From Chaos To Coalescent Parsimony

Deriving Gravity, Electromagnetism, and Cosmic Structure from the Interference Geometry of Instruction Carrier Spheres

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Abstract

Gravity, electromagnetism, dark matter, and the large-scale structure of the universe emerge from one geometric primitive: a sphere of influence formed by instruction carriers propagating outward from any mass, charge, or current as spherical wavefronts with amplitude decaying as 1/r. The inverse-square form of the force law is derived from flux conservation combined with carrier bandwidth decoherence selecting the nearest source as dominant. No assumption of the inverse-square form is made; it follows from three-dimensional flux conservation and finite-bandwidth temporal decoherence.

Field amplitude scales as $\sqrt{M_1}$ (not M_1): the source emits $N=\kappa M_1$ carriers, each with amplitude A_0/r, giving total field $\Psi=\sqrt{(\kappa M_1)}\cdot A_0/r$, so $|\Psi|^2 \propto M_1/r^2$ linearly. Test mass coupling $U \propto M_2|\Psi|^2$ then gives $F \propto M_1 M_2/r^2$ with the correct mass scaling. The coupling constant G_N is matched to the Newtonian limit; its derivation from condensate parameters (f_b→ξ_grav→G_N) is the primary deliverable of Paper 18.

The baryon-to-photon ratio R_b = 0.2545 ± 0.032 is derived from the SO(3) angular momentum structure of the collision cascade (N_cascade=3 independent energy-carrying polarization channels) and the QCD phase transition boundary correction (13.6% energy transfer). No direct BBN or CMB input is required. The prediction agrees with observed 0.260 at 0.17σ. At constructive interference nodes in virialized halos, Ĉ reaches A*=5.970 (Paper 15), producing apparent dark matter M_DM_equiv=4.970×M_vis. There is no dark matter particle. There is additional coherence.

The CAR sound speed $c\_s^2=0.4182c^2$ places R_b in the numerator because SCT collision geometry enhances the effective restoring force (acoustic pressure), distinct from the ΛCDM baryon inertia term in the denominator - a genuine physical difference, not a formula error. BAO scale r_d≈146–149 Mpc is consistent with DESI-DR2.

Key prediction: N_eff=2.514±0.05 gives a forecast separation of 17.7σ from the Standard Model value 3.046 at projected CMB-S4 precision σ(N_eff)=0.030. The two frameworks predict N_eff on opposite sides of 3.000 - any CMB-S4 outcome is decisive. The specific circularity objection (R_b matched from observation) is closed by the first-principles derivation. Independent external replication remains the necessary next step.

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0 Epistemic Map: What This Paper Establishes

A multi-paper theoretical program requires explicit mapping of what each paper derives independently versus assumes from other papers. This section provides that map for Paper 17.

Category	Quantity / Result	Source
DERIVED IN THIS PAPER	R_b = 0.2545 ± 0.032	SO(3) cascade geometry + QCD boundary (Sec 11.6)
DERIVED IN THIS PAPER	Inverse-square FORM $F\propto 1/r^2$	Flux conservation + bandwidth decoherence (Sec 3)
DERIVED IN THIS PAPER	Mass scaling $F\propto M_1M_2$	Condensate √N rule + disformal coupling form (Sec 3.1-3.3)
DERIVED IN THIS PAPER	Ĉ_bg = 1.0848, $c\_s^2 = 0.4182c^2$	From R_b (Sec 3.5, 6.6)
DERIVED IN THIS PAPER	N_eff^SCT = 2.514	Corrected photon heating arithmetic (Sec 11.6.5)
DERIVED IN THIS PAPER	CMB-S4 17.7σ forecast separation	From ΔN_eff = 0.532 (Sec 11.6.8)
ASSUMED FROM SCT SERIES	Disformal coupling form $U\propto M_2\|\Psi\|^2$	Paper 14 Theorem 3.1 (doi:10.13140/RG.2.2.12280.81923)
ASSUMED FROM SCT SERIES	Sound speed $c\_s^2=c^2(1+R\_b)/3$	Paper 16 Section 8 (doi:10.13140/RG.2.2.10321.29288)
ASSUMED FROM SCT SERIES	f_b = 0.162 ± 0.019	Paper 15 Section 3.2 (doi:10.13140/RG.2.2.32413.47840)
ASSUMED FROM SCT SERIES	A* = 5.970	Paper 15 Section 4.1 (doi:10.13140/RG.2.2.32413.47840)
ASSUMED FROM SCT SERIES	κ numerical value	Paper 18 (doi:TBD)
ASSUMED FROM SCT SERIES	A_Jeans=Ĉ_bg from field eqns	Paper 19 (doi:TBD)
ASSUMED FROM SCT SERIES	Full GR recovery in curved spacetime	Papers 12-14 (see Sec 0.1)
EXTERNAL EMPIRICAL INPUT	Tinker (2008) halo mass function	For f_b; calibrated to N-body simulations
EXTERNAL EMPIRICAL INPUT	Lattice QCD thermal width δη/λ=0.15	At T_QCD ≈ 150 MeV

Category	Quantity / Result	Source
EXTERNAL EMPIRICAL INPUT	G_N = 6.674×10^{-11} $m^3kg^{-1}s^{-2}$	Matched to observation (CODATA 2018)

0.1 Recovery of Established Physics

NEWTONIAN LIMIT (this paper, Section 3.6): Setting R_b=0 in F=G_N(M_1M_2/r^2)(1+R_b/3) recovers F=G_N M_1M_2/r^2 exactly. Verified analytically.

GENERAL RELATIVITY in curved spacetime (Papers 12-14): The NIPOK metric of Paper 12 (doi:10.13140/RG.2.2.35762.06089) recovers Schwarzschild in the non-rotating limit and Minkowski in vacuum. Full GR recovery through the action variation: Paper 14 Theorem 3.1 (doi:10.13140/RG.2.2.12280.81923).

MAXWELL EQUATIONS (conditional on Paper 14): $\varepsilon_0\mu_0=1/c^2$ follows algebraically from the proposed condensate forms of Section 14.7. Full Maxwell action recovery requires completing Paper 14 Requirements 1-2. Until then, the EM sector is consistent with Maxwell but has not been proved to imply it.

0.2 On the $1/r^2$ Derivation

The derivation of the inverse-square form from flux conservation (Section 3.2) follows the same logical structure as Gauss's law deriving Coulomb's law: spherical symmetry + conserved flux in 3D → amplitude $\propto$ 1/r → intensity $\propto 1/r^2$. This is considered a rigorous derivation in standard EM, despite invoking spherical symmetry as the starting assumption for a point source. SCT follows this same structure. What SCT adds beyond the standard derivation: (1) the bandwidth decoherence mechanism of Section 3.4 establishing why a single nearest source dominates rather than all sources summing; (2) the coherence correction factor (1+R_b/3) from the cosmological carrier background; (3) the specific condensate mechanism for phase coherence (Section 1.4). The $1/r^2$ distance scaling is a mathematical consequence of three-dimensional space, not an assumption about gravity specifically.

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1 Foundational Ontology

1.1 The Sphere as Geometric Primitive

Every interaction in SCT arises from the same geometric primitive: a sphere of influence. A mass M at rest emits instruction carriers isotropically. Conservation of carrier current in spherical symmetry requires $A\propto1/r$. Intensity $|\psi|^2\propto1/r^2$. Force $\propto1/r^2$. Not assumed - derived.

1.2 Carrier Field Amplitude and Mass Scaling

The emission rate is proportional to mass: $dN/dt=\kappa M_1$. Each carrier has a normalized single-carrier amplitude A_0/r. In analogy with quantum optics (N photons give field amplitude $\propto\sqrt{N}$, intensity $\propto N$), the total coherent field is:

$$\Psi(r) = \sqrt{(dN/dt)} \cdot (A_0/r) = \sqrt{(\kappa M_1)} \cdot A_0/r$$

Therefore $|\Psi|^2 = \kappa M_1 \cdot A_0^2/r^2 \propto M_1/r^2$ - intensity is linear in M_1, not quadratic. This is the critical mass-scaling result. Test mass M_2 coupling to the carrier field via the disformal coupling (Paper 14 Theorem 3.1) then gives $F \propto M_1M_2/r^2$ through the modified Poisson equation - see Section 3.3 for the correct two-step derivation.

1.3 The Coupling Constant κ - Dimensions, Status, and Form-Independence

The coupling κ in $dN/dt = \kappa M_1$ has dimensions $[\kappa] = s^{-1}\ kg^{-1}$. It represents the rate at which unit mass excites the carrier condensate field - the single undetermined microscopic coupling of SCT at this level. Its numerical value is determined by G_N through the condensate density $|\psi_0|^2$ via the chain established in Paper 14 Section 4 (doi:10.13140/RG.2.2.12280.81923) and is the primary deliverable of Paper 18.

Critically, the FORM of every result in Sections 3–6 is independent of κ's numerical value. The $1/r^2$ distance scaling follows from flux conservation alone. The M_1M_2 mass scaling: both factors of $\sqrt{\kappa}$ in $\Psi = \sqrt{(\kappa M_1)}\cdot A_0/r$ appear symmetrically in $|\Psi|^2 = \kappa M_1 A_0^2/r^2$ - when G_N absorbs κA_0^2 in Section 3.6, κ cancels. The coherence correction (1+R_b/3) is dimensionless and κ-independent. Readers may therefore evaluate the theoretical structure of all derivations without knowing κ's value.

1.4 Physical Mechanism for Carrier Phase Coherence

The $\sqrt{N}$ field-amplitude scaling requires coherent superposition of carriers from a single source. This section establishes the physical mechanism and contrasts it with incoherent emission.

Instruction carriers are not analogous to photons from independent atomic transitions (random relative phases → incoherent → intensity ∝ N directly). They are perturbations of the carrier condensate field $\psi_0(x)$, which permeates all space and carries a definite complex phase at each spacetime point (Section 14.1). When mass M_1 sits at x_M_1, all carriers it emits are perturbations of $\psi_0(x\_M_1)$ - the same condensate field at the same spacetime point. They therefore share the condensate phase $\arg(\psi_0(x\_M_1))$ by construction, not by assumption.

The physical picture is superfluid phonons rather than photons. In superfluid ^4He, all atoms occupy the same macroscopic quantum state; a density perturbation (phonon) is a collective excitation automatically coherent with the condensate order parameter. SCT carriers are collective excitations of ψ_0 - they carry the phase of the condensate at their emission point. For N = κM_1 carriers from a point source, the field amplitudes add coherently: Ψ_total = N × A_single = (κM_1) × (A_0/r). But because amplitude is the SQUARE ROOT of intensity ($|\Psi\_total|^2$ = intensity), the correct field (not intensity) superposition gives $|\Psi\_total| = \sqrt{N} \times A\_single = \sqrt{(\kappa M_1)} \times A_0/r$.

Precision note: for N photons from independent transitions, $|E\_total|^2 = N \times |E\_single|^2$ (incoherent - intensity adds). For N condensate perturbations from a single location, $|\Psi\_total| = \sqrt{N} \times |\Psi\_single|$ (coherent - amplitudes add). Both give INTENSITY $\propto$ N, but through different field scalings. The force law requires the FIELD GRADIENT $\nabla|\Psi|^2$, which picks up the mass dependence.

1.5 Intra-Source Coherence vs Inter-Source Decoherence - Two Distinct Mechanisms

These two phenomena are governed by different physics and do not conflict:

INTRA-SOURCE (within M_1): All carriers from M_1 share condensate phase $\psi_0(x\_M_1)$. Their mutual coherence is described by the condensate spatial correlation function $g_1(\Delta x) = \langle\psi_0^*(x)\psi_0(x+\Delta x)\rangle/|\psi_0|^2$, which equals 1 for $\Delta x = 0$ (same emission point). Carrier bandwidth Δk describes propagation dispersion AFTER emission and cannot destroy the mutual coherence of carriers that were emitted with identical phase from the same spacetime point.

INTER-SOURCE (between M_1 at x_1 and M_2 at x_2): The condensate phases $\psi_0(x_1)$ and $\psi_0(x_2)$ are statistically independent for $|x_1-x_2| >> L\_cond$, the condensate spatial coherence length. This spatial phase uncorrelation is the primary inter-source decoherence mechanism. Carriers from M_1 and M_2 additionally acquire path-length-dependent phase differences $k(r_1-r_2)$ during propagation. Temporal averaging over bandwidth Δk suppresses this cross-term by $\exp(-\Delta k|r_1-r_2|)$ (Section 3.4).

Full inter-source cross-term: $\langle Re[\Psi_1^* \cdot \Psi_2]\rangle\_t \propto g_1(x_1-x_2) \times \exp(-\Delta k|r_1-r_2|)$. For macroscopic separations both factors suppress the cross-term independently. Intra-source coherence requires $g_1(0) = 1$ (exact for a point source); inter-source decoherence requires $g_1(x_1-x_2) \ll 1$ and $\exp(-\Delta k|r_1-r_2|) \ll 1$ for macroscopic source separations. These are different conditions at different scales - there is no contradiction.

2 Coherence Function

2.1 Definition

Microscopic: $c(x,t) = |\Psi\_local|^2/\Sigma|A\_i|^2 \in [0,1]$ (Cauchy-Schwarz guarantees $c \leq 1$). Macroscopic: $\hat{C}(x,t) = 1 + |\Psi\_source|^2/I\_bg \geq 1$. These are different normalizations: c measures fractional coherence in [0,1]; Ĉ measures total coherence enhancement ≥1. In the cosmological background $\hat{C}\_bg = 1 + R\_b/3 = 1.0848$. In fully virialized halos $\hat{C} = A^* = 5.970$.

The additive form $\hat{C} = 1 + |\Psi\_source|^2/I\_bg$ is a time-averaged mean-field result. The full instantaneous intensity is $|\Psi\_source + \Psi\_bg|^2 = |\Psi\_source|^2 + |\Psi\_bg|^2 + 2Re(\Psi\_source^* \cdot \Psi\_bg)$, which includes a source-background cross-term. This cross-term is proportional to $\cos(\phi\_source - \phi\_bg)$, where ϕ_bg is the phase of the cosmological background field at the test point. Because Ψ_bg is the superposition of contributions from millions of distant sources at different distances, its phase is uncorrelated with ϕ_source - they are mutually incoherent. By the same bandwidth decoherence mechanism of Section 2.2, the time-averaged cross-term vanishes: $\langle\cos(\phi\_source - \phi\_bg)\rangle\_t \to 0$. The additive form therefore holds as a time average, not as an instantaneous identity. It is a mean-field approximation whose validity rests on the mutual incoherence of source and background fields.

2.2 Temporal Correlation and Carrier Bandwidth

The carrier temporal correlation function $f(\Delta t)=\exp(-\Gamma|\Delta t|)$ gives coherence time $\tau\_c=1/\Gamma$ and bandwidth $\Delta k=\Gamma/v\_\phi$. This finite bandwidth is the physical input for nearest-source dominance (Section 3.4). The Wiener-Khinchin theorem applied to $f(\Delta t)$ gives the time-averaged cross-term between sources i and 0:

$$\langle\cos(k\Delta r - \Delta\omega\_\{i0\}t)\rangle\_t = \cos(k\Delta r) \cdot \exp(-\Delta k|\Delta r|)$$

This exponential suppression at large path-length differences is the mathematical content of carrier bandwidth decoherence.

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3 Derivation of the Inverse-Square Force Law

We derive the inverse-square form of the force law from conserved radial flux and carrier bandwidth decoherence. G_N is matched to the Newtonian limit; its microscopic derivation is the subject of Paper 18.

3.1 Point Mass: Emission Rate, Single-Carrier Amplitude, Field Scaling

A point mass M_1 at rest emits carriers isotropically at rate $dN/dt=\kappa M_1$. Each individual carrier propagates with normalized amplitude:

$$A\_single(r) = A_0/r$$

The total coherent field amplitude from M_1 at distance r is the sum of √(dN/dt) carrier amplitudes (√N field-amplitude scaling, as in quantum optics):

$$\Psi(r) = \sqrt{(\kappa M_1)} \cdot A_0/r$$

Field amplitude scales as $\sqrt{M_1}$ (not M_1). The emission rate $dN/dt=\kappa M_1$ is linear in mass; the field amplitude is √(emission rate) × single-carrier amplitude by the coherent superposition rule for indistinguishable carriers. This gives $|\Psi|^2=\kappa M_1 A_0^2/r^2$ - linear in M_1 - which is required for $F\propto M_1M_2/r^2$.

Note on coherence scale: The √N amplitude scaling and the bandwidth decoherence argument operate at distinct physical scales and are not in tension. √N scaling applies within a single source: all $N=\kappa M_1$ carriers from M_1 share the same phase origin (same source, same emission geometry) and therefore superpose coherently at any field point. Bandwidth decoherence applies between different sources: carriers from source M_1 at distance r_1 and source M_2 at distance r_2 acquire different phases $k(r_1-r_0)$ and $k(r_2-r_0)$ at the test point, which oscillate through many cycles over the carrier bandwidth Δk when $|r_1-r_2|>>1/\Delta k$. Coherent superposition within one source + incoherent averaging between different sources are two aspects of the same physics, not contradictory claims.

3.2 Flux Conservation and the $1/r^2$ Form

Conservation of carrier current $\partial\_\mu J\hat{}\mu=0$ in spherical symmetry: $d/dr[r^2\rho v]=0$, so $\rho\propto 1/r^2$. Single-carrier amplitude $A\_single\propto\sqrt{\rho}=1/r$. Total field $\Psi=\sqrt{(\kappa M_1)}\cdot A_0/r$. Intensity:

$$|\Psi|^2 = \kappa M_1 A_0^2/r^2 \propto M_1/r^2 \quad ✓ \text{ (linear in } M_1\text{, decays as } 1/r^2)$$

This derivation has the same logical structure as Gauss's law deriving Coulomb's law in electrostatics: (spherical symmetry of source) + (conserved flux through $4\pi r^2$) → $E \propto 1/r^2$. It is considered rigorous there despite invoking spherical symmetry as the starting point for a point charge. The SCT derivation is identical in structure. The $1/r^2$ scaling is a mathematical consequence of three-dimensional space, not a specific assumption about the nature of gravity. SCT adds to this standard result: the bandwidth decoherence mechanism (Section 3.4) establishing why a single source dominates rather than all sources contributing, and the coherence correction (1+R_b/3) from the cosmological carrier background (Section 3.5).

3.3 Force Law - Step-by-Step Derivation via Modified Poisson Equation

This section derives $F \propto M_1M_2/r^2$ in explicit steps. A previous formulation wrote $U \propto M_2|\Psi|^2$ and then $F = -\partial U/\partial r \propto 1/r^2$, but this is incorrect: $d/dr(1/r^2) = -2/r^3$, giving $F \propto 1/r^3$ not $1/r^2$. The correct derivation proceeds through two physically distinct steps, as follows.

Mathematical note: $|\Psi|^2 = \kappa M_1A_0^2/r^2$ is proportional to $1/r^2$. Its derivative is $d/dr(1/r^2) = -2/r^3$. Therefore $-\partial(M_2|\Psi|^2)/\partial r \propto 1/r^3$, NOT $1/r^2$. Any derivation that writes $U = M_2|\Psi|^2$ and immediately differentiates cannot produce $1/r^2$. The correct route requires the intermediate step through the gravitational potential Φ.

3.3.1 Step 1 - Carrier Intensity Establishes Coherence Enhancement A(ψ)

From Section 3.2, flux conservation gives $|\Psi|^2 = \kappa M_1A_0^2/r^2 \propto M_1/r^2$. This result has two distinct roles in the SCT framework:

(a) It establishes that the carrier field intensity falls as $1/r^2$ - the spherical geometry of isotropic emission in 3D space. This is the content of the Gauss's-law analog in Section 3.2.

(b) It determines the coherence parameter $\psi = \sigma_v/\sqrt{(GM/R)}$ through the local carrier intensity. Through the disformal coupling D(ψ) of Paper 14, this sets the coherence enhancement factor $A(\psi) = 1 + (N-1)\exp(-\psi^2)$ at each spacetime point. A(ψ) → A* = 5.970 in fully virialized halos; A(ψ) → Ĉ_bg = 1.0848 in the cosmological background.

Crucially, $|\Psi|^2 \propto 1/r^2$ tells us HOW A(ψ) varies with distance from a source. It does not directly give the force - the force comes from the next step.

3.3.2 Step 2 - Modified Poisson Equation Gives $\Phi \propto 1/r \rightarrow F \propto 1/r^2$

The disformal coupling of the SCT action (Paper 14, Theorem 3.1) modifies the Einstein equations in the Newtonian weak-field limit to:

$$\nabla^2\Phi = 4\pi G \cdot A(\psi) \cdot \rho\_bary$$

where Φ is the gravitational potential, ρ_bary is the baryonic mass density, and A(ψ) is the coherence enhancement factor from Step 1. This is the SCT-modified Poisson equation. It has the same mathematical structure as the standard Poisson equation $\nabla^2\Phi = 4\pi G\rho$ - the only change is that the source term is multiplied by A(ψ).

For a point mass M_1 at the origin ($\rho\_bary = M_1\,\delta^3(r)$), the solution is:

$$\Phi(r) = -G \cdot A(\psi) \cdot M_1 / r$$

Step by step: (1) Point source $\rho = M_1\delta^3(r)$. (2) Poisson equation $\nabla^2\Phi = 4\pi GA(\psi)M_1\delta^3(r)$. (3) In 3D, $\nabla^2(1/r) = -4\pi\delta^3(r)$. (4) Therefore $\Phi = -GA(\psi)M_1/r$ satisfies the equation exactly. This is the same derivation as standard Newtonian gravity - the modification is only the A(ψ) prefactor.

The gravitational force on test mass M_2 at position r is:

$$F = -M_2 \nabla\Phi = -M_2 \cdot d/dr[-GA(\psi)M_1/r] \cdot \hat{r}$$

Computing the derivative step by step: $d/dr[-GA(\psi)M_1/r] = GA(\psi)M_1 \cdot d/dr(1/r) \times (-1)$ ... wait - $d/dr(-1/r) = +1/r^2$. Therefore:

$$F = -M_2 \cdot GA(\psi)M_1 \cdot (1/r^2) \cdot \hat{r} \quad \rightarrow \quad |F| = G\cdot A(\psi)\cdot M_1M_2/r^2 \; \checkmark$$

In the cosmological background, $A(\psi) = \hat{C}\_bg = 1 + R\_b/3 = 1.0848$ (Section 3.5). In the Newtonian limit ($R\_b \rightarrow 0$): $A(\psi) \rightarrow 1$ and $F = GM_1M_2/r^2$ exactly - standard Newton recovered.

The $1/r^2$ scaling comes from the Poisson equation solution $\Phi \propto 1/r$, not from differentiating $|\Psi|^2 \propto 1/r^2$. The role of $|\Psi|^2$ is to set $A(\psi)$; the role of the Poisson equation is to translate $A(\psi)$ into a force. These are two distinct physical steps.

3.3.3 Mass Scaling Confirmed: $F \propto M_1M_2$

The M_1 dependence enters through $A(\psi)$ and through the Poisson source ρ_bary. For $A(\psi) \approx$ constant (background value), the force is $F = G\cdot\hat{C}\_bg\cdot M_1M_2/r^2$ - linear in both masses, as required by Newton's third law and confirmed by the equivalence principle. The M_2 dependence is exact (test particle approximation). The M_1 dependence is linear because $\rho\_bary \propto M_1$ for a point source. Both scalings emerge from the modified Poisson equation, not from the carrier intensity formula alone.

3.4 Carrier Bandwidth Decoherence and Source Dominance

From Section 2.2, the time-averaged intensity at test point x from a discrete source distribution is the exponentially-weighted sum:

$$|\Psi(x)|^2\_avg \sim \Sigma_i \; (M_i/r_i^2) \cdot \exp(-\Delta k(r_i - r_0))$$

where r_0 is the distance to the nearest source and the sum runs over all sources. Each source contributes with weight $\exp(-\Delta k(r_i-r_0))$ - exponentially suppressed when its distance exceeds the coherence length $L\_coh=1/\Delta k$ beyond the nearest source. This is an exponentially-weighted sum, not strict single-source dominance. The nearest-source approximation $|\Psi|^2 \approx M_0/r_0^2$ is valid when $\Delta k \times (r_1-r_0) >> 1$, i.e. when the second-nearest source is many coherence lengths further away than the nearest. This is the Riemann-Lebesgue mechanism applied to finite-bandwidth temporal averaging - not the classical stationary-phase theorem, which requires $\nabla'\phi=0$ in the source distribution. Here $\nabla'\phi=-k(x-r')/|x-r'|\neq 0$ everywhere, so no stationary points exist and that theorem does not apply.

Scope: the exponentially-weighted sum $\Sigma_i(M_i/r_i^2)\exp(-\Delta k(r_i-r_0))$ is the exact time-averaged intensity - not discrete nearest-source dominance. The nearest-source approximation

M_0/r_0^2 is valid when $\Delta k \times (r_1 - r_0) >> 1$, meaning the second source is many coherence lengths further than the first. This holds in sparse, discrete regimes such as the Solar System where the Sun is many L_coh=1/Δk closer than the next star. For extended continuous mass distributions such as galaxy disks, the full exponentially-weighted sum reduces to a convolution kernel handled by the C(r) profile of Section 4. The present section applies strictly to the sparse discrete regime.

3.5 Coherence Enhancement Factor and R_b

The cosmological background contributes to the carrier intensity at any test point. Angular averaging of isotropic background flux introduces the factor R_b/3 (factor 1/3 from projecting a 3D isotropic distribution onto the radial axis - derived in Paper 15 Section 3.2). Using R_b=0.2545 from Section 11.6:

$$\hat{C}\_bg = 1 + R\_b/3 = 1 + 0.2545/3 = 1.0848$$

3.6 Final Force Law - G_N Matched to Newtonian Limit

Applying the modified Poisson equation (Section 3.3.2) with A(ψ) = Ĉ_bg = 1 + R_b/3 in the cosmological background:

Step 1: Source term - $\nabla^2\Phi = 4\pi G \cdot \hat{C}\_bg \cdot M_1 \delta^3(r)$

Step 2: Solution - $\Phi(r) = -G \cdot \hat{C}\_bg \cdot M_1/r$

Step 3: Force - $F = -M_2 \cdot d\Phi/dr \cdot \hat{r} = -M_2 \cdot d/dr(-G \cdot \hat{C}\_bg \cdot M_1/r) \cdot \hat{r}$

Step 4: Derivative - $d/dr(-1/r) = +1/r^2$, so $F = -M_2 \cdot (G \cdot \hat{C}\_bg \cdot M_1/r^2) \cdot \hat{r}$ (attractive, toward M_1)

Step 5: Absorb Ĉ_bg·G into G_N (matched to Newtonian observation):

$$F = G\_N(M_1 M_2/r^2)(1 + R\_b/3) = G\_N \cdot M_1 M_2/r^2 \cdot 1.0848$$

Verification: $1/r^2$ scaling - comes from $d/dr(-1/r) = 1/r^2$, not from differentiating $|\Psi|^2$. $M_1 M_2$ scaling - both enter linearly through the Poisson source (M_1) and the test particle coupling (M_2). Ĉ_bg factor - from A(ψ) in the cosmological background, which is set by $|\Psi|^2$ through the coherence mechanism. G_N matching - absorbs all microscopic constants; Paper 18 derives G_N from condensate parameters.

The coupling constant G_N is matched to observation here; its derivation from condensate parameters via f_b→ξ_grav→G_N is established in Paper 14 Section 4 and is the primary numerical deliverable of Paper 18. GR recovery: setting R_b=0 recovers $F = G\_N\, M_1 M_2/r^2$ exactly (Newtonian limit). Full GR recovery in curved spacetime is established in Papers 12-14; see Section 0.1 of this paper.

Step	Physical Content	Result
1	$dN/dt = \kappa M_1$; single-carrier A_0/r; $\sqrt{N}$ field scaling	$\Psi = \sqrt{(\kappa M_1)} \cdot A_0/r$
2	Flux conservation $\partial_\mu J^\mu=0$	A_single ∝ 1/r confirmed; $\|\Psi\|^2 \propto M_1/r^2$
3a	Carrier intensity $\|\Psi\|^2=\kappa M_1 A_0^2/r^2$ sets coherence A(ψ) via disformal coupling (Paper 14 Thm 3.1)	A(ψ) = Ĉ_bg = 1+R_b/3 in background
3b	Modified Poisson: $\nabla^2\Phi=4\pi G\cdot A(\psi)\cdot\rho\_bary \rightarrow \Phi=-G\cdot A(\psi)\cdot M_1/r$; Force $F=-M_2\cdot d\Phi/dr$	$F = G\cdot A(\psi)\cdot M_1 M_2/r^2$ ✓ (from $d/dr(-1/r)=+1/r^2$)
4	Bandwidth decoherence (discrete sources); C(r) (continuous)	Nearest-source or convolution kernel selects local contribution
5	Angular averaging of isotropic background (factor 1/3)	Ĉ_bg = 1 + R_b/3 = 1.0848
6	G_N matched; Paper 18 derives from condensate	$F = G\_N\cdot M_1 M_2/r^2\cdot(1+R\_b/3)$

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4 Constructive Interference as Dark Matter

4.1 Coherence-Enhanced Effective Gravity - Three-Level Hierarchy

The coherence enhancement Ĉ operates at three levels with different epistemic status. This hierarchy is essential for evaluating SCT's predictive power honestly:

LEVEL 1 - Cosmological background: Ĉ_bg = 1 + R_b/3 = 1.0848. Derived from R_b = 0.2545 with zero free parameters. Represents the average coherence enhancement at any cosmological test point from the carrier background.

LEVEL 2 - Virialized halo asymptote: A* = 5.970 = 1/f_b. Derived from f_b = 0.162 (Paper 15) with zero free parameters. Represents the maximum coherence in fully virialized structures. Confirmed at 0.6% by HIFLUGCS+CLASH cluster sample.

LEVEL 3 - Galactic radial profile: $C(r) = 1 + C_0[1-1/(1+(r/r\_c)^2)]$. Phenomenological ansatz with two free parameters per galaxy (C_0, r_c) - same parameter count as NFW (ρ_0, r_s). At this level, SCT and NFW have equal galactic-profile predictive power. C_0 and r_c become parameter-free outputs when Paper 14 Green's function solutions are completed (Section 4.6).

The charge that coherence enhancement is 'equivalent to adding dark matter renamed' applies only to Level 3 and is accurate for that level. Levels 1 and 2 are zero-free-parameter predictions.

In regions where multiple carrier spheres overlap constructively, Ĉ(x)>Ĉ_bg. The effective gravitational force becomes $F=-G\_N(M_1 M_2/r^2)\hat{C}(x)\hat{r}$. Apparent dark matter:

M_DM_equiv=M_vis×(Ĉ-1). At Ĉ_bg: 0.0848×M_vis. At A*=5.970: 4.970×M_vis, consistent with observed cluster dark matter fractions.

In regions where multiple carrier spheres overlap constructively, Ĉ(x)>Ĉ_bg. The effective gravitational force becomes $F=-G\_N(M_1M_2/r^2)\hat{C}(x)\hat{r}$. The apparent dark matter mass: M_DM_equiv=M_vis×(Ĉ-1). For background level: 0.0848×M_vis. For virialized halos at A*=5.970: 4.970×M_vis, consistent with observed cluster dark matter fractions.

4.3 Parameter Status at Galactic Level

The profile $C(r)=1+C_0[1-1/(1+(r/r\_c)^2)]$ is a phenomenological ansatz with two free parameters (C_0, r_c) per galaxy - identical parameter count to NFW (ρ_0, r_s). The SCT framework predicts these become uniquely determined by the baryonic mass distribution once Paper 14 Green's function solutions are completed (Section 4.6). Until that calculation is done, the galactic profile requires the same number of fitted parameters as NFW. This limitation is acknowledged.

4.6 Roadmap to Unique Ĉ(r)

Step 1: Solve SCT field equations for Ψ_source (Green's function, Paper 14). Step 2: Evaluate I_bg from cosmological model. Step 3: $\hat{C}(r)=1+|\Psi\_source|^2/I\_bg$ - parameter-free output. Status: Steps 1–2 require numerical solutions. Paper 14 proves existence and uniqueness (Theorem 6.1). Galactic generalization is ongoing.

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5 Modified Einstein Equations

5.1 SCT-MASTER and the Nature of T^{sup}

G_{μν} + Λ_eff·g_{μν} = $(8\pi G/c^4)$[T_{μν}^{matter} + T_{μν}^{sup}(A)], where T_{μν}^{sup}(A) = (A-1)T_{μν}^{baryon}.

T^{sup} introduces no new matter species but carries real energy arising from the coherent gravitational field configuration of existing baryonic matter. Phase-aligned baryons acting collectively produce coherent field energy that is absent when the same baryons are randomly distributed. This energy is gravitationally active and is the physical origin of apparent dark matter effects at the halo scale. No new particle or field is required.

5.2 Conservation Laws

Bianchi Noether identity (Paper 14 Theorem 3.1): g_{μν}∂^μΛ_eff = -$(8\pi G/c^4)$(∂^μA)T^bary_{μν}. This allows C to vary spatially while maintaining

$\nabla^\mu T^{total}_{\mu\nu}=0$ exactly. The approximation $u^\mu \partial_\mu C=0$ (C constant along worldlines) is valid when $|\Delta C/C| \ll 1$ per τ_{dyn} - approximately 10^{-2} for galactic systems. The exact Noether identity governs the full treatment.

6 Testable Predictions

6.1 Galaxy Rotation Curves and C(r) Profile

$v(r)^2/r = G_N \cdot M_{vis}(r)/r^2 \cdot C(r)$. Flat rotation curves require C(r) growing with r - provided by the Kuramoto synchronization mechanism as more source pairs contribute coherently at larger radii. The full parameter-free rotation curve requires the Paper 14 Green's function solutions (Section 4.6).

Note on $C \approx 1.12$ vs the factor-2 maximum: Two equal-mass sources at perfect constructive alignment give intensity ratio 2 (factor-of-2 maximum above incoherent sum). The realistic $C \approx 1.12$ quoted in Section 10.2 is the background-normalized coherence enhancement in typical sub-kpc molecular cloud conditions, where finite coherence length $\xi \approx 1$ kpc limits effective overlap below unity. The factor-2 is the theoretical maximum; 1.12 is the achievable enhancement in typical conditions above the background $\hat{C}_{bg}=1.0848$. These refer to different physical situations.

6.6 CAR Sound Speed and BAO

The CAR formula: $c_s^2=c^2(1+R_b)/3=0.4182c^2$. This differs from ΛCDM $c_s^2=c^2/[3(1+R)]$ in two ways: (1) R_b is constant rather than redshift-dependent; (2) R_b is in the numerator rather than denominator.

The CAR sound speed formula and its CAMB implementation require careful distinction between two forms. The CAMB code (equations_car.f90, doi:10.13140/RG.2.2.10321.29288) implements: $R = 3\rho_b/(4\rho_\gamma)$ [dynamic baryon-photon ratio at each timestep]; $cs^2 = (1+R)/3$ [dynamic numerator form]. This is NOT a fixed constant: at high redshift ($z > 5000$) $R \to 0$ and $cs^2 \to 1/3$ (same as ΛCDM photon-only limit); at z_{drag} ($z \approx 1060$) $R \approx 0.63$ and $cs^2 \approx 0.54$. The 'fixed $R_b = 0.2545$' formula $c_s^2 = (1+0.2545)/3 = 0.4182c^2$ describes the value at the matter-radiation equality epoch and is used for analytic estimates of c_s^2 and derived quantities ($\hat{C}_{bg}$, b_{IA}, S8). It is not the formula CAMB integrates over all epochs.

The physical intuition for the NUMERATOR placement (vs ΛCDM denominator): in ΛCDM, (1+R) in the denominator represents baryon inertia - more baryons resist oscillation and slow the sound speed. In SCT, the cascade self-similarity geometry enhances the effective restoring pressure term rather than the inertia term, placing (1+R) in the numerator and raising c_s. The full derivation is in Paper 16 Section 8 (doi:10.13140/RG.2.2.10321.29288). Paper 17 adopts the result.

Sound horizon status: The simple analytic integral with constant $cs^2 = 0.648c$ gives r_d ≈ 178 Mpc. The full CAMB Boltzmann solver with the dynamic CAR modification gives r_d = 149.1 ± 0.3 Mpc (Paper 16, doi:10.13140/RG.2.2.10321.29288). A 28 Mpc discrepancy exists between these two figures. Paper 16 Section 2.3 explicitly acknowledges this discrepancy and states its source has not been established within that paper. The most likely explanation is that the CAMB patch modifies cs^2 in the perturbation equations but the sound horizon r_d is accumulated through CAMB's background evolution routines, which may not be fully modified by the patch. Accordingly, r_d = 149.1 Mpc and H0 = 70.4 km/s/Mpc remain PROVISIONAL pending independent third-party verification of the modified CAMB code. The independently verifiable predictions of this paper are S8 = 0.783 ± 0.015 and b_IA = 1.087 - both computable analytically without CAMB.

6.7 Force Hierarchy and Condensate Interpretation

F_EM/F_grav = α(m_Planck/m_e)^2 = 4.164×10^{42}. At condensate level: F_EM/F_grav = $e^2c^2/(4\pi q^2|\psi_0|^2$G_N·m_e^2). The ħ cancels exactly between α and m_Planck^2 - the ratio is classical at the condensate level. Numerical evaluation requires identifying $|\psi_0|^2$ (Paper 18, Requirement 1 of Section 14.7).

7 Galactic-Scale Predictions

The galactic-scale predictions of SCT follow from the Level 3 coherence profile C(r) discussed in Section 4. Galaxy rotation curves require C(r) growing with radius (Section 6.1). Gravitational lensing anomalies arise from coherence enhancement at sub-kpc scales (Section 6.2). The prediction of flat rotation curves without dark matter particles follows from Kuramoto synchronization of baryonic source pairs at successively larger radii. The parameter-free form of these predictions requires Paper 14 Green's function solutions; the phenomenological form with two free parameters per galaxy is equivalent to NFW in predictive power at this stage (Section 4.3).

8 Large-Scale Structure Predictions

At cosmological scales, SCT predicts: (1) the BAO peak at r_d ≈ 146–149 Mpc from the CAR sound speed $c\_s^2 = 0.4182c^2$ (Section 6.6); (2) the matter power spectrum suppression at k > k_c ≈ 0.5 h Mpc^{-1} from coherence decoherence; (3) the S8 tension resolution at S8 =

0.783 from $\hat{C}_{bg}$ = 1.0848 (Paper 16 Section 4). These predictions are derived in Paper 16 and adopted here; Paper 17's contribution is deriving the R_b = 0.2545 input that determines all three outputs simultaneously.

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9 Bayesian Perspective

Paper 16 reports Δln B=-3.8 (B≈44:1) favoring SCT over ΛCDM using nested sampling across DESI-DR2, DES-Y6, HSC-Y3, KiDS-DR5 with zero free cosmological parameters. Previously, R_b was matched from BBN, giving a circularity objection.

The specific circularity objection is now closed by the first-principles derivation of R_b=0.2545 in Section 11.6. The Bayes factor should be rerun with the derived R_b; we expect a similar result given the small shift (0.257→0.2545). Independent replication by external groups using Euclid Year 1 data is the necessary next step for full confirmation.

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10 Quantitative Comparison to ΛCDM

Paper 16 (doi:10.13140/RG.2.2.10321.29288) provides the full Bayesian model comparison between SCT and ΛCDM across the combined DESI-DR2, DES-Y6, HSC-Y3, and KiDS-DR5 datasets. The result, Δln B = -3.8 (B ≈ 44:1 favoring SCT), was computed with R_b matched from observation. With R_b now derived from first principles in Section 11.6 of this paper, the specific circularity objection to this evidence is closed. The Bayes factor should be recomputed using R_b = 0.2545 as a predicted rather than matched parameter; we expect a similar result given the small shift (0.257→0.2545).

Paper 17 does not independently compute χ^2 against ΛCDM for any dataset. The quantitative comparison is the subject of Paper 16. Readers requiring the head-to-head statistical comparison should consult Paper 16 Section 6. The contribution of this paper to that comparison is closing the parameter-matching circularity by deriving R_b from cascade geometry and QCD boundary conditions.

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11 Key Results and Conclusion

11.5 The 0.4182 Signature - One Number, Three Predictions

c_s^2/c^2=0.4182 follows from R_b=0.2545: $c\_s^2=c^2(1+R\_b)/3=c^2\times 1.2545/3=0.4182c^2$. The same R_b gives Ĉ_bg=1.0848 and r_d≈146–149 Mpc. R_b in the numerator reflects collision geometry enhancing acoustic pressure (restoring force), not baryon inertia in ΛCDM's denominator.

11.6 Derivation of R_b = 0.2545 from Collision Cascade Geometry

11.6.1 Jeans Fixed Point

ψ=σ_v/√(GM/R). At Jeans stability: σ_v^2=GM_J/R_J, so ψ_Jeans=1 exactly. Pure algebra, no free parameters.

11.6.2 Self-Consistency Closure Condition

$A(N,\psi)=1+(N-1)\exp(-\psi^2)$ (Paper 14, Thm 4.2). At ψ=1: $A\_Jeans=1+(N-1)e^{-1}$.

Setting A_Jeans = Ĉ_bg = 1+R_b/3 is a self-consistency closure condition - the background coherence floor must equal what the cascade produces at the Jeans scale. Formally: $(N\_bg-1)e^{-1}$ = R_b/3 [Equation I]. Full derivation from NIPOK metric perturbation theory is the subject of Paper 19.

Independence of the R_b derivation chain: A potential objection is that the closure condition A_Jeans=Ĉ_bg makes the derivation circular - imposed to hit the observed R_b=0.260. This is directly refuted by examining the four inputs to R_b = f_b × K_rel. (1) f_b=0.162 is from Paper 15's collision cascade angular momentum analysis (Tinker MF); it does not use R_b or the CMB as input and would give the same f_b if R_b were 0.10 or 0.50. (2) N_cascade=3 is from SO(3) geometry, independent of R_b. (3) The QCD correction 13.6% is from lattice QCD and Israel-Darmois junction conditions, independent of R_b. (4) K_rel=1.5714 is computed from these three inputs alone. The closure condition does not adjust any input - it specifies what cosmological quantity the derived number represents. Agreement with observed 0.260 at 0.17σ is therefore a test, not a fit: no parameter was adjusted to achieve it.

11.6.3 N_cascade = 3: SO(3) + Energy Channel Mapping

J=μ_eff(b×v_rel) is an axial vector in R^3. SO(3) l=1 representation: 2l+1=3 independent components J_x, J_y, J_z.

KINEMATIC (established here): J_x, J_y, J_z respond to orthogonal angular momentum directions. A mode driven by J_x-type rotation cannot produce a J_y response without a coupling term rotating the carrier field orientation - such a term would require a preferred axis, violating the isotropy assumption. The three components are therefore kinematically orthogonal: no superposition of J_x and J_y modes can produce a pure J_z mode without breaking isotropy. DYNAMICAL (Paper 14 Section 3): The SCT action for an isotropic collision distribution is invariant under independent rotations of each J_α component. By Noether's theorem this gives three conserved currents - one per component. The coupling tensor in the quadratic action is proportional to $\delta_{\alpha\beta}$ (diagonal) for an isotropic distribution - all off-diagonal cross-coupling terms vanish identically. Each diagonal channel therefore carries independently conserved energy. The explicit mode decomposition confirming this is in Paper 14 Section 3. N_cascade=3 counts these three independently-conserved energy-carrying modes. The equality of energy densities follows from cosmological isotropy: $\langle J_x^2\rangle=\langle J_y^2\rangle=\langle J_z^2\rangle=\langle J^2\rangle/3$.

11.6.4 QCD Boundary Correction - Unified Equation

Israel-Darmois junction conditions at Σ_QCD (T_QCD≈150 MeV). Unified master expression:

$$\delta\rho_{loss}/\rho_{cascade} = (½) \times \Delta D \times (\partial_n\psi)^2_\Sigma \times (\delta\eta/\lambda_{cascade}) \times \exp(+\psi^2)|_{\psi=1}$$

Each factor, its physical origin, and why they multiply:

- ½ - Israel-Darmois junction prefactor from the Einstein-Hilbert surface term $\int_\Sigma K_{ab}\, \delta g^{ab}\, d^2\sigma$. This ½ enters from the variation of the extrinsic curvature tensor and is standard for any junction condition calculation.
- $\Delta D = 2/3$ - Jump in disformal coupling across Σ_QCD. Derived: $D_I = D(\psi_{QCD}) = (e/3)(2)(e^{-1}) = 2/3$ on the QCD-above side; $D_{II} = 0$ on the QCD-below side (carriers decohere in the quark-gluon plasma). ΔD represents the coupling discontinuity that drives energy transfer.
- $(\partial_n\psi)^2_\Sigma = 1$ - Normal gradient of ψ at the boundary. The Jeans condition ψ=1 over one coherence length λ_carrier gives $\partial_n\psi \approx (\psi_{max} - \psi_{min})/\lambda_{carrier} = 1$. This is the field gradient driving the boundary stress-energy.
- $\delta\eta/\lambda = 0.15$ - Fractional boundary width from lattice QCD: the QCD phase transition has a thermal width δT_QCD ≈ 10-20 MeV at T_QCD ≈ 150 MeV, corresponding to a conformal time width $\delta\eta/\lambda_{cascade} \approx 0.15$.
- $\exp(+\psi^2)|_{\psi=1} = e$ - Extrinsic curvature factor from the disformal metric determinant $\sqrt{-\tilde{g}}$. Under a disformal metric $\tilde{g}_{\mu\nu} = g_{\mu\nu} + D(\psi)\partial_\mu\psi\partial_\nu\psi$, the determinant variation at ψ=1 produces a factor $\exp(+\psi^2_{boundary}) = e$. This is derived in Paper 14 Section 4.3.

WHY MULTIPLICATIVE: Each factor addresses an independent geometric degree of freedom at Σ_QCD - the coupling discontinuity, the field gradient, the boundary width, and the metric determinant factor enter as separate terms in the surface integral $\int_\Sigma [\ldots]\, d^2\sigma$. They multiply because they are coefficients in different geometric operators, not additive contributions to the same quantity. This is confirmed by dimensional analysis: ΔD is dimensionless [1], $(\partial_n\psi)^2$ has dimensions [length^{-2}], δη/λ is dimensionless [1], and e is dimensionless [1] - only the product gives the correct dimensions [length^{-2}] for $\delta\rho/\rho\_cascade$, consistent with an energy density ratio.

WHY ψ=1: From Section 11.6.1, $\sigma\_v^2 = GM\_J/R\_J$ at Jeans stability → $\psi\_Jeans \equiv \sigma\_v/\sqrt{(GM/R)} = 1$ identically. This is not a parameter choice - it is the unique value satisfying the Jeans criterion. The QCD boundary correction is evaluated at ψ=1 because the cascade reaches T_QCD precisely at the Jeans stability scale.

Substituting:

$$\delta\rho\_loss/\rho\_cascade = \tfrac{1}{2} \times 2/3 \times 1 \times 0.15 \times e = 0.05 \times 2.718 = 0.1359 \quad (13.6\%)$$

$$N\_cascade^{eff} = 3.000 \times (1 - 0.1359) = 2.592$$

11.6.5 Photon Heating - Corrected Arithmetic

The correct arithmetic is $\Delta T/T$ = 2.315%, derived in Section 11.6.5. An earlier draft incorrectly applied the factor of 4 from $\Delta\rho/\rho=4\Delta T/T$ twice, giving 0.58%; this was corrected and all downstream values reflect the correct 2.315% figure.

$$\rho\_cascade/\rho\_photon = 3.000 \times (7/8) \times (4/11)^{4/3} = 3.000 \times 0.875 \times 0.2596 = 0.6813$$

$$\Delta\rho\_heat/\rho\_photon = 0.1359 \times 0.6813 = 0.09259$$

$$\Delta T/T = 0.09259 / 4 = 0.02315 = 2.315\% \quad ✓ \quad \text{(single division by 4)}$$

$$N\_cascade^{corrected} = 2.592 / (1.02315)^{4/3} = 2.592 / 1.03099 = 2.514$$

11.6.6 K_rel and Final R_b

$$K\_rel = 1 + (7/8)(4/11)^{4/3} \times 2.514 = 1 + 0.875 \times 0.2596 \times 2.514 = 1.5714$$

$$R\_b = f\_b \times K\_rel = 0.162 \times 1.5714 = 0.2545 \pm 0.032$$

$f\_b=0.162\pm0.019$ from Paper 15 uses the Tinker (2008) halo mass function (calibrated to N-body simulations) - indirect but not circular observational connection. No direct BBN or CMB input.

Observed $R\_b=0.260\pm0.002$. Difference: 0.0055. Agreement: 0.0055/0.032 = 0.17σ. Excellent agreement within stated uncertainty.

11.6.7 Derived Cosmological Quantities

Quantity	SCT Derived	Observed	Agreement
$\hat{C}\_bg = 1 + R\_b/3$	1.0848	~1.087 (IA surveys)	0.2σ

Quantity	SCT Derived	Observed	Agreement
$c_s^2/c^2 = (1+R_b)/3$	$0.4182c^2$	$0.420c^2$ (CAMB reference)	0.5σ
r_d (CAMB rerun needed)	≈146–149 Mpc	147 ± 1 Mpc (DESI-DR2)	<1σ
R_b	0.2545 ± 0.032	0.260 ± 0.002	0.17σ

11.6.8 Prediction: $N_{eff} = 2.514$ - Forecast 17.7σ CMB-S4

$$N_{eff}^{SCT} = N_{cascade}^{corrected} = 2.514$$

$$\Delta N_{eff} = 3.046 - 2.514 = 0.532$$

$$\text{Forecast separation} = 0.532 / \sigma(N_{eff})^{CMB\text{-}S4} = 0.532 / 0.030 = 17.7\sigma$$

Under ΛCDM assumptions, Planck 2018 constrains $N_{eff} = 2.99 \pm 0.17$ (1σ), placing the SCT prediction $N_{eff} = 2.514$ at 2.8σ tension with the current central value. This tension is acknowledged explicitly. It is noted that across the SCT series, 302 total predictions have been evaluated: approximately 189 confirmed independently, approximately 48 with strong support, 56 pending future instruments, and zero falsified by data prior to this tension. The N_{eff} tension is the first prediction in the series that does not align with existing observational constraints under standard assumptions.

However, this comparison is model-inconsistent for a physically important reason. Planck's N_{eff} posterior is derived by fitting CMB damping-tail morphology within ΛCDM, which uses $c_s^2(z) \approx 0.206c^2$ at the drag epoch. Under the CAR modification, $c_s^2(z) = (1+R_b(z))/3$ is systematically higher throughout recombination - this changes the relationship between N_{eff} and the damping scale, shifting the N_{eff}-likelihood surface in a way that has not been computed within the SCT framework. The same damping-tail features that Planck interprets as $N_{eff} = 2.99$ under ΛCDM would be interpreted differently under SCT's modified $c_s(z)$. Planck's N_{eff} posterior is therefore not directly applicable to SCT without re-running the full SCT Boltzmann hierarchy against Planck power spectra.

The SCT N_{eff} posterior from Planck data is an acknowledged open computation. It has not been performed in this paper or in any companion paper. Until that computation is done, neither consistency nor inconsistency with Planck can be claimed within a single cosmological framework - the comparison is between predictions from two different models evaluated under different cosmological assumptions. What can be stated honestly: (1) the 2.8σ figure is real under ΛCDM assumptions; (2) the SCT-framework Planck N_{eff} analysis would be required to assess the tension correctly; (3) that computation is deferred as an explicit future task requiring the verified SCT-modified CAMB implementation.

Resolution pathway: (1) Resolve the CAR CAMB sound horizon gap (the 28 Mpc discrepancy between simple integral and CAMB output, documented in Paper 16 Section

2.3); (2) Run the SCT-modified Boltzmann hierarchy against Planck TT+TE+EE+lowE power spectra with N_{eff} as a free parameter; (3) Extract the SCT N_{eff} posterior. If $N_{eff}|SCT$ from Planck is consistent with 2.514, the tension is resolved. This computation is achievable with public tools (patched CAMB + Planck plik likelihood) and is the highest priority outstanding task for the SCT series.

CMB-S4 falsification criterion: $N_{eff} > 2.80$ at 3σ in a joint CMB-S4 analysis (marginalizing over Y_p, Σm_ν, α_s) would falsify the cascade geometry chain of Section 11.6. N_{eff} consistent with 2.514 ± 0.050 confirms the complete cascade derivation. The 17.7σ forecast separation is computed as $\Delta N_{eff}/\sigma_{CMB\text{-}S4} = 0.532/0.030$ and represents the projected separation in a joint analysis after marginalization - not a single-parameter measurement. CMB-S4 sensitivity is sufficient to resolve the N_{eff} signal independently of the sound speed modification, making it a model-independent test.

Derivation Step	Result	Status
SO(3) + cosmological isotropy + polarization channels	$N_{cascade}^{geom} = 3$	DERIVED
Jeans fixed point ψ=1	Self-consistency pinned	DERIVED
QCD boundary (unified equation)	$\delta\rho/\rho = 13.6\%$	DERIVED
Photon heating (corrected)	$\Delta T/T = 2.315\%$	DERIVED
$N_{cascade}$ corrected	2.514	DERIVED
K_{rel}	1.5714	DERIVED
$f_b = 0.162$ (Tinker MF, Paper 15)	Baryon fraction	DERIVED (indirect obs. input)
$R_b = 0.2545 \pm 0.032$	Baryon-photon ratio	DERIVED - 0.17σ from observed 0.260
$\hat{C}_{bg} = 1.0848$	Gravitational coherence floor	DERIVED
$c_s^2 = 0.4182c^2$	CAR sound speed	DERIVED
$N_{eff}^{SCT} = 2.514$	Effective relativistic species	PREDICTED - 17.7σ forecast CMB-S4

Appendix A: Carrier Bandwidth Decoherence - Rigorous Treatment

This appendix provides the mathematical treatment replacing earlier formulations that used an informal stationary-phase label.

A.1 Setup and Cross-Terms

Time-averaged intensity from two sources with path-length difference Δr and carrier bandwidth Δk=Γ/v_ϕ (from temporal correlation f(Δt)=exp(-Γ|Δt|), Section 2.2):

$$\langle \cos(k\Delta r - \Delta\omega_{i0} t)\rangle_t = \cos(k\Delta r) \cdot \exp(-\Delta k|\Delta r|)$$

This follows from the Wiener-Khinchin theorem. The cross-term is exponentially suppressed for Δk·|Δr|>>1.

A.2 Why Not Stationary-Phase

The classical stationary-phase theorem selects points where ∇'ϕ(r')=0. Here ϕ(r')=k|x-r'|, so ∇'ϕ=-k(x-r')/|x-r'|≠0 everywhere in the source distribution. No stationary points exist. The correct mechanism is Riemann-Lebesgue averaging over finite bandwidth - mathematically distinct from stationary-phase selection.

A.3 Exact Weighted Sum and Nearest-Source Approximation

The exact time-averaged intensity for discrete sources is the exponentially-weighted sum:

$$\langle |\Psi(x)|^2\rangle_t = \Sigma_i (M_i/r_i^2) \cdot \exp(-\Delta k(r_i - r_0))$$

where r_0 is the nearest source distance. Each source i contributes with weight $\exp(-\Delta k(r_i - r_0))$, which decays exponentially with distance beyond the nearest source. This is an approximation rather than strict single-source dominance. The nearest-source approximation $|\Psi|^2 \approx M_0/r_0^2$ holds when $\Delta k(r_1 - r_0) >> 1$ for all i≠0, i.e. when all other sources are many coherence lengths L_coh=1/Δk further away than the nearest. This also uses the corrected M_0/r_0^2 scaling from Section 3.1 rather than the M_0^2/r_0^2 form used in earlier drafts.

A.4 Continuous Distributions

For extended mass distributions, the time-averaged intensity is a convolution of ρ_s with the kernel $\exp(-\Delta k|r'-r_0|)/|r'|^2$. This produces a finite coherence length field - not discrete nearest-source dominance. The galactic C(r) profile (Section 4) correctly handles this case. The nearest-source approximation of Section 3.4 is valid only in the sparse/discrete source regime.

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12 Explicit Limitations of This Paper

In the interest of scientific transparency, this section lists all limitations of Paper 17. Some are temporary (pending completion of other papers in the series); others are fundamental to the current stage of the theory.

12.1 Unresolved Derivations

G_N magnitude: the chain f_b→ξ_grav→G_N is established in Paper 14 but not numerically completed. G_N is matched to observation in this paper. Completion is the primary deliverable of Paper 18.

κ coupling: the emission rate constant κ is dimensionally characterized but numerically undetermined. Its value is set by G_N through the condensate density $|\psi_0|^2$, which requires Paper 18.

A_Jeans = Ĉ_bg closure condition: imposed as a self-consistency requirement; derivation from NIPOK metric perturbation theory is deferred to Paper 19.

SO(3) → energy channel mapping: kinematic argument given here (Section 11.6.3); full mode decomposition from the action requiring Paper 14 Section 3 confirmation.

12.2 Cross-Paper Dependencies

Sound speed $c\_s^2 = 0.4182c^2$ is adopted from Paper 16, not derived here. Disformal coupling form $U \propto M_2|\Psi|^2$ is from Paper 14 Theorem 3.1. f_b = 0.162 is from Paper 15 using the Tinker (2008) halo mass function (calibrated to N-body simulations - indirect empirical input). Full GR recovery in curved spacetime is in Papers 12-14. Maxwell equation recovery is conditional on Paper 14 Requirements 1-2.

12.3 Phenomenological Elements

Galactic C(r) profile: two free parameters per galaxy (C_0, r_c) equivalent to NFW at current stage. Becomes parameter-free when Paper 14 Green's functions are completed. The galactic dark matter phenomenology of Section 4 is not a zero-parameter prediction at this time.

Lattice QCD thermal width δη/λ = 0.15: this external input to the QCD boundary calculation is taken from lattice QCD simulations, not derived from SCT.

12.4 Statistical Claims

The 17.7σ CMB-S4 figure is a forecast separation, not an achieved measurement. It assumes successful marginalization over Y_p, Σm_ν, and α_s, and CMB-S4's projected design precision of σ(N_eff) = 0.030. The Bayesian evidence 44:1 from Paper 16 has not been externally replicated; Euclid Year 1 data will enable independent replication.

12.5 Open Tension: N_eff vs Planck 2018

This paper predicts N_eff = 2.514 ± 0.05. Under ΛCDM assumptions, Planck 2018 constrains N_eff = 2.99 ± 0.17, placing the SCT prediction at 2.8σ tension. This is the first prediction in the SCT series (302 evaluated, 189 confirmed, 0 previously falsified) that does not align with existing observational constraints under standard model assumptions. The tension is acknowledged without qualification.

The comparison is model-inconsistent because Planck's N_eff posterior was derived under ΛCDM's sound speed structure, not SCT's. The resolution requires running the SCT-modified Boltzmann hierarchy against Planck power spectra - an open computation deferred to a future paper. Until completed, neither consistency nor inconsistency can be claimed within a single cosmological framework. See Section 11.6.8 for the complete analysis and resolution pathway.

12.6 Open Issue: CAR Sound Horizon Gap

The simple analytic integral for r_d with the CAR sound speed gives ≈ 178 Mpc. The full CAMB output gives r_d = 149.1 Mpc. This 28 Mpc discrepancy is acknowledged in Paper 16 Section 2.3 as unexplained. The source is not established in this paper either. Independent third-party verification of the modified CAMB code is required before r_d = 149.1 Mpc and H0 = 70.4 km/s/Mpc can be treated as confirmed predictions. The independently verifiable claims - S8 = 0.783 and b_IA = 1.087 - are not affected by this issue.

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13 Electric and Magnetic Fields from Carrier Sphere Geometry

13.3 ε_0 and μ_0 - Proposed Forms

From the condensate Lagrangian of Section 14.1, the proposed forms are:

$$\varepsilon_0 = q^2|\psi_0|^2/c^2$$ [proposed form - conditional on Section 14.7 Requirements 1–2]

$$\mu_0 = 1/(q^2|\psi_0|^2)$$ [proposed form - conditional on Section 14.7 Requirements 1–2]

Their algebraic consequence $\varepsilon_0\mu_0=1/c^2$ is established as a theorem of the condensate structure. The individual numerical values require identifying $|\psi_0|^2$ from the SCT Lagrangian (Requirement 1) and confirming the Goldstone mode is massless and spin-1 (Requirement 2).

14 The Carrier Condensate

14.7 Open Requirements

Requirement 1: Identify κ from SCT Lagrangian → gives $|\psi_0|^2$ and dispersion relation (OPEN - Paper 18 primary deliverable).

Requirement 2: Confirm Goldstone mode massless and spin-1, or confirm vortex solutions (OPEN).

Requirement 3: Maxwell action from condensate - conditional on Requirement 2.

Until Requirements 1–2 are complete, the ε_0, μ_0, α, and force ratio expressions are proposed forms, not confirmed results.

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15 Predictions: Formal Register

All predictions are stated in the format required for evaluation: predicted quantity, predicted value, uncertainty (1σ), observational test, and explicit falsification condition. Status: F = forecast (instrument not yet operational), P = predicted (awaiting execution), O = open (derivation pending), C = conditional (on completing stated requirements).

#	Quantity	Predicted Value	1σ Uncertainty	Observational Test	Falsification Condition	Status
1	N_eff (effective relativistic species)	2.514	±0.050	CMB-S4 temperature+polarization power spectra; also: SCT N_eff posterior from Planck (open computation)	N_eff > 2.80 at 3σ after full parameter marginalization (CMB-S4); open tension: 2.8σ from Planck under ΛCDM assumptions (model-inconsistent comparison - see Sec 11.6.8, 12.5)	F - CMB-S4 2030+; Open tension with Planck under ΛCDM
2	r_d (BAO drag radius)	146–149 Mpc	±0.6 Mpc (after CAMB rerun with R_b=0.2545)	DESI Year 5 BAO measurement	r_d > 150.5 Mpc or < 145.0 Mpc at 3σ	F - DESI Y5 2028
3	Ĉ_bg (cosmological coherence floor)	1.0848	±0.004	Intrinsic alignment bias b_IA across DES/HSC/KiDS; must equal 1+R_b/3	b_IA inconsistent with 1+R_b/3 across 3 independent surveys at 3σ	P - current data marginal
4	Galactic C(r) profile	C(r)=f(M_baryon) only	No free parameters	Any galaxy with fully characterized baryonic mass distribution	C(r) requiring free parameters	O - Paper 14 Green's

#	Quantity	Predicted Value	1σ Uncertainty	Observational Test	Falsification Condition	Status
			after Paper 14		not determined by baryons	fns required
5	Vacuum birefringence $\delta\varepsilon_0/\varepsilon_0$	≈R_b/3 = 0.085	Order-of-magnitude	ALMA polarimetry near compact objects; ngEHT	No birefringence detected above noise floor	C - conditional on Paper 14 Req. 1-2
6	δα/α spatial variation	∝ δC/C	Proportional to local coherence	ELT + ESPRESSO multi-epoch spectra	Constant α at all environments at 10^{-6} precision	C - conditional on Paper 14
7	δG_N/G_N = 2×δα/α	Exact ratio = 2	Exact (no uncertainty in ratio)	Lunar Laser Ranging + ELT joint measurement of G_N and α	Ratio ≠ 2 at 3σ	C - conditional on Paper 18
8	f_DM(z) evolution	Follows Kuramoto coupling	No free parameters	Euclid weak lensing S8(z) profile	S8(z) inconsistent with Kuramoto Ĉ(r) prediction at 3σ	P - Euclid Year 1

Note on Prediction 1 (N_eff): The 17.7σ figure is computed as ΔN_eff/σ_CMB-S4 = 0.532/0.030. This is a forecast separation based on CMB-S4 design specifications. After marginalization over Y_p, Σm_ν, and α_s in a joint analysis, the effective separation will be reduced but remains statistically decisive given ΔN_eff = 0.532. If CMB-S4 measures N_eff consistent with the Standard Model value 3.046, the cascade geometry chain of Section 11.6 is falsified at high significance.

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