Quantum Field Theoretical Treatment of the Intrinsic Time Field in the T0 Model

Johann Pascher
Department of Communication Technology
Higher Technical Federal Institute (HTL), Leonding, Austria
johann.pascher@gmail.com

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Abstract

This work presents a systematic quantum field theoretical treatment of the intrinsic time field $T(x)$ in the T0 model. Starting from classical field theory, a complete quantization is developed, encompassing canonical commutation relations, path integral formalism, and interaction dynamics. Particular attention is given to the integration of the quantized time field with Standard Model fields through modified propagators and extended Feynman rules. The theory satisfies the requirements of unitarity and causality while providing a natural bridge between quantum mechanics and relativity according to the time-mass duality principle. The quantization yields specific experimental predictions, including quantum corrections to wavelength-dependent redshift and modified gravitational wave propagation. This consistent quantum theory of the intrinsic time field addresses open questions in foundational physics and establishes the T0 model as a promising alternative to conventional approaches to quantum gravity and unified theories.

Contents

1 Quantum Field Theoretical Treatment of the T0 Model

1.1 Foundations of the T0 Model

The T0 model provides a novel approach to fundamental physics based on the intrinsic time field $T(x)$ and time-mass duality. In the T0 framework, the intrinsic time field is defined as:

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

In natural units ($\hbar = c = G = k_B = 1$), this simplifies to:

$$T(x) = \frac{1}{m} \tag{2}$$

This relationship establishes energy as the fundamental unit, with $T(x)$ having dimension $[E^{-1}]$. The complete T0 model is built on unified natural units with $\alpha_{\text{EM}} = \beta_T = \alpha_W = 1$, as developed in [1].

1.2 Field Equations and Lagrangian Density

The field equation for the intrinsic time field is:

$$\nabla^2 T(x) = -\kappa \rho(x) T(x)^2 \tag{3}$$

where κ has dimension $[E]$ and ρ has dimension $[E^2]$ in natural units. As demonstrated in [2], this equation leads to emergent gravitation.

The total Lagrangian density for the T0 model is:

$$\mathcal{L}_{\text{Total}} = \mathcal{L}_{\text{Boson}} + \mathcal{L}_{\text{Fermion}} + \mathcal{L}_{\text{Higgs-T}} + \mathcal{L}_{\text{intrinsic}} \tag{4}$$

where:

$$\mathcal{L}_{\text{intrinsic}} = \frac{1}{2}\partial_\mu T(x) \partial^\mu T(x) - \frac{1}{2} T(x)^2 - \frac{\rho}{T(x)} \tag{5}$$

$$\mathcal{L}_{\text{Boson}} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \tag{6}$$

$$\mathcal{L}_{\text{Fermion}} = \bar{\psi} i \gamma^\mu D_{T\mu} \psi \tag{7}$$

$$\mathcal{L}_{\text{Higgs-T}} = |D_{T\mu}\Phi|^2 - V(\Phi) \tag{8}$$

with the T-modified derivatives:

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

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

These expressions maintain complete consistency with the field equations derived in [3] and [4].

1.3 Canonical Quantization

To quantize the intrinsic time field, we separate it into a classical background and quantum fluctuations:

$$T(x) = T_c(x) + \hat{T}(x) \tag{11}$$

The classical part satisfies:

$$\nabla^2 T_c(x) = -\kappa\rho(x)T_c(x)^2 \tag{12}$$

For the quantum fluctuations, the effective Lagrangian becomes:

$$\mathcal{L}_{\text{quantum}} \approx \frac{1}{2}\partial_\mu\hat{T}(x)\partial^\mu\hat{T}(x) - \frac{1}{2}\hat{T}(x)^2 - \frac{\rho}{T_c(x)^3}\hat{T}(x)^2 \tag{13}$$

The canonical momentum is:

$$\Pi(x) = \frac{\partial\mathcal{L}}{\partial(\partial_0\hat{T})} = \partial_0\hat{T}(x) \tag{14}$$

We impose canonical commutation relations:

$$[\hat{T}(\vec{x},t), \Pi(\vec{y},t)] = i\delta^3(\vec{x}-\vec{y}) \tag{15}$$

$$[\hat{T}(\vec{x},t), \hat{T}(\vec{y},t)] = [\Pi(\vec{x},t), \Pi(\vec{y},t)] = 0 \tag{16}$$

These relations follow directly from the principles of quantum field theory applied to the intrinsic time field, without importing Standard Model assumptions.

1.4 Mode Expansion and Hamiltonian

The effective mass for quantum fluctuations is:

$$m_{\text{eff}}^2(x) = 1 + \frac{2\rho}{T_c(x)^3} \tag{17}$$

In regions of approximately uniform mass density, we can express $\hat{T}(x)$ using mode expansion:

$$\hat{T}(x) = \int \frac{d^3k}{(2\pi)^3}\frac{1}{\sqrt{2\omega_{\vec{k}}}}\left(a_{\vec{k}}e^{-ik\cdot x} + a_{\vec{k}}^\dagger e^{ik\cdot x}\right) \tag{18}$$

where $\omega_{\vec{k}} = \sqrt{\vec{k}^2 + m_{\text{eff}}^2}$ and:

$$[a_{\vec{k}}, a_{\vec{k}'}^\dagger] = (2\pi)^3\delta^3(\vec{k}-\vec{k}') \tag{19}$$

The Hamiltonian density is:

$$\mathcal{H} = \frac{1}{2}\Pi(x)^2 + \frac{1}{2}(\nabla\hat{T}(x))^2 + \frac{1}{2}\left(1 + \frac{2\rho}{T_c(x)^3}\right)\hat{T}(x)^2 \tag{20}$$

After normal ordering, the Hamiltonian becomes:

$$H = \int \frac{d^3k}{(2\pi)^3}\omega_{\vec{k}} : a_{\vec{k}}^\dagger a_{\vec{k}} : + E_0 \tag{21}$$

The vacuum energy E_0 depends on the matter distribution through m_{eff}, providing a natural mechanism for vacuum energy to adjust to the presence of matter. This is fundamentally different from the Standard Model approach, which leads to the cosmological constant problem. In the T0 model, this issue is naturally addressed through the coupling between the time field and matter distribution, as detailed in [5].

1.5 Path Integral Formulation

The generating functional for the quantum time field is:

$$Z[J] = \int \mathcal{D}T \exp\left(i \int d^4x(\mathcal{L}_{\text{quantum}} + J(x)\hat{T}(x))\right) \tag{22}$$

which can be evaluated as:

$$Z[J] = \exp\left(-\frac{i}{2} \int d^4x d^4y J(x)\Delta_F(x-y)J(y)\right) \tag{23}$$

where $\Delta_F(x-y)$ is the Feynman propagator:

$$\Delta_F(x-y) = \int \frac{d^4k}{(2\pi)^4} \frac{i}{k^2 - m_{\text{eff}}^2 + i\epsilon} e^{-ik\cdot(x-y)} \tag{24}$$

This propagator includes the effective mass m_{eff} which contains the matter coupling, a feature unique to the T0 model not found in Standard Model approaches.

1.6 Modified Particle Propagators

The time field modifies the propagators of Standard Model particles. For fermions:

$$S_F^T(p) = \frac{i(\not{p} + m)}{p^2 - m^2 + i\epsilon} \cdot \frac{T_c}{T_0} \tag{25}$$

For gauge bosons:

$$D_{\mu\nu}^T(p) = \frac{-ig_{\mu\nu} + \frac{p_\mu p_\nu}{p^2}}{p^2 + i\epsilon} \cdot \left(\frac{T_c}{T_0}\right)^2 \tag{26}$$

These modifications follow directly from the coupling structure in the T0 model Lagrangian, without introducing additional parameters, consistent with the framework in [3].

1.7 Feynman Rules

The T0 model Feynman rules include:

1. $T(x)$-propagator: $\frac{i}{p^2 - m_{\text{eff}}^2 + i\epsilon}$
2. Fermion-$T(x)$ vertex: $i\gamma^\mu p_\mu$
3. Gauge boson-$T(x)$ vertex: $-2ig_{\mu\nu}T_c$
4. Higgs-$T(x)$ vertex: $ip_\mu \Phi^* \partial^\mu \Phi + \text{h.c.}$

These rules preserve the dimensional consistency with energy as the fundamental unit and follow directly from the T0 model Lagrangian densities derived in [6].

1.8 Quantum Corrections to Wavelength-Dependent Redshift

The classical wavelength-dependent redshift in the T0 model is:

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

Quantum fluctuations of the time field introduce corrections:

$$z(\lambda) = z_0 \left(1 + \ln \frac{\lambda}{\lambda_0} + \frac{\langle \hat{T}(x)^2 \rangle}{T_c(x)^2}\right) \tag{28}$$

The quantum correction term $\frac{\langle \hat{T}(x)^2 \rangle}{T_c(x)^2}$ is proportional to $\frac{1}{E_{\text{Pl}}}$, making it small for typical astronomical observations but potentially detectable in high-precision measurements, as discussed in [7].

1.9 Emergent Spacetime

The quantum time field gives rise to an emergent spacetime metric:

$$g_{\mu\nu}^{\text{eff}} = \eta_{\mu\nu} + 2\kappa \langle T(x) \rangle \partial_\mu \partial_\nu \langle T(x) \rangle - \kappa \eta_{\mu\nu} \partial_\alpha \langle T(x) \rangle \partial^\alpha \langle T(x) \rangle \tag{29}$$

This connects directly to the gravitational parameter $\kappa^{\text{nat}} = \beta_{\text{T}}^{\text{nat}} \cdot \frac{yv}{r_g^2} \beta_{\text{T}}^{\text{nat}} \cdot \frac{yv}{r_g^2}$ with $\beta_T = 1$ in natural units. The metric emerges naturally from the time field dynamics without assuming general relativity, as demonstrated in [2].

Gravitational waves arise as oscillations in the expectation value of the time field, with propagation speed:

$$v_{\text{GW}} = c \left(1 - \frac{1}{2} \frac{\langle \hat{T}(x)^2 \rangle}{T_c(x)^2}\right) \tag{30}$$

showing a small quantum correction that could potentially be measured in future gravitational wave observations.

1.10 Modified Uncertainty Relations

The time field leads to modified uncertainty relations:

$$\Delta x \Delta p \geq \frac{\hbar}{2} \left(1 + \langle \hat{T}(x) \rangle \Delta V\right) \tag{31}$$

This provides a natural bridge between quantum and classical regimes, with the standard uncertainty principle recovered in the limit of weak gravitational fields, as explored in [9].

2 Experimental Predictions

The quantum field theoretical treatment of the T0 model leads to several unique experimental predictions that distinguish it from the Standard Model:

2.1 Wavelength-Dependent Redshift

The T0 model predicts a specific wavelength dependence of cosmic redshift:

$$z(\lambda) = z_0 \left(1 + \ln \frac{\lambda}{\lambda_0}\right) \tag{32}$$

This can be tested through multi-wavelength observations of distant galaxies using instruments like the James Webb Space Telescope, as detailed in [7].

2.2 Modified Gravitational Potential

The gravitational potential in the T0 model takes the form:

$$\Phi(r) = -\frac{M}{r} + \kappa r \tag{33}$$

where $\kappa^{\text{nat}} = \beta_{\text{T}}^{\text{nat}} \cdot \frac{yv}{r_g^2} \beta_{\text{T}}^{\text{nat}} \cdot \frac{yv}{r_g^2}$ has dimension $[E]$ in natural units. This modified potential explains galaxy rotation curves without dark matter, as shown in [8].

2.3 Quantum Gravitational Effects

The T0 model predicts quantum gravitational effects at energies approximately:

$$E_{\text{QG}} \sim \sqrt{\xi} \cdot M_{\text{Pl}} \approx 10^{-2} M_{\text{Pl}} \tag{34}$$

where $\xi \approx 1.33 \times 10^{-4}$ relates the characteristic length scale r_0 to the Planck length: $r_0 = \xi \cdot l_P$. This places quantum gravitational effects potentially within reach of future experiments, as discussed in [10].

3 Conclusion

The quantum field theoretical treatment of the T0 model provides a consistent framework that:

1. Maintains energy as the fundamental unit throughout
2. Requires no new independent constants beyond those specified in the T0 model
3. Provides a natural explanation for redshift without cosmic expansion
4. Offers an elegant solution to the vacuum energy problem
5. Makes specific, testable predictions that distinguish it from the Standard Model

This development completes the theoretical structure of the T0 model, establishing it as a viable alternative to conventional approaches to quantum gravity and unified theories.

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