T0-Theory: Cosmic Relations

The universal ξ-constant as key
to gravitation, CMB and cosmic structures

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1 Introduction to T0-Theory

T0-Theory presents a novel framework connecting quantum phenomena with cosmological structures through a universal dimensionless constant ξ. This theory establishes fundamental relationships between microscopic quantum scales and macroscopic cosmic dimensions, offering a unified perspective on physics from the quantum realm to the cosmological horizon.

2 Fundamental Scales in ξ-Theory

The theory is built upon a universal, dimensionless constant:

$$\xi \equiv \frac{4}{3} \times 10^{-4}$$

This pure number is the fundamental parameter. To simplify the mathematical structure of the theory, we define a system of units where this number is assigned to the square of a characteristic energy E_0 (or equivalently, the inverse square of a characteristic length L_0).

This framework makes immediately clear:

- The pure number ξ is the fundamental input.
- E_0 (equiv. m_0) defines the energy/mass scale.
- L_0 defines the fundamental length scale.
- The relations $E_0^2 = \xi$ and $L_0^2 = 1/\xi$ are *definitions* within this specific theoretical framework, not independent postulates.

3 Microscopic Length L_0 in T0-Theory

3.1 Definition in "ξ-units" ($\hbar = c = 1$)

In the unit system of the theory, the fundamental constant defines the scales:

Quantity	Relation	Numerical Value
Constant ξ	-	$\frac{4}{3} \times 10^{-4}$
Energy E_0	$E_0 = \sqrt{\xi}$	$\sqrt{\frac{4}{3} \times 10^{-4}} \approx 0.0155$
Mass m_0	$m_0 = E_0$	0.0155
Length L_0	$L_0 = 1/E_0 = 1/\sqrt{\xi}$	≈ 64.5

Table 1: Characteristic microscopic quantities in the theory's natural units. Values are dimensionless.

3.2 Conversion to Physical SI Units

To express L_0 as a physical length, we must convert from natural units (where $L_0 \approx 64.5$) to meters using the conversion factor $\hbar c$:

$$1\,(\text{in energy}^{-1}\text{ units}) = \hbar c \approx 1.973 \times 10^{-16}\,\text{m}$$

$$L_0^{(\text{SI})} = L_0^{(\text{nat.})} \times \hbar c \approx 64.5 \times 1.973 \times 10^{-16}\,\text{m} \approx 1.27 \times 10^{-14}\,\text{m}$$

Important Note

T0-Theory postulates a minimal length $L_0 \approx 1.27 \times 10^{-14}$ m that cannot be exceeded. This minimal length emerges naturally from the Lagrangian density and the maximum field fluctuation, without any arbitrary parameters.

3.3 Physical Significance

- L_0 represents the fundamental microscopic length scale in T0-Theory
- It is not an arbitrary parameter but is determined by the universal constant ξ
- It serves as the basis for all other length scales in the theory
- The scale 10^{-14} m is comparable to the classical electron radius, suggesting a possible connection to fundamental electromagnetic phenomena

4 Characteristic Vacuum Length L_ξ and CMB Connection

4.1 Fundamental Relationship in T0-Theory

T0-Theory postulates a fundamental relationship between basic constants. Crucially, the ξ in this equation is the *dimensionless* constant:

Key Formula

$$\hbar c = \xi \cdot \rho_{\text{CMB}} \cdot L_\xi^4$$

This equation connects quantum mechanics ($\hbar c$), cosmology (ρ_{CMB}), and the theory's fundamental constant (ξ) to define the characteristic vacuum length (L_ξ).

4.2 Derivation of the Characteristic Vacuum Length L_ξ

From the fundamental relationship follows:

$$L_\xi = \left(\frac{\hbar c}{\xi \cdot \rho_{\text{CMB}}}\right)^{1/4}$$

4.2.1 CMB Energy Density

$$T_{\text{CMB}} \approx 2.725\,\text{K} \quad \Rightarrow \quad \rho_{\text{CMB}} = \frac{\pi^2}{15}\frac{(k_B T_{\text{CMB}})^4}{(\hbar c)^3} \approx 4.17 \times 10^{-14}\,\text{J/m}^3$$

4.2.2 Numerical Calculation

Using the values:

- $\hbar c = 3.16 \times 10^{-26}$ J $\cdot$ m
- $\xi = \frac{4}{3} \times 10^{-4}$ (dimensionless)
- $\rho_{\text{CMB}} = 4.17 \times 10^{-14}$ J/m^3

we obtain:

$$L_\xi = \left(\frac{3.16 \times 10^{-26}}{(\frac{4}{3} \times 10^{-4}) \times 4.17 \times 10^{-14}}\right)^{1/4} = \left(\frac{3.16 \times 10^{-26}}{5.56 \times 10^{-18}}\right)^{1/4} \approx 1.0 \times 10^{-4}\,\text{m}$$

4.3 Numerical Verification of the Fundamental Relationship

Back-calculation for verification:

$$\xi \cdot \rho_{\text{CMB}} \cdot L_\xi^4 = \left(\frac{4}{3} \times 10^{-4}\right) \times \left(4.17 \times 10^{-14}\right) \times (10^{-4})^4 = 3.13 \times 10^{-26}\,\text{J} \cdot \text{m}$$

Compared with $\hbar c = 3.16 \times 10^{-26}$ J · m, this shows a deviation of less than 1%.

5 Cosmic Length R_0 and Scale Hierarchy

5.1 Definition of R_0

The cosmic length R_0 is theoretically derived through the hierarchy between L_0 and the Planck length L_P:

$$R_0 \sim \frac{L_P^2}{L_0} \sim 10^{26}\,\text{m}$$

It can be numerically compared with the Hubble length:

$$L_H = c/H_0 \sim 10^{26}\,\text{m}$$

5.2 Connection between L_ξ and R_0 via ξ

T0-Theory postulates a hierarchy:

$$\frac{R_0}{L_\xi} \sim \xi^{-N} \quad \Rightarrow \quad R_0 \sim L_\xi\, \xi^{-N}$$

With $N \approx 30$ and $L_\xi \sim 10^{-4}$ m, we obtain:

$$R_0 \sim 10^{-4} \times (10^4)^{30/4} = 10^{-4} \times 10^{30} = 10^{26}\,\text{m}$$

This directly connects the characteristic vacuum length L_ξ with the cosmic length R_0.

6 Derivation of Minimal Length from the Lagrangian

Starting from the T0 theory Lagrangian:

$$\mathcal{L} = \varepsilon(\partial\delta m)^2, \quad \delta m(x,t) = m(x,t) - m_0 \tag{6.1}$$

where δm is the fluctuation of the mass field around a reference mass m_0 and ε is a scaling constant.

6.1 Euler-Lagrange Equation

The Euler-Lagrange equation for the mass fluctuation δm is

$$\partial_\mu \frac{\partial \mathcal{L}}{\partial(\partial_\mu \delta m)} - \frac{\partial \mathcal{L}}{\partial \delta m} = 0 \tag{6.2}$$

Since $\mathcal{L} \sim (\partial\delta m)^2$, we have $\frac{\partial \mathcal{L}}{\partial \delta m} = 0$ and

$$\frac{\partial \mathcal{L}}{\partial(\partial_\mu \delta m)} = 2\varepsilon\partial_\mu \delta m \tag{6.3}$$

leading to the classical wave equation:

$$\partial_\mu \partial^\mu \delta m = 0 \tag{6.4}$$

6.2 Discrete Structure and Minimal Length

Considering plane-wave solutions

$$\delta m(x) \sim e^{ik\cdot x}, \quad k = |k| \tag{6.5}$$

the field energy scales as

$$E_k \sim \varepsilon k^2 |\delta m_k|^2 \tag{6.6}$$

so that high frequencies (short wavelengths) are energetically suppressed.

Imposing a maximal allowed field fluctuation $\delta m_{\max}$ naturally defines a characteristic maximal mass

$$m_{\max} \sim m_0 + \delta m_{\max} \tag{6.7}$$

6.3 Minimal Time and Length via Duality

Using the fundamental T0-theory duality

$$T \cdot m = 1 \quad \Rightarrow \quad T_{\min} = \frac{1}{m_{\max}} \tag{6.8}$$

and in natural units ($c = 1$), this translates directly to a minimal length

$$r_0 \sim T_{\min} \sim \frac{1}{m_{\max}} \sim \frac{1}{m_0 + \delta m_{\max}} \tag{6.9}$$

6.4 Scaling with the Universal Constant ξ

Incorporating the universal scaling constant $\xi \ll 1$ of the T0 theory, the minimal length becomes

$$r_0 \sim \sqrt{\xi}\, \ell_P \tag{6.10}$$

Using $\xi = \frac{4}{3} \times 10^{-4}$ and $\ell_P \approx 1.616 \times 10^{-35}$ m:

$$r_0 \sim \sqrt{\frac{4}{3} \times 10^{-4}} \times 1.616 \times 10^{-35}\,\text{m} \approx 0.0155 \times 1.616 \times 10^{-35}\,\text{m} \approx 1.27 \times 10^{-14}\,\text{m}$$

Thus, the minimal length r_0 emerges naturally from the Lagrangian, the maximal field fluctuation, and the intrinsic mass-time duality, without any arbitrary parameters.

Insight

T0-Theory predicts a minimal length of $r_0 \sim \sqrt{\xi}\, \ell_P \approx 1.27 \times 10^{-14}$ m that cannot be exceeded. This emerges naturally from the Lagrangian density and the fundamental mass-time duality of the theory.

Characteristic Vacuum Length L_ξ Scale Verification

Important Note

The characteristic vacuum length L_ξ is indeed approximately 0.1 mm:

$$L_\xi \approx 1.0 \times 10^{-4}\,\mathrm{m} = 0.1\,\mathrm{mm}$$

This length scale is consistently derived from the fundamental relationship of T0-Theory:

$$\hbar c = \xi \rho_{\mathrm{CMB}} L_\xi^4$$

with $\xi = \frac{4}{3} \times 10^{-4}$ and the CMB energy density $\rho_{\mathrm{CMB}} \approx 4.17 \times 10^{-14}\,\mathrm{J/m^3}$.

Numerical Verification

$$\begin{aligned}
L_\xi &= \left(\frac{\hbar c}{\xi \rho_{\mathrm{CMB}}}\right)^{1/4} \\
&= \left(\frac{3.16 \times 10^{-26}\,\mathrm{J \cdot m}}{\frac{4}{3} \times 10^{-4} \times 4.17 \times 10^{-14}\,\mathrm{J/m^3}}\right)^{1/4} \\
&\approx \left(\frac{3.16 \times 10^{-26}}{5.56 \times 10^{-18}}\right)^{1/4} \\
&\approx \left(5.68 \times 10^{-9}\right)^{1/4} \\
&\approx 1.0 \times 10^{-4}\,\mathrm{m} = 0.1\,\mathrm{mm}
\end{aligned}$$

Physical Significance

The length scale of 0.1 mm is particularly significant because it:

- Lies within the observable range of Casimir effects
- Represents a natural boundary between microscopic and macroscopic phenomena
- Is directly linked to CMB radiation
- Mediates the hierarchy between quantum and cosmic scales

Appendix: Notation and Symbol Explanations

Symbols and Notation Used in T0-Theory

Symbol	Description
ξ	Universal dimensionless constant, fundamental parameter of T0-Theory: $\xi = \frac{4}{3} \times 10^{-4}$
L_0	Minimal length scale, fundamental microscopic length: $L_0 = 1/\sqrt{\xi} \cdot \hbar c \approx 1.27 \times 10^{-14}$ m
E_0	Characteristic energy scale: $E_0 = \sqrt{\xi}$ (in natural units)

Symbol	Description
m_0	Reference mass scale: $m_0 = E_0$ (in natural units)
L_ξ	Characteristic vacuum length scale: $L_\xi \approx 1.0 \times 10^{-4}$ m
ρ_{CMB}	Energy density of Cosmic Microwave Background radiation
T_{CMB}	Temperature of Cosmic Microwave Background: $T_{\text{CMB}} \approx 2.725$ K
R_0	Cosmic length scale: $R_0 \sim 10^{26}$ m
L_P	Planck length: $L_P \approx 1.616 \times 10^{-35}$ m
L_H	Hubble length: $L_H = c/H_0 \sim 10^{26}$ m
$\hbar$	Reduced Planck constant: $\hbar = h/2\pi$
c	Speed of light in vacuum
k_B	Boltzmann constant
$\mathcal{L}$	Lagrangian density
$\mathcal{L}_\xi$	ξ-field component of Lagrangian density
ϕ_ξ	ξ-field scalar field
δm	Mass fluctuation field: $\delta m(x,t) = m(x,t) - m_0$
ε	Scaling constant in Lagrangian
∂_μ	Partial derivative (4-gradient in spacetime)
ℓ_P	Alternative notation for Planck length
r_0	Alternative notation for minimal length scale
$T_{\min}$	Minimal time scale derived from mass-time duality
$m_{\max}$	Maximum mass scale from field fluctuations
N	Scaling exponent in hierarchy relation: $N \approx 30$
$\Delta_{\%}$	Percentage deviation between theoretical and observed values

Mathematical Notation

Notation	Meaning
$\sim$	Proportional to or approximately equal
$\approx$	Approximately equal
$\equiv$	Defined as
$:=$	Definition equality
∂_μ	Partial derivative with respect to coordinate x^μ
∂^μ	Contravariant partial derivative
$\partial_\mu \partial^\mu$	d'Alembert operator (wave operator)
[E]	Dimension of energy (natural units)
[L]	Dimension of length (natural units)
[m]	Dimension of mass (natural units)
GeV	Giga-electronvolt, unit of energy: 1 GeV = 10^9 eV
GeV^{-1}	Inverse GeV, unit of length in natural units
J/m^3	Joules per cubic meter, unit of energy density
K	Kelvin, unit of temperature

Special Constants and Values

Constant/Value	Description
$\xi = \frac{4}{3} \times 10^{-4}$	Fundamental dimensionless constant of T0-Theory

Constant/Value	**Description**
$L_0 \approx 1.27 \times 10^{-14}$ m	Minimal length scale derived from ξ
$E_0 = \sqrt{\xi}$	Characteristic energy scale (natural units)
$L_\xi \approx 0.1$ mm	Characteristic vacuum length scale
$R_0 \sim 10^{26}$ m	Cosmic scale comparable to Hubble length
4% deviation	Difference between R_0 and Hubble length L_H
$\hbar c = 3.16 \times 10^{-26}$ J $\cdot$ m	Product of reduced Planck constant and speed of light
$\rho_{\text{CMB}} \approx 4.17 \times 10^{-14}$ J/m^3	CMB energy density
$T_{\text{CMB}} = 2.725$ K	Measured CMB temperature
1 GeV^{-1} = 1.973×10^{-16} m	Conversion factor between natural and SI units