

# Dynamic Mass of Photons and Its Implications for Nonlocality in the T0 Model: Updated Framework with Complete Geometric Foundations

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## Abstract

This updated work examines the implications of assigning a dynamic, frequency-dependent effective mass to photons within the comprehensive framework of the T0 model, building upon the complete field-theoretic derivation and natural units system where  $\hbar = c = \alpha_{\text{EM}} = \beta_{\text{T}} = 1$ . The theory establishes the fundamental relationship  $T(x, t) = \frac{1}{\max(m, \omega)}$  with dimension  $[E^{-1}]$ , providing a unified treatment of massive particles and photons through the three fundamental field geometries. The dynamic photon mass  $m_\gamma = \omega$  introduces energy-dependent nonlocality effects, with testable predictions. All formulations maintain strict dimensional consistency with the fixed T0 parameters  $\beta = 2Gm/r$ ,  $\xi = 2\sqrt{G} \cdot m$ , and the cosmic screening factor  $\xi_{\text{eff}} = \xi/2$  for infinite fields.

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# 1 Introduction: T0 Model Foundation for Photon Dynamics

This updated analysis builds upon the comprehensive T0 model framework established in the field-theoretic derivation, incorporating the complete geometric foundations and natural units system. The dynamic effective mass concept for photons emerges naturally from the T0 model's fundamental time-mass duality principle.

## 1.1 Fundamental T0 Model Framework

The T0 model is based on the intrinsic time field definition:

$$T(x, t) = \frac{1}{\max(m(\vec{x}, t), \omega)} \quad (1)$$

**Dimensional verification:**  $[T(x, t)] = [1/E] = [E^{-1}]$  in natural units ✓  
This field satisfies the fundamental field equation:

$$\nabla^2 m(\vec{x}, t) = 4\pi G \rho(\vec{x}, t) \cdot m(\vec{x}, t) \quad (2)$$

From this foundation emerge the key parameters:

### T0 Model Parameters for Photon Analysis

$$\beta = \frac{2Gm}{r} \quad [1] \text{ (dimensionless)} \quad (3)$$

$$\xi = 2\sqrt{G} \cdot m \quad [1] \text{ (dimensionless)} \quad (4)$$

$$\beta_T = 1 \quad [1] \text{ (natural units)} \quad (5)$$

$$\alpha_{EM} = 1 \quad [1] \text{ (natural units)} \quad (6)$$

## 1.2 Photon Integration in Time-Mass Duality

For photons, the T0 model assigns an effective mass:

$$m_\gamma = \omega \quad (7)$$

**Dimensional verification:**  $[m_\gamma] = [\omega] = [E]$  in natural units ✓  
This gives the photon's intrinsic time field:

$$T(x, t)_\gamma = \frac{1}{\omega} \quad (8)$$

### Praktische Vereinfachung

**Vereinfachung:** Da alle Messungen in unserem endlichen, beobachtbaren Universum lokal erfolgen, wird nur die **lokalisierte Feldgeometrie** verwendet:

$\xi = 2\sqrt{G} \cdot m$  und  $\beta = \frac{2Gm}{r}$  für alle Anwendungen.

Der kosmische Abschirmfaktor  $\xi_{\text{eff}} = \xi/2$  entfällt.

**Physical interpretation:** Higher-energy photons have shorter intrinsic time scales, creating energy-dependent temporal dynamics.

## 2 Energy-Dependent Nonlocality and Quantum Correlations

### 2.1 Entangled Photon Systems

For entangled photons with energies  $\omega_1$  and  $\omega_2$ , the time field difference is:

$$\Delta T_\gamma = \left| \frac{1}{\omega_1} - \frac{1}{\omega_2} \right| \quad (9)$$

**Physical consequence:** Quantum correlations experience energy-dependent delays.

### 2.2 Modified Bell Inequality

The energy-dependent time fields lead to a modified Bell inequality:

$$|E(a, b) - E(a, c)| + |E(a', b) + E(a', c)| \leq 2 + \epsilon(\omega_1, \omega_2) \quad (10)$$

where:

$$\epsilon(\omega_1, \omega_2) = \alpha_{\text{corr}} \left| \frac{1}{\omega_1} - \frac{1}{\omega_2} \right| \frac{2G\langle m \rangle}{r} \quad (11)$$

with  $\alpha_{\text{corr}}$  being a correlation coupling constant and  $\langle m \rangle$  the average mass in the experimental setup.

## 3 Experimental Predictions and Tests

### 3.1 High-Precision Quantum Optics Tests

#### 3.1.1 Energy-Dependent Bell Tests

Predicted time delay between entangled photons:

$$\Delta t_{\text{corr}} = \frac{G\langle m \rangle}{r} \left| \frac{1}{\omega_1} - \frac{1}{\omega_2} \right| \quad (12)$$

For laboratory conditions with  $\langle m \rangle \sim 10^{-3}$  kg,  $r \sim 10$  m, and  $\omega_1, \omega_2 \sim 1$  eV:

$$\Delta t_{\text{corr}} \sim 10^{-21} \text{ s} \quad (13)$$

## 4 Dimensional Consistency Verification

## 5 Conclusions

### 5.1 Summary of Key Results

This updated analysis demonstrates that the dynamic photon mass concept integrates seamlessly into the comprehensive T0 model framework:

1. **Unified treatment:** Photons and massive particles follow the same fundamental relationship  $T = 1/\max(m, \omega)$

| Equation              | Left Side                      | Right Side   | Status |
|-----------------------|--------------------------------|--|--------|
| Photon effective mass | $[m_\gamma] = [E]$             | $[\omega] = [E]$                                     | ✓      |
| Photon time field     | $[T_\gamma] = [E^{-1}]$        | $[1/\omega] = [E^{-1}]$                              | ✓      |
| Energy loss rate      | $[d\omega/dr] = [E^2]$         | $[g_T \omega^2 2G/r^2] = [E^2]$                      | ✓      |
| Time field difference | $[\Delta T_\gamma] = [E^{-1}]$ | $[ 1/\omega_1 - 1/\omega_2 ] = [E^{-1}]$             | ✓      |
| Bell correction       | $[\epsilon] = [1]$             | $[\alpha_{\text{corr}} \Delta T_\gamma \beta] = [1]$ | ✓      |

Table 1: Dimensional consistency verification for photon dynamics in T0 model

2. **Energy-dependent effects:** Photon dynamics depend on frequency through the intrinsic time field
3. **Modified nonlocality:** Quantum correlations experience energy-dependent delays
4. **Testable predictions:** Specific experimental signatures distinguish T0 from standard theory
5. **Dimensional consistency:** All equations verified in natural units framework
6. **Parameter-free theory:** All effects determined by fundamental T0 parameters