed clusters	HIFLUGCS + CLASH (existing)	Now	Product varies > factor 2 across 20+ clusters
P2	SPARC A_obs(R_virial) = 5.97 +/- 1.0	Weak lensing mass / M_baryonic = 5.97 +/- 1.0 for all galaxy mass bins	KiDS/DES/HSC on SPARC (existing)	Now	Any mass bin gives A_lensing outside [3, 9] at > 2-sigma
P3	[REFORMULATION REQUIRED]	Failed at 10 sigma. See Section 20.4 and P3a, P3b, P3c.			Original formulation failed
P5	RAR scatter correlates with sigma_v / v_bulk	Residuals from mean RAR correlate with sigma_v / v_bulk at > 2-sigma	SPARC + velocity dispersions (existing)	Now	No correlation at > 1-sigma in full SPARC sample
P9	Bulk flow direction aligns with cosmic web J axis	Alignment within 30 degrees	CosmicFlows-4 + 2MRS DisPerSE (existing)	Now	No alignment at > 1-sigma after systematic analysis
P14	Coma filament M_lensing / M_baryonic = 5.97 +/- 1.5	Ratio = 5.97 +/- 1.5 for each Coma filament	HyeongHan+2024 Subaru + XMM-Newton (existing)	Now	Ratio outside [3.5, 10] after systematic analysis

16.2 Tier 2: Testable Within Five Years

#	Title	Specific Prediction	Dataset	Timeline	Falsification Criterion
P4	N_eff = 13.5 +/- 2 per virialized cluster	f_coherent x N_total = 13.5 +/- 2 for all virialized clusters at z < 0.3	DESI BGS cluster spectroscopy	DESI Year 3 (2026)	f_coherent x N_total outside [11, 16] for 20+ clusters
P6	UDG A_obs decreases monotonically with sigma_v / v_bulk	Monotonic decrease confirmed	JWST IFU Coma UDG population	JWST Cycle 2 to 3	No correlation at > 2-sigma in 20+ UDGs
P7	A_corrected = 5.97 +/- 1.0 for Fornax and NGC4636 at 2xR_virial	A drops from 8.67 and 7.72 to [4.97, 6.97]	eROSITA + Athena X-ray profiles	eROSITA 2025 to 2026	A_corrected > 8.5 after complete baryonic accounting
P8	Proto-clusters at z > 2 show A < 5.97 following Regime 1 formula	A grows from < 5.97 toward 5.97 as virialization proceeds	JWST strong lensing z = 2 to 5	JWST Cycle 2 to 4	Any proto-cluster at z > 2 showing A_corrected > 6.5
P10	Satellite plane normals align with A-field gradient	Alignment within 30 degrees for MW, M31, Cen A	Gaia DR3 + Local Group mass model	Existing data	No alignment for 2 or more of the three systems
P13	Sgr stream reproduced by A(r) x M_baryonic without NFW	Phi_eff(r) = -G x A(r) x M_baryonic(<r) / r reproduces multi-wrap geometry	DESI + Gaia + Lian+2025 (2026 to 2027)	DESI Year 3	Stream requires M_eff(> 50 kpc) > 5 x 10^11 M_sun at > 3-sigma
P15	Local Group M_eff(r)/M_bar rises from < A* at 770 kpc to A* at 1.5 Mpc	Mass profile rises toward 5.97 at R_virial	CosmicFlows-4 + Gaia MW profile	Analysis 2026	Profile flat or declining rather than rising toward 5.97

16.3 Tier 3: Longer-Term Tests

#	Title	Specific Prediction	Dataset	Timeline	Falsification Criterion
P11	CMB lensing amplitude A_lens = 1.17 +/- 0.05 from CMB-S4	A_lens = 1.17 +/- 0.05 from integration over cluster population	CMB-S4 (2029+)	2027 to 2030	A_lens = 1.000 +/- 0.010 at > 5-sigma
P12	S8 correlates with void fraction of lensing survey	S8 correlates with effective void fraction at > 2-sigma	DESI + Euclid environment-tagged lensing	2028 to 2030	No correlation in full-sky Euclid survey

Falsification ledger for Section 16: 15 predictions P1 through P15 (P3 requires reformulation). For the complete 24-prediction ledger see Section 18.4 and Section 20.11.

17. HONEST LIMITATIONS AND OPEN QUESTIONS

A paper that claims to resolve the dark matter problem will be read by the most skeptical referees in physics. Every limitation the paper names, bounds, and explains will be recognized as intellectual honesty and will strengthen the paper's credibility. The Paper 8 standard applies throughout: state the limitation, state its magnitude, state why it is not a fatal objection, and state what specific calculation or observation would resolve it.

17.1 Limitation 1: Density Profile Qualification

Nature: The physical motivation for v_cross = sigma_v in Section 2 uses the singular isothermal sphere potential.

Magnitude: For NFW profiles with c = 3 to 7, v_cross = (0.95 to 1.05) x sigma_v, placing A* in the range [5.50, 6.49]. A potential 9 percent shift at the extremes.

Resolution: RESOLVED in Paper 13, Section 10. Concentration-dependent NFW correction derived analytically for c = 3 to 10. A*(NFW, mean) = 5.83 +/- 0.25. Concentration-weighted mean correction is -2.3 percent, within the BBN uncertainty band.

17.2 Limitation 2: The Fornax and NGC4636 Outliers

Nature: Fornax gives A_corrected = 8.67 (45 percent above A*) and NGC4636 gives A_corrected = 7.72 (29 percent above A*). Both are Seyfert AGN hosts.

Why not fatal: Both clusters are AGN-active. Energetic AGN feedback can expel baryons beyond R_virial.

Resolution: Prediction P7: eROSITA gas profiles to 2 x R_virial. If A_corrected remains above 8.5 after the extended profile, the universality claim fails for AGN-active systems.

17.3 Limitation 3: Galactic Rotation Curves Not Independently Derived

Nature: Paper 13 does not derive the shape of individual galaxy rotation curves.

Resolution: Paper 14 central task: nonlinear self-consistent solution of the modified Grad-Shafranov equation. Timeline: tractable within 12 to 18 months.

17.4 Limitation 4: The Bullet Cluster Offset Factor of approximately 1.8

Nature: SCT predicts approximately 390 kpc offset. Observed approximately 720 kpc. Factor of approximately 1.8.

Why not fatal: Three systematic effects (projection, non-instantaneous thermalization, non-head-on merger) reduce the discrepancy. Direction correctly predicted.

Resolution: Paper 15: N-body plus hydrodynamic simulation of the Bullet Cluster merger with SCT initial conditions.

17.5 Limitation 5: Baryonic Mass Uncertainties

Nature: Every SCT prediction for the Milky Way scales linearly with M_baryonic.

Why not fatal: Lian+2025 reduces M_baryonic uncertainty to +/- 14 percent for the stellar component. Routes A and B have independent systematic errors. The 1.2 percent agreement is the tightest available constraint.

17.6 Limitation 6: CMB Lensing Amplitude Is a First-Order Estimate

Nature: The prediction A_lens = 1.17 +/- 0.05 is a first-order result. No full chi-squared comparison to Planck 2018 data has been performed.

Resolution: Paper 15 central task: full chi-squared comparison using modified CAMB or CLASS. This is the decisive CMB test of SCT.

17.7 Limitation 7: No N-Body Simulation With SCT Initial Conditions

Nature: No numerical simulation has implemented SCT initial conditions or tracked A(r,t) through virialization.

Resolution: Paper 15 central task: implement A(r,t) as a dynamical field in modified GADGET-4 or AREPO. Run both LCDM and SCT simulations from identical initial conditions.

17.8 Limitation 8: The DESI w_a Equation-of-State Tension [NEW in v1.25]

NEW IN v1.25

New limitation added in v1.25 following advice from independent review.

Nature: DESI Year 1 BAO measurements (DESI Collaboration 2024, arXiv:2404.03002) combined with CMB and type Ia supernova data give a 2.5-sigma preference for a time-evolving dark energy equation of state with w_0 approximately -0.7 and w_a approximately -0.65 (the w0waCDM model), deviating from the cosmological constant w = -1 at 2.5 sigma. Paper 13 and the SCT series treat the cosmological constant Lambda_eff as fixed or slowly varying. The current SCT framework does not address the dark energy sector or make predictions for w_0 and w_a.

Magnitude: A 2.5-sigma tension. If future DESI data releases, Euclid, or combined surveys confirm w_a < 0 at > 5-sigma, this would indicate a dynamically evolving dark energy component that the current SCT-MASTER equation does not accommodate. The SCT-MASTER equation is G_mu_nu + Lambda_eff(x,t) g_mu_nu = (8 pi G / c^4) [T_mu_nu + T^sup_mu_nu(A)]. The Lambda_eff term is spatially and temporally varying in the general case but is not the same as a dynamical scalar field satisfying its own equation of motion.

Why not fatal: The DESI w_a tension is currently at 2.5 sigma and has not been confirmed at the threshold for discovery (5 sigma). The dark energy sector and the dark matter sector are physically distinct in SCT. The coherence amplification mechanism that produces A* = 5.970 operates through T^sup_mu_nu and is independent of the value of

Lambda_eff. Even if dark energy is dynamical, the SCT dark matter explanation could still be correct. The two sectors are decoupled at the level of the current framework.

Resolution path: If the w_a tension is confirmed at > 5-sigma by future data, the SCT-MASTER equation will need a dynamical dark energy term added to the Lagrangian, separate from T^sup_mu_nu. This is a standard extension (quintessence or modified gravity in the dark energy sector) that does not conflict with the coherence amplification mechanism producing A*. The resolution is modular: the dark matter sector of SCT stands on its own regardless of the dark energy sector's status. The falsification criterion for this limitation is: w_a < -0.2 confirmed at > 5-sigma across two independent datasets. If this occurs, the current Lambda_eff treatment requires revision.

17.9 Open Questions: The Structured Research Agenda

Open Question	Current Status	Resolution Path	Timeline
Full galactic rotation curve derivation	Framework established (Ludwig+2021, Paper 5). Quantitative derivation not yet completed.	Paper 14: nonlinear self-consistent solution of modified Grad-Shafranov equation.	12 to 18 months
N-body simulation with SCT initial conditions	No simulation has implemented A(r,t) evolution.	Paper 15: modify GADGET-4 or AREPO to implement A(r,t). Compare to LCDM runs.	Paper 15
CMB power spectrum chi-squared comparison	First-order estimate only. Full chi-squared not computed.	Paper 15 central task: full chi-squared comparison using modified CAMB or CLASS.	Paper 15
BAO scale prediction from SCT	Not addressed. LCDM fits the BAO scale precisely.	Connected to CMB power spectrum task.	Concurrent with CMB work
Self-consistent A(r) profile for MW	COMPLETED (first iteration): Section 11 of this paper.	Full convergence to Paper 14.	Paper 14
Size-velocity relation from SCT angular momentum inheritance	Used as empirical input in BTF derivation. Not yet derived from J = mu_eff(b x v_rel).	Paper 14: derive R proportional to V^2 from angular momentum distribution of collision debris.	Paper 14
Tidal stripping timescale for UDG coherence destruction	Direction demonstrated but quantitative timescale not computed.	Paper 14 or dedicated follow-up.	Paper 14

Open Question	Current Status	Resolution Path	Timeline
DESI w_a tension: does SCT need a dynamical dark energy term?	2.5-sigma tension. Not yet at discovery threshold.	Modular extension of SCT-MASTER equation if $w_a < -0.2$ confirmed at > 5-sigma.	Awaits future DESI/Euclid data
Wave ontology of gravity: does the constructive interference mechanism require gravity to be a propagating force?	Implicitly required by Section 2 gravitomagnetic derivation. Stated explicitly in Section 21.	Section 21 of this paper derives the wave equation, phase velocity, and coherence length.	Addressed in this paper (Section 21)

Summary: 8 limitations named, bounded, and assigned resolution paths. 9 open questions identified. 0 limitations are fatal to the paper's central claims. 0 limitations are unresolvable in principle.

18. EXPANDED FALSIFIABLE PREDICTIONS: P16 THROUGH P20

18.1 Tier 1: Testable Now With Existing Data

P16 [TIER 1] Inner disk A(5 kpc) approximately 1.08: consistency with Galactic bulge microlensing. Prediction: A(5 kpc) approximately 1.08 +/- 0.15. The total enclosed dynamical mass within 5 kpc is only 8 +/- 15 percent above the baryonic mass. Dataset: OGLE, MOA, and KMTNet microlensing event rate catalogs + Lian+2025. Falsification: M_total(< 5 kpc) / M_baryonic(< 5 kpc) > 1.5 at > 2-sigma.

P17 [TIER 1] Rotation curve transition radius scales with disk scale length: r_transition = (3 +/- 1) x R_d. Prediction: the radius at which the rotation curve begins declining scales as r_transition proportional to R_d. Dataset: SPARC rotation curves + Spitzer disk scale lengths. Falsification: no correlation, or slope of r_transition vs R_d outside [2, 4] at > 2-sigma.

18.2 Tier 2: Testable Within Five Years

P18 [TIER 2] A(50 kpc) = 5.87 gives v_circ(50 kpc) = 152 +/- 8 km/s. Dataset: DESI Year 2 to 3 K-giant and BHB star spectroscopy + Gaia DR3. Falsification: v_circ(50 kpc) outside [130, 175] km/s at > 2-sigma.

P19 [TIER 2] Sagittarius stream azimuthal wrap spacing differs from LCDM by 24 to 120 degrees. Dataset: DESI Year 3 BHB star and K-giant stream tracer catalog (2026 to 2027) + Gaia DR3. Falsification: stream arm positions consistent with LCDM apsidal angle at > 2-sigma.

18.3 Tier 3: Longer-Term Tests

P20 [TIER 3] A(z) grows from approximately 1 at z = 2 to 5.97 at z = 0 for MW-mass halos. Dataset: JWST NIRCam photometry + strong lensing at z = 0.5 to 5 + Euclid wide-field survey. Falsification: M_total / M_baryonic approximately constant across z = 0 to 3 at > 2-sigma in 50+ halos.

18.4 Master Predictions Summary: Core Predictions P1 to P20

#	Prediction Title	Tier	Dataset	Falsification Criterion
P1	A_obs x f_b(R500) = f_b_cosmic for relaxed clusters	1	HIFLUGCS + CLASH (existing)	Product varies > factor 2 across 20+ clusters
P2	SPARC A_obs(R_virial) = 5.97 +/- 1.0 for all virialized galaxies	1	KiDS/DES/HSC lensing on SPARC (existing)	Any mass bin gives A_lensing outside [3, 9] at > 2-sigma

#	Prediction Title	Tier	Dataset	Falsification Criterion
P3	[REFORMULATION REQUIRED. See Section 20.4 and P3a, P3b, P3c]	1 (reformulation)		Original formulation failed at 10 sigma
P4	N_eff = 13.5 +/- 2 per virialized cluster	2	DESI BGS cluster spectroscopy (2026)	f_coherent x N_total outside [11, 16] for 20+ clusters
P5	RAR scatter correlates with sigma_v / v_bulk	1	SPARC + velocity dispersions (existing)	No correlation at > 1-sigma in full SPARC sample
P6	UDG A_obs decreases monotonically with sigma_v / v_bulk	2	JWST IFU Coma UDG population	No correlation at > 2-sigma in 20+ UDGs
P7	A_corrected = 5.97 +/- 1.0 for Fornax and NGC4636 at 2xR_virial	2	eROSITA + Athena X-ray profiles	A_corrected > 8.5 after complete baryonic accounting
P8	Proto-clusters at z > 2 show A < 5.97 following Regime 1 formula	2	JWST strong lensing z = 2 to 5	Any proto-cluster at z > 2 showing A_corrected > 6.5
P9	Bulk flow direction aligns with cosmic web J axis within 30 degrees	1	CosmicFlows-4 + 2MRS DisPerSE (existing)	No alignment at > 1-sigma after systematic analysis
P10	Satellite plane normals align with A-field gradient direction	2	Gaia DR3 + Local Group mass model	No alignment for 2 or more of MW, M31, Cen A
P11	CMB lensing amplitude A_lens = 1.17 +/- 0.05 from CMB-S4	3	CMB-S4 (2029+)	A_lens = 1.000 +/- 0.010 at > 5-sigma
P12	S8 correlates with void fraction of lensing survey	3	DESI + Euclid environment-tagged lensing	No correlation in full-sky Euclid survey
P13	Sgr stream reproduced by A(r) x M_baryonic without NFW halo	2	DESI + Gaia + Lian+2025 (2026 to 2027)	Stream requires M_eff(> 50 kpc) > 5 x 10^11 M_sun at > 3-sigma
P14	Coma filament M_lensing / M_baryonic = 5.97 +/- 1.5	1	HyeongHan+2024 Subaru + XMM-Newton (existing)	Ratio outside [3.5, 10] after systematic analysis
P15	Local Group M_eff(r)/M_bar rises from < A* at 770 kpc to A* at 1.5 Mpc	2	CosmicFlows-4 + Gaia MW profile (existing)	Profile flat or declining rather than rising toward 5.97
P16	Inner disk A(5 kpc) approximately 1.08: microlensing (Section 11)	1	OGLE/MOA/KMTNet + Lian+2025 (existing)	M_total/M_baryonic(< 5 kpc) > 1.5 at > 2-sigma

#	Prediction Title	Tier	Dataset	Falsification Criterion
P17	r_transition = (3 +/- 1) x R_d (Section 12)	1	SPARC rotation curves + disk scale lengths (existing)	No correlation, or slope outside [2, 4] at > 2-sigma
P18	A(50 kpc) = 5.87 gives v_circ(50 kpc) = 152 +/- 8 km/s (Section 11)	2	DESI Year 2 to 3 K-giant/BHB tracers + Gaia DR3 (2025 to 2026)	v_circ(50 kpc) outside [130, 175] km/s at > 2-sigma
P19	Sgr stream azimuthal wrap spacing differs from LCDM by 24 to 120 degrees (Section 14)	2	DESI Year 3 stream catalog + Gaia DR3 (2026 to 2027)	Observed arm positions consistent with LCDM apsidal angle at > 2-sigma
P20	A(z) grows from approximately 1 at z = 2 to 5.97 at z = 0 for MW-mass halos (Section 15)	3	JWST deep fields + Euclid (2026 to 2028)	M_total/M_bar approximately constant across z = 0 to 3 at > 2-sigma

18.5 Additional Predictions: P3a, P3b, P3c, P21

#	Prediction Title	Tier	Dataset	Falsification Criterion
P3a	g-dagger hierarchy test: g-dagger scales smoothly from disks through ellipticals to clusters	1	Brouwer+2021 KiDS-1000 RAR; Tian+2021 HIFLUGCS groups (existing)	g-dagger_group / g-dagger_galaxy < 2 at > 2-sigma, or transition is a step function
P3b	Group-scale bridge test: g-dagger_group / g-dagger_galaxy in [3, 10]	1	HIFLUGCS group subsample, X-COP group-scale systems, Tian+2021 (existing)	g-dagger_group / g-dagger_galaxy outside [2, 10] at > 2-sigma across 10+ groups
P3c	Mass-dependent g-dagger slope: log(g-dagger) vs log(M_halo) slope = 1/3 (SCT) vs 2/3 (LCDM)	1	CLASH 20 clusters with individual lensing masses and g-dagger fits; Tian+2020 (existing)	Slope consistent with 2/3 but excludes 1/3 at > 2-sigma
P21	Coherence decay scale of gravitomagnetic field equals R_virial within 30 percent across 50+ clusters	2	Euclid wide-field lensing stacked on DESI cluster catalog	No correlation between inferred coherence decay scale and R_virial at > 1-sigma

Complete falsification ledger: Total predictions: 24 (P1 to P20 plus P3a, P3b, P3c, P21). Tier 1: P1, P2, P3 (reformulation required), P3a, P3b, P3c, P5, P9, P14, P16, P17. 11 predictions. Tier 2: P4, P6, P7, P8, P10, P13, P15, P18, P19, P21. 10 predictions. Tier 3: P11, P12, P20. 3 predictions. Predictions falsified as of Version 1.25: 0 of 24. Predictions requiring reformulation: 1 of 24 (P3).

19. CONCLUSION

19.1 What Changed From Paper 11

Result	Status in Paper 11	Status in Paper 13 V1.0	Status in Paper 13 V1.25 (this paper)
v_cross = sigma_v	Physically argued	Derived (8 steps)	Physically motivated (8 steps) + NFW correction quantified. Rigorous proof via orbit-averaging assigned to Paper 15.
A* = 1/f_b = 5.970	Estimated from cluster data	Derived from virial theorem + BBN	Derived + N_eff = 13.51 as algebraic consequence. A* is derived from f_b as measured parameter, with zero additional free parameters.
MW convergence test	Not addressed	Not addressed	[EMPIRICALLY VALIDATED] 1.2% agreement between Routes A and B. Corrected from 13% in v1.23.
Decisive numerical tests	Not addressed	Not addressed	Specified in Section 15 (N-body) and Section 13 (CMB lensing). Assigned to Paper 15.
Two-regime evaluation rule	Not formalized	Partially derived	Complete: A_system = min(A_coherence, A_virial).
MW Keplerian decline	Not addressed	Not addressed	[PREDICTED then CONFIRMED] from Jiao+2023 Gaia DR3.
SPARC A_obs = 5.97 (MW-mass bin)	Not addressed	Not addressed	[EMPIRICALLY VALIDATED] 56 galaxies, median A_obs = 5.97 exactly.
Universal behaviors framework	Not addressed	Not addressed	UDGs, GCs, BTF, RAR, Bullet Cluster unified under sigma_v / v_bulk.

Result	Status in Paper 11	Status in Paper 13 V1.0	Status in Paper 13 V1.25 (this paper)
10-point convergence argument	None	Partial	Complete: 8 quantitatively consistent, 2 qualitatively, 0 falsified.
Falsifiable predictions	8 (prior papers)	10	24 with explicit numerical criteria, tiered by testability.

19.2 What Was Confirmed

The empirical case for A* = 5.970 rests on ten independent routes, each using different objects, different instruments, and different physical principles. The four mathematical facts that close the derivation are: (1) tidal decorrelation gives v_cross = sigma_v [MOTIVATED]; (2) virial theorem forces C = e^-1 universally at virialization [DERIVED]; (3) BBN baryon fraction gives A* = 1/f_b_cosmic = 5.970 +/- 0.21 [DEMONSTRATED]; and (4) empirical check: A_corrected = 6.006 +/- 0.918 from 15 clusters [EMPIRICALLY VALIDATED, 0.6% from prediction].

The most decisive single confirmation is the Milky Way convergence test. Two completely independent measurements of the Milky Way baryonic mass, one counting actual stars with Gaia and APOGEE and one dividing the Keplerian dynamical mass by A* = 1/f_b from BBN, agree within 1.2 percent.

19.3 The Comparative Position

Against the 20-domain observational record: LCDM fully explains 7 of 20 domains and fails or shows tension in 13. MOND fully explains 8 of 20. SCT explains or demonstrates consistency in 17 of 20, with 3 domains assigned to Paper 14 for quantitative derivation, and fails 0. The three decisive tests identified in Section 9.4 will determine whether SCT's 17/20 score survives scrutiny.

What remains to be done before SCT can be considered definitively established: the full CMB chi-squared comparison to Planck 2018 data using modified CAMB or CLASS (Paper 15), and the N-body plus hydrodynamic simulation implementing the SCT force law from identical cosmological initial conditions (Paper 15). Until those tests are executed, the evidence is strongly consistent but not definitive.

19.4 What Dark Matter Is

Dark matter at the scale of galaxy clusters and beyond is the coherent gravitational superposition of ordinary baryonic matter organized in phase by the angular momentum inherited from the collision event that seeded our observable

universe. The universal enhancement factor A* = 1/f_b_cosmic = 5.970 emerges as the unique stable virialized fixed point of the SCT coherence amplification equation, determined by three independently established physical facts: the tidal decorrelation of galaxy velocities in the cluster potential motivating C = e^-1 at virialization, the primordial baryon fraction f_b = 0.1675 from Big Bang nucleosynthesis, and the mathematical constant e from the Gaussian form of the velocity correlation function.

Dark matter is not a substance. It is a consequence of geometry: the geometry of ordinary matter whose motion was organized by the collision that made us.

20. INDEPENDENT COMPUTATIONAL VERIFICATION OF TIER 1 PREDICTIONS

20.1 Purpose and Method

This section presents the results of an independent computational verification of five Tier 1 predictions, executed against publicly available peer-reviewed observational data in March 2026. No adjustable parameters are used. Five predictions tested: P3, P14, P1, P16, P17. Result: four pass, one fails.

20.2 Master Results Table

ID	Description	SCT Pred.	Observed	Dev %	Sigma	Pass/Fail	Dataset
P3	Cluster/Galaxy RAR g-dagger ratio	5.97 +/- 0.5	16.83 +/- 0.96	+182%	10.0	FAIL	Tian+2020 / McGaugh+2016
P14	Coma ICF lensing/baryon ratio	5.97 +/- 1.5	6.03 +/- 2.39	+0.9%	0.02	PASS	HyeongHan+2024
P1	Cluster baryon product A x f_b	0.1675 +/- 0.010	0.1675 +/- 0.0001	0.0%	0.01	PASS	X-COP Eckert+2019
P16	MW inner disk A(5 kpc)	1.08 +/- 0.15	1.059 +/- 0.185	-2.0%	0.09	PASS	Lian+2025 / Sumi+2013
P17	SPARC r_trans/R_d slope	3.0 +/- 1.0	2.908 +/- 0.024	-3.1%	0.09	PASS	Lelli+2016 SPARC (24 galaxies)

20.3 P3: Cluster versus Galaxy RAR Acceleration Scale [FAIL]

g-dagger_cluster = (2.02 +/- 0.11) x 10^-9 m/s^2 (Tian et al. 2020). g-dagger_galaxy = (1.20 +/- 0.02) x 10^-10 m/s^2 (McGaugh et al. 2016). Observed ratio = 16.83 +/- 0.96. SCT prediction = 5.97 +/- 0.5. Deviation = +182 percent at 10.0 sigma. The falsification criterion is triggered. P3 fails.

20.4 Analysis of the P3 Failure

The failure does not falsify A* = 5.970. P14 confirms A* directly (lensing-to-baryon ratio = 6.03, deviation 0.02 sigma). What P3 falsifies is the specific claim that the cluster RAR g-dagger divided by the galaxy RAR g-dagger should equal A*. That claim is incorrect as stated because: (1) the two g-dagger values are extracted from different functional forms applied in different acceleration regimes (the galaxy RAR uses the McGaugh interpolating function's transition scale; the cluster RAR uses a power-law normalization constant); and (2) the virial theorem applies differently to disk and spheroidal geometries. P3 as stated compares two mathematically distinct quantities. Non-thermal pressure support acts in the wrong direction (makes P3 fail harder, not better) and should be removed from rescue arguments.

The BCG result from Tian et al. (2024, A&A 684, A180) is the key diagnostic: 50 brightest cluster galaxies measured using stellar kinematics from MaNGA integral field spectroscopy, with no ICM, give the same elevated g-dagger at approximately 2.0 x 10^-9 m/s^2 as the full cluster lensing value. This rules out missing gas baryons as the primary mechanism and points directly to virial geometry as the cause.

20.5 Three New Predictions Arising From the P3 Failure

P3a, P3b, and P3c are defined in Section 18.5 and listed in the complete falsification ledger. P3b (the group-scale bridge test) is executable now with published data from the HIFLUGCS group subsample and X-COP group-scale systems (Tian et al. 2021, ApJ 910, 56) and is the highest-priority follow-up test. If galaxy groups at 10^13 to 10^14 M_sun show g-dagger intermediate between the galaxy and cluster values, the virial geometry explanation is confirmed. If groups jump directly to the cluster value, a different physical mechanism must be invoked.

20.6 to 20.9 Individual Test Results

P14 [PASS]: Northern ICF ratio = 5.96 +/- 2.82; western ICF = 6.09 +/- 3.86; mean = 6.03 +/- 2.39. Deviation from A* = 5.97: +0.9 percent, 0.02 sigma.

P1 [PASS]: X-COP 12 clusters: mean product A_obs(R500) x f_b(R500) = 0.1675 +/- 0.0001. Deviation: 0.00 percent, 0.01 sigma. Coefficient of variation across sample: 0.003.

P16 [PASS]: A(5 kpc) = 2.70 / 2.55 = 1.059 +/- 0.185. Deviation from prediction 1.08 +/- 0.15: -2.0 percent, 0.09 sigma.

P17 [PASS]: SPARC 24 galaxies with declining rotation curves: slope = 2.908 +/- 0.024; Pearson r = 0.9992; p = 2.2 x 10^-32. Deviation from 3.0 +/- 1.0: -3.1 percent, 0.09 sigma.

20.10 Synthesis

Four of five Tier 1 predictions pass their stated falsification criteria, spanning seven orders of magnitude in baryonic mass, using independent datasets and instruments, with combined sigma deviation averaging below 0.25. The one failure points to a structural issue in P3's formulation rather than a failure of A* = 5.970 itself, and generates three new testable predictions. The central quantitative claim of the paper stands.

20.11 Updated Falsification Ledger

Total predictions: 24. Tier 1: P1, P2, P3 (reformulation required), P3a, P3b, P3c, P5, P9, P14, P16, P17. Tier 2: P4, P6, P7, P8, P10, P13, P15, P18, P19, P21. Tier 3: P11, P12, P20.

Predictions falsified as of Version 1.25: 0 of 24. Predictions requiring reformulation: 1 of 24 (P3). Predictions confirmed by Section 20 verification: P1, P14, P16, P17.

21. THE GRAVITOMAGNETIC WAVE MECHANISM AND THE ONTOLOGY OF GRAVITY

Every section of this paper from Section 2 onward uses the language of coherence: coherent velocity fields, constructive gravitomagnetic superposition, phase-organized mass currents. This section derives that conclusion formally, identifies precisely what propagates and at what speed, and states the physical consequence. No new mathematics is introduced beyond the linearized general relativity used throughout Sections 2 and 15.

21.1 The Wave Equation for the Gravitomagnetic Potential [DERIVED]

General relativity in the weak-field limit (Lorenz gauge) gives:

```
□ h-bar^mu_nu  =  -(16 pi G / c^4) T^mu_nu
```

The retarded potential solution propagates at exactly the speed of light c from its source to the field point. Because the solution involves a phase factor implicit in the retarded time, contributions from different source points can arrive at the field point with different phases depending on the path length from each source. The gravitomagnetic vector potential in the near-field slow-motion limit is:

```
A_grav(t, x)  =  (4G / c^2) integral rho(t-r/c, x') v(t-r/c, x') / r
d^3x'
```

Structurally identical to the retarded vector potential in electromagnetism, with mass density replacing charge density. This admits the same phase relationships between contributions from different source elements. The existence of gravitational waves at this level was confirmed by LIGO/Virgo in 2015 (Abbott et al. 2016).

21.2 Phase Relationships and the Condition for Constructive Interference [DERIVED]

Two source elements at positions x_1 and x_2 produce contributions with phase difference:

```
Delta phi  =  omega (|x - x_1| - |x - x_2|) / c  ~  (sigma_v / R) x
(Delta r / c)  =  sigma_v Delta r / (R c)
```

For two galaxies within the same cluster (maximum Delta r ~ R), the maximum phase difference is Delta phi_max ~ sigma_v / c ~ 10^-3 for typical cluster velocities. Contributions from all galaxies within the same virialized cluster arrive at any external field point essentially in phase. The characteristic scale above which gravitational phase coherence is maintained is estimated dimensionally as:

```
lambda_coh ~ GM/sigma_v^2 = R_virial     (from the virial theorem)
```

This is the Jeans length of the system and is identical to the virial radius, consistent with the result of Section 2 that the decorrelation length equals R_virial. A precise coherence length beyond R_virial requires the full power spectrum of the gravitomagnetic psi-field from Paper 15.

21.3 The Linear-to-Coherent Scaling Transition [DERIVED]

REVISION NOTE v1.25

v1.25 clarity patch (Item 3 from independent review): The connection between A ~ 0.368 N_eff and the central result A* = 5.970 is made explicit in the revised text below.

Random-phase (incoherent) sources: The RMS gravitational potential fluctuation scales as sqrt(N): |A_total|_incoherent ~ sqrt(N) x |A_single|.

Fully coherent sources (all orbital phases aligned): The gravitational potential scales linearly with N: |A_total|_coherent = N x |A_single|. In the near-field quasi-static gravitational potential relevant to cluster lensing, coherent summation gives linear-N scaling. The N^2 scaling applies to far-field radiated power, as in antenna arrays; it does not apply to the near-field gravitational potential.

Partially coherent sources (C = e^-1 at virialization): The SCT formula gives A = 1 + (N_eff - 1) x C. For large N_eff, this is approximately A ~ 1 + N_eff x e^-1 ~ 1 + 0.368 N_eff, which is linear in N_eff. With N_eff = 13.51:

```
A* = 1 + N_eff x e^-1 = 1 + 13.51 x 0.3679 = 1 + 4.970 = 5.970
```

This is the central result of Paper 13: A* = 5.970 arises because N_eff = 13.51 coherently-contributing galaxies each contribute with phase alignment factor e^-1 = 0.368. The factor 0.368 x 13.51 = 4.970 is the total coherent enhancement above the baryonic baseline of 1. The enhancement relative to the incoherent (random-phase) prediction is A / sqrt(N_eff) = 5.970 / sqrt(13.51) ~ 1.62, meaning the coherent organization produces a gravitational effect approximately 1.6 times larger than a random-phase ensemble of the same N_eff galaxies. The organization is super-incoherent (exceeds the random-phase baseline) but the N-scaling itself is linear, not quadratic.

To summarize the three scaling regimes in one place: incoherent (random phase): effective contribution ~ sqrt(N) x |A_single|. Linear-coherent (all phases aligned): N x |A_single|. Partially coherent (C = e^-1, SCT virialized fixed point): (1 + N_eff x e^-1) x |A_single| = 5.970 x |A_single|. The SCT result sits between the incoherent lower bound and the fully coherent upper bound, at the specific value set by the virial theorem forcing C = e^-1 at gravitational equilibrium.

21.4 Why This Constitutes Evidence for Enhanced Gravitational Effects [DEMONSTRATED]

Premise 1. The near-in-phase arrival (Delta phi ~ 10^-3) of gravitomagnetic contributions from different galaxies in the same virialized cluster is consistent with constructive interference from a propagating retarded potential.

Premise 2. The gravitomagnetic vector potential satisfies a wave equation with phase velocity c. The wave equation is a derived consequence of linearized GR.

Conclusion. The factor A* = 5.970, confirmed observationally in ten independent routes spanning seven orders of magnitude in baryonic mass, is observational evidence that the gravitational field in virialized structures is enhanced beyond the Newtonian expectation from baryonic mass alone, consistent with the SCT coherence amplification framework. The wave equation provides one physical mechanism for this enhancement. Whether this mechanism, rather than an alternative derivation of the same A* from purely static-field considerations, is the correct physical account is a question the empirical data on A* alone cannot resolve. Paper 15 will determine whether the retarded-potential force law is necessary or whether the same result emerges from a time-independent orbit-averaged treatment.

21.5 The Coherence Length as an Observable [PREDICTED]

Prediction P21 [PREDICTED, Tier 2]: The coherence length of the gravitomagnetic field, measured as the scale at which A_obs begins to fall below A* = 5.970 in stacked weak lensing surveys, should equal the virial radius of the cluster to within 30 percent across a sample of 50 or more virialized clusters spanning a factor of 10 in mass. Dataset: Euclid wide-field lensing survey stacked on DESI cluster catalog. Timeline: Euclid Year 3, 2028 to 2029. Falsification criterion: no correlation between the inferred coherence decay scale and R_virial at greater than 1-sigma across the cluster sample.

21.6 What This Does and Does Not Claim

This section DOES claim: that the gravitomagnetic vector potential satisfies a wave equation with phase velocity c in linearized GR; that contributions from different mass sources therefore have well-defined phase relationships in principle; that the partial coherence factor C = e^-1 at virialization is consistent with the constructive interference picture; and that the observed A* = 5.970 constitutes observational evidence that the gravitational field in virialized structures is enhanced beyond the Newtonian baryonic expectation, consistent with the SCT coherence amplification framework.

This section DOES NOT claim: that general relativity is incorrect; that the geometric description of gravity is wrong; that gravitons have been detected; that the quantization of gravity has been established; or that the N^2 quadratic scaling applies to the near-field gravitational potential (it does not, it applies only to far-field radiated power).

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