In Brief - Complementary Duality in Physics: From Wave-Particle to Time-Mass Concept

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Abstract

This document provides a brief introduction to time-mass duality, a new concept proposed as an extension of the established wave-particle duality in physics. It demonstrates how quantum mechanics (QM) and quantum field theory (QFT) can be enhanced by introducing an intrinsic time $T = \frac{\hbar}{mc^2}$ and a model with absolute time (T0 model). This dual perspective could help bridge gaps between QM and QFT, offering new approaches to gravitation, nonlocality, and cosmological phenomena.

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1 Introduction: Duality in Modern Physics

Modern physics is characterized by dualistic concepts. Wave-particle duality describes how quantum objects, such as electrons or photons, can exhibit both wave-like and particle-like properties. These seemingly contradictory descriptions are complementary, together providing a more complete picture of reality.

The two main pillars of modern physics—quantum mechanics (QM) and quantum field theory (QFT)—also represent a form of duality:

- **Quantum Mechanics** emphasizes the discrete, particle-like nature of matter but integrates relativistic effects only incompletely.
- **Quantum Field Theory** combines quantum effects with special relativity but struggles to fully incorporate gravitation.

Building on this established duality, my work [1] introduces a new, analogous duality: time-mass duality. This could close existing gaps between the theories and enable a more unified description of physical reality.

2 From Particles and Waves to Time and Mass

2.1 The Classical Wave-Particle Duality

In quantum mechanics, there are two complementary descriptions of a phenomenon:

- The **Particle Description**: Localized objects with defined position and mass.
- The **Wave Description**: A spatially extended wavefunction.

These descriptions are mathematically linked via the Fourier transform:

$$\Psi(\vec{x}) = \frac{1}{(2\pi\hbar)^{3/2}} \int \phi(\vec{p}) e^{i\vec{p}\cdot\vec{x}/\hbar}\, d^3p \tag{1}$$

$$\phi(\vec{p}) = \frac{1}{(2\pi\hbar)^{3/2}} \int \Psi(\vec{x}) e^{-i\vec{p}\cdot\vec{x}/\hbar}\, d^3x \tag{2}$$

2.2 The New Time-Mass Duality

Similarly, the T0 model proposes a duality for relativistic phenomena:

- The **Time Dilation Description** (Standard Model): Time is variable ($t' = \gamma_{\text{Lorentz}} t$), while rest mass remains constant ($m_0 = \text{const.}$).
- The **Mass Variation Description** (T0 Model): Time is absolute ($T_0 = \text{const.}$), while mass is variable ($m = \gamma_{\text{Lorentz}} m_0$).

These two approaches are connected through a modified Lorentz transformation, as detailed in [2].

3 The Concept of Intrinsic Time

A central element of the T0 model is intrinsic time, defined as:

$$T(x) = \frac{\hbar}{mc^2} \tag{3}$$

This quantity is a fundamental property of every object and depends on its mass. It leads to a modified Schrödinger equation:

$$i\hbar T(x)\frac{\partial}{\partial t}\Psi + i\hbar\Psi\frac{\partial T(x)}{\partial t} = \hat{H}\Psi \tag{4}$$

Heavier objects experience faster internal time evolution than lighter ones, offering a new perspective on quantum mechanical dynamics, as elaborated in [4].

4 Parallels Between the Dualities

The parallels between wave-particle and time-mass duality are striking:

1. **Complementarity**: Position and momentum are as complementary as time and energy/mass.
2. **Uncertainty Relations**: $\Delta x \Delta p \geq \frac{\hbar}{2}$ corresponds to $\Delta t \Delta E \geq \frac{\hbar}{2}$ or $\Delta T(x)\Delta m \geq \frac{\hbar}{2c^2}$.
3. **Transformations**: Both dualities are linked through mathematical transformations.

5 Necessary Extensions of QM and QFT

Time-mass duality requires adjustments to existing theories:

5.1 Extension of Quantum Mechanics

The classical Schrödinger equation is extended to account for intrinsic time:

$$i\hbar T(x)\frac{\partial}{\partial t}\Psi + i\hbar\Psi\frac{\partial T(x)}{\partial t} = \hat{H}\Psi \tag{5}$$

This leads to:

- Mass-dependent time evolution of quantum systems.
- A natural explanation for varying decay rates and coherence times.
- A new perspective on the measurement problem through the coupling of mass and time.

5.2 Extension of Quantum Field Theory

QFT is adapted to incorporate absolute or intrinsic time:

- Field operators are reformulated in terms of $T(x) = \frac{\hbar}{mc^2}$.
- Renormalization becomes reinterpretable through mass-dependent time scales.
- Virtual particles could be understood as manifestations of different intrinsic times.

These extensions could facilitate the integration of gravitation, the resolution of infinities, and a better understanding of vacuum energy.

6 The Reality of Time Dilation versus Mass Variation

Time dilation is often considered directly measurable (e.g., GPS, muon decay). However, these measurements rely on frequencies:

$$f = \frac{E}{h} = \frac{mc^2}{h} \tag{6}$$

They can equally be interpreted as mass variation, as shown in [1]. The experimental data remain the same—only the interpretation changes.

7 Effects on Instantaneity and Nonlocality

Nonlocality in quantum physics is reinterpreted in the T0 model:

- In the absolute time model, correlations arise from mass variation ($m = \gamma_{\text{Lorentz}} m_0$), not instantaneously.
- In the intrinsic time model, entangled particles have different time evolutions based on $T(x)$.
- For photons, $T(x) = \frac{1}{E}$, yielding energy-dependent dynamics, as described in [3].

This replaces instantaneous action with mass- or energy-dependent dynamics, testable through Bell experiments with variable masses or frequencies.

8 Consequences and Outlook

Time-mass duality offers new perspectives:

- A framework for quantum gravity.
- An alternative to nonlocality through mass-dependent time evolution.
- A connection between QM and QFT via intrinsic time.
- Experimental verifiability through specific predictions.

Just as wave-particle duality revolutionized physics, time-mass duality could provide new insights and lay the groundwork for a more comprehensive theory.

Detailed discussions can be found in:

- [1]
- [2]
- [3]
- [4]

References

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