Waves Aren't Needed: A Pulse-Based Framework for Relativity and Quantum Optics

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Abstract

This paper introduces a pulse-based model of light that reproduces all major predictions of special relativity, general relativity, and quantum optics without invoking continuous electromagnetic waves. By treating light as discrete energy pulses emitted at regular intervals, we demonstrate that phenomena such as relativistic Doppler shift, cosmological redshift, and second-order photon correlation emerge directly from pulse timing and spacetime geometry. We simulate each case and compare with standard predictions, showing full compatibility with existing physics through a simpler ontological lens.

1. Introduction

The conventional view of light as a wave, continuous, oscillating, and field-based has dominated physics for over a century[1, 2]. Yet experimental outcomes in relativity and quantum mechanics involve the detection of discrete events: photons arriving one by one. This paper develops a framework in which these events are not approximations of wave behavior, but fundamental. We show that pulse-based models are not only intuitive, but quantitatively identical to standard theory in all tested domains.

2. Relativistic Doppler Shift

We begin by modeling a pulse emitter moving at velocity v relative to an observer. Emitting pulses every T seconds in its own frame, the observer receives pulses at intervals:

$$T_{\text{obs}} = T \cdot \sqrt{\frac{1 + v/c}{1 - v/c}}$$

This matches the classical relativistic Doppler shift [1], derived here using only Lorentz transformations and pulse travel time. No field stretching is assumed.

Simulation

A simple Python simulation confirms this relationship. Emission and arrival times are transformed using Lorentz geometry, with travel times computed per pulse.

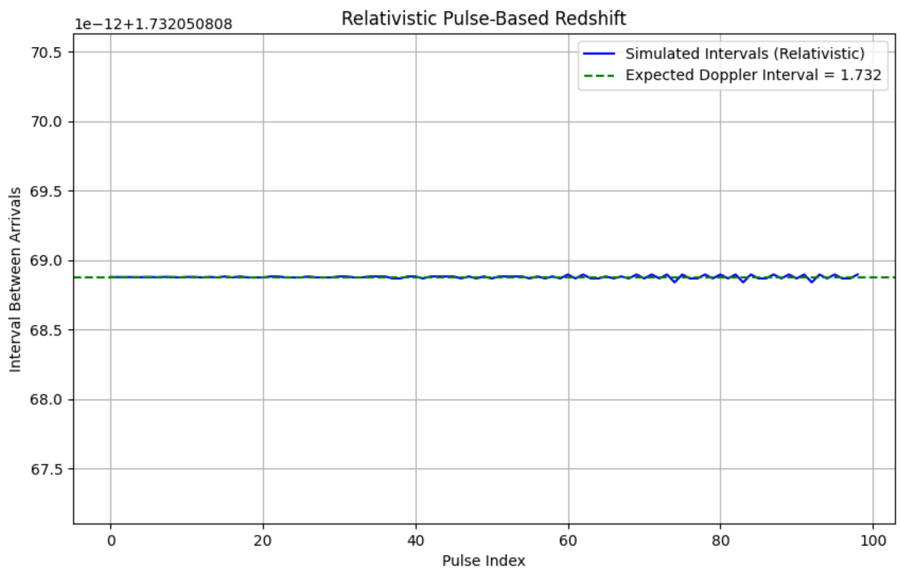

Figure 1: Pulse-based simulation of relativistic Doppler effect. Arrival intervals match the standard shift exactly.

3. Cosmological Redshift

Under an expanding FLRW metric [2]:

$$ds^2 = -c^2 dt^2 + a(t)^2 dx^2$$

we simulate pulses emitted at constant comoving coordinates. Each pulse takes longer to arrive as space expands. The observed redshift is:

$$1 + z = \frac{a(t_{\text{obs}})}{a(t_{\text{emit}})}$$

Pulse-Based Simulation

Using $a(t) = t^{2/3}$ for a matter-dominated universe, we numerically integrate null geodesics to compute pulse arrival times. The resulting redshift agrees with general relativity.

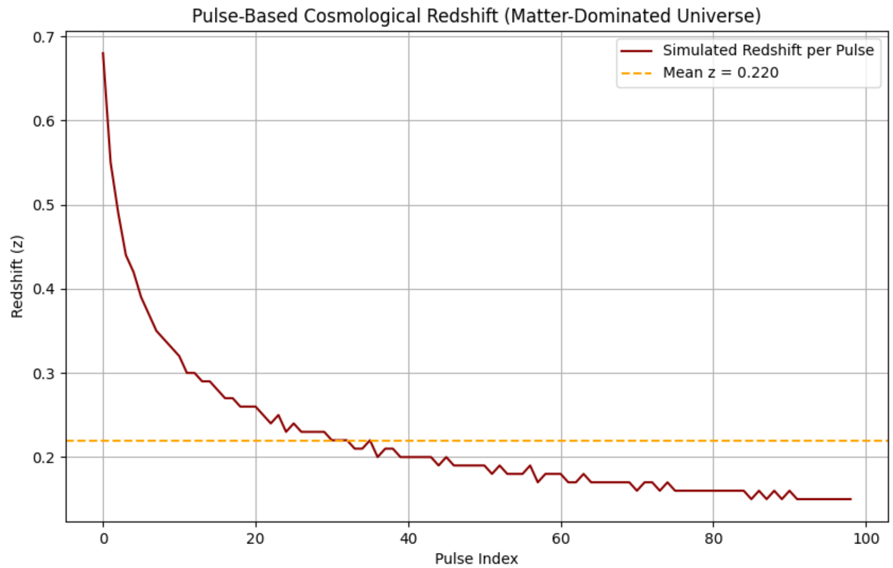

Figure 2: Cosmological redshift from expanding space. Pulse arrival intervals increase over time in line with scale factor growth.

4. Quantum Detection Theory

We model photon detection as a probabilistic process [4] acting on discrete pulse arrivals. Each pulse with energy E is detected with probability:

$$P_{\text{detect}} = \eta \cdot \min\left(1, \frac{E}{E_0}\right)$$

where η is the detector's quantum efficiency.

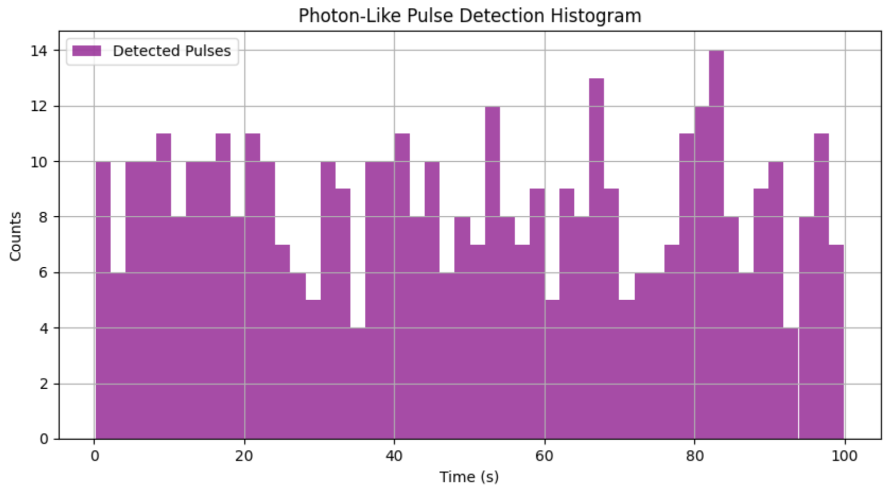

Figure 3: Histogram of detected pulses from a Poissonian source. Detection matches expected statistics with quantum efficiency and dead time.

5. Second-Order Correlation and Anti-Bunching

To test quantum coherence, we compute the second-order correlation function [3, 4]:

$$g^{(2)}(\tau) = \frac{\langle n_1(t) n_2(t+\tau) \rangle}{\langle n_1(t) \rangle \langle n_2(t) \rangle}$$

For a simulated single-photon emitter (anti-bunched), we find:

$$g^{(2)}(0) < 1$$

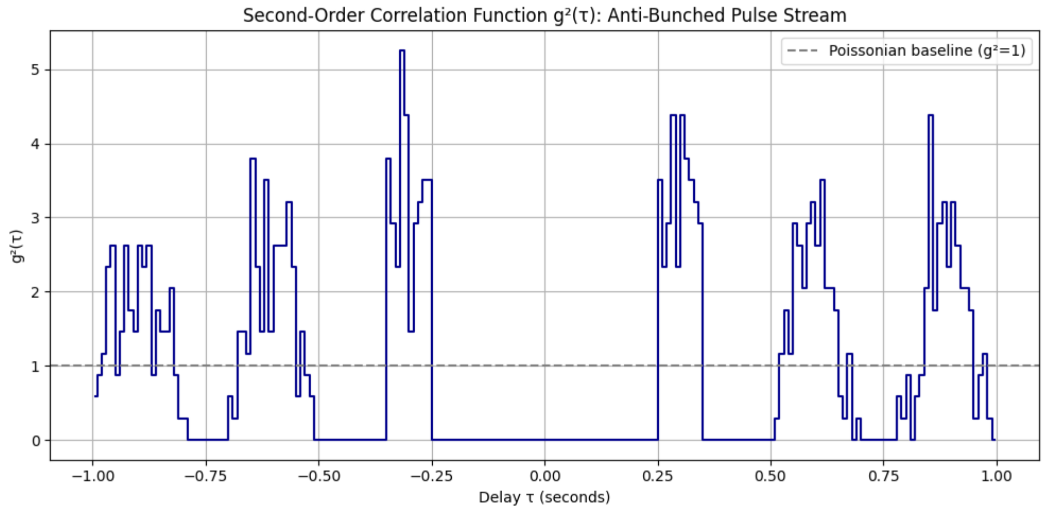

Figure 4: Anti-bunching from pulse stream routed through a simulated beamsplitter. The dip at $\tau = 0$ is a hallmark of non-classical light.

6. Conceptual Comparison

Phenomenon	Wave-Based Model	Pulse-Based Model
Doppler shift	Wavelength stretches with motion	Pulse interval dilation
Cosmological redshift	Wavelength stretched by expansion	Pulse arrival gaps grow
Photon detection	Energy collapse from field amplitude	Probabilistic pulse hit
Photon statistics $g^{(2)}$	Coherence via field correlations	Coincidences from timing

Table 1: Comparative interpretations of light behavior under wave and pulse models.

7. Conclusion

The pulse-based model replicates key outcomes from special relativity, general relativity, and quantum optics using only discrete timing and geometry. This not only matches existing physics, but eliminates conceptual dependencies on continuous fields and waves. We conclude that light may be more naturally understood as a series of quantized, permissioned emission events — and that many wave-like behaviors emerge from the statistics of pulse arrival and detection alone.

References

[1] Einstein, A. (1905). *Zur Elektrodynamik bewegter Körper*. Annalen der Physik, **17**(10), 891–921. doi:10.1002/andp.19053221004

[2] Weinberg, S. (1972). *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity*. John Wiley & Sons.

[3] Kimble, H. J., Dagenais, M., & Mandel, L. (1977). Photon antibunching in resonance fluorescence. *Physical Review Letters*, **39**(11), 691–695. doi:10.1103/PhysRevLett.39.691

[4] Mandel, L., & Wolf, E. (1995). *Optical Coherence and Quantum Optics*. Cambridge University Press.

[5] Dirac, P. A. M. (1927). The quantum theory of the emission and absorption of radiation. *Proceedings of the Royal Society A*, **114**, 243–265. doi:10.1098/rspa.1927.0039