

Temporal Efficiency as a First Principle: Why Photons Propagate

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Abstract

We propose temporal efficiency as a first principle, deriving special relativity and a bridge to quantum mechanics from a conserved partition of temporal drive. This framework explains photon propagation as perfect coupling to the forward temporal gradient in the TSFT scalar potential Θ . Mass emerges as resistance to temporal advance, and the invariant speed c as the signature of perfect efficiency. Predictions include GNSS clock modulations, accelerator phase drifts, and lensing asymmetries, consistent with prior TSFT empirical tests (3; 2).

1 Motivation: the Unanswered Question

In conventional physics, the propagation of light is treated as axiomatic. Maxwell's equations describe how electromagnetic fields evolve once defined, and relativity constrains their invariant speed, but neither framework explains why a massless excitation propagates at all rather than remaining stationary or undefined (4; 5).

Photons are not pushed by a medium, do not accelerate, and experience no proper time. Yet they advance inexorably. This work proposes that photon propagation is not caused by impulse or force, but by perfect coupling to an underlying temporal gradient (8; 9).

2 Postulate 1 — Temporal Partition Principle

We postulate that time is an active scalar field whose forward advance supplies a conserved temporal drive. For any physical system, this drive partitions between internal temporal evolution and external propagation.

Let the dimensionless efficiencies satisfy:

$$\eta_{\text{int}}^2 + \eta_{\text{prop}}^2 = 1$$

where:

- $\eta_{\text{int}} \in [0, 1]$ quantifies allocation to internal state evolution (proper time),
- $\eta_{\text{prop}} \in [0, 1]$ quantifies allocation to forward causal propagation.

This relation is not kinematic by definition; it is a conservation law on temporal allocation (6; 7).

3 Postulate 2 — Temporal Field Coupling

Let $\Theta(x)$ denote the TSFT scalar time potential. Define a dimensionless temporal coupling factor:

$$\alpha(\Theta) \equiv e^{-\Theta(x)}$$

which modulates the locally available temporal advance per coordinate interval dt . The exponential form $\alpha(\Theta) = e^{-\Theta}$ is motivated by TSFT's temporal flux conservation: Θ acts as a scalar potential that suppresses local temporal advance multiplicatively, analogous to a barrier factor rather than a linear force (1). The exponential form is the minimal choice ensuring positivity, multiplicative composability along worldlines, and a well-defined weak-field expansion.

We define:

$$\eta_{\text{int}} \equiv \frac{d\tau}{\alpha(\Theta) dt}$$

$$\eta_{\text{prop}} \equiv \frac{1}{c} \frac{d\ell}{\alpha(\Theta) dt}$$

where:

- $d\tau$ is proper time,
- $d\ell$ is spatial displacement in the chosen frame.

Substitution into the partition constraint yields:

$$\left(\frac{d\tau}{\alpha(\Theta) dt} \right)^2 + \left(\frac{1}{c} \frac{d\ell}{\alpha(\Theta) dt} \right)^2 = 1$$

In the flat-field limit $\Theta \rightarrow 0$, this reduces to special relativity (4).

4 Lemma 1 — Recovery of Special Relativity

For inertial motion in flat space:

$$d\tau = dt \sqrt{1 - \frac{v^2}{c^2}}$$

Thus, time dilation emerges as a redistribution of temporal efficiency, not a geometric deformation of spacetime (6; 21).

5 Photon Limit and Perfect Temporal Efficiency

For a photon:

- $d\tau = 0$,
- internal evolution vanishes,
- no temporal budget is spent on self-maintenance.

Therefore:

$$\eta_{\text{int}} = 0 \quad \eta_{\text{prop}} = 1$$

This is the defining physical property of radiation.

Photons propagate because they couple with 100% efficiency to the forward temporal gradient.

They are not accelerated, pushed, or driven by force. They are pulled forward by time itself, following extremal paths of temporal advance (null geodesics) without resistance.

Gravitational lensing, redshift, and horizon behavior arise because photons trace gradients in $\Theta(x)$; they do not oppose those gradients (15; 16).

6 Postulate 3 — Phase as Temporal Bookkeeping

Physical observables are governed by accumulated phase. For massive systems:

$$\varphi = \frac{1}{\hbar} \int mc^2 d\tau$$

For radiation, phase accumulates along null propagation constrained by $\Theta(x)$.

Stationary phase paths extremize temporal allocation subject to the partition constraint, yielding wave dynamics. In the nonrelativistic limit, this reduces to the Schrödinger equation; in the null limit, to electromagnetic propagation. The phase extremization reproduces wave equations, with \hbar setting the granularity of temporal phase bookkeeping (10; 11; 12).

Measurement corresponds to enforced reallocation of temporal efficiency between propagation and internal degrees of freedom, inducing the appearance of collapse via efficiency redistribution; no violation of unitarity is claimed (13; 14).

7 Lemma 4 — Weak-Field Gravity

$$\eta_{\text{int}} = \frac{d\tau}{dt} = \alpha(\Theta) \approx \sqrt{g_{00}} \sim 1 - \Theta$$

This shows:

- gravitational time dilation is temporal efficiency suppression,
- photons ($\eta_{\text{int}} = 0$) follow extremal temporal paths,
- lensing is gradient-following, not force-driven (15; 16).

8 Predictions

Temporal efficiency varies with Earth–Sun distance and orbital velocity; predicts seasonal residual structure (already observed, $r \approx -0.65$ (3)).

At extreme γ , small deviations in phase accumulation relative to SR/QM baselines may appear during rapid η reallocation (collisions, beam compression) (17; 18).

Higher-order deviations in photon paths in steep Θ gradients (black hole shadows, solar limb tests) (19; 20).

9 Interpretation

- Mass is resistance to temporal advance.
- Energy is stored temporal allocation.
- Motion is not through space but with time.
- Light propagates because it cannot do otherwise.

The invariant speed c is not a property of space; it is the signature of perfect temporal efficiency.

References

- [1] J. G. Farrell, Zebra Poker: The Ultimate Unification of Physics (2025).
- [2] J. G. Farrell, Time-Scalar Field Theory Derivation of Mercury’s Perihelion Precession (2025).

- [3] J. G. Farrell, A Preregistered Test of Time-Scalar Field Theory Using GNSS Clock Residuals (2025).
- [4] P. A. M. Dirac, The quantum theory of the electron, Proc. R. Soc. Lond. A 117, 610–624 (1928).
- [5] A. Einstein, Zur Elektrodynamik bewegter Körper, Ann. Phys. 322, 891–921 (1905).
- [6] M. Szirko, Why is Time Frame-dependent in Relativity? Minkowski’s spacetime as a Kantian ‘condition of possibility’ for relativistic calculations, PhilSci Archive (2005).
- [7] D. V. Buonomano, Relativity Theory and Time Perception: Single or Multiple Clocks?, PLoS ONE 4, e6268 (2009).
- [8] Photon, Wikipedia (accessed 2025).
- [9] DOE Explains...Photons, U.S. Department of Energy (accessed 2025).
- [10] P. Busch, On the energy-time uncertainty relation, Found. Phys. 20, 1–32 (1990).
- [11] Y. Aharonov and D. Bohm, Time in the Quantum Theory and the Uncertainty Relation for Time and Energy, Phys. Rev. 134, B1417 (1964).
- [12] M. Zych et al., Quantum interferometric visibility as a witness of general relativistic proper time, Nat. Commun. 10, 3772 (2019).
- [13] E. Castro Ruiz et al., Quantum clocks and the temporal localisability of events in the presence of gravitating quantum systems, Nat. Commun. 8, 15738 (2017).
- [14] I. Pikovski et al., Universal decoherence due to gravitational time dilation, Nat. Phys. 11, 668–672 (2015).
- [15] N. G. Sánchez, Unifying quantum mechanics with Einstein’s general relativity, Research Outreach (2019).
- [16] J. Oppenheim, A postquantum theory of classical gravity?, Phys. Rev. X 13, 041040 (2023).
- [17] Q. Zhao et al., Relativistic effects in BDS-3 high-accuracy intersatellite time synchronization, Adv. Space Res. 71, 2643–2655 (2023).
- [18] A. Bauch, Relativistic corrections in the European Laser Timing (ELT) experiment, Adv. Space Res. 37, 154–160 (2006).
- [19] S. Amar et al., Relativistic framework for high-precision GNSS-based navigation in deep space, arXiv:2411.12058 (2024).

- [20] D. Arnold et al., A Study of Outliers in GNSS Clock Products, *Sensors* 24, 799 (2024).
- [21] D. Nugraha, Dirac’s Refined Unification of Quantum Mechanics and Special Relativity, *PhilArchive* (2019).
- [22] A. Kryukov, Geometry of the unification of quantum mechanics and relativity of accelerated frames, *arXiv:0903.4641* (2009).
- [23] S. Wolfram, Finally We May Have a Path to the Fundamental Theory of Physics... and It’s Beautiful, *Writings* (2020).
- [24] Č. Brukner, Quantum clocks and quantum causality, *FQXi Conference Slides* (2014).
- [25] E. M. Standish, *Astron. Astrophys.* 233, 252 (1990).
- [26] E. V. Pitjeva, *Sol. Syst. Res.* 39, 176 (2005).
- [27] L. Iorio, *Mon. Not. R. Astron. Soc.* 375, 1311 (2007).
- [28] E. Griggs et al., *Radio Sci.* 50, 813–822 (2015).
- [29] P. Steigenberger et al., *GPS Solut.* 24, 111 (2020).
- [30] N. Ashby, *Living Rev. Relativ.* 6, 1 (2003).
- [31] J. Kouba, *GPS Solut.* 8, 1–12 (2004).
- [32] G. Petit and B. Luzum, *IERS Technical Note No. 36* (2010).
- [33] L. Pan et al., *Chin. J. Geophys.* 63, 2802–2814 (2020).
- [34] N. Wang et al., *Adv. Space Res.* 51, 2151–2163 (2013).
- [35] J. R. Ray and B. J. Luzum, *GPS Solut.* 3, 55–61 (1999).
- [36] K. Senior et al., *IEEE Trans. Ultrason. Ferroelectr. Freq. Control* 55, 2253–2257 (2008).
- [37] P. Defraigne et al., *Meas. Sci. Technol.* 26, 063018 (2015).
- [38] L. Chen et al., *Remote Sens.* 15, 3858 (2023).
- [39] Z. Liu et al., *Measurement* 212, 112678 (2023).
- [40] G. Huang et al., *Geo-spat. Inf. Sci.* 24, 14–25 (2021).
- [41] K. Sosnica et al., *Meas. Sci. Technol.* 34, 025014 (2023).
- [42] A. Hauschild et al., *Navigation* 67, 333–346 (2012).