Temperature Units in Natural Units: Field-Theoretic Foundations and CMB Analysis (Revised Edition with Universal T0 Methodology)

Johann Pascher

May 27, 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 establish the universal T0 methodology where all practical calculations use the localized model parameters $\xi = 2\sqrt{G} \cdot m$ regardless of theoretical geometry. The analysis reveals that CMB temperature evolution follows $T(z) = T_0(1+z)(1+\beta_T \ln(1+z))$ with $\beta_T = 1$ in natural units. 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 Universal T0 Methodology

Universal T0 Calculation Method

Key Discovery: All practical T0 calculations should use the localized model parameters $\xi = 2\sqrt{G}\cdot m$ regardless of the theoretical geometry of the physical system. This unification arises because the extreme nature of T0 characteristic scales makes geometric distinctions practically irrelevant for all observable physics.

The T0 model employs a universal methodology for all scales:
Universal Parameters:

$$r_0 = 2Gm \quad \text{(characteristic length)} \tag{3}$$

$$\beta = \frac{r_0}{r} = \frac{2Gm}{r} \quad \text{(dimensionless parameter)} \tag{4}$$

$$\xi = \frac{r_0}{\ell_P} = 2\sqrt{G} \cdot m \quad \text{(universal for all calculations)} \tag{5}$$

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

2 Natural Unit Systems and Dimensional Analysis

2.1 Unified Natural Unit Framework

In the complete T0 natural unit system:

$$\hbar = 1 \tag{6}$$

$$c = 1 \tag{7}$$

$$k_B = 1 \tag{8}$$

$$G = 1 \tag{9}$$

$$\beta_T = 1 \quad \text{(field-theoretically derived)} \tag{10}$$

$$\alpha_{EM} = 1 \quad \text{(electromagnetic unification)} \tag{11}$$

$$\alpha_W = 1 \quad \text{(Wien constant unification)} \tag{12}$$

This system reduces all physics to energy dimensions:

$$[L] = [E^{-1}] \tag{13}$$
$$[T] = [E^{-1}] \tag{14}$$
$$[M] = [E] \tag{15}$$
$$[T_{\text{temp}}] = [E] \tag{16}$$

2.2 Wien's Displacement Law Modification

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

$$\nu_{\max} = \alpha_{\text{W}} \frac{k_B T}{h} \quad \text{(standard form)} \tag{17}$$

to:

$$\nu_{\max} = \frac{T}{2\pi} \quad \text{(unified form)} \tag{18}$$

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

3 T0 Field Equations and Solutions

3.1 Universal Field Formulation

For all mass distributions, the T0 field equation is:

Field equation:

$$\nabla^2 m(r) = 4\pi G \rho(r) \cdot m(r) \tag{19}$$

Solution for point mass:

$$T(x)(r) = \frac{1}{m}\left(1 - \frac{r_0}{r}\right) \tag{20}$$

Universal parameters (used for all calculations):

$$r_0 = 2Gm \tag{21}$$
$$\beta = \frac{2Gm}{r} \tag{22}$$
$$\xi = 2\sqrt{G} \cdot m \tag{23}$$

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:

$$\frac{dE}{dr} = -g_T \omega^2 \frac{2G}{r^2} \tag{24}$$

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:

$$z = \frac{\Delta E}{E} = g_T \omega \frac{2G}{r} \tag{25}$$

For wavelength-dependent coupling:

$$z(\lambda) = z_0 \left(1 - \beta_{\mathrm{T}} \ln \frac{\lambda}{\lambda_0}\right) \tag{26}$$

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

$$\boxed{z(\lambda) = z_0 \left(1 + \ln \frac{\lambda}{\lambda_0}\right)} \tag{27}$$

5 CMB Temperature Analysis

5.1 Temperature-Redshift Relationship

The fundamental temperature evolution in the T0 model is:

$$\boxed{T(z) = T_0(1+z)\,(1 + \beta_{\mathrm{T}} \ln(1+z))} \tag{28}$$

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

5.2 T0 CMB Temperature Calculation

Using universal T0 parameters with $\beta_{\mathrm{T}} = 1$:

$$\begin{aligned} T(1100) &= T_0(1+z)(1+\ln(1+z)) && (29)\\ &= T_0 \times 1101 \times (1 + \ln(1101)) && (30)\\ &= T_0 \times 1101 \times (1 + 7.00) && (31)\\ &= T_0 \times 1101 \times 8.00 && (32) \end{aligned}$$

Parameter-free calculation in natural units:

$$T(1100) = 2.725\ \mathrm{K} \times 1101 \times 8.00 \approx 24{,}000\ \mathrm{K} \tag{33}$$

Note: This calculation follows the parameter-free, ratio-based approach where all physics reduces to energy relationships in natural units, consistent with the principle that $E = m$ and avoiding arbitrary SI conversion factors.

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 Model	$T_0(1+z)(1+\ln(1+z))$	$\approx$ 24,000 K	Parameter-free energy scaling

Table 1: CMB temperature predictions comparison

6 Physical Implications

6.1 Recombination Physics at Higher Temperatures

At $T \approx 24{,}000$ K instead of 3,000 K:

Saha equation modification: The ionization balance becomes:

$$\frac{n_e n_p}{n_H} = \frac{2}{n_H}\left(\frac{2\pi m_e k_B T}{h^2}\right)^{3/2} \exp\left(-\frac{13.6 \text{ eV}}{k_B T}\right) \tag{34}$$

At 24,000 K: $k_B T \approx 2.1$ eV, giving dramatically different ionization fractions.

Thomson scattering optical depth:

$$\tau = \sigma_T \int n_e dl \tag{35}$$

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(λ/λ_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:

$$T_{\text{eff}}(\nu) = T_0 \frac{1 + z(\nu)}{1 + z_0} \tag{36}$$

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	$[\xi] = [1]$	$[r_0/\ell_P] = [1]$	✓
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 Universal Parameter Relations

All T0 calculations use the same parameter set:

$$\xi_{\text{universal}} = 2\sqrt{G} \cdot m \tag{37}$$

$$\beta_{\text{universal}} = \frac{2Gm}{r} \tag{38}$$

$$\beta T_{\text{universal}} = 1 \tag{39}$$

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

9 Integration with Quantum Field Theory

9.1 Higgs Mechanism Connection

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

$$\beta_\text{T} = \frac{\lambda_h^2 v^2}{16\pi^3 m_h^2 \xi} \tag{40}$$

where:

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

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.

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 a characteristic scale 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.

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:

$$\lambda_J = \sqrt{\frac{\pi c_s^2}{G\rho}} \tag{41}$$

11.2 Growth Rate Modifications

Without cosmic expansion, density perturbations grow according to:

$$\frac{d^2\delta}{dt^2} = 4\pi G\rho\delta - \frac{\partial^2\Phi_T}{\partial t^2} \tag{42}$$

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 analysis establishes:

1. **Universal T0 methodology**: All practical calculations use the localized model parameters $\xi = 2\sqrt{G} \cdot m$ regardless of theoretical geometry.
2. **Modified CMB temperature**: At recombination epoch (z = 1100), the temperature reaches approximately 24,000 K using universal T0 parameters 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 using universal parameters.
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:

12.3 Mathematical Completeness

The universal T0 methodology provides mathematical completeness across all scales:

- Universal parameters: $\xi = 2\sqrt{G} \cdot m$ for all calculations
- No regime-dependent modifications

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
Parameter count	>20 free parameters	0 free parameters

Table 4: Fundamental paradigm comparison

- Consistent field-theoretic foundation
- Complete dimensional verification

This unified framework eliminates the need for separate treatments of different physical regimes.

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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