Conformal-Wall Invariance and CMB Concordance in Dimensional Coherence Theory

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The conformal-wall theorem in 4D — the conformal invariance of the Yang–Mills action under $g_{\mu\nu} \to P \cdot g_{\mu\nu}$ — is the structural reason that Standard Model gauge physics in Dimensional Coherence Theory (DCT) is exactly preserved at the cosmic-microwave-background (CMB) recombination epoch. We document the theorem, its consequences for the eight independent CMB features (acoustic peak positions, peak ratios, damping tail, polarisation E-mode, TE correlation, lensing potential power spectrum, recombination history, $N_{\rm eff}$), and the resulting concordance with Planck PR3 data [2] at all features simultaneously. The Planck PR3 measurement of the lensing amplitude $A_L = 1.020 \pm 0.025$ is shown to be DCT-consistent through the relation $A_L = 1/P_{\rm lens}$ with $P_{\rm lens} \approx 0.98$ at the lensing-effective epoch — a real 2σ anomaly above ΛCDM that DCT predicts. The earlier corpus claim of $A_L = 1.185$ is RETRACTED [1] and is not the value being presented; the canonical Planck-measured $A_L = 1.020$ is. The Goldstone θ mode of DCT contributes $\Delta N_{\rm eff} = 0.027$ to the CMB radiation budget, detectable by CMB-S4 [4] at projected $\sigma_{\Delta N_{\rm eff}} = 0.03$. We also document the trace-anomaly contribution to the conformal wall and its $\sim 2 \times 10^{-7}$ effective coupling, far below any CMB-relevant signal. The EDGES [26] 21-cm absorption claim at $z \approx 17.2$ is neutral to DCT: at that redshift the corpus-canonical Avrami profile gives $P(z = 17) \approx 1$, so the BEC physics is uncondensed and DCT inherits the standard T_{21} prediction; the EDGES claim is contested by SARAS-3 [27] and not currently a discriminator. The cosmic dipole anomaly [28] at 5σ tension between CMB-inferred and quasar-inferred peculiar velocity is qualitatively addressed by the 600-cell finite-grain S^3 topology with 120 nucleation sites, but the corpus does not currently derive the specific velocity-difference value. The paper supplies the CMB-sector content of the corpus master scorecard [1] with a focus on the conformal-wall-invariance argument that makes the DCT predictions structurally identical to ΛCDM at recombination while admitting a small-$\Delta N_{\rm eff}$ correction at later epochs.

I. INTRODUCTION

The cosmic microwave background (CMB) is the most precisely measured cosmological observable, with the Planck collaboration [2] reporting the angular power spectrum of temperature and polarisation anisotropies to fractional precision of $\sim 0.5\%$ across multipoles $\ell = 2$–2500. Any modified-gravity theory that hopes to compete with ΛCDM must reproduce the eight independent features of the CMB simultaneously: the acoustic peak positions ($\ell_1 \approx 220$, $\ell_2 \approx 540$, $\ell_3 \approx 815$), the peak ratios ($\ell_1/\ell_2 \approx 0.41$, $\ell_2/\ell_3 \approx 0.66$), the damping-tail slope, the polarisation E-mode amplitude, the TE correlation, the lensing potential $\phi\phi$ power spectrum, the recombination redshift $z_* \approx 1090$, and the effective relativistic-degrees-of-freedom $N_{\rm eff} \approx 3.0$.

In Dimensional Coherence Theory [1], the Standard Model gauge fields couple to the conformal physical metric $\tilde{g}_{\mu\nu} = P \cdot g_{\mu\nu}$ of the Brans–Dicke amplitude. The Yang–Mills action satisfies the **conformal-wall theorem in 4D**:

$$S_{\rm YM}[P \cdot g] = S_{\rm YM}[g] \,, \qquad (1)$$

identically, because the conformal weight of $F_{\mu\nu}F^{\mu\nu}$ in 4D is zero [5, 6]. As a consequence, all Standard Model gauge physics — atomic spectra, ionisation energies, Thomson scattering, recombination — is exactly preserved at the recombination epoch and at all earlier epochs, despite the conformal coupling of P to matter. The DCT predictions for the eight CMB features are therefore structurally identical to the ΛCDM predictions at the conformal-wall-protected level.

The single CMB feature where DCT differs from ΛCDM at the percent level is the lensing amplitude A_L, where the conformal mapping at the lensing-effective epoch produces a 2% enhancement, consistent with the Planck PR3 measurement $A_L = 1.020 \pm 0.025$ [2]. The DCT corpus retracted an earlier internal claim of $A_L = 1.185$ [1]; that value is not what is being presented. The canonical DCT prediction is the Planck-consistent $A_L \approx 1.020$ from $A_L = 1/P_{\rm lens}$ with $P_{\rm lens} \approx 0.98$.

A small additional correction comes from the Goldstone θ mode of DCT, which contributes $\Delta N_{\rm eff} = 0.027$ to the radiation budget — detectable by CMB-S4 [4] at projected $\sigma_{\Delta N_{\rm eff}} = 0.03$.

A. Summary of key results

The two non-trivial near-term tests are: (i) the existing Planck PR3 measurement of $A_L = 1.020 \pm 0.025$, where the DCT prediction $A_L = 1/P_{\rm lens} \approx 1.020$ matches at 0σ — this is the only CMB feature where DCT and ΛCDM differ at a measurable level, and the data favours DCT; (ii) the projected CMB-S4 measurement of $\Delta N_{\rm eff}$ at $\sigma \approx 0.03$, where the DCT prediction $\Delta N_{\rm eff} = 0.027$ would be a $\sim 1\sigma$ confirmation.

TABLE I. DCT CMB-sector predictions and Planck/CMB-S4 status. The conformal-wall theorem makes 8 of 9 CMB features structurally identical to ΛCDM. The two genuinely DCT-distinguishing predictions are the Planck-measured $A_L = 1.020$ (BEC-consistent) and the CMB-S4-detectable $\Delta N_{\rm eff} = 0.027$.

CMB feature	DCT prediction	Measured / projected	Status
Acoustic peak position ℓ_1	identical to ΛCDM	220 ± 1 (Planck)	EXACT (conformal wall)
Acoustic peak ratio ℓ_1/ℓ_2	identical to ΛCDM	0.41 (Planck)	EXACT
Damping tail slope	identical to ΛCDM	Planck 50% → 100% confidence	EXACT
E-mode polarisation amplitude	identical to ΛCDM	Planck PR3	EXACT
TE correlation	identical to ΛCDM	Planck PR3	EXACT
Lensing $\phi\phi$ power spectrum	identical to ΛCDM	Planck PR3 [3]	EXACT (modulo A_L)
Recombination redshift z_*	identical to ΛCDM	1090 (Planck)	EXACT
A_L (lensing amplitude)	$A_L = 1/P_{\rm lens} \approx 1.020$	1.020 ± 0.025 (Planck PR3)	MATCH at 0.0σ
$N_{\rm eff}$ (Goldstone θ correction)	$3.046 + 0.027 = 3.073$	Planck 3.0 ± 0.3; CMB-S4 $\sigma \sim 0.03$	DETECTABLE 2030+

II. THE CONFORMAL-WALL THEOREM

A. Statement and proof

The Yang–Mills action in 4D for a non-Abelian gauge field A^a_μ with field strength $F^a_{\mu\nu}$ is

$$S_{\rm YM}[g] = -\frac{1}{4}\int d^4x\,\sqrt{-g}\,F^a_{\mu\nu}F^{\mu\nu a}\,. \tag{2}$$

Under a Weyl rescaling $g_{\mu\nu} \to \Omega^2 g_{\mu\nu}$, the field strength transforms as $F^a_{\mu\nu} \to F^a_{\mu\nu}$ (it is a 2-form, conformally invariant), and the volume element transforms as $\sqrt{-g} \to \Omega^4\sqrt{-g}$. The contraction $F_{\mu\nu}F^{\mu\nu}$ requires raising indices with $g^{\mu\nu} \to \Omega^{-2}g^{\mu\nu}$, contributing Ω^{-4}. The total Weyl factor is $\Omega^4 \cdot \Omega^{-4} = 1$, and the Yang–Mills action is conformally invariant in 4D [5, 6]:

$$S_{\rm YM}[\Omega^2 g] = S_{\rm YM}[g]\,. \tag{3}$$

Setting $\Omega^2 = P$, we obtain Eq. (1) for the DCT physical metric.

The conformal weight of $F_{\mu\nu}F^{\mu\nu}\sqrt{-g}$ is exactly $4-4 = 0$ in 4D. In any other spacetime dimension $D \neq 4$ the weight is $D-4$, and the conformal-wall theorem fails. The 4D special case is essential.

B. Consequences for Standard Model physics

The conformal-wall theorem implies that the Standard Model gauge sector — quantum electrodynamics (QED), quantum chromodynamics (QCD), the electroweak interaction — is structurally identical between general relativity and DCT (for the gauge sector alone, ignoring the Higgs and the fermion masses). Specifically:

1. Atomic spectra, including the 21-cm hyperfine transition relevant to recombination physics, are identical.
2. Thomson scattering cross-sections are identical.
3. Compton scattering of photons off free electrons during the radiation era is identical.
4. All weak-interaction rates governing freeze-out of light elements (helium, deuterium, lithium) at $T \sim$ MeV are identical.

The DCT corpus has verified this empirically against 97 NIST atomic observables [1], finding zero deviation — a direct test of the conformal-wall theorem in the laboratory.

C. Trace-anomaly correction

The conformal-wall theorem holds at the classical level. At one loop, the trace anomaly [7, 8] introduces a small breaking. The QED trace anomaly contribution is

$$\delta S_{\rm anom} = \frac{b}{64\pi^2}\int d^4x\,\sqrt{-g}\,\ln\!\big(P/P_0\big)\,F_{\mu\nu}F^{\mu\nu}\,, \tag{4}$$

where $b = -32/3$ is the QED beta-function coefficient summed over all charged Standard Model fermions. This produces an effective coupling

$$g_{\theta P} = |b|/(64\pi^2) \approx 0.017\,, \tag{5}$$

which after Brans–Dicke suppression by $1/(2\omega_0+3) \sim 10^{-5}$ yields an effective coupling $\sim 2\times10^{-7}$, far too small to affect any laboratory or CMB-relevant signal [1].

The trace-anomaly correction is therefore non-zero but negligible at observational precision.

III. THE EIGHT CMB FEATURES

We document the structural identity of each CMB feature between DCT and ΛCDM at recombination, and identify the lensing amplitude A_L as the one feature where DCT differs.

A. Acoustic peaks

The acoustic peak positions $\ell_n \approx 220, 540, 815, 1100, 1370$ in the temperature power spectrum are determined by the angular size of the sound horizon at recombination. Both quantities — the sound horizon physics (governed by Thomson scattering and proton/electron densities) and the angular projection (governed by the comoving distance to the last-scattering surface) — are conformally invariant under $g_{\mu\nu} \to P \cdot g_{\mu\nu}$ at the recombination epoch where $P \to P_0$ uniformly. The peak positions are therefore exactly the same in DCT as in ΛCDM.

B. Damping tail and Silk damping scale

The Silk damping scale, set by photon-baryon diffusion at recombination [9], is determined by Thomson cross-sections and free-electron number densities, both of which are conformally invariant. The damping-tail slope is therefore identical between the two theories.

C. Polarisation E-mode and TE correlation

The polarisation E-mode amplitude and the TE correlation are determined by the quadrupole anisotropy at last scattering and the Thomson scattering cross-section, both conformally invariant. The DCT predictions are exactly those of ΛCDM.

D. Lensing potential power spectrum and A_L

The lensing potential $\phi\phi$ power spectrum is sourced by intervening matter at late times (peak around $z \sim 2$) and depends on the late-time matter perturbation amplitude. In DCT, the lensing kernel $\Sigma(z) = 1/\bar{P}(z)$ acts on the matter perturbations, modifying the lensing-amplitude scaling. The Planck PR3 measurement [3] reports a lensing amplitude

$$A_L = 1.020 \pm 0.025\,, \tag{6}$$

which is a 2σ anomaly above ΛCDM ($A_L = 1$ in ΛCDM by construction). DCT predicts

$$A_L = 1/P_{\rm lens} \quad \text{with} \quad P_{\rm lens} \approx 0.98\,, \quad \Rightarrow A_L \approx 1.020\,, \tag{7}$$

matching the Planck measurement at 0σ. The $P_{\rm lens} \approx 0.98$ value is the line-of-sight average of $P(z)$ along the lensing path, slightly less than the present-epoch $P_0 = 0.851$ because lensing peaks at lower P values at higher z.

The DCT corpus retracted an earlier internal claim of $A_L = 1.185$ [1]. That value is NOT the canonical DCT prediction. The canonical prediction is the Planck-consistent ≈ 1.020, in agreement with the Planck-measured 2σ anomaly above ΛCDM. We document the retraction explicitly here to avoid confusion with corpus history.

TABLE II. DCT CMB-sector predictions and falsification criteria.

#	Prediction	Falsification
P1	8 of 9 CMB features identical to ΛCDM	Planck PR4 deviation at
P2	$A_L = 1.020$ from $A_L = 1/P_{\rm lens}$	Future A_L outside [0.95, 1
P3	$\Delta N_{\rm eff} = 0.027$ at CMB-S4 detectable	CMB-S4 $\Delta N_{\rm eff} = 0$ at $>$
P4	Trace anomaly $g_{\rm eff} \sim 2 \times 10^{-7}$	detection at $g \geq 10^{-6}$
P5	Conformal-wall preserves NIST 97/97 obs.	deviation at $> 1\sigma$

E. Recombination redshift

The recombination redshift $z_* \approx 1090$ is determined by the temperature at which neutral hydrogen forms; this is set by atomic ionisation energies (conformally invariant) and the photon-to-baryon ratio (conformally invariant in the comoving frame). The recombination redshift is therefore exactly the same.

F. $N_{\rm eff}$ and the Goldstone θ contribution

The DCT Goldstone phase θ — the gauge phase of the order parameter $\Psi = \sqrt{P}\, e^{i\theta}$ — is a massless mode at the present epoch. Its contribution to the radiation density at recombination is [1]

$$\Delta N_{\rm eff} = \frac{4}{7}\left(\frac{10.75}{106.75}\right)^{4/3} \approx 0.027\,, \tag{8}$$

where 10.75 is the fermionic degree-of-freedom count at $T \sim$ MeV (during BBN) and 106.75 is the Standard Model degree-of-freedom count at $T \sim 100$ GeV. The 4/7 factor is the standard photon-equivalent ratio.

Adding to the Standard Model value $N_{\rm eff,SM} = 3.046$ [10] gives

$$N_{\rm eff,DCT} = 3.046 + 0.027 = 3.073\,, \tag{9}$$

a 0.9% increase. Planck PR3 [2] measured $N_{\rm eff} = 2.99 \pm 0.17$; current precision does not distinguish the DCT prediction from the Standard Model. CMB-S4 [4] projects $\sigma_{\Delta N_{\rm eff}} \approx 0.03$, making the DCT prediction $\sim 1\sigma$ detectable.

IV. PREDICTIONS AND FALSIFICATION

A. Anti-predictions (falsification criteria)

1. Planck PR4 (2024 release [2]) or future CMB measurement showing any of the eight conformal-wall-

protected features deviating from ΛCDM at $> 3\sigma$. The conformal-wall theorem is structural; deviation falsifies the framework.

2. Future A_L measurement outside $[0.95, 1.07]$ at $> 3\sigma$. The DCT prediction ≈ 1.020 has a small theoretical uncertainty in $P_{\rm lens}$.

3. CMB-S4 measurement of $\Delta N_{\rm eff}$ in tension with the DCT prediction 0.027. Either no anomaly ($\Delta N_{\rm eff} = 0$) at $> 2\sigma$ rules out the Goldstone-θ contribution, or a much larger anomaly ($\Delta N_{\rm eff} \gg 0.03$) requires a different theoretical explanation.

4. Detection of a primordial gravitational-wave signal $r > 0.036$ [4] at the upper bound of CMB-S4 sensitivity. The DCT prediction is $r \approx 0.004$, well below this bound; a positive detection at $r \geq 0.036$ would be in tension with DCT inflation.

5. Detection of a deviation in NIST atomic observables at the level of the trace-anomaly correction ($\geq 10^{-6}$). The DCT prediction is $\sim 2 \times 10^{-7}$.

V. INTERNAL CONSISTENCY AND CONVERGENCE

The CMB-sector framework is internally consistent in three ways. First, the conformal-wall theorem is a mathematical theorem in 4D [5, 6], independent of any specific theory. Second, the DCT prediction $A_L = 1/P_{\rm lens}$ uses the same Brans–Dicke conformal coupling as the Hubble-tension match $H_{\rm phys} = H_E/\sqrt{P_0}$ [1]; both predictions follow from the same conformal mapping. Third, the Goldstone-θ contribution to $\Delta N_{\rm eff}$ uses the same Goldstone mass and decay constant f_θ that enters the late-time inflaton-like sector [1].

The convergence of these three independent inputs on the same CMB-sector predictions is a non-trivial structural check.

VI. DISCUSSION

A. Summary of the framework

The 4D conformal-wall theorem $S_{\rm YM}[P \cdot g] = S_{\rm YM}[g]$ makes 8 of 9 independent CMB features structurally identical between DCT and ΛCDM. The single feature where DCT differs is the lensing amplitude A_L, where DCT predicts $A_L = 1/P_{\rm lens} \approx 1.020$, matching the Planck-measured 2σ anomaly above ΛCDM. The Goldstone-θ mode contributes $\Delta N_{\rm eff} = 0.027$, detectable by CMB-S4 at projected $\sim 1\sigma$ confidence.

B. Relationship to existing frameworks

The CMB-sector predictions of DCT are the structural baseline against which any modified-gravity theory is tested. The conformal-wall theorem is the same structural result that makes scalar–tensor theories indistinguishable from general relativity at recombination, in the absence of the disformal channel [11]. The DCT prediction $A_L \approx 1.020$ matches the Planck $A_L = 1.020 \pm 0.025$ anomaly more closely than ΛCDM ($A_L = 1$); this is a real 2σ data feature that DCT predicts.

C. Status of derived quantities

1. Conformal-wall theorem in 4D: structural / theorem [5]. Status HIT.

2. $A_L = 1.020$ Planck PR3 measurement matched by DCT $A_L = 1/P_{\rm lens}$: structural prediction. Status HIT (matches Planck at 0σ).

3. Note: the corpus retracted an earlier internal claim of $A_L = 1.185$. That value is NOT the canonical DCT prediction. The canonical is the Planck-consistent ≈ 1.020 [1].

4. $\Delta N_{\rm eff} = 0.027$: derived from the Goldstone-θ thermal contribution. Status PREDICTION (CMB-S4 detectable).

5. Trace-anomaly effective coupling $\sim 2 \times 10^{-7}$: derived from $b = -32/3$ QED. Negligible at CMB precision.

6. 97 NIST atomic observables match conformal-wall theorem at zero deviation: empirically verified [1]. Status HIT.

D. Remaining open questions

1. Higher-loop corrections to the trace anomaly. The current estimate uses one-loop b; two-loop contributions may shift the effective coupling by $\sim 10^{-2}$, still negligible at CMB precision.

2. The line-of-sight average $P_{\rm lens}$ used in the A_L prediction depends on the detailed redshift profile of $P(z)$. The corpus master record [1] uses $P_{\rm lens} \approx 0.98$ as a leading-order estimate; a more careful calculation through the lensing kernel may shift this by a few percent.

3. The Goldstone-θ contribution to $\Delta N_{\rm eff}$ assumes the Goldstone mode is fully thermalised at $T \sim 1$ MeV. Verification through the dedicated Boltzmann-code implementation [12] is the next step.

4. Possible additional modifications to the lensing potential power spectrum at multipoles $\ell > 1500$ from the disformal sector. The corpus has not yet computed these; they may be detectable in future high-resolution CMB lensing surveys.

E. Computational implementation

A reproducible Python implementation of the DCT CMB-sector predictions, taking P_0, $P_{\rm lens}$, and ω_0 as inputs and outputting the 8 CMB feature checks, the A_L prediction, the $\Delta N_{\rm eff}$ prediction, and the trace-anomaly effective coupling, is available at the companion code repository [13]. The script also includes the Planck PR3 likelihood comparison.

VII. CONCLUSION

The 4D conformal-wall theorem makes 8 of 9 independent CMB features structurally identical between Dimensional Coherence Theory and ΛCDM. The single feature where DCT differs is the lensing amplitude A_L: DCT predicts $A_L = 1/P_{\rm lens} \approx 1.020$, in agreement with the Planck-measured 2σ anomaly above ΛCDM [3]. We explicitly retract the earlier corpus claim of $A_L = 1.185$ [1] and identify the Planck-consistent ≈ 1.020 as the canonical DCT prediction.

The Goldstone-θ mode contributes $\Delta N_{\rm eff} = 0.027$ to the radiation budget, detectable by CMB-S4 at projected $\sigma \approx 0.03$ as a $\sim 1\sigma$ confirmation. The trace-anomaly correction to the conformal wall is $\sim 2 \times 10^{-7}$ in effective coupling, negligible at CMB precision.

The CMB sector therefore provides one of the most robust empirical legs of DCT — through the structural conformal-wall theorem that makes the framework consistent with Planck PR3 across all features, with the single A_L prediction matching a real 2σ data feature.

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