From Chaos To Concordance Spectra

A Theoretical Framework Demonstrating CMB Power Spectrum Compatibility within Successive Collision Theory

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

March 7 2026
https://doi.org/10.13140/RG.2.2.20310.31042
Version 3.7

Abstract

Successive Collision Theory (SCT) proposes that the observable universe is a thermalized collision product embedded within an infinite, eternally evolving manifold, replacing the singular hot-dense-center assumption of Lambda-CDM with a succession of superluminal intersections between nested comoving frames. This paper presents a rigorous mathematical framework demonstrating that SCT is fully compatible with the observed CMB temperature angular power spectrum within current observational precision, and identifies the conditions under which future data can discriminate between the two frameworks. Six specific physical requirements are addressed in turn: (1) generation of a hot, fully thermalized photon-baryon plasma; (2) a nearly scale-invariant primordial perturbation spectrum with spectral index n_s = 0.965 +/- 0.004; (3) adiabatic initial conditions; (4) acoustic peak structure consistent with Planck 2018 multipole positions and amplitudes; (5) a modified stress-energy tensor incorporating constructive gravitational superposition as a dark-matter analog; and (6) the Silk diffusion-damping tail. For each requirement, the SCT-specific physics is developed from first principles and shown to reduce to the standard Boltzmann-Einstein photon-baryon system with modified initial conditions and an enriched expansion history. Where SCT departs from Lambda-CDM, falsifiable observational signatures are identified, including a dipolar spectral-distortion anisotropy, a BAO sound-horizon shift, a tensor-to-scalar ratio r approximately 0, and a predicted A_lens > 1. Numerical implementation via a modified Boltzmann solver is identified as the essential next step for a direct chi-squared comparison against Planck data

Keywords: *cosmic microwave background; alternative cosmology; acoustic oscillations; Successive Collision Theory; dark matter analog; spectral distortions; primordial perturbations*

I. Introduction and Motivation

The cosmic microwave background (CMB) angular power spectrum is the single most constraining dataset in observational cosmology. The Planck satellite measured the temperature power spectrum C_l^TT to cosmic-variance-limited precision up to l ≈ 2500, determining eight TT peaks, five EE peaks, and twelve TE extrema [1,2,3]. Under Lambda-CDM, six parameters suffice to fit these data: Omega_b h^2, Omega_c h^2, n_s, tau, A_s, and theta_*, as summarized in Table 1.

Parameter	**Planck 2018 Value**	**Physical Meaning**
Omega_c h^2	0.120 ± 0.001	Cold dark matter density
Omega_b h^2	0.0224 ± 0.0001	Baryon density
n_s	0.965 ± 0.004	Primordial spectral index
tau	0.054 ± 0.007	Optical depth to reionisation
100 theta_*	1.0411 ± 0.0003	Angular sound horizon
H_0	(67.4 ± 0.5) km/s/Mpc	Hubble constant

Table 1. Planck 2018 best-fit Lambda-CDM cosmological parameters.

Despite this remarkable success, Lambda-CDM faces several persistent tensions and anomalies. The Hubble tension — a ~5-sigma discrepancy between H_0 inferred from the CMB and from the local distance ladder — remains unresolved [2,4]. The S_8 tension (~3.4 sigma), the A_lens anomaly (>2 sigma), directional parameter variations at ~3 sigma, and large-angle CMB anomalies including the Cold Spot, the quadrupole-octupole alignment, and hemispherical power asymmetry collectively suggest that the standard six-parameter model may be incomplete [2,4].

Successive Collision Theory (SCT) [23] proposes that the observable universe is not the product of an isolated singular event but a thermalized collision product embedded within an infinite, eternally evolving manifold. In SCT, the hot photon-baryon plasma responsible for the CMB arises from the superluminal intersection of two large-scale comoving pockets — a process consistent with both General Relativity and Special Relativity, as established in detail in the companion foundational paper [23].

The central question this paper addresses is: Can SCT reproduce the observed CMB angular power spectrum with fidelity comparable to Lambda-CDM? The answer is affirmative, because the physics of acoustic oscillations in a photon-baryon plasma depends only on five conditions: (a) the existence of a hot, ionised, radiation-dominated fluid; (b) a nearly scale-invariant spectrum of initial density perturbations; (c) adiabatic initial conditions; (d) the expansion history H(z); and (e) the matter-energy content rho_i(z). SCT provides all five through different physical mechanisms than Lambda-CDM but arrives at the same photon-baryon fluid equations. This paper develops each mechanism in turn.

An important epistemological note: this paper demonstrates theoretical compatibility between SCT and the observed CMB, not a completed Planck-precision chi-squared fit. Numerical implementation via a modified CAMB or CLASS Boltzmann solver, with fully specified forms of the superposition function f[N, alpha, r] and the expansion history H_SCT(z), is identified as the essential next step. The theoretical framework presented here establishes that no fundamental obstacle prevents such a fit, and identifies the parameter mappings and observational signatures that will constrain or falsify SCT when the numerics are complete.

This paper is organized as follows. Section II reviews the standard CMB power spectrum formalism that is model-independent. Sections III through VIII address each of the six physical requirements in turn. Section IX assembles the complete SCT power spectrum expression. Section X presents testable predictions. Section XI discusses open questions. Appendix A summarizes the twelve premises from [23] most load-bearing for the CMB argument, identified by their original premise numbers.

II. The Standard CMB Power Spectrum Formalism

II.1 Angular Power Spectrum

The CMB temperature anisotropy Theta(n-hat) = DeltaT/T is decomposed in spherical harmonics. The angular power spectrum is [5]:

C_l = 4pi * integral [Delta_zeta^2(k) * |Theta_l(k) / zeta(k)|^2] d(ln k) *(1)*

where Theta_l(k)/zeta(k) is the photon transfer function and Delta_zeta^2(k) is the dimensionless primordial power spectrum. Equation (1) is exact and model-independent: it holds for any theory that produces perturbations zeta in a Robertson-Walker background [5]. The entire debate between Lambda-CDM and SCT therefore reduces to whether each theory can supply the correct primordial spectrum and transfer function.

II.2 The Photon-Baryon Fluid

In the tight-coupling limit, the photon-baryon system satisfies the continuity and Euler equations [6,7]:

Theta-dot_0 = -(k/3) v_gamma + 3 Phi-dot *(2)*

v-dot_gamma = k Theta_0 - (k/6) pi_gamma - tau-dot (v_gamma - v_b) *(3)*

where R = 3 rho_b / (4 rho_gamma) is the baryon-photon momentum ratio, tau-dot = n_e sigma_T a is the differential optical depth, and Psi, Phi are the Bardeen potentials. In the tight-coupling limit these reduce to a driven harmonic oscillator [6]:

Theta-ddot_0 + (k^2 / 27|tau-dot|) A_d Theta-dot_0 + k^2 c_s^2 Theta_0 = F(k, eta) *(4)* with sound speed $c_s^2 = 1/[3(1+R)]$ [8,9]. This equation governs the acoustic peaks regardless of how the plasma was created. SCT must supply the correct R, the correct initial conditions for Θ_0 and v_γ, and the correct expansion history entering through H(z). These are addressed in Sections III, V, and VII respectively.

II.3 The Complete Transfer Function

After recombination, free-streaming yields the transfer function [5]:

$$\Theta_l(\eta_0) = [\Theta_0(\eta_{rec}) - \Phi(\eta_{rec})]\, j_l(k\,\Delta\eta) + 3\,\Theta_1(\eta_{rec})\, j_l'(k\,\Delta\eta) \quad (5a)$$

$$- 2 \int_{\eta_{rec}}^{\eta_0} \dot{\Phi}(\eta_1)\, j_l(k(\eta_0 - \eta_1))\, d\eta_1 \quad (5b)$$

The three terms represent monopole (SW), dipole (Doppler), and integrated Sachs-Wolfe contributions. Crucially, Equations (1)-(5) depend on the primordial spectrum, background expansion, and matter-energy content — not on the mechanism that created the hot plasma. This is the foundation of the compatibility argument.

III. Requirement 1 — Hot Plasma from Superluminal Collisions

III.1 The Physical Mechanism

In Lambda-CDM, the hot plasma arises from reheating after inflation. In SCT, it arises from the kinetic energy released during the superluminal intersection of two large-scale comoving pockets ([23], P20-P25). When two pockets with relative velocity $v_{rel} \gg c$ intersect, the intersection front propagates through each pocket faster than any internal signal can travel. The entire overlap volume is engulfed before any internal communication can warn the interior, depositing the full kinetic energy into the overlap volume essentially simultaneously. The kinetic energy per unit mass available for thermalization is:

$$\epsilon_{kin} = (\gamma_{rel} - 1)\, m c^2 \quad (6)$$

where γ_{rel} can be extremely large for pockets that have never shared a causal reference frame. This is not a violation of Special Relativity. The SR speed limit applies to the local acceleration of objects within a single inertial frame. Two pockets separated by distances exceeding $c/H_0 \sim 14.4$ Gly inherit their momenta from independent formation histories and are subject to the same reasoning that standard cosmology applies to superluminal Hubble recession — a precedent already universally accepted [23, P20-P22].

III.2 Thermalization Guarantee

For the collision-generated plasma to produce the observed CMB, it must achieve a thermal Planck distribution. Three independent thermalization processes guarantee this. First, the Compton scattering rate at $T \sim 10^9$ K is $\Gamma_{Compton} \sim 10^{18}\ s^{-1}$, while the expansion rate $H \sim 1\ s^{-1}$, giving $\Gamma/H \sim 10^{18}$ — a ratio that guarantees thermalization on timescales vastly shorter than any relevant cosmological process [10]. Second, bremsstrahlung and double Compton scattering at $T > 10^7$ K adjust the photon number to its thermal equilibrium value. Third, complete thermalization is guaranteed for $z > z_{th} \sim 2 \times 10^6$, and since the SCT cascade terminates before $t \sim 1$ second ([23], P36-P40) — corresponding to $z \gg z_{th}$ — the resulting radiation field is a nearly perfect blackbody, exactly as established by COBE/FIRAS [10].

III.3 Plasma Equivalence Theorem

Theorem 1 (Plasma Equivalence).
If the SCT collision cascade produces a fully thermalized radiation-dominated plasma at temperature $T_{init} > T_{BBN} \sim 10^9$ K with small perturbations $|\delta| \ll 1$, and if the cascade terminates before $t \sim 1$ second (guaranteed by BBN abundance constraints and FIRAS spectral purity; [23] P36-P40), then the subsequent evolution of the photon-baryon fluid is governed by the identical Boltzmann-Einstein system as in Lambda-CDM, independent of the plasma's origin. Proof: The Boltzmann equation for photons, $df/dt + \hat{p} \cdot \nabla f - Hp(df/dp) = C[f]$, depends only on the current phase-space distribution $f(x,p,t)$, the metric perturbations, and the electron density. It contains no memory of how f was initialized ([23], P29-P30). Given identical thermodynamic state parameters $\{T_{dec}, \eta, Y_p, \tau_{reion}, k_{eq}, r_s\}$ and identical expansion histories, the solutions are identical. The cascade termination time ($t < 1$ s) is constrained by three independent observational requirements stated in P36-P40 of the companion paper, none of which involves the CMB acoustic structure itself, eliminating circularity. QED.

Requirement 1 is therefore satisfied: SCT produces a hot thermalized plasma that is observationally indistinguishable from the Lambda-CDM plasma at all epochs relevant to CMB formation.

III.4 FIRAS Blackbody Preservation

COBE/FIRAS constrains the CMB monopole spectrum to $|\mu| < 9 \times 10^{-5}$ and $|y| < 1.5 \times 10^{-5}$ at 95% CL [10]. Any viable alternative to Lambda-CDM must demonstrate that its energy injection history does not generate distortions exceeding these limits. In SCT, three energy injection channels are present:

Channel 1 — Acoustic (Silk) dissipation: identical to Lambda-CDM at leading order (established in Theorem 4). The associated mu-distortion from a Harrison-Zel'dovich-type spectrum is $\mu_{Silk} \sim 2 \times 10^{-8}$, six orders of magnitude below the FIRAS limit.

Channel 2 — Gravitational superposition heating: the superposition functional $S(z) \to 0$ as $z \to \infty$ ([23], P45-P48), so no anomalous energy density is present in the photon epoch. No additional injection arises from this channel.

Channel 3 — Direct collision kinetic energy: at $z > 10^3$, the photon energy density $\rho_\gamma \propto (1+z)^4$ dominates baryonic kinetic energy by many orders of magnitude. The fractional injection is $\delta\rho_\gamma / \rho_\gamma \leq 10^{-8}$ — well below any distortion threshold.

Theorem 2 (FIRAS Blackbody Preservation).
Let $\dot{Q}_{SCT}(z)$ be the total rate of energy injection into the photon bath from all SCT processes. For $z \geq z_{rec} \sim 1100$, the cumulative fractional distortions satisfy $\mu_{SCT} \ll 9 \times 10^{-5}$ and $y_{SCT} \ll 1.5 \times 10^{-5}$. Proof: All three SCT injection channels either (i) are identical to Lambda-CDM contributions already known to satisfy FIRAS limits, or (ii) are suppressed by the ratio of baryonic kinetic energy to photon energy density at $z \geq 10^3$, which is $\leq 10^{-8}$. The FIRAS constraints are therefore satisfied with ample margin, and the CMB blackbody spectrum is preserved to better than 10^{-5} precision. QED.

A specific SCT prediction distinguishable from Lambda-CDM for next-generation experiments such as PIXIE or PRISM: a dipolar y-distortion aligned with the collision axis (the same axis that produces the large-angle CMB anomalies). This constitutes a falsifiable signature unique to SCT, simultaneously consistent with all FIRAS data and testable with future spectral surveys.

IV. Requirement 2 — Scale-Invariant Primordial Perturbation Spectrum

IV.1 The Observational Requirement

The observed CMB requires a primordial power spectrum [11,2]:

$$\Delta_\zeta^2(k) = A_s (k/k_*)^{n_s - 1} \qquad (7)$$

with $A_s \sim 2.1 \times 10^{-9}$ and $n_s = 0.965 \pm 0.004$. A purely scale-invariant (Harrison-Zel'dovich) spectrum corresponds to $n_s = 1$ [12,13]. Any viable alternative to inflation must explain both the near-scale-invariance and the modest red tilt without fine-tuning.

IV.2 The Collision Perturbation Spectrum

In SCT, primordial perturbations arise from the superposition of density fluctuations generated during successive collision events ([23], P25, P29, P35-P36). Each collision event i generates a perturbation field delta_i(x) with characteristic scale L_i and amplitude A_i. The total perturbation field is the sum over all N_coll events.

IV.3 Scale Invariance from the Central Limit Theorem

Theorem 3 (Collision Scale Invariance).
If successive collisions span a range of scales {L_i} with a power-law distribution dN/dL ∝ L^{-alpha}, and the cascade has terminated before t ~ 1 second (Theorem 1), and each collision generates statistically independent perturbations with comparable energy densities ([23], P36-P40), then the resulting dimensionless power spectrum satisfies Delta^2(k) ∝ k^{alpha-1}, giving spectral index n_s = alpha.

A critical point on statistical independence: the independence assumption requires that successive collision stages are not correlated in their density perturbation outputs. This is guaranteed by cascade termination before t ~ 1 second ([23], P36-P40): by the time the photon-baryon fluid begins its acoustic evolution (t ~ 10^4 years), more than 10^{11} thermalization timescales have elapsed, erasing all memory of the stage-to-stage correlations that existed during the non-equilibrium cascade. The perturbations imprinted on the fluid at the start of acoustic evolution are therefore effectively independent realizations for the purposes of the CLT argument.

The derivation proceeds as follows. Each collision at scale L_i generates a Fourier perturbation:

|delta-tilde_i(k)|^2 ~ A_i^2 L_i^3 exp[-(k L_i)^2 / 2] *(8)*

The total power spectrum, summing over the collision scale distribution, is:

P(k) ∝ rho_kin * integral_{L_min}^{L_max} L^{3-alpha} exp[-(kL)^2/2] dL *(9)*

Substituting u = kL and taking the limits to (0, infinity) for observable scales:

P(k) ∝ k^{alpha-4} => Delta^2(k) = k^3 P(k) / (2pi^2) ∝ k^{alpha-1} *(10)*

giving n_s = alpha, confirming the theorem.

IV.4 Physical Origin of the Red Tilt

Scale invariance (n_s = 1) corresponds to alpha = 1: the number of collision events per logarithmic interval in scale is constant. This is the natural expectation for a scale-free process in an infinite, scale-invariant universe ([23], P07). The observed n_s = 0.965 corresponds to alpha = 0.965 — slightly more small-scale collisions per logarithmic interval.

This red tilt has a physically motivated origin independent of the CMB measurement. As the cascade progresses ([23], P35, P48), successive daughter collisions inherit reduced kinetic energies from their parent events. The characteristic scale of each new stage is set by the daughter pocket size, which decreases systematically with each generation. This produces a slight excess of small-scale relative to large-scale collision events, parameterised as:

$$dN/dL = N_0 L^{-1} [1 + \beta \ln(L/L_0)]^{-1} \quad (11)$$

giving $n_s = 1 - \beta$. The observed value requires $\beta = 0.035$. While this remains a parameter to be constrained by data, its physical interpretation — the fractional scale reduction per cascade generation — is not a free parameter in the same sense as the inflation slow-roll epsilon: it is tied to the pocket size ratio, which is independently constrained by the large-scale structure predictions of SCT ([23], P49-P53). A joint constraint across CMB and LSS data will be required to fix beta without circularity.

IV.5 Gaussianity and Non-Gaussianity

By the Central Limit Theorem, the superposition of $N_{coll} \gg 1$ independent collision events (after cascade termination; see IV.3 above) produces a nearly Gaussian perturbation field, with corrections of order $1/\sqrt{N_{coll}}$. This is consistent with the Planck constraint $f_{NL}^{local} = -0.9 \pm 5.1$ [2]. SCT predicts small but potentially detectable non-Gaussianity from (a) the finite number of cascade stages, (b) residual geometric asymmetry of the collision, and (c) the preferred collision axis. The predicted f_{NL} is of order $1/\sqrt{N_{coll}}$, intermediate between the near-zero prediction of slow-roll inflation and the generically large f_{NL} of ekpyrotic models [17], making it a useful discriminant as measurement precision improves.

V. Requirement 3 — Adiabatic Initial Conditions

V.1 The Requirement

CMB data strongly favor adiabatic initial conditions, in which all species share the same fractional perturbation in number density [18]:

$$\delta_\gamma / 4 = \delta_b / 3 = \delta_c / 3 = \delta_\nu / 4 \quad (12)$$

Isocurvature modes are constrained to $\beta_{iso} < 0.038$ at 95% CL [2].

V.2 Adiabaticity from Complete Thermalization

Theorem 4 (Adiabaticity).

Superluminal collisions that fully thermalize all species produce strictly adiabatic initial conditions. Proof: In a superluminal collision ([23], P20-P25), the kinetic energy per collision $E_{kin} \gg m_{species} c^2$ for all Standard Model particles. All species are *produced thermally at temperature $T_{coll}(x) = \bar{T}_{coll} [1 + \delta_T(x)]$, giving $\delta n_i / n_i = (d \ln n_i / d \ln T) \delta_T = 3 \delta_T$ for all relativistic species i. Since all species respond identically to δ_T, the condition $\delta n_i / n_i = \delta n_j / n_j$ holds automatically — these are adiabatic initial conditions by definition. Isocurvature modes are suppressed because all species are generated from the same thermal bath, and because the SCT dark-matter analog arises from gravitational superposition of baryonic structures ([23], P45-P49) rather than a separate particle species, eliminating the primary source of CDM isocurvature modes. QED.*

VI. Requirement 4 — Acoustic Peak Structure

VI.1 Peak Positions

Acoustic peaks arise from coherent oscillations of the photon-baryon fluid. The n-th peak occurs at [1]:

$$\ell_n \sim n \pi \cdot d_A(z_*) / r_s(z_*) \quad (13)$$

where the sound horizon is [9,19]:

$$r_s(z_*) = \int_{z_*}^{\infty} c_s \, dz / H(z) \quad (14)$$

Peak positions depend on $H(z)$ and Ω_b/Ω_γ — not on how the plasma was created. SCT reproduces the correct peak positions by supplying the correct $H_{SCT}(z)$ and baryon density, as developed in Section VII.

VI.2 Peak Heights and Baryon Loading

The WKB solution for the oscillating fluid with a gravitational potential gives [20,5]:

$$[\Theta_0 + \Phi](\eta) = (1/3 + A) \cos(k r_s) - A \quad (15)$$

where $A = R \Psi$ represents the baryon-loading offset. The odd/even peak height ratio depends on $\Omega_b h^2$ through R. In SCT, the baryon density is identical to Lambda-CDM (set by BBN; Section VIII), so R is the same and the odd/even ratio is reproduced to leading order. The gravitational potential Ψ differs only through the modified expansion history $H_{SCT}(z)$, entering at second order in $S(z_*)$.

VI.3 The First Peak and Geometry

The first peak at $\ell_1 \sim 220$ constrains $100 \theta_* = 1.0411 \pm 0.0003$ [11,2]. In SCT, this constrains:

$$d_A^{SCT}(z_*) / r_s^{SCT}(z_*) = d_A^{LCDM}(z_*) / r_s^{LCDM}(z_*) \quad (16)$$

Given the freedom in Lambda_eff(z) and S(z), SCT can satisfy this constraint. The consistency of this satisfaction with other observables — particularly the BAO sound horizon in the matter power spectrum — is addressed in Section X as a falsifiable prediction.

VII. Requirement 5 — Modified Stress-Energy Tensor

VII.1 The SCT Field Equations

The standard Einstein equations G_mu_nu + Lambda g_mu_nu = 8piG T_mu_nu are modified in SCT by two of the three EFE modifications established in the companion paper ([23], P59-P61):

$$G_{\mu\nu} + \Lambda_{eff}(x,t)\, g_{\mu\nu} = (8\pi G/c^4) * f[N, \alpha, r] * T^{\mu\nu}_{matter} \quad (17)$$

where Lambda_eff(x,t) is the dynamical cosmological ratio ([23], P17) and f[N, alpha, r] is the constructive gravitational superposition function ([23], P45-P48). Both reduce to their standard values in appropriate limits: f -> 1 for a single isolated body (N = 1), and Lambda_eff averaged over a Hubble volume reproduces the observed Lambda_obs ~ 1.1 x 10^{-52} m^{-2}.

VII.2 The Constructive Superposition Function

The f[N, alpha, r] function captures the coherent gravitational contribution of all comoving sources in the nested frame hierarchy. When N massive bodies share the same bulk velocity (comoving condition), their gravitational contributions arrive with correlated phases at points within the frame, producing constructive superposition. The effective additional density is:

$$\rho_{super}(x) = -(1/4\pi G) \sum_{i<j} \nabla\Phi_i \cdot \nabla\Phi_j \quad (18)$$

At the background level, this yields an effective gravitational constant G_eff(z) = G [1 + S(z)], giving:

$$H_{SCT}^2(z) = (8\pi G/3) [\rho_r (1+z)^4 + (1+S(z))\, \rho_b (1+z)^3 + \rho_\nu] + \Lambda_{eff}(z)/3 \quad (19)$$

VII.3 Boundary Conditions on S(z)

The superposition enhancement factor S(z) obeys two physically motivated boundary conditions derived from the nested frame hierarchy ([23], P45-P48):

First, S(z) -> 0 as z -> infinity. At very high redshift, structure has not yet formed: all matter is in a uniform, unclustered plasma. In the absence of distinct comoving substructures, N -> 1 and the coherent superposition enhancement vanishes. Quantitatively, S(z) ~ delta^2(z) where delta(z) is the matter overdensity, which is perturbatively small at z >> 1. At the CMB epoch, S(z_*) ~ 10^{-5}.

Second, S(z_0) ~ Omega_CDM / Omega_b - 1 ~ 4.4 at z = 0, required to reproduce the observed total matter density. This boundary condition is not a free choice — it is fixed by the same observational data that fix Omega_c h^2 in Lambda-CDM. The function S(z) interpolates between these two values, tracking the growth of structure. Its specific functional form must be determined by the N-body structure formation implementation identified in Section XI as future work.

VII.4 Variable Dark Energy

The dynamical cosmological ratio Lambda_eff(z) = Lambda_0 * f_mesh(z) [23, P17] represents mesh dissipation propagating through the nested parent frame hierarchy ([23], P14). For z >> 1, Lambda_eff(z) -> 0, so dark energy is negligible at recombination — exactly as in Lambda-CDM. The CMB acoustic spectrum is therefore insensitive to the specific form of f_mesh(z), which governs only the late-time expansion history.

VII.5 SCT-to-Lambda-CDM Parameter Correspondence

Lambda-CDM Parameter	SCT Equivalent	Physical Origin in SCT
Omega_b h^2	Identical	Big Bang nucleosynthesis (unchanged)
Omega_c h^2	S(z) x Omega_b h^2	Constructive gravitational superposition
n_s	alpha = 1 - beta	Collision scale distribution (Theorem 3)
A_s	A_SCT	Collision kinetic energy density
tau	Identical	Reionisation physics (unchanged)
theta_*	Constrained by H_SCT(z)	Modified expansion history via Eq. (19)
Lambda	Lambda_0 * f_mesh(z)	Gravitational mesh dissipation ([23], P17)

Table 2. Parameter correspondence between Lambda-CDM and SCT for CMB fitting.

The SCT framework has the same number of free parameters as Lambda-CDM for fitting the CMB (six), but replaces three with physically motivated quantities derivable from the companion foundational framework [23].

VIII. Requirement 6 — The Silk Diffusion Damping Tail

VIII.1 Physical Origin

The CMB damping tail arises from photon diffusion through the imperfectly coupled baryon-photon fluid. Photons random-walk out of overdense regions, carrying energy and washing out anisotropies on scales smaller than the diffusion length. The physics is entirely local and microphysical, depending on the Thomson cross section σ_T, electron density $n_e(z)$, ionisation fraction $x_e(z)$, and baryon-photon ratio R — none of which depend on the origin of the plasma [21,6].

VIII.2 The Silk Damping Scale

The damping wavenumber from the Boltzmann hierarchy is [22,6]:

$$k_D^{-2} = (1/6) * \int_0^{\eta_*} \left[\frac{d\eta}{n_e \sigma_T a} \right] * \frac{R^2 + 16(1+R)/15}{(1+R)^2} \tag{20}$$

The comoving Silk scale at recombination is approximately [22]:

$$\lambda_{Silk} \sim 5.7\, (\Omega_m h^2)^{-3/4} (\Omega_b / \Omega_m)^{-1/2}\ \text{Mpc} \tag{21}$$

VIII.3 SCT Damping Equivalence

Theorem 5 (Silk Damping Equivalence).
The Silk damping scale in SCT equals the Lambda-CDM value to within perturbative corrections: $k_D^{SCT} = k_D^{LCDM} \times [1 + O(S(z_*)^2)]$. Since $S(z_*) \sim 10^{-5}$, this correction is of order 10^{-10} and entirely negligible. Proof: The recombination history $x_e(z)$ is determined by atomic physics — hydrogen recombination via the Peebles three-level atom — which is identical in SCT because the plasma composition is the same as established in Requirements 1 and 3. The expansion rate enters through $H_{SCT}(z) = H_{LCDM}(z) * [1 + O(S(z_*))]$, making the damping scale effectively indistinguishable between the two frameworks. QED.

IX. The Complete SCT Angular Power Spectrum

IX.1 Assembly

Combining all six requirements, the SCT prediction for the angular power spectrum is:

$$C_l^{SCT} = 4\pi * \int \Delta_{SCT}^2(k)\, |T_l^{SCT}(k)|^2\, d\ln k \tag{22}$$

where the primordial spectrum (from Requirement 2) is:

$$\Delta_{SCT}^2(k) = A_{SCT} (k/k_*)^{\alpha - 1} \qquad (23)$$

and the SCT photon transfer function (from Requirements 1, 4, 5, 6) is:

$$T_l^{SCT}(k) = [\Theta_0^{SCT}(\eta_*) + \Phi^{SCT}(\eta_*)] j_l(k \Delta\eta) + 3 \Theta_1^{SCT}(\eta_*) j_l'(k \Delta\eta) \qquad (24a)$$

$$- 2 \int_{\eta_*}^{\eta_0} \dot{\Phi}^{SCT}(\eta_1) j_l(k(\eta_0 - \eta_1)) d\eta_1 \qquad (24b)$$

IX.2 Deviation from Lambda-CDM

For the observable range $2 \leq l \leq 2500$, the fractional deviation between SCT and Lambda-CDM predictions can be written as a sum of three terms:

$$(C_l^{SCT} - C_l^{LCDM}) / C_l^{LCDM} = \epsilon_1(l) + \epsilon_2(l) + \epsilon_3(l) \qquad (25)$$

where $\epsilon_1 \sim O(\beta - (1 - n_s))$ arises from the collision spectral index; $\epsilon_2 \sim O(S(z_*)) \sim O(10^{-5})$ from gravitational superposition at recombination; and $\epsilon_3 \sim O(\Lambda_{eff}(z_*)/\Lambda)$ from variable dark energy. Since ϵ_2 and ϵ_3 are suppressed at $z \sim 1100$, the total deviation is controlled by ϵ_1 — which vanishes when beta is fixed to its observed value. A quantitative chi-squared comparison therefore awaits numerical implementation of the modified Boltzmann solver (Section XI).

X. Testable Predictions and Discriminating Signatures

X.1 Large-Angle CMB Anomalies

SCT provides a common geometric origin for several CMB anomalies that Lambda-CDM treats as independent statistical fluctuations. All derive from the collision geometry:

- Hemispherical power asymmetry: the asymmetric collision geometry introduces dipolar power modulation, naturally explaining the observed ~7% asymmetry [4].
- Quadrupole-octupole alignment (axis of evil): the collision axis defines a preferred spatial direction, producing correlated alignment of the lowest multipoles.
- Odd-parity preference: a grazing collision with net angular momentum ([23], P31) breaks the symmetry between even and odd multipoles.
- Cold Spot: a geometrically distinct high-density boundary region of the collision produces a localized temperature decrement with the angular scale characteristic of the pocket interaction zone.

Crucially, all four anomalies are predicted to share the same preferred axis — the collision axis — making their mutual alignment a falsifiable cross-check rather than a post-hoc explanation.

X.2 Quantitative Falsifiable Predictions

Observable	Lambda-CDM Prediction	SCT Prediction	Current Data
r (tensor/scalar)	0.001-0.1 (model-dep.)	~ 0 (no inflationary GWB)	< 0.06 [2]
f_NL^local	~ 0 (slow roll)	~ 1/sqrt(N_coll)	-0.9 ± 5.1 [2]
A_lens	1.0	> 1 (superposition lensing)	1.18 ± 0.065 [2,3]
alpha_s (running)	Model-dependent	-beta^2 ~ -0.001	-0.0045 ± 0.0067 [2]
BAO sound horizon r_s	~ 147 Mpc (CDM+baryon)	Slightly shifted upward	DESI/Euclid (forthcoming)
Dipolar y-distortion	Absent	Aligned with collision axis	Testable at PIXIE/PRISM
Large-scale spin alignment	< 100 Mpc (tidal torque)	> 1 Gpc (inheritance)	Observed >100 Mpc [23]
Dark matter detection	Particle detectable	No particle; null results	Ongoing null results

Table 3. Falsifiable predictions distinguishing SCT from Lambda-CDM.

Of particular note: the A_lens > 1 preference in Planck data (A_lens = 1.18 ± 0.065 at > 2-sigma) is a natural consequence of the additional lensing power provided by the constructive gravitational superposition term in Equation (17). Lambda-CDM has no physical explanation for A_lens ≠ 1; SCT predicts it as a consequence of the parent-frame mesh contributing coherent lensing power beyond the local matter distribution.

XI. Discussion

XI.1 Summary of Results

This paper demonstrates that SCT is theoretically compatible with the observed CMB angular power spectrum. The six physical requirements for CMB formation are each satisfied through SCT-specific mechanisms that reduce to the standard photon-baryon Boltzmann system:

- Requirement 1 (Hot plasma): the collision cascade produces a fully thermalized plasma with Gamma/H ~ 10^{18}, guaranteed by three independent processes.

- Requirement 2 (Scale invariance): the CLT applied to $N_{coll} \gg 1$ independent collision events generates a near-Harrison-Zel'dovich spectrum with a red tilt physically motivated by cascade kinematics.
- Requirement 3 (Adiabaticity): complete thermalization from a single thermal bath automatically produces adiabatic conditions; isocurvature modes are suppressed because no separate dark-matter particle species exists.
- Requirement 4 (Acoustic peaks): identical photon-baryon oscillation physics reproduces peak positions; baryon loading is unchanged; peak heights differ only at order $S(z_*) \sim 10^{-5}$.
- Requirement 5 (Modified stress-energy): gravitational superposition provides an effective dark-matter-like term that grows from $S(z_*) \sim 0$ at recombination to $S(z_0) \sim 4.4$ today, with all GR limits recovered exactly.
- Requirement 6 (Damping tail): identical Silk damping physics, with deviations suppressed at order $S(z_*)^2 \sim 10^{-10}$.

XI.2 Essential Next Steps

Four areas of future work are essential to elevate this framework to a fully tested alternative:

- Numerical implementation: the SCT expansion history $H_{SCT}(z)$ and the superposition function $S(z)$ must be implemented in a modified CAMB or CLASS Boltzmann solver to produce numerical C_l curves for direct chi-squared comparison against Planck data. This requires specifying the functional form of $S(z)$ between its boundary conditions.
- BBN consistency: the expansion rate $H_{SCT}(z)$ at $z \sim 10^9$ (nucleosynthesis epoch) must be verified to produce the observed light-element abundances $Y_p = 0.2449 \pm 0.0040$ and $D/H = (2.527 \pm 0.030) \times 10^{-5}$.
- Matter power spectrum: the gravitational superposition mechanism must reproduce the observed $P(k)$ and halo mass function, and the predicted BAO peak shift must be computed at the precision level of DESI and Euclid.
- CMB lensing: the lensing power spectrum $C_l^{\phi\phi}$ must be computed under SCT, including the coherent mesh contribution, to make a specific prediction for the A_{lens} anomaly.

XI.3 Advantages of the SCT Framework

SCT eliminates the need for inflation, inflaton fields, and dark-matter particles — three entities for which no direct observational evidence exists — while simultaneously providing natural explanations for the Hubble tension (local Λ_{eff} variability), the A_{lens} anomaly (coherent mesh lensing), large-angle CMB anomalies (collision geometry), the absence of dark-matter detections (no particle to detect), and anomalously large early structures (residual collision clumps seeding early galaxy formation). These are not independent post-hoc explanations: they follow from a single change to a single assumption about the universe's origin.

Acknowledgements

The author gratefully acknowledges the foundational observational and theoretical work on which this paper rests. The accidental discovery of the CMB by Arno Penzias and Robert Wilson (1965) made the entire observational program possible. The acoustic oscillation framework was established by R.K. Sachs, A.M. Wolfe, Joseph Silk, P.J.E. Peebles, Rashid Sunyaev, and Yakov Zel'dovich across the 1960s-70s. The analytic CMB formalism of Wayne Hu and Naoshi Sugiyama, the CAMB Boltzmann solver of Antony Lewis and Anthony Challinor, and the CLASS code of Julien Lesgourgues and collaborators provide the numerical scaffolding against which SCT predictions will be benchmarked. The Planck Collaboration's 2018 legacy data release defines the observational precision standard this work aspires to meet. Precedent for scale-invariant perturbation spectra from non-inflationary mechanisms is owed to Paul Steinhardt, Neil Turok, Anna Ijjas, and collaborators in the ekpyrotic and bouncing cosmology programs.

The author used AI-assisted drafting tools during preparation of this manuscript as a writing and literature-organization aid. All physical premises, theoretical claims, mathematical derivations, and scientific conclusions are the author's own, and the author accepts full responsibility for the content.

Appendix A. Key Premises from SCT Relevant to CMB Physics

This appendix summarizes the twelve premises from the companion foundational paper [23] most directly load-bearing for the CMB compatibility argument. Each entry is identified by its original premise number from that document. Full derivations, the logical chain connecting all 61 premises, and the complete observational prediction set appear in [23].

Premise P01–P02: ***Eternal Time and Infinite Space (P01–P02)***
Time has no beginning or end; space has no boundary. These eliminate horizon and flatness problems without inflation.

Premise P07: ***Scale-Free Universe and Hierarchy (P07)***

The Copernican principle, applied globally to an infinite manifold, produces a scale-free hierarchy of structure under GR with no preferred length or time scale.

Premise P03: ***Embedded Observable Universe (P03)***
The observable universe (radius ~46.5 Gly) is a finite region within the infinite manifold, bounded by our light cone, not by any physical edge.

Premise P04–P05: ***Ubiquitous Mass-Energy (P04–P05)***
Mass-energy is distributed throughout the infinite manifold. Confinement to our patch alone would require an unexplained selection mechanism.

Premise P20–P21: ***Superluminal Inter-Pocket Velocities are SR-Consistent (P20–P21)***
SR's speed limit governs locally accelerated objects within a single inertial frame. Two pockets formed independently in causally disconnected regions inherit bulk velocities not constrained by local SR — the identical reasoning standard cosmology applies to superluminal Hubble recession.

Premise P23–P30: ***Collision Thermalization and Observational Equivalence (P23–P30)***
When two pockets with v_rel > 2c intersect, the overlap volume is engulfed before any internal signal can respond. Full thermalization is guaranteed by Gamma_Compton/H ~ 10^18. The cascade terminates before t ~ 1 s, constrained by BBN abundances and FIRAS spectral purity — independently of CMB acoustic structure.

Premise P36–P40: ***Cascade Termination and Statistical Independence (P36–P40)***
After termination before t ~ 1 s, more than 10^11 thermalization timescales elapse before acoustic evolution begins. All memory of inter-stage correlations is erased; perturbations imprinted on the fluid at acoustic horizon entry are statistically independent.

Premise P31–P32: ***Angular Momentum Inheritance (P31–P32)***

Angular momentum J = mu(b x v_rel) deposited by the collision impact parameter b is conserved through thermalization (Noether's theorem) and inherited by all descendant structures, producing coherent spin alignment across all scales.

Premise P14: ***Orbital Decay and Gravitational Mesh Dissipation (P14)***
No orbit in any gravitational N-body system is stable across infinite time. Progressive mesh weakening through dynamical friction and three-body ejection propagates through the hereditary time chain, producing an observational signal identical to apparent cosmic acceleration.

Premise P17: ***The Dynamical Cosmological Ratio (P17)***
Lambda_eff(x,t) = kappa * [U_local / U_parent] replaces the fixed cosmological constant. Averaged over a Hubble volume it reproduces Lambda_obs; locally it varies at the ~1% level, providing a framework for the Hubble tension.

Premise P49: ***Baryon-Only Matter Content and Structure Formation (P49)***
SCT contains no cold dark matter particle. The matter power spectrum is sourced entirely by baryons plus the superposition enhancement of [23], P45-P48.

Premise P45–P48: ***Constructive Gravitational Superposition (P45–P48)***
Comoving bodies in a shared frame contribute coherently to the gravitational potential at points within that frame. The enhancement factor f[N, alpha, r] satisfies f -> 1 for N = 1 (recovering standard GR), and f -> 5-10 at cluster outskirts where the mesh dominates. The boundary conditions S(z_*) ~ 10^{-5} and S(z_0) ~ 4.4 follow from the overdensity field and the observed total matter fraction respectively.

References

[1] Hu, W., & Dodelson, S. (2002). Cosmic microwave background anisotropies. Annual Review of Astronomy and Astrophysics, 40, 171-216.

[2] Planck Collaboration. (2020). Planck 2018 results VI: Cosmological parameters. Astronomy & Astrophysics, 641, A6. https://doi.org/10.1051/0004-6361/201833910

[3] Planck Collaboration. (2020). Planck 2018 results V: CMB power spectra and likelihoods. Astronomy & Astrophysics, 641, A5.

[4] Migkas, K., et al. (2021). Directional variations of cosmological parameters from the Planck CMB data. Astronomy & Astrophysics, 649, A148.

[5] Zaldarriaga, M., & Seljak, U. (1997). All-sky analysis of polarisation in the microwave background. Physical Review D, 55, 1830.

[6] Hu, W., & Sugiyama, N. (1995). Anisotropies in the cosmic microwave background: An analytic approach. Astrophysical Journal, 444, 489-506.

[7] Ma, C.-P., & Bertschinger, E. (1995). Cosmological perturbation theory in the synchronous and conformal Newtonian gauges. Astrophysical Journal, 455, 7.

[8] Peebles, P.J.E., & Yu, J.T. (1970). Primeval adiabatic perturbation in an expanding universe. Astrophysical Journal, 162, 815-836.

[9] Eisenstein, D.J., & Hu, W. (1998). Baryonic features in the matter transfer function. Astrophysical Journal, 496, 605-614.

[10] Fixsen, D.J. (2009). The temperature of the cosmic microwave background. Astrophysical Journal, 707, 916-920. https://doi.org/10.1088/0004-637X/707/2/916

[11] Hu, W., et al. (2001). Cosmic microwave background acoustic peak locations. Physical Review D, 63, 023504.

[12] Harrison, E.R. (1970). Fluctuations at the threshold of classical cosmology. Physical Review D, 1, 2726.

[13] Zel'dovich, Ya.B. (1972). A hypothesis, unifying the structure and entropy of the universe. Monthly Notices of the Royal Astronomical Society, 160, 1P.

[14] Steinhardt, P.J., & Turok, N. (2002). A cyclic universe. Science, 296, 1436.

[15] Lehners, J.-L. (2008). Ekpyrotic and cyclic cosmology. Physics Reports, 465, 223-263.

[16] Hamber, H.W., & Yu, L.H.S. (2019). Gravitational fluctuations as an alternative to inflation II. CMB power spectrum. Physical Review D, 99, 124015.

[17] Lehners, J.-L., & Steinhardt, P.J. (2008). Non-Gaussianities in new ekpyrotic cosmology. Physical Review D, 78, 023506.

[18] Bucher, M., et al. (2000). The general primordial cosmic perturbation. Physical Review D, 62, 083508.

[19] Hu, W. (1995). Wandering in the background: a CMB explorer. PhD thesis, University of California, Berkeley.

[20] Hu, W., & White, M. (1996). Acoustic signatures in the cosmic microwave background. Astrophysical Journal, 471, 30.

[21] Silk, J. (1968). Cosmic black-body radiation and galaxy formation. Astrophysical Journal, 151, 459.

[22] Hu, W., & White, M. (1997). The damping tail of CMB anisotropies. Astrophysical Journal, 479, 568.

[23] Nipok, J.M. (2026). From chaos to convergent foundations: The foundational premises of Successive Collision Theory. Version 3.7. https://doi.org/10.13140/RG.2.2.20310.31042