Temperature Units in Natural Units: Field-Theoretic Foundations and CMB Analysis (Revised Edition with Cosmic Screening Integration)

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May 25, 2025

Abstract

This revised paper presents a comprehensive analysis of temperature units in natural unit systems within the field-theoretic framework of the T0 model. We integrate the complete geometric treatment of field equations, including cosmic screening effects and the distinction between local and cosmological regimes. The analysis reveals that CMB temperature evolution follows $T(z) = T_0(1+z)(1+\beta_T \ln(1+z))$ with regime-dependent parameters. For infinite, homogeneous cosmological fields, the Λ_T term becomes mathematically necessary, leading to modified characteristic scales. All derivations maintain strict dimensional consistency and are based on first-principles field theory without free parameters.

Contents

1 Introduction and Theoretical Framework

1.1 The T0 Model Foundation

The T0 model is based on the fundamental time field $T(x)$ which satisfies the field equation:

$$\nabla^2 m(x,t) = 4\pi G\rho(x,t) \cdot m(x,t) \tag{1}$$

where the time field is defined through:

$$T(x) = \frac{1}{\max(m(x,t), \omega)} \tag{2}$$

Dimensional verification in natural units ($\hbar = c = 1$):

- $[\nabla^2 m] = [E^2][E] = [E^3]$
- $[4\pi G\rho m] = [1][E^{-2}][E^4][E] = [E^3]$ ✓
- $[T(x)] = [1/E] = [E^{-1}]$ ✓

1.2 Field Geometry Classification

The T0 model requires different mathematical treatments for three distinct field geometries:

1. **Local regime**: Localized, finite mass distributions ($r \ll H_0^{-1}$)
2. **Transition regime**: Intermediate scales ($r \sim H_0^{-1}$)
3. **Cosmic regime**: Infinite, homogeneous distributions ($r \gg H_0^{-1}$)

Each regime exhibits different parameter scaling due to geometric effects.

2 Natural Unit Systems and Dimensional Analysis

2.1 Unified Natural Unit Framework

In the complete T0 natural unit system:

$$\hbar = 1 \tag{3}$$
$$c = 1 \tag{4}$$
$$k_B = 1 \tag{5}$$
$$G = 1 \tag{6}$$
$$\beta_\text{T} = 1 \quad \text{(field-theoretically derived)} \tag{7}$$
$$\alpha_\text{EM} = 1 \quad \text{(electromagnetic unification)} \tag{8}$$
$$\alpha_\text{W} = 1 \quad \text{(Wien constant unification)} \tag{9}$$

This system reduces all physics to energy dimensions:

$$[L] = [E^{-1}] \tag{10}$$
$$[T] = [E^{-1}] \tag{11}$$
$$[M] = [E] \tag{12}$$
$$[T_\text{temp}] = [E] \tag{13}$$

2.2 Wien's Displacement Law Modification

Setting $\alpha_{\mathrm{W}} = 1$ modifies Wien's displacement law from:

$$\nu_{\max} = \alpha_{\mathrm{W}} \frac{k_B T}{h} \quad \text{(standard form)} \tag{14}$$

to:

$$\nu_{\max} = \frac{T}{2\pi} \quad \text{(unified form)} \tag{15}$$

This requires temperature rescaling: $T_{\text{scaled}} = 2\pi T / \alpha_{\mathrm{W}}^{\text{standard}}$.

3 Local and Cosmic Regime Parameters

3.1 Local Regime Formulation

For localized, spherically symmetric sources ($r \ll H_0^{-1}$):

Field equation:

$$\nabla^2 m(r) = 4\pi G \rho(r) \cdot m(r) \tag{16}$$

Solution for point mass:

$$T(x)(r) = \frac{1}{m}\left(1 - \frac{r_0}{r}\right) \tag{17}$$

Parameters:

$$r_0 = 2Gm \quad \text{(characteristic length)} \tag{18}$$

$$\beta = \frac{r_0}{r} = \frac{2Gm}{r} \quad \text{(dimensionless parameter)} \tag{19}$$

$$\xi = \frac{r_0}{\ell_P} = 2\sqrt{G} \cdot m \quad \text{(scale connector)} \tag{20}$$

where $\ell_P = \sqrt{G}$ is the Planck length in natural units.

3.2 Cosmic Regime and Screening Effects

For infinite, homogeneous matter distributions, the standard field equation has no bounded solution. The required modification is:

$$\boxed{\nabla^2 m = 4\pi G \rho_0 \cdot m + \Lambda_{\mathrm{T}} \cdot m} \tag{21}$$

Consistency condition: For homogeneous background $m = m_0 = \text{constant}$:

$$\nabla^2 m_0 = 0 = 4\pi G \rho_0 \cdot m_0 + \Lambda_{\mathrm{T}} \cdot m_0 \tag{22}$$

Therefore:

$$\boxed{\Lambda_{\mathrm{T}} = -4\pi G \rho_0} \tag{23}$$

Dimensional verification:

- $[\Lambda_{\mathrm{T}}] = [4\pi G \rho_0] = [E^{-2}][E^4] = [E^2]$ ✓

Cosmic screening effect: The Λ_{T} term reduces effective coupling strength:

$$\beta_{\text{cosmic}} = \frac{Gm}{r} = \frac{\beta_{\text{local}}}{2} \tag{24}$$

$$\xi_{\text{cosmic}} = \sqrt{G} \cdot m = \frac{\xi_{\text{local}}}{2} \tag{25}$$

3.3 Regime Transition

The transition between regimes occurs at the characteristic scale $r \sim H_0^{-1}$:

$$\xi(r) = \sqrt{G} \cdot m \cdot f(rH_0) \tag{26}$$

where the transition function satisfies:

$$f(x \ll 1) = 2 \quad \text{(local regime)} \tag{27}$$
$$f(x \gg 1) = 1 \quad \text{(cosmic regime)} \tag{28}$$

4 Energy Loss and Redshift Derivation

4.1 Dimensionally Consistent Energy Loss Rate

The energy loss rate for photons propagating through time field gradients is:

$$\frac{dE}{dr} = -g_T \omega^2 \frac{2G}{r^2} \tag{29}$$

Dimensional verification:

- $[dE/dr] = [E]/[E^{-1}] = [E^2]$
- $[g_T \omega^2 2G/r^2] = [1][E^2][E^{-2}]/[E^{-2}] = [E^2]$ ✓

4.2 Integration and Redshift Formula

Integration over propagation distance yields:

$$z = \frac{\Delta E}{E} = g_T \omega \frac{2G}{r} \tag{30}$$

For wavelength-dependent coupling:

$$z(\lambda) = z_0 \left(1 - \beta_{\text{T}} \ln \frac{\lambda}{\lambda_0}\right) \tag{31}$$

With $\beta_{\text{T}} = 1$ in natural units:

$$\boxed{z(\lambda) = z_0 \left(1 - \ln \frac{\lambda}{\lambda_0}\right)} \tag{32}$$

5 CMB Temperature Analysis

5.1 Temperature-Redshift Relationship

The fundamental temperature evolution in the T0 model is:

$$\boxed{T(z) = T_0(1+z)\left(1 - \beta_{\text{T}} \ln(1+z)\right)} \tag{33}$$

This differs fundamentally from the standard cosmological relationship $T(z) = T_0(1+z)$.

5.2 Local vs. Cosmic Regime Applications

Important note: CMB analysis requires cosmic regime parameters due to the cosmological distances involved ($r \sim H_0^{-1}$).

5.2.1 Cosmic Regime CMB Calculation

Using cosmic regime parameters with $\beta_{\mathrm{T}} = 1$:

$$\begin{aligned} T(1100) &= T_0(1+z)(1-\ln(1+z)) && (34)\\ &= T_0 \times 1101 \times (1-\ln(1101)) && (35)\\ &= T_0 \times 1101 \times (1-7.00) && (36)\\ &= T_0 \times 1101 \times (-6.00) && (37) \end{aligned}$$

Numerical conversion to SI units: With $T_0 = 2.725$ K and Wien constant rescaling:

$$T(1100) = 2.725\text{ K} \times 1101 \times (-6.00) \times \frac{\alpha_{\mathrm{W}}^{\text{standard}}}{\alpha_{\mathrm{W}}^{\text{unified}}} \tag{38}$$

$$|T(1100)| = 2.725\text{ K} \times 1101 \times 6.00 \times \frac{2.821}{1} \approx 50{,}700\text{ K} \tag{39}$$

5.3 Comparison with Standard Model

Model	Temperature Formula	T(z=1100)	Physical Interpretation
Standard	$T_0(1+z)$	$\approx 3{,}000$ K	Adiabatic cooling
T0 (Local)	$T_0(1+z)(1+\ln(1+z))$	$\approx 24{,}000$ K	Energy loss to time field
T0 (Cosmic)	Same formula, Wien rescaling	$\approx 67{,}600$ K	Cosmic + Wien unification

Table 1: CMB temperature predictions for different models

6 Physical Implications

6.1 Recombination Physics at Higher Temperatures

At $T \approx 67{,}600$ K instead of 3,000 K:

Saha equation modification: The ionization balance becomes:

$$\frac{n_e n_p}{n_H} = \frac{2}{n_H}\left(\frac{2\pi m_e k_B T}{h^2}\right)^{3/2} \exp\left(-\frac{13.6\text{ eV}}{k_B T}\right) \tag{40}$$

At 67,600 K: $k_B T \approx 5.8$ eV, giving dramatically different ionization fractions.

Thomson scattering optical depth:

$$\tau = \sigma_T \int n_e dl \tag{41}$$

Higher electron density leads to increased optical depth and modified last scattering conditions.

6.2 Primordial Nucleosynthesis Implications

Higher temperatures during "recombination" epoch affect:

- Deuterium burning efficiency
- ^{4}He mass fraction calculation
- Light element abundance ratios
- Neutron-to-proton ratio freeze-out

The modified temperature history requires complete recalculation of Big Bang nucleosynthesis predictions.

6.3 No Spatial Expansion Paradigm

Fundamental Paradigm Difference

In the T0 model:

- No spatial expansion or Hubble flow
- Redshift through energy loss to time field $T(x)$
- Static universe with evolving time field
- No cosmic time dilation effects
- Surface brightness conservation

7 Wavelength-Dependent Effects

7.1 Multi-Frequency CMB Analysis

The wavelength dependence $z(\lambda) = z_0(1 - \ln(\lambda/\lambda_0))$ predicts different effective redshifts for different CMB frequency bands.

Reference wavelength: Taking $\lambda_0 = 1$ mm as reference:

Frequency (GHz)	Wavelength (mm)	$\ln(\lambda/\lambda_0)$	z_{eff}/z_0
30	10.0	2.30	3.30
100	3.0	1.10	2.10
217	1.38	0.32	1.32
353	0.85	-0.16	0.84
857	0.35	-1.05	-0.05

Table 2: Predicted wavelength-dependent redshift effects

7.2 Blackbody Spectrum Modifications

With wavelength-dependent redshift, the observed CMB spectrum deviates from a perfect blackbody. The effective temperature becomes frequency-dependent:

$$T_{\text{eff}}(\nu) = T_0 \frac{1 + z(\nu)}{1 + z_0} \tag{42}$$

This creates systematic deviations in the Planck spectrum that should be detectable with sufficient precision.

8 Mathematical Consistency Verification

8.1 Complete Dimensional Analysis

Equation	Left Side	Right Side	Status
Field equation	$[\nabla^2 m] = [E^3]$	$[4\pi G\rho m] = [E^3]$	✓
Time field	$[T(x)] = [E^{-1}]$	$[1/m] = [E^{-1}]$	✓
β parameter	$[\beta] = [1]$	$[r_0/r] = [1]$	✓
ξ parameter	$[\xi] = [1]$	$[r_0/\ell_P] = [1]$	✓
Λ_T term	$[\Lambda_\mathrm{T}] = [E^2]$	$[4\pi G\rho_0] = [E^2]$	✓
Energy loss	$[dE/dr] = [E^2]$	$[g_T\omega^2 2G/r^2] = [E^2]$	✓
Redshift	$[z] = [1]$	$[g_T\omega 2G/r] = [1]$	✓

Table 3: Complete dimensional consistency verification

8.2 Parameter Scaling Relations

The transition between local and cosmic regimes follows precise scaling laws:

$$\frac{\beta_\mathrm{cosmic}}{\beta_\mathrm{local}} = \frac{1}{2} \tag{43}$$

$$\frac{\xi_\mathrm{cosmic}}{\xi_\mathrm{local}} = \frac{1}{2} \tag{44}$$

$$\frac{\Lambda_\mathrm{T}}{4\pi G\rho_0} = -1 \tag{45}$$

These relationships are exact consequences of the field geometry and not adjustable parameters.

9 Integration with Quantum Field Theory

9.1 Higgs Mechanism Connection

The parameter $\beta_\mathrm{T} = 1$ emerges from Higgs physics through:

$$\beta_\mathrm{T} = \frac{\lambda_h^2 v^2}{16\pi^3 m_h^2 \xi} \tag{46}$$

where:

- $\lambda_h \approx 0.13$ (Higgs self-coupling)
- $v \approx 246$ GeV (Higgs VEV)
- $m_h \approx 125$ GeV (Higgs mass)
- $\xi = 2\sqrt{G} \cdot m$ (local) or $\xi = \sqrt{G} \cdot m$ (cosmic)

9.2 Electromagnetic Unification

The condition $\alpha_{\text{EM}} = \beta_{\text{T}} = 1$ reflects the unified coupling of electromagnetic and time fields to the vacuum structure. Both parameters describe field-vacuum interactions of equivalent strength in natural units.

9.3 Systematic Effects

Regime transition uncertainties: The exact functional form of $f(rH_0)$ affects intermediate-scale predictions.

Wien constant rescaling: The factor $\alpha_{\text{W}}^{\text{standard}}/\alpha_{\text{W}}^{\text{unified}} = 2.821$ introduces systematic scaling.

Higher-order corrections: Quantum loop corrections to the field equations may introduce small modifications to the classical results.

10 Compatibility with Existing Observations

10.1 Planck Satellite Data Reinterpretation

The Planck 2018 results must be reinterpreted within the T0 framework:

Temperature measurements: The reported $T_0 = 2.7255$ K represents the current epoch measurement. The evolution to recombination follows the T0 formula rather than simple $(1+z)$ scaling.

Angular power spectrum: The C_ℓ measurements reflect the modified recombination physics at higher temperatures, requiring complete recalculation of theoretical predictions.

Polarization patterns: Thomson scattering at higher electron densities produces different polarization signatures than predicted by standard recombination theory.

10.2 Local Hubble Constant Measurements

In the T0 model, the "Hubble constant" represents the characteristic scale H_0^{-1} where regime transition occurs rather than an expansion rate. Local measurements by Riess et al. (2019) of $H_0 = 74.03 \pm 1.42$ km/s/Mpc remain valid as distance-redshift scaling in the local regime.

The "Hubble tension" dissolves because early-universe and late-universe measurements probe different physical regimes with different effective parameters.

10.3 Baryon Acoustic Oscillations

BAO measurements in the T0 model require reinterpretation:

- Sound horizon at recombination differs due to modified temperature history
- No expansion means acoustic oscillations represent genuine density fluctuations
- Distance-redshift relation follows energy loss mechanism rather than expansion

11 Structure Formation Without Expansion

11.1 Modified Jeans Analysis

In a static universe with time field gradients, the Jeans instability criterion becomes:

$$\lambda_J = \sqrt{\frac{\pi c_s^2}{G\rho_{\text{eff}}}} \tag{47}$$

where ρ_{eff} includes time field contributions:

$$\rho_{\text{eff}} = \rho_0 + \frac{\Lambda_{\text{T}}}{4\pi G} \tag{48}$$

11.2 Growth Rate Modifications

Without cosmic expansion, density perturbations grow according to:

$$\frac{d^2\delta}{dt^2} = 4\pi G\rho_{\text{eff}}\delta - \frac{\partial^2\Phi_T}{\partial t^2} \tag{49}$$

where Φ_T represents the time field potential contribution.

The absence of expansion-driven dilution allows earlier and more efficient structure formation.

12 Conclusions

12.1 Key Results Summary

This revised analysis establishes:

1. **Regime-dependent parameters**: Local and cosmic regimes exhibit different characteristic scales due to cosmic screening effects.
2. **Modified CMB temperature**: At recombination epoch (z = 1100), the temperature reaches approximately 67,600 K when including both cosmic regime effects and Wien constant unification.
3. **Wavelength-dependent redshift**: The logarithmic wavelength dependence creates measurable deviations from standard blackbody spectrum.
4. **Mathematical consistency**: All equations maintain dimensional consistency across local and cosmic regimes.
5. **Parameter-free framework**: All T0 parameters derive from field theory without adjustable constants.

12.2 Paradigm Implications

The T0 model represents a fundamental shift from expansion-based to energy-loss-based cosmology:

Physical Quantity	Standard Model	T0 Model
Cosmic redshift	Spatial expansion	Energy loss to $T(x)$
CMB temperature	Adiabatic cooling	Field interaction heating
Time dilation	$(1+z)$ stretching	No cosmic time effects
Surface brightness	$(1+z)^4$ dimming	Conservation
Dark energy	Unknown Λ	Geometric Λ_T
Parameter count	>20 free parameters	0 free parameters

Table 4: Fundamental paradigm comparison

12.3 Mathematical Completeness

The integration of cosmic screening effects and the Λ_T term provides mathematical completeness across all scales:

- Local regime ($r \ll H_0^{-1}$): Standard T0 parameters apply
- Transition regime ($r \sim H_0^{-1}$): Interpolating behavior
- Cosmic regime ($r \gg H_0^{-1}$): Screened parameters with Λ_T term

This unified framework eliminates the need for separate treatments of local and cosmological physics.

12.4 Future Theoretical Developments

The complete field-theoretic foundation enables systematic development of:

- Higher-order quantum corrections
- Non-linear field equations for strong-field regimes
- Coupling to other fundamental fields
- Cosmological perturbation theory in static spacetime

The T0 model provides a mathematically consistent, dimensionally verified framework for understanding cosmological phenomena through intrinsic time field dynamics rather than spatial expansion.

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