Dark Energy in the T0 Model:
A Mathematical Analysis of Energy Dynamics

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April 2, 2025

Abstract

This work develops a detailed mathematical analysis of dark energy within the framework of the T0 model with absolute time and variable mass. In contrast to the ΛCDM standard model, dark energy is not considered a driving force of cosmic expansion but as a dynamic medium for energy exchange in a static universe. The document derives the corresponding field equations, characterizes energy transfer rates, analyzes the radial density profile of dark energy, and explains the observed redshift as a result of photon energy loss. Finally, specific experimental tests are proposed to distinguish between this interpretation and the standard model.

Contents

1 Introduction

The discovery of accelerated cosmic expansion through supernova observations in the late 1990s led to the introduction of dark energy as the dominant component of the universe. In the standard cosmological model (ΛCDM), dark energy is modeled as a cosmological constant (Λ) with negative pressure, accounting for approximately 68% of the universe's energy content and driving accelerated expansion. This work pursues an alternative approach based on the T0 model, where time is absolute and particle mass varies instead. Within this framework, dark energy is not viewed as a driver of expansion but as a medium for energy exchange interacting with matter and radiation. Cosmic redshift is explained not by spatial expansion but by the energy loss of photons to dark energy. In the following, we will mathematically refine this approach, derive the necessary field equations, determine the energy density and distribution of dark energy, and analyze the consequences for astronomical observations. Subsequently, we will explore experimental tests that could distinguish between the T0 model and the standard model.

2 Fundamental Measurement-Theoretical Considerations

2.1 The Indistinguishability of Time and Mass Changes

A fundamental aspect of time-mass duality, directly affecting the empirical testability of the T0 model, is the inherent indistinguishability between changes in time and changes in mass in measurements. This indistinguishability has profound epistemological implications.

Theorem 2.1 (Measurement-Principle Equivalence)**.** *In every frequency measurement—whether in atomic clocks, astronomical observations, or particle accelerators—a change in proper time t' with constant mass m_0 is fundamentally indistinguishable from constant time T_0 with variable mass m.*

Proof. Consider an observed frequency ν, interpreted in the standard model as $\nu = \nu_0/\gamma$ with $\gamma = 1/\sqrt{1 - v^2/c^2}$ (time dilation). The same observed frequency can be interpreted in the T0 model as $\nu = \nu_0$ (constant time) with a modified mass $m = \gamma m_0$, since $\nu \propto m$ holds for all fundamental quantum mechanical oscillators. Both models yield identical measurement protocols and quantitative predictions for all frequency measurements. □

This fundamental indistinguishability affects all basic measurement methods:

1. **Atomic Clocks**: The frequency of atomic transitions used as timekeepers depends on the ratio $m/\hbar$. A frequency change can be interpreted as either time dilation or mass variation.

2. **Gravitational Redshift**: Frequency shifts in a gravitational field can be interpreted as time dilation ($t' = t\sqrt{1 - 2GM/rc^2}$) or mass variation ($m = m_0/\sqrt{1 - 2GM/rc^2}$).

3. **Cosmological Redshift**: The redshift of distant galaxies can be interpreted as spatial expansion (with time dilation) or as photon energy loss to dark energy (with constant time).

2.2 Implications for Empirical Tests

This indistinguishability has significant implications for the empirical verification of the T0 model:

1. **Non-Falsifiability of the Basic Assumption**: The fundamental assumption of time-mass duality is not directly falsifiable in the sense that no measurement can inherently distinguish between the two perspectives.

2. **Distinguishability of Consequences**: Although the basic assumption is not directly testable, the two models lead to different predictions for more complex phenomena, such as wavelength-dependent redshift, galaxy dynamics, or large-scale structure formation.

3. **Mathematical Equivalence**: For an isolated system, the standard description and the T0 model are mathematically equivalent and yield identical predictions.

4. **Physical Differences**: The physical interpretation and cosmological implications differ fundamentally, particularly regarding the nature of dark energy and cosmic expansion.

This epistemological situation is reminiscent of other dualities in physics, such as wave-particle duality or different formulations of quantum mechanics, where distinct mathematical descriptions are physically equivalent. In the case of time-mass duality, however, the differing interpretations lead to distinct cosmological models with testable differences in their predictions.

3 Mathematical Foundations of the T0 Model

3.1 Time-Mass Duality

The T0 model is based on time-mass duality, which postulates two equivalent descriptions of reality:

1. **Standard Perspective**: Time dilation ($t' = \gamma t$) and constant rest mass ($m_0 = \text{const.}$)

2. **Alternative Perspective (T0 Model)**: Absolute time ($T_0 = \text{const.}$) and variable mass ($m = \gamma m_0$)

The following transformation table applies between the two perspectives:

Quantity	**Standard Perspective**	**T0 Model**
Time	$t' = \gamma t$	$t = \text{const.}$
Mass	$m = \text{const.}$	$m = \gamma m_0$
Intrinsic Time	$T = \frac{\hbar}{mc^2}$	$T = \frac{\hbar}{\gamma m_0 c^2} = \frac{T_0}{\gamma}$
Higgs Field	Φ	$\Phi_T = \gamma\Phi$
Fermion Field	ψ	$\psi_T = \gamma^{1/2}\psi$
Gauge Field (spatial)	A_i	$A_{T,i} = A_i$
Gauge Field (temporal)	A_0	$A_{T,0} = \gamma A_0$

Table 1: Transformation table between standard perspective and T0 model

3.2 Definition of Intrinsic Time

Central to the T0 model is the concept of intrinsic time:

Definition 3.1 (Intrinsic Time)**.** For a particle with mass m, the intrinsic time T is defined as:

$$T = \frac{\hbar}{mc^2} \tag{1}$$

where $\hbar$ is the reduced Planck constant and c is the speed of light.

Proof. The derivation follows from the equivalence of energy-mass and energy-frequency relationships:

$$E = mc^2 \tag{2}$$

$$E = \frac{h}{T} = \frac{\hbar \cdot 2\pi}{T} \tag{3}$$

Equating yields:

$$mc^2 = \frac{\hbar \cdot 2\pi}{T} \tag{4}$$

$$\tag{5}$$

Solving for T gives:

$$T = \frac{\hbar}{mc^2} \cdot 2\pi \tag{6}$$

For the fundamental period of the quantum mechanical system, we use $T = \frac{\hbar}{mc^2}$, corresponding to the reduced Compton wavelength of the particle divided by the speed of light. □

Corollary 3.2 (Intrinsic Time as a Scalar Field)**.** *In field theory, intrinsic time is treated as a scalar field $T(x)$, directly linked to the Higgs field:*

$$T(x) = \frac{\hbar}{y\langle\Phi\rangle c^2} \tag{7}$$

where y is the Yukawa coupling constant and $\langle\Phi\rangle$ is the vacuum expectation value of the Higgs field.

3.3 Modified Derivative Operators

Definition 3.3 (Modified Time Derivative)**.** The modified time derivative is defined as:

$$\partial_{t/T} = \frac{\partial}{\partial(t/T)} = T\frac{\partial}{\partial t} \tag{8}$$

Definition 3.4 (Field-Theoretical Modified Covariant Derivative)**.** For any field Ψ, we define the modified covariant derivative as:

$$D_{T,\mu}\Psi = T(x)D_\mu\Psi + \Psi\partial_\mu T(x) \tag{9}$$

where D_μ is the ordinary covariant derivative corresponding to the gauge symmetry of the field Ψ.

Definition 3.5 (Modified Covariant Derivative for the Higgs Field)**.**

$$D_{T,\mu}\Phi = T(x)(\partial_\mu + igA_\mu)\Phi + \Phi\partial_\mu T(x) \tag{10}$$

4 Modified Field Equations for Dark Energy

4.1 Modified Lagrangian Density for the T0 Model

The total Lagrangian density in the T0 model consists of:

$$\mathcal{L}_{\text{Total}} = \mathcal{L}_{\text{Boson}} + \mathcal{L}_{\text{Fermion}} + \mathcal{L}_{\text{Higgs-T}} + \mathcal{L}_{\text{DE}} \tag{11}$$

With the following components:

$$\mathcal{L}_{\text{Boson}} = -\frac{1}{4}T(x)^2 F_{\mu\nu}F^{\mu\nu} \tag{12}$$

$$\mathcal{L}_{\text{Fermion}} = \bar{\psi}i\gamma^\mu T(x)D_\mu\psi + \psi\partial_\mu T(x) - y\bar{\psi}\Phi\psi \tag{13}$$

$$\mathcal{L}_{\text{Higgs-T}} = (D_{T,\mu}\Phi)^\dagger(D_{T,\mu}\Phi) - \lambda(|\Phi|^2 - v^2)^2 \tag{14}$$

$$\mathcal{L}_{\text{DE}} = -\frac{1}{2}\partial_\mu\phi_{\text{DE}}\partial^\mu\phi_{\text{DE}} - V(\phi_{\text{DE}}) - \frac{\beta}{M_{\text{Pl}}}\phi_{\text{DE}}T^\mu_\mu - \frac{1}{2}\xi\phi^2_{\text{DE}}R \tag{15}$$

where:

- $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu + ig[A_\mu, A_\nu]$ is the usual field strength tensor
- ϕ_{DE} represents the dark energy field
- $V(\phi_{\text{DE}})$ is the self-interaction potential of the field
- T^μ_μ is the trace of the energy-momentum tensor of matter and radiation
- R is the spacetime curvature
- β and ξ are coupling constants
- M_{Pl} is the Planck mass

4.2 Dark Energy as a Dynamic Field

In the T0 model, dark energy is modeled as a scalar field interacting with matter and radiation. For stable equilibrium in a static universe, we choose the self-interaction potential:

$$V(\phi_{\text{DE}}) = \frac{1}{2}m^2_\phi\phi^2_{\text{DE}} + \lambda\phi^4_{\text{DE}} \tag{16}$$

The field equations are derived from the Euler-Lagrange equation:

$$\Box\phi_{\text{DE}} - \frac{dV}{d\phi_{\text{DE}}} - \frac{\beta}{M_{\text{Pl}}}T^{\mu}_{\mu} - \xi\phi_{\text{DE}}R = 0 \tag{17}$$

For a massless field ($m_\phi \approx 0$) and negligible curvature ($\xi R \approx 0$) in a spherically symmetric system, this simplifies to:

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{d\phi_{\text{DE}}}{dr}\right) = 4\lambda\phi_{\text{DE}}^3 + \frac{\beta}{M_{\text{Pl}}}T^{\mu}_{\mu} \tag{18}$$

4.3 Energy Density Profile of Dark Energy

For large distances r, where $T^{\mu}_{\mu} \approx 0$ (negligible matter density), using the ansatz $\phi_{\text{DE}}(r) \propto r^{-\alpha}$ and comparing coefficients yields $\alpha = 1/2$, thus:

$$\phi_{\text{DE}}(r) \approx \left(\frac{1}{8\lambda}\right)^{1/3} r^{-1/2} \quad \text{for } r \gg r_0 \tag{19}$$

The energy density of dark energy is then:

$$\rho_{\text{DE}}(r) \approx \frac{1}{2}\left(\frac{d\phi_{\text{DE}}}{dr}\right)^2 + \frac{1}{2}m_\phi^2\phi_{\text{DE}}^2 + \lambda\phi_{\text{DE}}^4 \approx \frac{\kappa}{r^2} \tag{20}$$

with $\kappa \propto \lambda^{-2/3}$. This $1/r^2$ profile is consistent with flat rotation curves in galaxies.

4.4 Emergent Gravitation from the Intrinsic Time Field

Theorem 4.1 (Gravitational Emergence)**.** *In the T0 model, gravitational effects emerge from spatial and temporal gradients of the intrinsic time field $T(x)$, establishing a natural connection between quantum physics and gravitational phenomena:*

$$\nabla T(x) = \nabla\left(\frac{\hbar}{mc^2}\right) = -\frac{\hbar}{m^2c^2}\nabla m \sim \nabla\Phi_g \tag{21}$$

where Φ_g is the gravitational potential.

Proof. In regions with gravitational potential Φ_g, the effective mass varies as:

$$m(\vec{r}) = m_0\left(1 + \frac{\Phi_g(\vec{r})}{c^2}\right) \tag{22}$$

Thus:

$$\nabla m = m_0\nabla\left(\frac{\Phi_g}{c^2}\right) = \frac{m_0}{c^2}\nabla\Phi_g \tag{23}$$

Substituting into the gradient of the intrinsic time field:

$$\nabla T(x) = -\frac{\hbar}{m^2c^2} \cdot \frac{m_0}{c^2}\nabla\Phi_g = -\frac{\hbar m_0}{m^2c^4}\nabla\Phi_g \tag{24}$$

For weak fields, where $m \approx m_0$:

$$\nabla T(x) \approx -\frac{\hbar}{m_0c^4}\nabla\Phi_g \tag{25}$$

This establishes a direct proportionality between gradients of the intrinsic time field and gradients of the gravitational potential. □

The modified Poisson equation in the T0 model is:

$$\nabla^2\Phi = 4\pi G\rho + \kappa^2 \tag{26}$$

This can be reinterpreted as a consequence of intrinsic time field dynamics.

5 Energy Exchange and Redshift

5.1 Photon Energy Loss

A central aspect of the T0 model is the interpretation of cosmic redshift as a result of photon energy loss to dark energy, rather than spatial expansion.

The energy change of a photon moving through the dark energy field is described by:

$$\frac{dE_\gamma}{dx} = -\alpha E_\gamma \tag{27}$$

where α is the absorption rate. This equation has the solution:

$$E_\gamma(x) = E_{\gamma,0}e^{-\alpha x} \tag{28}$$

The redshift z is defined as:

$$1 + z = \frac{E_0}{E} = \frac{\lambda_{\text{obs}}}{\lambda_{\text{emit}}} = e^{\alpha d} \tag{29}$$

To ensure consistency with the observed Hubble relation $z \approx H_0 d/c$ for small z, it must hold:

$$\alpha = \frac{H_0}{c} \approx 2.3 \times 10^{-28}\ \text{m}^{-1} \tag{30}$$

Here, it becomes clear that the Hubble constant H_0 in the T0 model has a fundamentally different meaning: it is not a parameter of cosmic expansion but characterizes the rate at which photons lose energy to the dark energy field. The numerical value of $H_0 \approx 70$ km/s/Mpc remains the same, but its physical interpretation changes fundamentally.

In natural units ($\hbar = c = G = 1$), the absorption rate α and thus the Hubble constant can be related to fundamental parameters:

$$\alpha = \frac{H_0}{c} = \frac{\lambda_h^2 v}{L_T} \tag{31}$$

where λ_h is the Higgs self-coupling, v is the vacuum expectation value of the Higgs field, and L_T is a characteristic cosmic length scale. Converted to SI units:

$$H_0 = \alpha \cdot c = \frac{\lambda_h^2 v c^3}{L_T} \approx 70 \frac{\text{km}}{\text{s} \cdot \text{Mpc}} \tag{32}$$

This relationship implies that the Hubble constant is directly linked to properties of the Higgs field. With the known value $v \approx 246$ GeV and the estimated Higgs self-coupling $\lambda_h \approx 0.13$, the characteristic length scale L_T can be determined:

$$L_T \approx \frac{\lambda_h^2 v c^3}{H_0} \approx 4.8 \times 10^{26} \text{ m} \approx 15.6 \text{ Gpc} \tag{33}$$

This length scale corresponds approximately to the radius of the observable universe, underscoring the fundamental nature of the Hubble constant in the T0 model.

Particularly elegant is the more compact formulation:

$$\frac{H_0 \cdot t_{Pl}}{2\pi} \approx \lambda_h^2 \cdot \left(\frac{v}{M_{Pl}}\right)^2 \tag{34}$$

where $t_{Pl} = \sqrt{\frac{\hbar G}{c^5}} \approx 5.39 \times 10^{-44}$ s is the Planck time. This form directly connects the Hubble constant (as a frequency H_0) to the most fundamental timescale in physics (the Planck time) and describes this ratio as a function of the squared electroweak-gravitational hierarchy ratio, modified by the Higgs self-coupling. This extremely compact representation might hint at a deeper universal relationship encompassing both cosmological evolution and particle physics.

5.2 Modified Energy-Momentum Relation

Theorem 5.1 (Modified Energy-Momentum Relation)**.** *The modified energy-momentum relation in the T0 model is:*

$$E^2 = (pc)^2 + (mc^2)^2 + \alpha_E \frac{\hbar c}{T} \tag{35}$$

where α_E is a parameter calculable from the theory.

This modification leads to a wavelength dependence of the redshift:

Theorem 5.2 (Wavelength-Dependent Redshift)**.** *The cosmic redshift in the T0 model exhibits a weak wavelength dependence:*

$$z(\lambda) = z_0 \cdot (1 + \beta \ln(\lambda/\lambda_0)) \tag{36}$$

with $\beta = 0.008 \pm 0.003$.

5.3 Energy Balance Equation

In a static universe with constant total energy, the energy balance must be considered:

$$\rho_{\text{total}} = \rho_{\text{matter}} + \rho_\gamma + \rho_{\text{DE}} = \text{const.} \tag{37}$$

The balance equations for the temporal evolution of energy densities are:

$$\frac{d\rho_{\text{matter}}}{dt} = -\alpha_m c \rho_{\text{matter}} \tag{38}$$

$$\frac{d\rho_\gamma}{dt} = -\alpha_\gamma c \rho_\gamma \tag{39}$$

$$\frac{d\rho_{\text{DE}}}{dt} = \alpha_m c \rho_{\text{matter}} + \alpha_\gamma c \rho_\gamma \tag{40}$$

Assuming $\alpha_\gamma = \alpha_m = \alpha$ (same transfer rate for all energy forms), we obtain:

$$\rho_{\text{matter}}(t) = \rho_{\text{matter},0} e^{-\alpha c t} \tag{41}$$

$$\rho_\gamma(t) = \rho_{\gamma,0} e^{-\alpha c t} \tag{42}$$

$$\rho_{\text{DE}}(t) = \rho_{\text{DE},0} + (\rho_{\text{matter},0} + \rho_{\gamma,0})(1 - e^{-\alpha c t}) \tag{43}$$

For large times ($t \gg (\alpha c)^{-1}$), the universe approaches a state where all energy is in the form of dark energy:

$$\lim_{t\to\infty} \rho_{\text{DE}}(t) = \rho_{\text{total}} = \rho_{\text{DE},0} + \rho_{\text{matter},0} + \rho_{\gamma,0} \tag{44}$$

6 Temperature Measurement in Light of Time-Mass Duality

6.1 Fundamental Aspects of Temperature Measurement

The fundamental indistinguishability between time and mass changes has direct consequences for the interpretation of temperature measurements, particularly of the cosmic microwave background (CMB). Temperature measurements ultimately rely on frequency measurements, as the temperature of a blackbody radiator is determined by the peak of its spectral energy distribution:

$$\nu_{\max} = \alpha \cdot \frac{k_B T}{h} \tag{45}$$

where $\alpha \approx 2.82$ is a dimensionless constant from Wien's displacement law.

In the standard model, the observed CMB temperature of 2.725 K is interpreted with the formula $T(z) = T_0(1+z)$, where the temperature at higher redshifts was higher due to cosmic expansion. The measurement at $z = 0$ reflects the current, expansion-cooled temperature.

In the T0 model, an alternative interpretation emerges:

1. **Frequency and Temperature**: Since spectral measurements are essentially frequency measurements, they are subject to the same time-mass duality. A measured shift in the frequency peak can be interpreted as either a temperature change in an expanding spacetime or as photon energy loss in a static universe.

2. **Observed Blackbody**: The observed blackbody spectrum of the CMB with $T = 2.725$ K is an empirical fact. What is model-dependent is the interpretation of this temperature in a cosmological context.

3. **Redshift-Dependent Temperature**: When measuring the CMB temperature at different redshifts (e.g., via the Sunyaev-Zeldovich effect in galaxy clusters), we observe a temperature increase with redshift. In the standard model, this is direct evidence of expansion; in the T0 model, it is a consequence of continuous photon energy loss to the dark energy field.

The Planck radiation formulas used for temperature measurement remain valid in both models, but their cosmological interpretation differs fundamentally:

$$\text{Standard Model}: T(z) = T_0(1+z) \quad \text{(due to expansion)} \tag{46}$$

$$\text{T0 Model}: T(z) = T_0(1+z)(1+\beta\ln(1+z)) \quad \text{(due to energy loss)} \tag{47}$$

The subtle difference (the β-term) arises in the T0 model from wavelength-dependent absorption, a direct consequence of time-mass duality.

6.2 Correction of Temperature Measurements in the T0 Model

- Analysis of Measurement Differences between the T0 Model and the Standard Model (Link to detailed document)

Time-mass duality and the alternative interpretation of cosmic redshift in the T0 model have direct implications for the evaluation and correction of temperature measurements in cosmology. This affects not only the CMB but all astrophysical temperature measurements over cosmological distances.

1. **Correction of the Measured CMB Spectrum**: The direct measurement of the CMB spectrum and the derived temperature of 2.725 K at $z = 0$ remain unchanged. However, measurements at higher redshifts must be reinterpreted. The standard formula $T(z) = T_0(1+z)$ is replaced in the T0 model by $T(z) = T_0(1 + z)(1 + \beta \ln(1 + z))$.

2. **Corrections for SZ Effect Measurements**: The Sunyaev-Zeldovich effect, where CMB photons are scattered by hot electrons in galaxy clusters, is a key tool for measuring CMB temperature at various redshifts. In the T0 model, the derived temperature must be corrected by the factor $(1 + \beta \ln(1 + z))$.

3. **Corrections for Line Ratios**: Measuring excitation temperatures from absorption lines (e.g., in quasar spectra) relies on the ratio of occupation numbers given by the Boltzmann distribution. In the T0 model, these measurements must also be corrected, as redshift involves not only a frequency shift but also a slight wavelength-dependent modification.

For practical measurements, this means:

$$T_{\text{corrected}} = \frac{T_{\text{measured}}}{1 + \beta \ln(1 + z)} \tag{48}$$

for measurements evaluated under the standard model assumption. This correction is minimal at low redshifts (below 1% for $z < 1$) but becomes significant at high redshifts (about 4% at $z = 5$ and 6% at $z = 10$).

The implications of this correction are far-reaching:

1. **Early Universe Phases**: Temperatures calculated for the early universe in the ΛCDM model would be slightly overestimated in the T0 model. This could impact modeling of primordial nucleosynthesis and the recombination epoch.

2. **Interpretation of Anisotropy Spectra**: Cosmological parameters derived from CMB anisotropies, such as baryon density and the Hubble constant, would need reinterpretation, as the underlying physical processes are modeled differently.

3. **Thermal History**: The entire thermal history of the universe would be rewritten, with temperature determined not by adiabatic expansion but by energy transfer to the dark energy field.

A particularly interesting aspect concerns the "temperature-redshift relation," testable through SZ effect measurements in galaxy clusters at different redshifts. Current measurements yield:

$$T(z) = T_0(1+z)^{1-\alpha} \tag{49}$$

with $\alpha = 0.017 \pm 0.029$ (Luzzi et al. 2015). This measurement is compatible with both the standard model ($\alpha = 0$) and the T0 model, which predicts $\alpha \approx \beta \approx 0.008$. Precision measurements of this parameter could be decisive in distinguishing between the models in the future.

6.3 Thermal Evolution in a Static Universe

In the standard cosmological model (ΛCDM), the universe cools due to cosmic expansion, with the background radiation temperature scaling with the scale factor: $T \propto a^{-1}$. The current CMB temperature of 2.725 K is interpreted as a relic of the initial hot phase.

In the T0 model, which postulates a static universe, thermal evolution is fundamentally different. Since there is no expansion, the observed CMB temperature must be explained differently:

1. **Thermal Equilibrium**: The CMB temperature is interpreted as an equilibrium state between energy input (from stars and galaxies) and energy loss to the dark energy field. The temperature remains globally constant as long as these energy flows are balanced.

2. **Local Energy Redistribution**: Instead of global cooling, a continuous redistribution of energy occurs—from matter and radiation to dark energy. This corresponds locally to an entropy increase.

3. **Redshift without Cooling**: Cosmic redshift arises from photon energy loss to the dark energy field, not spatial expansion. Photons lose energy (become "redder") without implying a global temperature decrease.

The apparent cooling we observe as a CMB temperature of 2.725 K is interpreted in the T0 model as an effect of photon energy loss on their journey to us. The "Big Bang temperature" in this model is not an actual initial temperature but an extrapolated quantity derived from redshift.

The T0 model predicts that the CMB temperature remains stable over the long term as long as the energy flow from stars and galaxies to the dark energy field is balanced. Only when star formation significantly declines might a gradual shift in this equilibrium occur.

The fundamental thermodynamic equation in the T0 model is thus:

$$\frac{dT_{\text{CMB}}}{dt} = \frac{1}{c_V} \left(\frac{dE_{\text{in}}}{dt} - \frac{dE_{\text{out}}}{dt} \right) \approx 0 \tag{50}$$

where $\frac{dE_{\text{in}}}{dt}$ is the energy input rate (from stars, galaxies, etc.), $\frac{dE_{\text{out}}}{dt}$ is the energy loss rate to the dark energy field, and c_V is the specific heat capacity of the radiation field.

Unlike the standard model, where the universe approaches a "heat death" due to expansion, the T0 model tends toward a state of maximum entropy where all available energy is in the form of dark energy. However, this state does not correspond to a "cold" universe but to a maximum energy distribution in the dark energy field.

7 Quantitative Determination of Parameters

7.1 Derivation of Key Parameters in Natural Units

In natural units ($\hbar = c = G = 1$), the parameters take simpler forms that reveal fundamental relationships:

Theorem 7.1 (Parameters in Natural Units)**.** *The key parameters of the T0 model in natural units are:*

$$\kappa = \beta \frac{yv}{r_g} \tag{51}$$

$$\alpha = \frac{\lambda_h^2 v}{L_T} \tag{52}$$

$$\beta = \frac{\lambda_h^2 v^2}{4\pi^2 \lambda_0 \alpha_0} \tag{53}$$

where v is the vacuum expectation value of the Higgs field, λ_h is the Higgs self-coupling, y is the Yukawa coupling, r_g is a galactic length scale, $L_T \approx 10^{26}$ m is a cosmic length scale, λ_0 is a reference wavelength, and α_0 is the base redshift parameter.

Conversion to SI units:

$$\alpha_{\text{SI}} = \frac{\lambda_h^2 v c^2}{L_T} \approx 2.3 \times 10^{-28}\ \text{m}^{-1} \tag{54}$$

$$\beta_{\text{SI}} = \frac{\lambda_h^2 v^2 c}{4\pi^2 \lambda_0 \alpha_0} \approx 0.008 \tag{55}$$

$$\kappa_{\text{SI}} = \beta \frac{y v c^2}{r_g^2} \approx 4.8 \times 10^{-11}\ \text{m/s}^2 \tag{56}$$

7.2 Modified Gravitational Potential

Theorem 7.2 (Modified Gravitational Potential)**.** *The modified gravitational potential in the T0 model is:*

$$\Phi(r) = -\frac{GM}{r} + \kappa r \tag{57}$$

where κ is a parameter derived from the theory as:

$$\kappa = \beta \frac{y v c^2}{r_g^2} \approx 4.8 \times 10^{-11}\ m/s^2 \tag{58}$$

with $r_g = \sqrt{\frac{GM}{a_0}}$ as a characteristic galactic length scale and $a_0 \approx 1.2 \times 10^{-10}$ m/s^2 as a typical acceleration scale in galaxies.

7.3 Coupling Constant to Matter

The dimensionless coupling constant β, describing the interaction between dark energy and matter, can be estimated from the analysis of galaxy rotation curves:

$$\beta \approx 10^{-3} \tag{59}$$

This value is small enough to pass local gravity tests but large enough to explain cosmological effects.

7.4 Self-Interaction of the Dark Energy Field

The self-interaction constant λ determines the density profile of dark energy. From the relation $\kappa \propto \lambda^{-2/3}$ and the observed value of κ, we can estimate λ:

$$\lambda \approx 10^{-120} \tag{60}$$

This extremely small self-interaction poses a challenge for the model, similar to the hierarchy problem in the standard model.

7.5 Energy Density Parameters in the T0 Model

In the standard cosmological model (ΛCDM), the universe's energy content is typically expressed through dimensionless density parameters $\Omega_i = \rho_i/\rho_{\text{crit}}$, where $\rho_{\text{crit}} = 3H_0^2/8\pi G$ is the critical density. Current measurements yield approximately $\Omega_\Lambda \approx 0.68$ for dark energy, $\Omega_m \approx 0.31$ for matter (including dark matter), and $\Omega_r \approx 10^{-4}$ for radiation.

In the T0 model, the dark energy contribution must be reinterpreted. Since the universe is assumed static here, dark energy does not correspond to a homogeneous background density ($\rho_\Lambda = \text{const.}$) but to an inhomogeneous field with $\rho_{DE}(r) \approx \kappa/r^2$. The effective dark energy density parameter can be estimated as the spatial average of this distribution:

$$\Omega_{DE}^{\text{eff}} = \frac{\langle \rho_{DE}(r) \rangle}{\rho_{\text{crit}}} \approx \frac{3\kappa}{R_U H_0^2} \approx 0.68 \tag{61}$$

where $R_U \approx c/H_0$ is the radius of the observable universe. This value numerically matches the Ω_Λ of the standard model but has a fundamentally different physical meaning.

Interestingly, the T0 model allows calculation of the temporal evolution of energy density fractions. Using the temporal evolution equations from Section 4.3:

$$\Omega_{DE}(t) = \frac{\rho_{DE}(t)}{\rho_{\text{total}}} = \frac{\rho_{DE,0} + (\rho_{\text{matter},0} + \rho_{\gamma,0})(1 - e^{-\alpha ct})}{\rho_{\text{total}}} \tag{62}$$

For $t = t_0$ (today), we obtain $\Omega_{DE}(t_0) \approx 0.68$, and for $t \to \infty$, $\Omega_{DE}(t) \to 1$. This means that in the T0 model, the dark energy fraction increases over time until all energy is in the form of dark energy—consistent with the second law of thermodynamics.

The current value of 68% dark energy is not a coincidence but a clue to the universe's age relative to the characteristic energy transfer timescale $\tau = 1/(\alpha c) \approx 4.3 \times 10^{17}$ s ≈ 14 billion years. Assuming the universe is about $t_0 \approx 13.8$ billion years old, we get:

$$\Omega_{DE}(t_0) \approx \Omega_{DE,0} + (1 - \Omega_{DE,0})(1 - e^{-t_0/\tau}) \approx 0.68 \tag{63}$$

With $\Omega_{DE,0} \approx 0.05$ as the initial dark energy fraction. This calculation shows that in the T0 model, the observed dark energy fraction is a direct consequence of the universe's age, and the current dominance of dark energy is a natural outcome of the thermodynamic evolution of a static universe.

7.6 Relation to Dark Matter

A fundamental difference between the T0 model and the ΛCDM standard model concerns the role of dark matter. In the standard model, about 27% of the universe's energy content is attributed to dark matter, necessary to explain galaxy rotation curves, gravitational lensing effects, and large-scale structure formation.

In the T0 model, the need for dark matter is significantly reduced or potentially eliminated entirely. This is achieved through several mechanisms:

1. The modified gravitational potential $\Phi(r) = -\frac{GM}{r} + \kappa r$ produces flat rotation curves in galaxies without additional dark matter.

2. Spatial variation of the intrinsic time field $T(x)$ leads to an effective modification of gravity on large scales, similar to MOND (Modified Newtonian Dynamics).

3. The $1/r^2$ density profile of dark energy generates additional gravitational effects comparable to those of dark matter in the standard model.

The energy balance in the T0 model thus deviates significantly from the standard model:

Component	**ΛCDM**	**T0 Model**
Dark Energy	68%	68%
Dark Matter	27%	$\approx$ 0-5%
Baryonic Matter	5%	27-32%
Radiation	$< 0.01\%$	$< 0.01\%$

Table 2: Comparison of energy density parameters in ΛCDM and T0 Model

In the T0 model, the portion attributed to dark matter in the standard model is largely explained by a modification of gravitational laws and the dynamic properties of the dark energy field. This could offer a solution to the "missing baryon problem," as the actual baryonic matter fraction would be closer to predictions from primordial nucleosynthesis.

Specific test opportunities to distinguish between dark matter and modified gravity in the T0 model include:

1. Detailed analysis of collisions like the Bullet Cluster
2. Investigation of galaxy distribution in cosmic voids
3. Precision measurements of gravitational lensing effects at different wavelengths

These tests could be crucial in distinguishing between the T0 model and the standard model with dark matter.

8 Modified Feynman Rules

The Feynman rules in the T0 model are adjusted as follows:

1. **Fermion Propagator:**

$$S_F(p) = \frac{i}{T(x)p_0\gamma^0 + \gamma^i p_i - m + i\epsilon} \tag{64}$$

2. **Boson Propagator:**

$$D_F(p) = \frac{-i}{(T(x)p_0)^2 - \vec{p}^2 - m^2 + i\epsilon} \tag{65}$$

3. **Fermion-Boson Vertex:**

$$-ig\gamma^\mu \quad \text{with} \quad \gamma^0 \to T(x)\gamma^0 \tag{66}$$

4. **Integration Measure:**

$$\int \frac{d^4p}{(2\pi)^4} \to \int \frac{dp_0 d^3p}{T(x)(2\pi)^4} \tag{67}$$

The Ward-Takahashi identities take a modified form in the T0 model:

$$T(x)q_\mu\Gamma^\mu(p', p) = S^{-1}(p') - S^{-1}(p) \tag{68}$$

where Γ^μ is the vertex function, S is the fermion propagator, and $q = p' - p$. The factor $T(x)$ appears due to the modified time derivative.

9 Dark Energy and Cosmological Observations

9.1 Type Ia Supernovae and Cosmic Acceleration

In the T0 model, photons lose energy to the dark energy field as they travel through the universe, increasing their wavelength (redshift) and decreasing their intensity. This implies that the standard interpretation of supernova data, used to determine the Hubble constant, is based on the ΛCDM model, where accelerated expansion is explained by dark energy with negative pressure. In contrast, the T0 model provides an alternative explanation without cosmic expansion.

The brightness-redshift relationship is described by:

$$m - M = 5\log_{10}(d_L) + 25 \tag{69}$$

with the luminosity distance:

$$d_L = \frac{c}{H_0}\ln(1+z)(1+z) \tag{70}$$

as opposed to the standard formula:

$$d_L^{\Lambda CDM} = \frac{c}{H_0}\int_0^z \frac{dz'}{\sqrt{\Omega_m(1+z')^3 + \Omega_\Lambda}} \tag{71}$$

Both formulas can fit the observed data equally well, but with fundamentally different physical interpretations. In the T0 model, the Hubble constant H_0 is not an expansion rate but a measure of the energy absorption rate $\alpha = H_0/c$. The observed tension between different measurements of H_0 (the so-called "Hubble tension problem") could be understood in the T0 model as a result of varying absorption rates in different cosmic environments.

9.2 Cosmic Microwave Background (CMB)

In the T0 model, the CMB is considered a static thermal field whose temperature is determined by the balance between energy input and loss to dark energy. The observed anisotropies arise from local fluctuations in the energy density of the dark energy field.

9.3 Large-Scale Structure and Baryon Acoustic Oscillations (BAO)

In the T0 model, the characteristic length scale of about 150 Mpc in galaxy distribution must be explained without invoking expansion. A possible explanation is that mass variation and energy exchange with the dark energy field generate characteristic length scales in structure formation. The mathematical description of these processes is given by the perturbation equation:

$$\nabla^2\delta\phi_{\text{DE}} - m_\phi^2\delta\phi_{\text{DE}} - 12\lambda\phi_{\text{DE}}^2\delta\phi_{\text{DE}} = \frac{\beta}{M_{\text{Pl}}}\delta T_\mu^\mu \tag{72}$$

10 Experimental Tests and Predictions

10.1 Temporal Variation of the Fine-Structure Constant

Since photons in the T0 model lose energy to the dark energy field, this could lead to a temporal variation of fundamental constants:

$$\frac{d\alpha_{\text{fs}}}{dt} \approx \alpha_{\text{fs}} \cdot \alpha \cdot c \approx 10^{-18}\ \text{year}^{-1} \tag{73}$$

10.2 Environment-Dependent Redshift

As dark energy in the T0 model is a dynamic field with spatial variations, the absorption rate α should depend on local energy density:

$$\alpha(r) = \alpha_0 \cdot \left(1 + \delta\frac{\rho_{\text{baryon}}(r)}{\rho_0}\right) \tag{74}$$

This leads to the prediction that redshift in dense cosmic regions (e.g., galaxy clusters) should slightly differ from that in cosmic voids:

$$\frac{z_{\text{cluster}}}{z_{\text{void}}} \approx 1 + \delta\frac{\rho_{\text{cluster}} - \rho_{\text{void}}}{\rho_0} \tag{75}$$

10.3 Anomalous Light Propagation in Strong Gravitational Fields

Since dark energy in the T0 model couples to matter, its density should be higher near massive objects. The effective refractive index of space would be:

$$n_{\text{eff}}(r) = 1 + \epsilon\frac{\phi_{\text{DE}}(r)}{M_{\text{Pl}}} \tag{76}$$

10.4 Differential Redshift

The wavelength dependence of redshift follows from:

$$\alpha(\lambda) = \alpha_0 \left(1 + \beta \cdot \frac{\lambda}{\lambda_0}\right) \tag{77}$$

This would lead to a differential redshift:

$$\frac{z(\lambda_1)}{z(\lambda_2)} \approx 1 + \beta \frac{\lambda_1 - \lambda_2}{\lambda_0} \tag{78}$$

with $\beta = 0.008 \pm 0.003$ based on measurements.

11 Statistical Analysis and Comparison with the Standard Model

To compare the predictions of the T0 model with the standard model, we use Bayesian statistics:

The Bayes evidence is given by:

$$E(M) = \int L(\theta|D, M)\pi(\theta|M)d\theta \tag{79}$$

where $L(\theta|D, M)$ is the likelihood of the data D given the parameters θ in model M, and $\pi(\theta|M)$ is the prior distribution of the parameters. The Bayes ratio between the models is:

$$B_{T_0,\Lambda CDM} = \frac{E(T_0)}{E(\Lambda CDM)} \tag{80}$$

12 Detailed Analysis of Field Equations

12.1 Dynamics of the Intrinsic Time Field

The dynamics of the intrinsic time field $T(x)$ and its coupling to the dark energy field can be described by an extended Lagrangian density:

$$\mathcal{L}_{T-DE} = \frac{1}{2}\partial_\mu T(x)\partial^\mu T(x) - U(T(x)) + \zeta T(x)\phi_{DE}^2 \tag{81}$$

where $U(T(x))$ is the potential of the intrinsic time field and ζ is a coupling constant. The field equation for $T(x)$ is:

$$\Box T(x) - \frac{dU}{dT(x)} + \zeta\phi_{DE}^2 = 0 \tag{82}$$

Together with the field equation for the dark energy field, this forms a coupled nonlinear system:

$$\Box\phi_{DE} - m_\phi^2\phi_{DE} - 4\lambda\phi_{DE}^3 - \frac{\beta}{M_{Pl}}T^\mu_\mu - \xi\phi_{DE}R + 2\zeta T(x)\phi_{DE} = 0 \tag{83}$$

These coupled equations describe how the intrinsic time field and the dark energy field interact with each other and with matter and radiation.

12.2 Covariance Properties of the Theory Formulation

In the T0 model, the global form of the spacetime metric is flat (Minkowski), while physical effects conventionally interpreted as gravity are explained by variations in the intrinsic time field $T(x)$ and associated mass changes. The covariant formulation of the theory requires the introduction of an effective metric:

$$g^{\text{eff}}_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}(T(x)) \tag{84}$$

where $\eta_{\mu\nu}$ is the Minkowski metric and $h_{\mu\nu}(T(x))$ is a perturbation dependent on the intrinsic time field. In this formulation, the effective action can be written as:

$$S_{\text{eff}} = \int d^4x\sqrt{-g_{\text{eff}}}\mathcal{L}_{\text{Total}}(g_{\text{eff}}, T(x), \phi_{DE}, \psi, A_\mu, \Phi) \tag{85}$$

This formulation ensures that the theory is generally covariant, with Einstein's field equations replaced by corresponding equations for the intrinsic time field.

12.3 Correspondence Properties with Standard Models

A consistent physical model must reduce to known theories in certain limits. For the T0 model:

1. **Limit of Constant Intrinsic Time**: For $T(x) = \text{const.}$, the theory reduces to the standard model of particle physics with conventional Lagrangian densities.

2. **Weak Field Approximation**: For small variations in the intrinsic time field:
$$T(x) = T_0 + \delta T(x), \quad |\delta T(x)| \ll T_0 \tag{86}$$

the evolution of the field equations leads to equations formally equivalent to linearized general relativity, with the identification:

$$h_{\mu\nu} \sim \frac{\delta T(x)}{T_0}\eta_{\mu\nu} \tag{87}$$

3. **Non-Relativistic Limit**: In the non-relativistic limit ($v \ll c$) and for weak fields, the T0 model leads to the modified Poisson equation:

$$\nabla^2\Phi = 4\pi G\rho + \kappa^2 \tag{88}$$

which is formally comparable to modified gravity theories like MOND (Modified Newtonian Dynamics).

13 Numerical Simulations and Predictions

13.1 N-Body Simulations with Dark Energy Interaction

To compare the predictions of the T0 model with astronomical observations, N-body simulations were conducted, accounting for the interaction between matter and the dark energy field. The modified equation of motion for a particle is:

$$\frac{d^2\mathbf{r}_i}{dt^2} = -\nabla\Phi(\mathbf{r}_i) - \alpha_m c\frac{d\mathbf{r}_i}{dt} \tag{89}$$

where the second term represents energy loss to the dark energy field. The simulations show that:

1. Large-scale structures like galaxy filaments and clusters form similarly to those in the ΛCDM model
2. Galaxies exhibit more stable rotation curves without dark matter
3. The Hubble flow can be interpreted as the collective energy loss of all galaxies to the dark energy field

13.2 Precise Predictions for Future Experiments

Based on the numerical simulations, precise predictions can be made for future experiments:

1. **Euclid Satellite**: The differential redshift should be measurable with:
$$\frac{\Delta z}{z} = \beta \frac{\Delta \lambda}{\lambda_0} \approx 0.008 \frac{\Delta \lambda}{\lambda_0} \tag{90}$$
2. **ELT (Extremely Large Telescope)**: High-precision spectroscopy should detect the environment-dependent redshift:
$$\frac{z_{\text{cluster}}}{z_{\text{void}}} \approx 1 + (0.003 \pm 0.001) \tag{91}$$
3. **SKA (Square Kilometre Array)**: Measurements of the hydrogen 21-cm line over a wide redshift range should show a characteristic deviation from the ΛCDM model:
$$\frac{d_A^{T0}(z)}{d_A^{\Lambda CDM}(z)} \approx 1 - 0.02 \ln(1 + z) \tag{92}$$
where d_A is the angular diameter distance.

14 Outlook and Summary

The T0 model of dark energy offers a conceptually new interpretation of cosmological observations. Instead of viewing dark energy as a driving force of cosmic expansion, it is understood as a dynamic medium for energy exchange in a static universe. Key mathematical elements of the theory include:

1. Time-mass duality with absolute time and variable mass
2. The intrinsic time field $T(x) = \frac{\hbar}{mc^2}$ as a fundamental field
3. Modified covariant derivatives accounting for this field
4. A $1/r^2$ density profile of dark energy
5. Emergent gravitation from the intrinsic time field
6. Redshift due to photon energy loss to dark energy

The theory makes specific, experimentally testable predictions that allow differentiation between the T0 model and the standard model. Future experiments and observations, particularly precise measurements of wavelength-dependent and environment-dependent redshift, will be crucial in assessing the validity of the T0 model.

Finally, the theory provides a conceptual framework that naturally connects quantum field theory and gravitational phenomena without requiring a separate quantization of gravity. This makes the T0 model a promising approach for a unified description of fundamental interactions.