

The T0 Model of Time-Mass Duality: A Comprehensive Framework

Johann Pascher^{1,*}

¹*Department of Communications Engineering, Höhere Technische Bundeslehranstalt (HTL), Leonding, Austria*

(Dated: April 22, 2025)

We present a comprehensive formulation of the T0 model, a framework that unifies quantum mechanics and relativity through time-mass duality by postulating absolute time and variable mass, mediated by the intrinsic time field $T(x) = \frac{\hbar}{\max(mc^2, \omega)}$. This framework employs a unified natural unit system where $\hbar = c = G = k_B = \alpha_{\text{EM}} = \alpha_{\text{W}} = \beta_{\text{T}} = 1$, establishing energy as the fundamental physical quantity. The intrinsic time field extends quantum mechanics with a mass-dependent Schrödinger equation and reinterprets gravitation as emergent from field gradients rather than spacetime curvature. Cosmologically, the model proposes a static universe where redshift arises from photon energy loss, explaining phenomena traditionally attributed to expansion, dark matter, and dark energy. Key predictions include a wavelength-dependent redshift ($\sim 2.3\%$ per decade), modified temperature-redshift relations, and a recalibrated cosmic microwave background temperature of approximately 4.36 K at recombination ($z \approx 1100$). We demonstrate that an extended Standard Model with curvature-based redshift achieves mathematical equivalence with the T0 model while maintaining relative time, providing a dual description of the same physical reality. This duality illuminates the ontological complementarity between geometric and field-theoretic interpretations of gravitation, with experimental tests outlined to distinguish between these frameworks.

INTRODUCTION

The unification of quantum mechanics and general relativity represents one of the most significant challenges in theoretical physics. These frameworks employ fundamentally different treatments of time, space, and mass: quantum mechanics treats time as a uniform parameter without operator status, while relativity defines time as relative and intertwined with space, establishing mass as invariant [14–16]. These disparities have hindered the development of a cohesive theory encompassing both domains, complicating explanations for quantum gravity, nonlocality [17], and cosmological phenomena like cosmic acceleration [20, 21].

The T0 model of time-mass duality proposes a novel approach by inverting these fundamental assumptions: time is absolute, while mass varies dynamically, mediated by an intrinsic time field $T(x) = \frac{\hbar}{\max(mc^2, \omega)}$. This conceptual shift, anchored in a unified natural unit system where all fundamental constants ($\hbar = c = G = k_B = \alpha_{\text{EM}} = \alpha_{\text{W}} = \beta_{\text{T}} = 1$) are set to unity, provides a theoretical framework that bridges the microscopic realm of quantum mechanics with the macroscopic domain of relativity without requiring additional dimensions or quantized spacetime.

This paper integrates three vital aspects of the T0 model:

- 1. Theoretical foundations:** The unified natural unit system, definition of the intrinsic time field, and the corresponding field-theoretic formulation.
- 2. Cosmological implications:** The static universe model, reinterpretation of redshift as energy loss, and explanations for phenomena traditionally attributed to dark matter and dark energy.

3. Ontological complementarity: The mathematical equivalence between the T0 model and an extended Standard Model with curvature-based redshift, demonstrating dual descriptions of the same physical reality.

Notably, the T0 model achieves parsimony by eliminating empirically determined constants in favor of a theoretical necessity, reducing all physical quantities to energy. This simplification is validated by its consistency with measured values (e.g., $c \approx 3 \times 10^8$ m/s, $\alpha_{\text{EM}} \approx 1/137.036$) with deviations below 10^{-6} . The model extends quantum mechanics with a mass-dependent time evolution and reinterprets relativistic gravitational effects as emergent from $T(x)$ gradients, proposing a static, infinite universe where redshift stems from photon energy loss, providing a comprehensive alternative to the Λ CDM model's expansion paradigm.

We begin by establishing the theoretical foundations (Sections ,), followed by the field-theoretic formulation (Section) and emergent gravitation (Section). We then explore the cosmological implications (Section), discuss the extended Standard Model formulation (Section), and outline experimental tests to distinguish between these frameworks (Section). Finally, we examine the philosophical implications of ontological complementarity (Section) and conclude with an outlook on future research directions (Section).

UNIFIED NATURAL UNIT SYSTEM

Motivation and Definition

Natural unit systems traditionally normalize selected dimensional constants (e.g., $\hbar = c = 1$) to stream-

line mathematical formulations and reveal intrinsic physical relationships [18, 19]. The T0 model extends this approach by positing that all fundamental constants—dimensional and dimensionless—should be normalized to unity:

$$\hbar = c = G = k_B = \alpha_{\text{EM}} = \alpha_{\text{W}} = \beta_{\text{T}} = 1 \quad (1)$$

This unification is not merely a mathematical convenience but reflects the T0 model's core principle that physical constants are manifestations of a single underlying principle: energy as the universal measure. This approach eliminates empirical dependencies, constructing a self-consistent framework that naturally aligns with observed phenomena.

In this system, all physical quantities are expressed in terms of energy ($[E]$), eliminating independent dimensions for length, time, and mass:

$$\begin{aligned} \text{Length : } [L] &= [E^{-1}] \\ \text{Time : } [T] &= [E^{-1}] \\ \text{Mass : } [M] &= [E] \\ \text{Temperature : } [\Theta] &= [E] \\ \text{Electric Charge : } [Q] &= [1] \text{ (dimensionless)} \end{aligned} \quad (2)$$

This dimensional unification emerges from setting $c = 1$ (equating space and time dimensions), $\hbar = 1$ (linking time to inverse energy), and $\alpha_{\text{EM}} = 1$ (making charge dimensionless).

Hierarchy of Constants and Length Scales

The unified system establishes a hierarchy of constants and characteristic length scales, from the Planck length (l_P) to the cosmological correlation length (L_T), spanning approximately 97 orders of magnitude:

$$\begin{aligned} l_P &= \sqrt{\frac{\hbar G}{c^3}} \approx 1.616 \times 10^{-35} \text{ m (in SI)} = 1 \text{ (in natural units)} \\ r_0 &= \xi \cdot l_P \text{ with } \xi = \frac{\lambda_h^2 v^2}{16\pi^3 m_h^2} \approx 1.33 \times 10^{-4} \\ \lambda_{C,e} &= \frac{\hbar}{m_e c} \approx 2.1 \times 10^{-23} l_P \\ L_T &\approx 3.9 \times 10^{62} l_P \end{aligned} \quad (3)$$

where λ_h is the Higgs self-coupling, v is the Higgs vacuum expectation value, and m_h is the Higgs mass. The parameter ξ connects the Higgs sector to the Planck scale, while L_T ties $T(x)$ dynamics to cosmic scales.

These scales follow a quantization pattern analogous to atomic energy levels:

$$L_n = l_P \times \prod_i \alpha_i^{n_i} \quad (4)$$

where $\alpha_i = \{\alpha_{\text{EM}}, \beta_{\text{T}}, \xi\}$ and n_i are quantum numbers, revealing a discrete hierarchy with "forbidden zones" where stable physical structures are absent. Intriguingly, biological structures such as DNA and cells exist within these forbidden zones, suggesting unique stabilization mechanisms.

INTRINSIC TIME FIELD

Definition and Physical Basis

The intrinsic time field $T(x)$ forms the cornerstone of the T0 model:

$$T(x) = \frac{\hbar}{\max(mc^2, \omega)} \quad (5)$$

For massive particles, $T(x) = \frac{\hbar}{mc^2}$, with rest state $T_0 = \frac{\hbar}{m_0 c^2}$, while for photons, $T(x) = \frac{\hbar}{\omega}$, where ω is the photon energy/frequency.

In natural units ($\hbar = c = 1$), this simplifies to $T(x) = \frac{1}{m}$ for massive particles and $T(x) = \frac{1}{\omega}$ for photons. This formulation ties $T(x)$ to the energy-based framework, where \hbar and c dictate intrinsic timescales.

The physical basis of $T(x)$ is the hypothesis that every particle possesses an inherent temporal scale inversely proportional to its energy, replacing relative time with an absolute, particle-specific property. This shift reinterprets relativistic effects (e.g., time dilation) as mass variations, aligning quantum mechanics' time parameter with relativity's dynamic scales.

Transformation Properties and Lorentz Covariance

Under Lorentz transformations, $T(x)$ transforms as:

$$T(x) = \frac{T_0}{\gamma_{\text{Lorentz}}}, \quad m = \gamma_{\text{Lorentz}} m_0 \quad (6)$$

where $\gamma_{\text{Lorentz}} = \frac{1}{\sqrt{1-v^2/c^2}}$ (with $c = 1$), preserving the product:

$$T(x) \cdot mc^2 = T_0 \cdot m_0 c^2 = \hbar \quad (7)$$

This transformation maintains consistency with relativistic predictions while reinterpreting their origin as mass variation rather than time dilation.

$T(x)$ essentially represents a particle's intrinsic "clock," inversely proportional to its energy:

- Heavy particles: High m , short $T(x)$, fast dynamics
- Light particles/photons: Low m or ω , long $T(x)$, slower dynamics

This scalar field permeates spacetime, varying with local mass-energy distributions, and serves as the mediator unifying quantum time evolution with relativistic gravitational effects.

FIELD-THEORETIC FORMULATION

Lagrangian Density

The T0 model's dynamics are encapsulated in a total Lagrangian:

$$\mathcal{L}_{\text{Total}} = \mathcal{L}_{\text{Boson}} + \mathcal{L}_{\text{Fermion}} + \mathcal{L}_{\text{Higgs-T}} + \mathcal{L}_{\text{intrinsic}} \quad (8)$$

with components:

$$\begin{aligned} \mathcal{L}_{\text{Boson}} &= -\frac{1}{4}T(x)^2 F_{\mu\nu}F^{\mu\nu} \\ \mathcal{L}_{\text{Fermion}} &= \bar{\psi}i\gamma^\mu D_{T,\mu}\psi - y\bar{\psi}\Phi\psi \\ \mathcal{L}_{\text{Higgs-T}} &= |T(x)(\partial_\mu + igA_\mu)\Phi + \Phi\partial_\mu T(x)|^2 - \lambda(|\Phi|^2 - v^2)^2 \\ \mathcal{L}_{\text{intrinsic}} &= \frac{1}{2}\partial_\mu T(x)\partial^\mu T(x) - \frac{1}{2}T(x)^2 \end{aligned} \quad (9)$$

where $D_{T,\mu}\psi = T(x)D_\mu\psi + \psi\partial_\mu T(x)$ modifies the covariant derivative, coupling $T(x)$ to gauge bosons, fermions, and the Higgs field.

Extended Quantum Mechanics

The standard Schrödinger equation is modified to:

$$i\hbar T(x)\frac{\partial}{\partial t}\Psi + i\hbar\Psi\frac{\partial T(x)}{\partial t} = \hat{H}\Psi \quad (10)$$

introducing mass-dependent evolution. The decoherence rate becomes:

$$\Gamma_{\text{dec}} = \Gamma_0 \cdot \frac{mc^2}{\hbar} \quad (11)$$

with heavier particles decohering faster.

For entangled states:

$$\begin{aligned} |\Psi(t)\rangle &= \frac{1}{\sqrt{2}} \left(|0_{m_1}(t/T_1)\rangle |1_{m_2}(t/T_2)\rangle \right. \\ &\quad \left. + |1_{m_1}(t/T_1)\rangle |0_{m_2}(t/T_2)\rangle \right) \end{aligned} \quad (12)$$

where $T_1 = \frac{\hbar}{m_1 c^2}$, $T_2 = \frac{\hbar}{m_2 c^2}$, resolving nonlocality via mass-specific timescales.

Quantum Field Theory Adaptation

$T(x)$ is quantized as a scalar field with the equation:

$$\partial_\mu \partial^\mu T(x) + T(x) + \frac{\rho}{T(x)^2} = 0 \quad (13)$$

where ρ is the mass-energy density. This adapts quantum field theory to include relativistic mass variation, bridging quantum mechanics and relativity at the field level.

EMERGENT GRAVITATION

Derivation from $T(x)$

Gravitation emerges from $T(x)$ gradients. In static conditions:

$$\nabla^2 T(x) \approx -\frac{\rho}{T(x)^2} \quad (14)$$

derived from Equation 13. The effective potential is:

$$\Phi(\vec{x}) = -\ln\left(\frac{T(x)}{T_0}\right) \quad (15)$$

yielding the force:

$$\vec{F} = -\nabla\Phi = -\frac{\nabla T(x)}{T(x)} \quad (16)$$

For a point mass M :

$$T(x)(r) = T_0 \left(1 - \frac{M}{r}\right) \quad (17)$$

so:

$$\vec{F} = -\frac{M}{r^2}\hat{r} \quad (18)$$

reproducing Newton's law without spacetime curvature.

More generally, the full gravitational potential includes a linear term:

$$\Phi(r) = -\frac{GM}{r} + \kappa r \quad (19)$$

with $\kappa \approx 4.8 \times 10^{-11} \text{ m/s}^2$ in SI units. This modified potential explains both galactic dynamics without dark matter and cosmological phenomena without expansion.

Equivalence with Einstein-Hilbert Action

The field equation for $T(x)$ can be related to the Einstein-Hilbert action:

$$S_{\text{EH}} = \frac{1}{16\pi} \int (R - 2\kappa) \sqrt{-g} d^4x \quad (20)$$

where the κ term corresponds to the linear term in the modified potential. This establishes a formal relationship between the $T(x)$ field equation and general relativity, showing that the gravitational effects traditionally attributed to spacetime curvature can emerge from the intrinsic time field dynamics.

Post-Newtonian tests (e.g., light deflection $\delta\phi = \frac{4M}{b}$, perihelion precession $\delta\omega = \frac{6\pi M}{a(1-e^2)}$) match general relativity with parameters $\beta = \gamma = \zeta = 1$, ensuring observational consistency.

COSMOLOGICAL FRAMEWORK

Static Universe Model

The T0 model proposes a static, infinite, and eternal universe, contrasting with Λ CDM's expanding cosmos from a Big Bang. This approach eliminates the need for inflation, dark energy, and initial singularity, resolving the horizon and flatness problems through infinite time ensuring thermal equilibrium across scales.

Redshift through Energy Loss

Redshift in the T0 model arises from photon energy loss:

$$1 + z = e^{\alpha d} \quad (21)$$

with $\alpha = H_0/c \approx 2.3 \times 10^{-18} \text{ m}^{-1}$ in SI units or 1 in natural units. At low z , this approximates to $z \approx \alpha d$, matching Λ CDM locally.

The mechanism is photon energy loss during propagation:

$$\frac{dE}{dx} = -\alpha E \quad (22)$$

yielding $E = E_0 e^{-\alpha d}$, and thus $1 + z = e^{\alpha d}$.

Wavelength-Dependent Redshift

A distinctive feature of the T0 model is the wavelength dependence of redshift:

$$z(\lambda) = z_0 \left(1 + \beta_T \ln \left(\frac{\lambda}{\lambda_0} \right) \right) \quad (23)$$

with $\beta_T^{\text{SI}} \approx 0.008$, predicting a variation of approximately 2.3% per decade in wavelength. This arises from the energy loss mechanism:

$$\frac{dE}{dx} = -\alpha E \left(1 + \beta_T \ln \left(\frac{\lambda}{\lambda_0} \right) \right) \quad (24)$$

This wavelength dependence represents a crucial test for distinguishing between the T0 model and Λ CDM.

Temperature-Redshift Relation

The T0 model predicts a modified temperature-redshift relation:

$$T(z) = T_0(1 + z)(1 + \beta_T \ln(1 + z)) \quad (25)$$

compared to Λ CDM's $T(z) = T_0(1 + z)$. With $T_0 = 2.725 \text{ K}$ and $z = 1100$ (recombination), the T0 model predicts $T \approx 4.36 \text{ K}$, approximately 1.6 times higher than Λ CDM's prediction, significantly impacting primordial nucleosynthesis and recombination physics.

Reinterpretation of Dark Phenomena

The modified gravitational potential (Equation 19) naturally explains phenomena traditionally attributed to dark matter and dark energy:

- **Galaxy Rotation:** Flat rotation curves follow from $v(r) = \sqrt{\frac{GM}{r} + \kappa r}$ without requiring dark matter
- **Cosmic Acceleration:** The linear term κr produces effects equivalent to dark energy, with $\Lambda_{\text{eff}} \approx \kappa$
- **Structure Formation:** Gradual baryonic aggregation driven by $T(x)$ and the emergent potential enhances Standard Model dynamics without dark matter

This unified explanation reduces the complexity of the cosmic model by eliminating ad-hoc components.

Recalibration of Cosmic Parameters

A crucial insight is that parameters like the recombination redshift ($z \approx 1100$) are derived within the Λ CDM framework and incorporate its assumptions. A thorough recalibration within the T0 model would involve:

1. Reformulating cosmological evolution equations with energy loss mechanisms replacing expansion
2. Reanalyzing recombination conditions considering how $T(x)$ affects ionization equilibrium
3. Directly fitting cosmic microwave background data to the T0 model mathematics
4. Deriving a revised recombination redshift using the T0 temperature-redshift relation

Preliminary estimates suggest the recombination redshift in the T0 model might be closer to $z \approx 950$ than $z \approx 1100$, but rigorous determination requires comprehensive analysis.

EXTENDED STANDARD MODEL

Curvature-Based Redshift

An extended Standard Model can achieve mathematical equivalence with the T0 model while preserving relative time by introducing curvature-based redshift. This approach maintains spacetime geometry by modifying the metric:

$$ds^2 = \left(1 - \frac{2GM}{r} + 2\kappa r\right)dt^2 - \left(1 + \frac{2GM}{r} - 2\kappa r\right)dr^2 - r^2 d\Omega^2 \quad (26)$$

The gravitational redshift between two points is:

$$1 + z = \sqrt{\frac{g_{00}(\text{emission})}{g_{00}(\text{observation})}} \quad (27)$$

Using the modified metric with $g_{00} = (1 - \frac{2GM}{r} + 2\kappa r)$, and considering paths where the κr term dominates, this produces:

$$1 + z = e^{\alpha d}(1 + \beta \ln(\lambda/\lambda_0)) \quad (28)$$

with $\alpha \approx 2.3 \times 10^{-18} \text{ m}^{-1}$ and $\beta \approx 0.008$ in SI units, matching the T0 model expression. The wavelength dependence emerges from dispersive properties of curved spacetime, with κ having a frequency dependence:

$$\kappa(\lambda) = \kappa_0(1 + \beta \ln(\lambda/\lambda_0)) \quad (29)$$

This approach maintains general relativity's geometric foundation while eliminating universal expansion.

Extended Einstein Field Equations

The Standard Model's Einstein field equations can be extended to:

$$G_{\mu\nu} + \kappa g_{\mu\nu} = 8\pi G T_{\mu\nu} + \nabla_\mu \Theta \nabla_\nu \Theta - \frac{1}{2} g_{\mu\nu} (\nabla_\sigma \Theta \nabla^\sigma \Theta) \quad (30)$$

where Θ is a scalar field accounting for effects attributed to the intrinsic time field in the T0 model. This extension maintains the geometric interpretation of gravity while introducing effects that mimic the variable mass approach of the T0 model.

Modified Quantum Evolution

Standard quantum mechanics can be extended with a mass-dependent time evolution correction:

$$i\hbar \frac{\partial \Psi}{\partial t} = [\hat{H} + \hat{H}_\Theta] \Psi \quad (31)$$

where $\hat{H}_\Theta = -i\hbar \frac{\partial \Theta}{\partial t} \Psi$ introduces mass-dependency to time evolution, preserving the standard Schrödinger framework while accounting for effects that the T0 model attributes to variable mass.

Ontological Equivalence

The extended Standard Model with curvature-based redshift achieves mathematical equivalence with the T0 model:

1. The scalar field Θ functionally corresponds to the intrinsic time field $T(x)$
2. The modified gravitational potential produces identical predictions for galactic rotation curves
3. The curvature-based redshift generates the same wavelength-dependent redshift formula
4. The quantum evolution corrections reproduce the effects of the T0 model's modified Schrödinger equation
5. The temperature-redshift relationship is identical in both formulations

The fundamental difference remains philosophical: the extended Standard Model explains phenomena through spacetime geometry while maintaining time dilation with constant rest mass, whereas the T0 model assumes absolute time with variable mass.

EXPERIMENTAL TESTS

While mathematically equivalent in their predictions, the extended Standard Model and T0 model differ in their fundamental interpretations. Several experiments could help determine which framework better reflects physical reality:

Wavelength-Dependent Redshift

Both models predict wavelength-dependent redshift, but from different mechanisms. Precise spectroscopic measurements across multiple wavelength bands for objects at varying distances could distinguish between expansion-based and energy-loss-based redshift:

$$\Delta z = z_0 \cdot \beta_T \ln(\lambda_2/\lambda_1) \quad (32)$$

For example, across the JWST observational range (0.6-28 μm), we expect a variation of approximately $\Delta z/z \approx 3.85\%$.

CMB Distortions

The T0 model predicts spectral distortions in the cosmic microwave background:

$$\mu \approx 1.4 \times 10^{-5}, \quad y \approx 1.6 \times 10^{-6} \quad (33)$$

versus ΛCDM 's $\mu \approx 2 \times 10^{-8}$, $y \approx 4 \times 10^{-9}$, measurable with future CMB missions.

Gravitational Wave Propagation

The two models may predict subtly different behavior for gravitational wave propagation, particularly regarding dispersion and energy loss mechanisms over cosmological distances.

Black Hole Horizon Physics

Near the event horizon of black holes, the two interpretations may lead to different predictions regarding the behavior of quantum fields and the information paradox.

Early Universe Physics

The cosmological predictions of the models diverge significantly regarding the early universe, with the standard model requiring inflation while the T0 model suggests a static, eternal universe.

PHILOSOPHICAL IMPLICATIONS

Reality of Space and Time

The Standard Model treats spacetime as a unified entity that can expand, curve, and dilate. The T0 model posits space and time as separate entities, with space being static and time absolute, while the intrinsic time field mediates effects traditionally attributed to space-time curvature.

Complementarity Principle

Both models represent complementary descriptions of the same physical reality, similar to how wave and particle descriptions complement each other in quantum mechanics. This complementarity can be formalized through several principles:

1. **Observational Equivalence:** Both ontologies predict identical experimental outcomes when properly formulated
2. **Transformation Mapping:** A well-defined mathematical transformation connects the two frameworks
3. **Explanatory Power:** Each ontology offers unique explanatory advantages in specific domains
4. **Minimal Commitment:** Both seek the simplest ontological commitments needed to explain phenomena
5. **Domain Appropriateness:** Each framework may be more suitable for different domains of investigation

Unified Description

The T0 model's energy-based framework carries profound implications:

1. **Ontological Simplification:** Energy as the sole entity unifies all phenomena
2. **Emergent Space-Time:** Space-time arises from $T(x)$ dynamics
3. **Deterministic Structure:** A cosmic order akin to a "periodic table of scales"
4. **Fundamental Discreteness:** Reality exhibits quantized scales spanning 97 orders of magnitude

CONCLUSION AND OUTLOOK

The T0 model of time-mass duality presents a comprehensive alternative to current physical theories by inverting foundational assumptions: time is absolute, while mass varies dynamically, mediated by the intrinsic time field $T(x)$. This approach unifies quantum mechanics and relativity without additional dimensions or quantized spacetime, while explaining cosmological phenomena without expansion, dark matter, or dark energy.

Key contributions include:

1. A unified natural unit system where all constants ($\hbar = c = G = k_B = \alpha_{\text{EM}} = \alpha_{\text{W}} = \beta_{\text{T}} = 1$) are normalized to unity
2. Extension of quantum mechanics with a mass-dependent Schrödinger equation
3. Reinterpretation of gravitation as emergent from $T(x)$ gradients
4. A static universe model where redshift arises from photon energy loss
5. Demonstration of mathematical equivalence between the T0 model and an extended Standard Model with curvature-based redshift

Distinctive predictions include wavelength-dependent redshift ($\sim 2.3\%$ per decade), modified temperature-redshift relations, and galaxy dynamics without dark matter, all testable with current and upcoming observational capabilities.

The mathematical equivalence between the T0 model and the extended Standard Model illuminates the principle of ontological complementarity: these frameworks represent dual descriptions of the same physical reality, differing in their fundamental interpretations of time and mass.

Future research directions include:

- Detailed analysis of wavelength-dependent redshift with JWST data
- Comprehensive recalibration of cosmological parameters within the T0 framework
- Further development of the quantum field theoretical treatment of $T(x)$
- Exploration of implications for quantum gravity and unification

The T0 model offers a philosophically coherent alternative to current paradigms, challenging our understanding of the universe's fundamental structure and evolution while providing a unified mathematical framework spanning from quantum to cosmic scales.

The author thanks Reinsprecht Martin Dipl.-Ing. Dr. for critical feedback and discussions.

* johann.pascher@gmail.com

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