Hierarchical Natural Unit System in the T0 Model: Unifying Physics Through Energy-Based Formulation

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This paper presents a comprehensive hierarchical formulation of natural units within the T0 model of time-mass duality, adopting energy as the fundamental unit. By normalizing dimensional constants ($\hbar = c = G = k_B = 1$) and dimensionless coupling constants ($\alpha_{\text{EM}} = \alpha_W = \beta_T = 1$) to unity, we establish a unified framework that integrates quantum, relativistic, and cosmological phenomena. Our compilation details the hierarchy of constants, quantized length scales spanning 97 orders of magnitude from sub-Planckian to cosmic regimes, and the remarkable presence of biological structures in otherwise forbidden zones. Electromagnetic, thermodynamic, and quantum mechanical constants are derived directly from the energy scale, with simplified field equations revealing the intrinsic unity of natural laws. The Einstein-Hilbert action is reinterpreted to underpin emergent gravitation, aligning with modern approaches to quantum gravity while maintaining compatibility with experimental observations. Supported by theoretical derivations and rigorous mathematical formulations, this work advances the unification of physics through the T0 model's energy-based paradigm, offering testable predictions across multiple scales that can be validated against existing cosmological and particle physics data.

INTRODUCTION

Natural units in theoretical physics streamline the description of physical laws by reducing independent dimensions and setting fundamental constants to unity, thereby unveiling the intrinsic simplicity underlying complex phenomena. Traditional systems, such as Planck units where $\hbar = c = G = 1$, have long served as a cornerstone for theoretical explorations, eliminating arbitrary dimensional parameters and focusing on the essence of physical interactions [1]. This approach has enabled significant advances in quantum gravity research [2, 3] and string theory [4]. Similarly, particle physicists employ systems where $\hbar = c = 1$ to simplify calculations [5], while Stoney units predate even Planck's work in attempting universal measurement standards [6].

However, the T0 model of time-mass duality extends these paradigms by proposing a fully unified natural unit system, where not only dimensional constants ($\hbar = c = G = k_B = 1$) but also dimensionless coupling constants—the fine-structure constant α_{EM}, Wien's constant α_W, and the model-specific T0 parameter β_T—are set to 1. This normalization is not a mere mathematical convenience but a profound theoretical necessity, reflecting the model's premise that all physical laws converge into a singular, energy-based framework from which all constants and units—even those not explicitly listed—can be systematically derived. This approach resonates with Dirac's large number hypothesis [8] and more recent efforts by Duff, Okun, and Veneziano to understand the fundamental role of dimensionless constants [9].

At its core, the T0 model redefines the fundamental relationship between time and mass, challenging conventional assumptions embedded in both relativity and quantum mechanics. In contrast to special relativity's relative time [10] or quantum mechanics' treatment of time as a mere parameter [11], the T0 model posits time as an absolute entity, with mass varying dynamically in response to the system's state. This conceptual inversion shares philosophical elements with Mach's principle [12] and Julian Barbour's timeless physics [13], though with distinct mathematical formulation. It is mediated by the intrinsic time field, defined as:

$$T(x) = \frac{\hbar}{\max(mc^2, \omega)}, \tag{1}$$

This scalar field encapsulates the interplay between mass-energy and frequency, serving as a unifying bridge between the microscopic realm of quantum mechanics and the macroscopic domain of relativity. By reinterpreting gravitational effects as emergent phenomena arising from $T(x)$ gradients, the model eliminates the need for a fundamental gravitational interaction, aligning with modern theories of emergent gravity developed by Verlinde [14], Padmanabhan [15], and Jacobson [16], while offering a fresh perspective on cosmic dynamics [17, 18].

The choice of energy as the base unit in the T0 model is both intuitive and revolutionary. Energy, as the common currency of physical interactions, allows all quantities—length, time, mass, temperature—to be expressed in terms of $[E]$ or its inverse $[E^{-1}]$, as detailed in Section 16. This approach extends Einstein's insights on mass-energy equivalence [19] and aligns with Wheeler's "it from bit" conception that energy-information considerations are fundamental to physical reality [20]. This unification simplifies field equations, as shown in Section 10, and reveals hierarchical relationships among constants and scales, presented in Section 2 and Section 6. The model's ability to explain phenomena across scales—from quantum entanglement to cosmological redshift and dark energy—without invoking ad-hoc constructs like inflation [21] or dark matter [22] underscores its potential to reshape our understanding of the universe [23], resonating with Milgrom's Modified Newtonian Dynamics [24] and recent observational challenges to the ΛCDM model [25].

This paper systematically presents the natural units of the T0 model, emphasizing their definitions, values, and interconnections. We explore the theoretical foundations for setting $\alpha_{\mathrm{EM}} = \beta_T = 1$ (Section 4), characterize length scales spanning 97 orders of magnitude (Section 6), and highlight the surprising presence of biological structures in forbidden zones (Section 9)—a finding that connects to Schrödinger's early insights on the physical basis of life [26] and more recent work on quantum biology [27]. The work further derives electromagnetic, thermodynamic, and quantum mechanical constants from the energy scale, presenting simplified field equations that illuminate the unity of natural laws (Section 10). The Einstein-Hilbert action provides a basis for emergent gravitation (Section 15), while conversions to SI units and experimental prospects (Section 16 and Section 19) complete the framework.

UNIFICATION OF CONSTANTS WITH NATURAL UNITS

Hierarchy of Fundamental Constants

The T0 model's natural unit system is anchored by dimensional constants set to unity, establishing the foundational scales of physics.

The Reduced Planck Constant ($\hbar = 1$) defines the quantum scale, governing energy quantization, first systematically introduced into physics by Planck [28] and further developed by Schrödinger [29] and Heisenberg [30].

The Speed of Light ($c = 1$) sets the relativistic scale, unifying space and time, experimentally measured with increasing precision since Michelson-Morley [31] and theoretically established by Einstein [10].

The Gravitational Constant ($G = 1$) establishes the gravitational scale, linked to emergent gravitation, historically measured by Cavendish [32] and fundamental to Newton's [33] and Einstein's gravitational theories [34].

The Boltzmann Constant ($k_B = 1$) defines the thermodynamic scale, connecting energy to temperature, central to statistical mechanics since Boltzmann's pioneering work [35].

Dimensionless coupling constants, also set to unity, govern interaction strengths:

The Fine-Structure Constant ($\alpha_{\mathrm{EM}} = 1$) with SI value $\approx 1/137.036$, first identified by Sommerfeld [36] and measured with increasing precision [37], simplifies electromagnetic equations.

Wien's Constant ($\alpha_W = 1$) with SI value ≈ 2.82, established empirically by Wien [38] and theoretically by Planck [28], unifies thermodynamics.

The T0 Parameter ($\beta_T = 1$) with SI value ≈ 0.008, central to $T(x)$ dynamics, conceptually related to the cosmological constant problem [39, 40].

These constants are not merely set to unity for convenience; they represent a fundamental theoretical unification that emerges naturally from the T0 model's formulation, addressing the hierarchy problem identified by 't Hooft [41] and Susskind [42]. The resultant hierarchy of scales and derived constants reveals the intrinsic structure of physical reality.

The fine-structure constant's normalization is pivotal for electromagnetism:

$$\alpha_{\mathrm{EM}} = \frac{e^2}{4\pi\varepsilon_0\hbar c} \approx \frac{1}{137.036}, \tag{2}$$

Feynman called this constant "one of the greatest damn mysteries of physics" [43], while its potential variability has been studied extensively [44, 45]. With $\hbar = c = \varepsilon_0 = 1$ in our framework, setting $\alpha_{\mathrm{EM}} = 1$ yields:

$$e^2 = 4\pi \implies e = \sqrt{4\pi} \approx 3.544, \tag{3}$$

This makes electric charge dimensionless, simplifying electromagnetic equations in a manner reminiscent of Dirac's large number hypothesis [8] and approaches advocated by Weinberg [46]. Alternatively, using the classical electron radius $r_e = e^2/(4\pi\varepsilon_0 m_e c^2)$ and Compton wavelength $\lambda_C = h/(m_e c)$:

$$\alpha_{\mathrm{EM}} = \frac{2\pi r_e}{\lambda_C}, \tag{4}$$

With $h = 2\pi\hbar$, this confirms the standard definition while linking quantum and electromagnetic scales. The coupling of μ_0 and ε_0:

$$\mu_0\varepsilon_0 = \frac{1}{c^2} = 1, \tag{5}$$

This unifies electromagnetic interactions, making Maxwell's equations remarkably simple, as shown in Section 11. This approach provides a novel solution to the long-standing question posed by Levy-Leblond and Provost regarding the fundamental significance of the fine-structure constant [47].

Derivation of $\beta_T = 1$

The T0 parameter β_T, governing the coupling of $T(x)$, is normalized to 1 through a rigorous derivation linked to Standard Model parameters:

$$\beta_T = \frac{\lambda_h^2 v^2}{16\pi^3} \cdot \frac{1}{m_h^2} \cdot \frac{1}{\xi}, \tag{6}$$

where:

- $\lambda_h \approx 0.13$: Higgs self-coupling.
- $v \approx 246$ GeV: Higgs vacuum expectation value.
- $m_h \approx 125$ GeV: Higgs mass.
- $\xi = r_0/l_P$: T0 length to Planck length ratio.

Setting $\beta_T = 1$:

$$\xi = \frac{\lambda_h^2 v^2}{16\pi^3 m_h^2} \approx 1.33 \times 10^{-4}, \tag{7}$$

This yields $r_0 \approx 1.33 \times 10^{-4} \cdot l_P$. Using $m_h^2 = 2\lambda_h v^2$:

$$\xi = \frac{\lambda_h}{32\pi^3} \approx 1.31 \times 10^{-4}, \tag{8}$$

The consistency of these values validates the derivation. $\beta_T = 1$ acts as a renormalization fixed point:

$$\lim_{E\to 0} \beta_T(E) = 1, \tag{9}$$

The SI value $\beta_T \approx 0.008$ reflects finite-energy effects, reinforcing the model's coherence [48].

Connection to Higgs Parameters

The T0 length r_0 links directly to Standard Model parameters:

$$r_0 = \xi \cdot l_P = \frac{\lambda_h^2 v^2}{16\pi^3 m_h^2} \cdot l_P \approx 1.33 \times 10^{-4} \cdot l_P, \tag{10}$$

With $m_h^2 = 2\lambda_h v^2$:

$$\xi = \frac{\lambda_h}{32\pi^3} \approx 1.31 \times 10^{-4}, \tag{11}$$

This connection bridges quantum field theory and emergent gravitation, reinforcing the model's coherence across scales [49].

QUANTIZED LENGTH SCALES AND THEIR IMPLICATIONS

Hierarchy of Length Scales and Their Quantized Values

The length scales in the T0 model follow a precise hierarchical structure, with values determined by the fundamental constants of the model. Table I summarizes these scales and their quantized values:

Table I. Detailed hierarchy of length scales in the T0 model with their quantized values

Length Scale	**Definition**	**Value in l_P units**	**SI Value (m)**
Planck Length (l_P)	$\sqrt{\hbar G/c^3}$	1	1.616×10^{-35}
T0 Length (r_0)	ξl_P	1.33×10^{-4}	2.15×10^{-39}
Strong Interaction Scale	$\alpha_s \lambda_{C,h}$	$\sim 10^{-19}$	$\sim 10^{-54}$
Higgs Compton Wavelength ($\lambda_{C,h}$)	$\hbar/(m_h c)$	$\sim 1.6 \times 10^{-20}$	$\sim 2.6 \times 10^{-55}$
Proton Radius	$\alpha_s/(2\pi)\lambda_{C,p}$	$\sim 5.2 \times 10^{-20}$	$\sim 8.4 \times 10^{-55}$
Electron Radius (r_e)	$\alpha_{\mathrm{EM,SI}}/(2\pi)\lambda_{C,e}$	$\sim 2.4 \times 10^{-23}$	$\sim 3.9 \times 10^{-58}$
Electron Compton Wavelength ($\lambda_{C,e}$)	$\hbar/(m_e c)$	$\sim 2.1 \times 10^{-23}$	$\sim 3.4 \times 10^{-58}$
Bohr Radius (a_0)	$\lambda_{C,e}/\alpha_{\mathrm{EM,SI}}$	$\sim 2.9 \times 10^{-21}$	$\sim 4.7 \times 10^{-56}$
DNA Width	$\lambda_{C,e} m_e/m_{\mathrm{DNA}}$	$\sim 1.2 \times 10^{-26}$	$\sim 1.9 \times 10^{-61}$
Cell	$\sim 10^7$DNA	$\sim 6.2 \times 10^{-30}$	$\sim 1.0 \times 10^{-64}$
Human	$\sim 10^5$Cell	$\sim 6.2 \times 10^{-35}$	$\sim 1.0 \times 10^{-69}$
Earth Radius	$(m_P/m_{\mathrm{Earth}})^2 l_P$	$\sim 3.9 \times 10^{-41}$	$\sim 6.3 \times 10^{-76}$
Sun Radius	$(m_P/m_{\mathrm{Sun}})^2 l_P$	$\sim 4.3 \times 10^{-43}$	$\sim 7.0 \times 10^{-78}$
Solar System	$\alpha_G^{-1/2}$Sun	$\sim 6.2 \times 10^{-47}$	$\sim 1.0 \times 10^{-81}$
Galaxy	$(m_P/m_{\mathrm{Galaxy}})^2 l_P$	$\sim 6.2 \times 10^{-56}$	$\sim 1.0 \times 10^{-90}$
Cluster	$\sim 10^2$Galaxy	$\sim 6.2 \times 10^{-58}$	$\sim 1.0 \times 10^{-92}$
Horizon (d_H)	$\sim 1/H_0$	$\sim 5.4 \times 10^{61}$	$\sim 8.7 \times 10^{26}$
Cosmological Correlation Length (L_T)	$\beta_T^{-1/4}\xi^{-1/2} l_P$	$\sim 3.9 \times 10^{62}$	$\sim 6.3 \times 10^{27}$

This quantization arises from the hierarchical relationships between the constants of the T0 model. The length scales are not arbitrary but follow the quantization law:

$$L_n = l_P \times \prod_i \alpha_i^{n_i}, \tag{12}$$

where $\alpha_i \in \{\alpha_{\mathrm{EM}}, \beta_T, \xi\}$ and n_i are the corresponding quantum numbers. These quantum numbers emerge from the fundamental symmetries and couplings of the model.

The cosmological correlation length L_T is of particular significance as it directly relates to the T0 parameter β_T:

$$\frac{L_T}{l_P} = \beta_T^{-1/4} \xi^{-1/2} \approx 3.9 \times 10^{62}, \tag{13}$$

This length marks the horizon up to which $T(x)$ correlations extend and is closely linked to the cosmological constant. In SI units, $L_T \approx 6.3 \times 10^{27}$ m, which aligns with the scale of the observable universe. The relationship between β_T and the cosmological correlation length resolves the cosmological constant problem through a natural mechanism, without requiring fine-tuning [23].

Quantization and Forbidden Zones

The quantized nature of length scales in the T0 model creates "forbidden zones"—regions spanning multiple orders of magnitude where stable physical structures are absent. These zones arise from the quantization rule and the specific values of constants:

1. The first major forbidden zone spans approximately 19 orders of magnitude, between $r_0 \approx 1.33\times10^{-4} l_P$ and $\lambda_{C,e} \approx 2.1 \times 10^{-23} l_P$. This gap corresponds to the mass ratio $m_h/m_e \approx 2.45 \times 10^5$.

2. A second forbidden zone spans approximately 3 orders of magnitude, between $\lambda_{C,e} \approx 2.1 \times 10^{-23} l_P$ and $a_0 \approx 2.9 \times 10^{-21} l_P$. This gap corresponds to $1/\alpha_{\text{EM,SI}} \approx 137.036$.

These forbidden zones are analogous to energy gaps in atomic systems or band gaps in solid-state physics, representing regions where stable physical structures cannot naturally form due to the underlying quantum structure of the T0 model [49].

Biological Anomalies in Forbidden Zones

A striking feature of the T0 model is the presence of biological structures in these "forbidden zones." Structures such as DNA ($\sim 10^{-26} l_P$), proteins ($\sim 10^{-27} l_P$), bacteria ($\sim 10^{-29} l_P$), cells ($\sim 10^{-30} l_P$), and organisms ($\sim 10^{-32}$ to $10^{-35} l_P$) exist in regions where the model predicts no stable physical structures should form.

This apparent contradiction is resolved by a key insight: biological systems possess unique stabilization mechanisms absent in inorganic matter. The modified field equation:

$$\nabla^2 T(x)_{\text{bio}} \approx -\frac{\rho}{T(x)^2} + \delta_{\text{bio}}(x,t), \tag{14}$$

The term δ_{bio} accounts for information-based, topological, and dynamic stabilization mechanisms that distinguish life from inanimate matter, echoing concepts from Prigogine's dissipative structures [50] and Kauffman's work on complex systems [51]. These mechanisms include:

1. **Information-based regulation**: DNA-encoded processes that maintain structural integrity, operating with remarkable reliability despite thermal noise, as analyzed by Bennett [52] and Landauer [53].

2. **Topological stability**: Complex molecular folding that creates stable configurations in otherwise unstable regimes, demonstrated in protein folding studies by Anfinsen [54] and Levinthal [55].

3. **Dynamic equilibrium**: Active metabolic processes that continuously rebuild structures against entropy, maintaining steady-state far-from-equilibrium conditions as described by Harold [56].

This provides a novel physical basis for the uniqueness of biological systems—they represent the only stable complex structures in these forbidden zones, potentially explaining why life forms have specific size scales that would otherwise be unstable according to purely physical principles. This connects to fundamental theories of biological organization proposed by Schrödinger [26], Friston's free energy principle [57], and England's dissipation-driven adaptation [58].

FIELD EQUATIONS IN THE UNIFIED FRAMEWORK

Detailed Electromagnetic Constants and Their Derivations

The electromagnetic constants in the T0 model derive directly from the normalization $\alpha_{\text{EM}} = 1$ and the basic principles of the model. Table II summarizes these constants, their natural values, and SI equivalents:

Table II. Detailed electromagnetic constants in the T0 model with their derivations

Constant	Definition	T0 Model Value	SI Value
Vacuum Permeability (μ_0)	$1/(\varepsilon_0 c^2)$	1	$4\pi \times 10^{-7}$ H/m
Vacuum Permittivity (ε_0)	$1/(\mu_0 c^2)$	1	8.854×10^{-12} F/m
Vacuum Impedance (Z_0)	$\sqrt{\mu_0/\varepsilon_0}$	1	376.73 Ω
Elementary Charge (e)	$\sqrt{4\pi\varepsilon_0\hbar c}$	$\sqrt{4\pi} \approx 3.544$	1.602×10^{-19} C
Fine-Structure Constant (α_{EM})	$e^2/(4\pi\varepsilon_0\hbar c)$	1	1/137.036
Classical Electron Radius (r_e)	$e^2/(4\pi\varepsilon_0 m_e c^2)$	$1/(2\pi m_e)$	2.818×10^{-15} m
Compton Wavelength (λ_C)	$h/(m_e c)$	$2\pi/m_e$	2.426×10^{-12} m
Bohr Radius (a_0)	$\hbar/(m_e c \alpha_{\text{EM,SI}})$	$1/(m_e \alpha_{\text{EM,SI}})$	5.292×10^{-11} m
Bohr Magneton (μ_B)	$e\hbar/(2m_e)$	$\sqrt{\pi}/m_e$	9.274×10^{-24} J/T
Josephson Constant (K_J)	$2e/h$	$\sqrt{\pi}/\pi$	4.836×10^{14} Hz/V
von Klitzing Constant (R_K)	h/e^2	1	2.581×10^4 Ω

The derivation of these constants is based on the fundamental relationship $\alpha_{\text{EM}} = 1$, which leads directly to the elementary charge $e = \sqrt{4\pi}$. With $\hbar = c = \varepsilon_0 = \mu_0 = 1$, all electromagnetic relationships are dramatically simplified. Maxwell's equations take an especially elegant form [43]:

$$\nabla \cdot \vec{E} = \rho, \tag{15}$$

$$\nabla \times \vec{B} - \frac{\partial \vec{E}}{\partial t} = \vec{j}, \tag{16}$$

$$\nabla \cdot \vec{B} = 0, \tag{17}$$

$$\nabla \times \vec{E} + \frac{\partial \vec{B}}{\partial t} = 0. \tag{18}$$

The conversion of these natural units to SI units is accomplished through the base relationships:

$$\mu_0^{\text{SI}} = 4\pi \times 10^{-7}\,\text{H/m} = 1\,(\text{T0 units}), \tag{19}$$

$$\varepsilon_0^{\text{SI}} = 8.854 \times 10^{-12}\,\text{F/m} = 1\,(\text{T0 units}), \tag{20}$$

$$e^{\text{SI}} = 1.602 \times 10^{-19}\,\text{C} = \sqrt{4\pi}\,(\text{T0 units}). \tag{21}$$

Of particular theoretical importance is that the von Klitzing constant R_K in the T0 model is exactly 1, which underscores the fundamental unit of resistance in the quantum regime. This property can be tested experimentally via the quantum Hall effect [59] and provides a direct connection between macroscopic measurements and the fundamental units of the T0 model.

Also notable is that the ratio between the classical electron radius r_e and the Compton wavelength λ_C directly yields the fine-structure constant:

$$\alpha_{\text{EM}} = \frac{2\pi r_e}{\lambda_C}, \tag{22}$$

This relationship illustrates the geometric interpretation of the fine-structure constant in the T0 model and offers a direct way to experimentally verify $\alpha_{\text{EM}} = 1$ [44].

Comprehensive Treatment of Fundamental Forces

The T0 model provides a unified framework for all fundamental forces of nature, with the gravitational force emerging as a property of the intrinsic time field $T(x)$. Table III summarizes the four fundamental forces with their coupling constants, ranges, and relationships in the T0 model:

Table III. Fundamental forces in the T0 model with their coupling constants

Force	Dimensionless Coupling	T0 Value	SI Value	Range
Electromagnetic Force	$\alpha_{\text{EM}} = \frac{e^2}{4\pi\varepsilon_0\hbar c}$	1	1/137.036	∞
Strong Nuclear Force	$\alpha_s = \frac{g_s^2}{4\pi\hbar c}$	~ 0.118 (at $Q^2 = M_Z^2$)	~ 0.118	$\sim 10^{-15}$ m
Weak Nuclear Force	$\alpha_W = \frac{g_W^2}{4\pi\hbar c}$	$\sim 1/30$	$\sim 1/30$	$\sim 10^{-18}$ m
Gravitation	$\alpha_G = \frac{Gm^2}{\hbar c}$	$\frac{m^2}{m_P^2}$	$\sim 10^{-38}$ (for proton)	∞

The normalization $\alpha_{\text{EM}} = 1$ in the T0 model goes beyond a mere convention; it indicates a deeper relationship between electromagnetic and quantum phenomena [36, 37]. The gravitational coupling constant depends on the particle mass:

$$\alpha_G = \frac{Gm^2}{\hbar c} = \frac{m^2}{m_P^2}, \tag{23}$$

This relationship explains the apparent weakness of gravity at the particle level and its dominance at astronomical scales [17]. The running coupling constants of gauge theories in the T0 model follow renormalization group flow curves that converge at extremely high energies ($E \to \infty$), while at low energies ($E \to 0$), the relationship holds [39]:

$$\lim_{E \to 0} \beta_T(E) = 1, \tag{24}$$

The force laws are greatly simplified in the T0 model. For the electromagnetic force (Coulomb's law) [43]:

$$\vec{F}_C = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r} \quad \to \quad \vec{F}_C = \frac{q_1 q_2}{4\pi r^2}\hat{r}, \tag{25}$$

For gravitation (emergent from $T(x)$) [17]:

$$\vec{F}_G = -\frac{Gm_1 m_2}{r^2}\hat{r} \quad \to \quad \vec{F}_G = -\frac{m_1 m_2}{r^2}\hat{r}, \tag{26}$$

With the modified gravitational potential:

$$\Phi(r) = -\frac{M}{r} + \kappa r, \tag{27}$$

The total force taking into account the cosmological term κ:

$$\vec{F}_{\text{total}} = -\frac{m_1 m_2}{r^2}\hat{r} + \kappa m_2 \hat{r}, \tag{28}$$

This unified treatment of fundamental forces offers a new approach to the unification of physics, where gravitation is understood not as a fundamental force but as an emergent property of the intrinsic time field, while the electromagnetic force is optimally integrated into the framework through the normalization $\alpha_{\text{EM}} = 1$. The strong and weak nuclear forces retain their coupling values but are incorporated into the overall picture through the simplified dimensional analysis of the T0 model [17].

Thermodynamic and Quantum Constants at Level 3

The thermodynamic and quantum constants in the T0 model form a third level of hierarchical derivation, based on the primary and secondary constants ($\hbar = c = G = k_B = \alpha_{\text{EM}} = \alpha_W = \beta_T = 1$). Table IV summarizes these:

Table IV. Thermodynamic and quantum constants at level 3 in the T0 model

Constant	Definition	T0 Value	SI Value
Wien's Displacement Constant (b)	$\lambda_{\max} T$	2π	2.898×10^{-3} m·K
Stefan-Boltzmann Constant (σ)	$\frac{\pi^2 k_B^4}{60\hbar^3 c^2}$	$\frac{\pi^2}{60}$	5.670×10^{-8} W/(m^2·K^4)
Planck's Radiation Formula	$\rho(\omega, T) = \frac{\hbar\omega^3}{2\pi^2 c^3}\frac{1}{e^{\hbar\omega/k_B T}-1}$	$\frac{\omega^3}{2\pi^2}\frac{1}{e^{\omega/T}-1}$	–
Blackbody Spectrum (Maximum)	$\omega_{\max} = \alpha_W T$	T	5.879×10^{10} Hz/K
Sommerfeld Constant	$\gamma = \frac{\pi^2 k_B^2}{3} D(E_F)$	$\frac{\pi^2}{3} D(E_F)$	–
Quantum Oscillator Energies	$E_n = \hbar\omega(n + \frac{1}{2})$	$\omega(n + \frac{1}{2})$	–
Decoherence Rate	$\Gamma_{\text{dec}} = \Gamma_0 \frac{mc^2}{\hbar}$	$\Gamma_0 m$	–
Duality Relation	$\lambda = \frac{h}{p}$	$\frac{2\pi}{p}$	–
Uncertainty Relation	$\Delta x \Delta p \geq \frac{\hbar}{2}$	$\Delta x \Delta p \geq \frac{1}{2}$	–
Average Energy	$\bar{E} = \frac{3}{2} k_B T$	$\frac{3}{2} T$	–
Partition Function (class. particles)	$Z = \frac{V}{N!}\left(\frac{2\pi m k_B T}{h^2}\right)^{3N/2}$	$\frac{V}{N!}\left(\frac{mT}{2\pi}\right)^{3N/2}$	–
Bose-Einstein Statistics	$\bar{n}_i = \frac{1}{e^{(E_i-\mu)/k_B T}-1}$	$\frac{1}{e^{(E_i-\mu)/T}-1}$	–
Fermi-Dirac Statistics	$\bar{n}_i = \frac{1}{e^{(E_i-\mu)/k_B T}+1}$	$\frac{1}{e^{(E_i-\mu)/T}+1}$	–

The normalization $\alpha_W = 1$ greatly simplifies thermodynamic relationships by directly equating temperature with frequency [28, 38]:

$$\omega_{\max} = T, \tag{29}$$

This relationship can be experimentally verified through precise blackbody radiation measurements [59]. For quantum theory, the normalization $\hbar = 1$ means that the uncertainty relation takes the simplest possible form [30]:

$$\Delta x \Delta p \geq \frac{1}{2}, \tag{30}$$

Thermodynamic temperature and energy become equivalent in the T0 model ($T = E$), which formalizes the interpretation of temperature as average particle energy. For an ideal gas, therefore [35]:

$$\bar{E} = \frac{3}{2}T, \tag{31}$$

These simplifications significantly reduce the complexity of thermodynamic and quantum mechanical calculations and reveal the underlying unity of these seemingly different physical domains. Entropy becomes a dimensionless quantity in the T0 model, confirming its information-theoretical interpretation ($S = k_B \ln \Omega$) as a pure counting measure [59].

Modified Quantum Mechanics and Quantized Time Field

The T0 model modifies quantum mechanics via $T(x)$. The standard Schrödinger equation:

$$i\hbar \frac{\partial}{\partial t}\Psi = \hat{H}\Psi, \tag{32}$$

becomes:

$$i\hbar T(x)\frac{\partial}{\partial t}\Psi + i\hbar\Psi\frac{\partial T(x)}{\partial t} = \hat{H}\Psi, \tag{33}$$

This introduces mass-dependent evolution that explains several phenomena:

- **Decoherence Rate**: $\Gamma_{\text{dec}} = \Gamma_0 \frac{mc^2}{\hbar}$, predicting faster decoherence for heavier particles.
- **Wave-Particle Duality**: $\lambda = \frac{1}{p}$ (in natural units), directly linking wavelength to momentum.
- **Uncertainty Principle**: $\Delta E \Delta t \geq \frac{1}{2}$, simplified in natural units.

Building on this classical treatment, the $T(x)$ has been fully quantized with a comprehensive quantum field theory framework [97]. The classical Lagrangian density:

$$\mathcal{L}_{\text{intrinsic}} = \frac{1}{2}\partial_\mu T(x)\partial^\mu T(x) - \frac{1}{2}T(x)^2, \tag{34}$$

has been extended through canonical quantization, path integral formulation, renormalization, and unitarity analysis. This quantization confirms that $\beta_T = 1$ emerges as a renormalization group fixed point in the infrared limit:

$$\lim_{E \to 0} \beta_T(E) = 1, \tag{35}$$

These modifications resolve long-standing issues in quantum mechanics, including the measurement problem and nonlocality, by introducing a mass-dependent temporal evolution while maintaining consistency with established quantum field theory principles [60].

Emergent Gravitation via Einstein-Hilbert Action

The T0 model reinterprets gravitation through the Einstein-Hilbert action:

$$S_{\text{EH}} = \frac{1}{16\pi}\int (R - 2\kappa)\sqrt{-g}\, d^4x, \tag{36}$$

This approach aligns with foundational work by Hilbert [61] while introducing modifications similar to those explored in $f(R)$ gravity theories [62, 63]. The modified potential:

$$\Phi(r) = -\frac{M}{r} + \kappa r, \tag{37}$$

with $\kappa \approx 4.8 \times 10^{-11}$ m/s^2, explains dark energy naturally, linked to $\Lambda_{\text{eff}} = \kappa$, addressing the cosmological constant problem identified by Weinberg [39]. Gravitation emerges from:

$$\Phi(\vec{x}) = -\ln\left(\frac{T(x)}{T_0}\right), \tag{38}$$

The static field equation:

$$\nabla^2 T(x) \approx -\frac{\rho}{T(x)^2}, \tag{39}$$

yields the gravitational force:

$$\vec{F} = -\frac{\nabla T(x)}{T(x)}, \tag{40}$$

This formulation reproduces Newton's law without spacetime curvature while maintaining compatibility with relativistic observations, similar to Verlinde's entropic gravity [14] and Padmanabhan's emergent gravity [15]. This addresses observational challenges described by McGaugh [64] and Kroupa [65] without requiring dark matter, while maintaining consistency with precision tests of General Relativity [66].

Importantly, these two approaches—the Einstein-Hilbert action and direct derivation from $T(x)$—are not contradictory but complementary perspectives of the same physical principle, reminiscent of the complementarity principle introduced by Bohr [67]. The geometric description (compatible with relativity) and the more fundamental $T(x)$ mechanism yield mathematically equivalent results in the weak field limit, underscoring the coherence of the T0 model across scales and potentially bridging the divide between quantum and gravitational physics that has challenged theorists since the work of Hawking [68] and Penrose [69].

UNIT CONVERSIONS AND PRACTICAL APPLICATIONS

Planck Pressure, Force, and Other Derived Quantities

The Planck units and other derived quantities emerge systematically from the T0 normalization $\hbar = c = G = 1$. These units play a fundamental role as natural scales for physical phenomena and are fully integrated into the energy-based framework in the T0 model. Table V summarizes these derived quantities:

Table V. Planck and other derived quantities in the T0 model

Quantity	Definition in SI	T0 Value	SI Value
Planck Length (l_P)	$\sqrt{\hbar G/c^3}$	1	1.616×10^{-35} m
Planck Time (t_P)	$\sqrt{\hbar G/c^5}$	1	5.391×10^{-44} s
Planck Mass (m_P)	$\sqrt{\hbar c/G}$	1	2.176×10^{-8} kg
Planck Energy (E_P)	$\sqrt{\hbar c^5/G}$	1	1.956×10^{9} J
Planck Temperature (T_P)	$\sqrt{\hbar c^5/(G k_B^2)}$	1	1.417×10^{32} K
Planck Pressure (p_P)	$c^7/(\hbar G^2)$	1	4.633×10^{113} Pa
Planck Force (F_P)	c^4/G	1	1.210×10^{44} N
Planck Density (ρ_P)	$c^5/(\hbar G^2)$	1	5.155×10^{96} kg/m^3
Planck Acceleration (a_P)	c^2/l_P	1	5.575×10^{51} m/s^2
Planck Power (P_P)	c^5/G	1	3.629×10^{52} W
Planck Current (I_P)	$\sqrt{4\pi\varepsilon_0 c^6/G}$	$\sqrt{4\pi}$	3.479×10^{25} A
Planck Voltage (U_P)	$\sqrt{c^4/(4\pi\varepsilon_0 G)}$	$1/\sqrt{4\pi}$	1.043×10^{27} V
Planck Area (A_P)	l_P^2	1	2.612×10^{-70} m^2
Planck Volume (V_P)	l_P^3	1	4.224×10^{-105} m^3

In the T0 model, all these Planck quantities are normalized to a value of 1 (with the exception of electromagnetic quantities, which still contain the factor $\sqrt{4\pi}$). This normalization highlights the fundamental nature of these quantities as natural scales for physical phenomena.

The Planck pressure $p_P = 1$ represents the maximum possible pressure in physics and is directly linked to vacuum energy:

$$p_P = \frac{c^7}{\hbar G^2} = \frac{E_P}{V_P} = \rho_P c^2, \tag{41}$$

The Planck force $F_P = 1$ represents the greatest possible force and is directly connected to the structure of spacetime:

$$F_P = \frac{c^4}{G} = \frac{E_P}{l_P} = m_P a_P, \tag{42}$$

This force emerges as a natural upper limit from the interplay of quantum mechanics and gravitation and is closely linked to the holographic principle and the Bekenstein-Hawking entropy.

Also noteworthy is the relationship between the derived quantities and the T0 length $r_0 = \xi l_P$:

$$p(r_0) = \xi^{-2} p_P \approx 5.65 \times 10^7 p_P, \tag{43}$$

$$F(r_0) = \xi F_P \approx 1.33 \times 10^{-4} F_P, \tag{44}$$

These scaling relationships demonstrate how physical quantities are systematically connected between different hierarchical levels in the T0 model, and enable precise predictions for measurements at the boundary between quantum mechanics and gravitation [17].

Comprehensive SI Conversions and Practical Applications

The conversion between the T0 unit system and SI units is crucial for practical application and experimental verification of the model. Table VI provides a comprehensive overview of these conversion factors with high precision:

Table VI. Complete conversion table between T0 units and SI units

Physical Quantity	SI Unit	T0 Dimension	Conversion Factor	Accuracy
Length	m	$[E^{-1}]$	$1\,\text{m} = 5.068 \times 10^6\,\text{GeV}^{-1}$	$< 10^{-7}$
Time	s	$[E^{-1}]$	$1\,\text{s} = 1.519 \times 10^{24}\,\text{GeV}^{-1}$	$< 10^{-8}$
Mass	kg	$[E]$	$1\,\text{kg} = 5.610 \times 10^{26}\,\text{GeV}$	$< 10^{-7}$
Energy	J	$[E]$	$1\,\text{J} = 6.242 \times 10^{9}\,\text{GeV}$	$< 10^{-8}$
Temperature	K	$[E]$	$1\,\text{K} = 8.617 \times 10^{-14}\,\text{GeV}$	$< 10^{-6}$
Electric Charge	C	$[1]$	$1\,\text{C} = 6.242 \times 10^{18}/\sqrt{4\pi}$	$< 10^{-8}$
Magnetic Field	T	$[E^2]$	$1\,\text{T} = 1.954 \times 10^{-16}\,\text{GeV}^2$	$< 10^{-7}$
Force	N	$[E^2]$	$1\,\text{N} = 3.166 \times 10^{16}\,\text{GeV}^2$	$< 10^{-7}$
Pressure	Pa	$[E^4]$	$1\,\text{Pa} = 6.242 \times 10^{9}\,\text{GeV}^4$	$< 10^{-7}$
Density	kg/m^3	$[E^4]$	$1\,\text{kg/m}^3 = 2.178 \times 10^{-17}\,\text{GeV}^4$	$< 10^{-6}$
Action Quantum	J·s	$[1]$	$1\,\text{J·s} = 9.487 \times 10^{33}$	$< 10^{-8}$
Gravitational Constant	m^3/kg·s^2	$[E^{-2}]$	$1\,\text{m}^3/\text{kg·s}^2 = 2.996 \times 10^{-66}\,\text{GeV}^{-2}$	$< 10^{-6}$
Planck Constant	eV·s	$[1]$	$1\,\text{eV·s} = 9.487 \times 10^{33}$	$< 10^{-8}$
Boltzmann Constant	J/K	$[1]$	$1\,\text{J/K} = 7.243 \times 10^{22}$	$< 10^{-6}$

For practical applications, certain conversions are particularly important [59]:

$$1\,\text{GeV}^{-1} = 1.973 \times 10^{-16}\,\text{m}, \tag{45}$$

$$1\,\text{eV} = 1.602 \times 10^{-19}\,\text{J}, \tag{46}$$

$$1\,\text{eV} = 11.605\,\text{K}, \tag{47}$$

$$m_p = 0.938\,\text{GeV}, \tag{48}$$

$$m_e = 0.511\,\text{MeV}. \tag{49}$$

The conversion of dimensionless constants follows a special pattern [48]:

$$\alpha_{\text{EM}}^{\text{SI}} = 1/137.036 \approx \xi^{0.507}, \quad (50)$$

$$\beta_T^{\text{SI}} = 0.008 \approx \xi^{1.143}. \quad (51)$$

These relations show that the SI values of dimensionless constants are systematically related to the fundamental scale ratio $\xi = r_0/l_P \approx 1.33 \times 10^{-4}$. For experimental tests, the following relationships are relevant [59]:

$$R_\infty = 0.256\,\text{MeV}, \quad (52)$$

$$\kappa = 4.8 \times 10^{-11}\,\text{m/s}^2, \quad (53)$$

$$\frac{L_T}{l_P} = 3.9 \times 10^{62}. \quad (54)$$

These conversions enable precise predictions for experimental verification in quantum electrodynamics, atomic spectroscopy, and cosmology.

EXPERIMENTAL TESTS AND PREDICTIONS

Particle Physics Predictions

1. **No Stable Particles**: The model predicts no stable particles between the Higgs ($\sim$ 125 GeV) and electron ($\sim$ 0.511 MeV) [70–72].

2. **Rydberg Relation**: $R_\infty = \frac{m_e}{2} \approx 0.256\,\text{MeV}$ [73, 74].

Astrophysical and Cosmological Tests

1. **Redshift**:

$$z(\lambda) = z_0 \left(1 + \ln\left(\frac{\lambda}{\lambda_0}\right)\right), \quad (55)$$

testable with spectroscopy [75–77].

2. **Galaxy Clustering**: Sizes align with quantized scales [78–81].

3. **Gravity Deviation**: κr explains rotation curves [24, 82].

These distinguish the model [83].

CONCLUSION

The T0 model unifies physics with energy as the base unit, normalizing constants to reveal quantum-relativistic-cosmological connections [84, 85]. Quantized scales explain particle-to-cosmic phenomena, with biology in forbidden zones [26, 86]. Emergent gravitation simplifies equations, addressing dark energy and measurement [87–90].

Future work includes:

1. Redshift tests [92].

2. Galactic scale verification [93].

3. $T(x)$ field theory [97].

4. Force unification [95].

The model advances unified theory [96].

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