CMB Thermodynamic Interpretation

A compatibility and null-test framework under entropy-constrained structure formation

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Abstract

This document establishes a framework for testing consistency between Energy-Flow Cosmology (EFC) and Cosmic Microwave Background (CMB) observables. Recent JWST observations reveal systematic excess of massive galaxies at $z > 6$, exceeding even physical halo limits at $z > 8$. These observations empirically constrain the entropy profile $S(z)$. We test whether this independently-derived $S(z)$ remains compatible with established CMB constraints, identify observables where EFC predicts deviations from LambdaCDM, and define falsifiable null tests. No CMB parameters are fitted within this work; all entropy-related quantities are constrained independently prior to CMB comparison.

1. Empirical Foundation

1.1 High-Redshift Galaxy Excess

Analysis of COSMOS-Web data (Magnusson 2026a) reveals systematic excess of massive galaxies at $z > 6$ that exceeds forward-modeled predictions and, critically, the physical halo limit assuming complete baryon-to-star conversion:

Redshift	Excess vs LambdaCDM	Excess vs Halo Limit	Physical Status
z = 5-6	23x	3.1x	Within baryonic physics
z = 7-8	124x	7.7x	Exceeds standard models
z = 8-9	259x	10.4x	Exceeds epsilon = 1 limit
z = 9-10	529x	10.6x	Exceeds epsilon = 1 limit

Table 1. COSMOS-Web galaxy abundances compared to LambdaCDM predictions and halo limits.

At $z > 8$, observations exceed the unphysical epsilon = 1 limit by factors of 3-10x. This tension cannot be resolved by adjusting star formation efficiency, feedback parameters, or duty cycle assumptions.

1.2 Regime Structure

The excess exhibits systematic structure rather than random scatter. Analysis across redshift bins (Magnusson 2026b) yields chi-squared = 47.3, df = 4, $p < 10^{-9}$, rejecting uniform distribution at > 99.99% confidence. This establishes regime-dependence as an empirical constraint.

1.3 Cross-Scale Correspondence

The EFC framework (Magnusson 2026c) identifies entropy-gradient-driven energy flow as a unifying mechanism operating at both galactic (kpc) and cosmological (Gpc) scales. The phenomenological decomposition $E_{total} = E_{flow} + E_{latent}$ accounts for both SPARC rotation curve behavior at $z \sim 0$ and accelerated structure formation at $z > 6$.

2. Methodology

2.1 Causal Structure

The analysis follows a specific causal ordering: JWST observations constrain the entropy profile S(z), and we subsequently test whether CMB observables remain consistent with this independently-derived profile. This ordering ensures that S(z) is not fitted to CMB data post-hoc. This causal ordering is enforced to prevent circular inference between late-time structure formation and early-universe observables.

2.2 Scope

This framework tests consistency where consistency is required (early-universe constraints), identifies predictions where EFC differs from LambdaCDM (late-time observables), and defines null tests that can falsify EFC without parameter adjustment. The framework does not attempt to explain CMB physics or replace standard recombination theory.

2.3 Analysis Flow

Figure 1 illustrates the causal and observational structure of this framework. The entropy profile S(z) is derived exclusively from JWST/COSMOS-Web observations without CMB input. This profile is then tested against CMB observables, with no parameter fitting permitted during comparison. Early-universe constraints (acoustic scale, peak structure, damping) must be satisfied; late-time observables (lensing amplitude, ISW phase, growth evolution) may exhibit predicted deviations.

3. Compatibility Constraints

The following observables probe early-universe physics (z > 1000) and are required to remain compatible with Planck 2018 results:

Observable	Reference Value	Compatibility Requirement
Acoustic scale theta_s	100.09 +/- 0.30 arcmin	Within stated uncertainty
Peak ratio R = A_2/A_1	~0.42	Within 2 sigma
Damping scale l_D	Silk damping form	Standard functional form
TE/EE correlation	Positive	Sign preserved

Table 2. CMB compatibility constraints.

If the S(z) profile derived from JWST observations violates these constraints, the EFC framework is falsified at the CMB level.

4. Prediction Zones

All predicted deviations arise from late-time growth and potential evolution; no modification to recombination physics or early-time perturbation dynamics is assumed. The following observables probe late-time physics where EFC predicts deviations from LambdaCDM:

4.1 Lensing Amplitude

The entropy gradient S(r) produces smoother halo profiles than NFW predictions. This implies reduced small-scale lensing power, with predicted lensing amplitude A_L < 1.0. Current constraints from Planck 2018 lensing and ACT/SPT data can test this prediction.

4.2 ISW Phase Structure

Energy-flow coupling introduces temporal phase variation in the Integrated Sachs-Wolfe signal. The predicted phase shift delta_phi(l) ~ 0.01-0.1 rad at l > 1000 will be testable with CMB-S4 precision.

4.3 Lensing Spectrum Evolution

The observed sSFR correlation with redshift (rho = 0.33, p < 10^-10) implies entropy gradient evolution. This predicts z-dependent deviation in the lensing power spectrum C_l^(phi phi) at high multipoles.

5. Null Tests

The following tests are designed to falsify EFC without recourse to parameter adjustment:

5.1 Peak Position Invariance

If EFC modifies H(z), the angular diameter distance changes, shifting CMB peak positions. The null hypothesis requires theta_s(EFC) = theta_s(LambdaCDM) within 0.5%. Deviation beyond this tolerance falsifies the framework.

5.2 Damping Consistency

If EFC modifies baryon-photon coupling, the damping tail shape changes. The null hypothesis requires l_D(EFC) = l_D(LambdaCDM) within 5%. Systematic deviation in the damping tail falsifies the framework.

5.3 Lensing-Growth Consistency

The lensing amplitude A_L relates growth history sigma_8(z) to observed lensing. EFC predicts smoother halos and therefore A_L in the range 0.9-0.95. Observation of A_L >= 1.0 at high significance would falsify the entropy-gradient interpretation proposed here.

6. Parameter Mapping

Translation between EFC variables and Boltzmann code parameters:

EFC Variable	Physical Meaning	CMB Effect	Code Module
S(z)	Entropy evolution	H(z), d_A	background
grad S	Entropy gradient	Growth rate f(z)	perturbations
c(S)	Effective propagation	theta_s, l_D	thermodynamics
Lambda_eff(S)	Dynamic dark energy	Late ISW	background

Table 3. EFC to Boltzmann code parameter mapping.

7. EFC Parameters

The framework introduces four parameters beyond standard LambdaCDM:

Parameter	Definition	Observational Constraint
S_0	Entropy at z = 0	SPARC rotation curve analysis
S_eq	Entropy at matter-radiation equality	CMB peak structure compatibility
alpha_S	Entropy coupling strength	JWST sSFR-redshift correlation
n_S	Entropy profile exponent	Cross-scale consistency requirement

Table 4. EFC parameters and observational constraints.

Standard cosmological parameters (Omega_m, Omega_b, h, n_s, A_s) retain LambdaCDM values. These parameters are not introduced to improve CMB agreement and are held fixed during all CMB comparisons.

8. References

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