A Phenomenological Two-Channel Model for the Lorentz Factor

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Abstract

We present a phenomenological model that reproduces the Lorentz factor $\gamma = 1/\sqrt{1 - v^2/c^2}$ using simple operational definitions and a two-channel budget principle. The model is based on the reduced Compton wavelength of the electron as a natural length scale (the "step") and the corresponding light travel time as the fundamental time unit (the "tick"). A postulated conservation law $k^2 + R^2 = 1$ expresses the fixed total capacity per tick shared between a progress channel and an internal cycling channel. Using reversal symmetry and a first-order expansion, we obtain linear rates for the two channels, and the requirement that both channels must complete for a tick to occur leads to the geometric mean as the effective rate. The Lorentz factor then follows directly. The model is not intended as a replacement for special relativity, but as a complementary phenomenological picture that highlights the counting origin of time dilation. Limitations and possible extensions are discussed.

Contents

1 Introduction

The Lorentz factor $\gamma = 1/\sqrt{1 - v^2/c^2}$ is one of the most fundamental expressions in physics, yet its derivation is usually presented as a consequence of the Minkowski space-time structure and the postulates of special relativity. The question of whether this factor can be understood from more primitive operational principles has a long history, dating back to Lorentz, Poincaré, and more recently explored by thinkers such as Bell [1], Penrose [2], and 't Hooft [3].

In this paper, we present a phenomenological model that reproduces the Lorentz factor using only operational definitions, counting, and symmetry. The model does not claim to replace special relativity; rather, it offers a complementary perspective that may shed light on the counting origin of time dilation. The core idea is simple: each fundamental cycle (a "tick") has a fixed capacity that must be shared between two independent channels. When the system moves, the balance between these channels shifts, leading to a reduced effective tick rate – i.e., time dilation.

The paper is organized as follows. Section 2 defines the operational units (step and tick). Section 3 introduces the budget principle as a postulate. Section 4 shows how the progress share is related to speed. Section 5 presents the linear bias model for channel rates. Section 6 derives the effective tick rate as the geometric mean. Section 7 obtains the Lorentz factor and also sketches how length contraction follows from the same framework. Section 8 discusses limitations, and Section 9 concludes with suggestions for future work.

2 Operational Definitions: Step and Tick

We define the fundamental length unit (the "step") as the reduced Compton wavelength of the electron:

$$L_{\text{step}} = \bar{\lambda}_C = \frac{\hbar}{m_e c} = 3.8616 \times 10^{-13}\ \text{m}. \tag{1}$$

This choice is motivated by the fact that the Compton wavelength sets the natural scale for the electron's internal structure. The fundamental time unit (the "tick") is defined as the time required for light to traverse one step:

$$T_{\text{tick}} = \frac{L_{\text{step}}}{c} = 1.2870 \times 10^{-21}\ \text{s}. \tag{2}$$

Thus $c = L_{\text{step}}/T_{\text{tick}}$ serves as a calibration constant, not a theoretical postulate. These definitions anchor the model to a concrete physical scale.

3 The Two-Channel Budget Principle

We postulate that each tick carries a fixed total capacity, normalized to $C_{\text{tot}} = 1$. This capacity is shared between two independent channels:

- **Progress channel:** the part that advances the pattern along the direction of motion,
- **Internal channel:** the part that maintains internal cycling.

Let Δx be the progress (in steps) during one tick, and $\Delta\tau$ the internal activity (in ticks) during the same tick. The total capacity is defined as the Euclidean norm:

$$C_{\text{tot}}^2 = (\Delta x)^2 + (\Delta\tau)^2. \tag{3}$$

Defining the normalized shares $k = \Delta x$ and $R = \Delta\tau$, we obtain the invariant

$$k^2 + R^2 = 1. \tag{4}$$

Intuitive analogy: This quadratic form can be intuitively understood by analogy with a harmonic oscillator, where the total energy is the sum of squares of position and momentum. Here, the two independent channels combine orthogonally to conserve the total per-tick capacity. Equation (4) is the central postulate of the model; it expresses the idea that the total "activity" per tick is conserved and that the two channels are independent. In the rest frame, $k = 0$ and $R = 1$; as speed increases, k grows and R shrinks.

4 Relating k to Speed

Consider an observer moving with speed v. In a time interval Δt, the observer covers a distance Δx. Operational definitions give:

$$\Delta x = N_{\text{step}} L_{\text{step}}, \quad \Delta t = N_{\text{tick}} T_{\text{tick}}.$$

Hence

$$v = \frac{\Delta x}{\Delta t} = \frac{N_{\text{step}}}{N_{\text{tick}}} \cdot \frac{L_{\text{step}}}{T_{\text{tick}}} = \frac{N_{\text{step}}}{N_{\text{tick}}} \cdot c.$$

For a one-tick interval, $N_{\text{tick}} = 1$ and $N_{\text{step}} = k$. Thus

$$v = k \cdot c \quad \Rightarrow \quad \boxed{k = \frac{v}{c}}. \tag{5}$$

This relation is derived, not assumed.

5 Linear Bias Model for Channel Rates

Let $f_0 = 1/T_{\text{tick}}$ be the tick rate in the rest frame. In the moving frame, the two channels operate at rates f_{fwd} (forward) and f_{bwd} (backward). Reversal symmetry requires

$$f_{\text{fwd}}(v) = f_{\text{bwd}}(-v). \tag{6}$$

Expanding to first order in v around $v = 0$ and using $f_{\text{fwd}}(0) = f_{\text{bwd}}(0) = f_0$, we obtain the simplest linear parametrization:

$$f_{\text{fwd}} = f_0(1 + \beta), \qquad f_{\text{bwd}} = f_0(1 - \beta), \tag{7}$$

where $\beta = v/c$. This is a phenomenological approximation; higher-order terms (e.g., quadratic in β) are in principle possible and would lead to testable modifications of the Lorentz factor. The linear model is the simplest choice consistent with symmetry and is sufficient for the present purpose. It also satisfies the natural boundary condition that when $\beta = 1$, the backward rate vanishes.

6 Effective Tick Rate as the Geometric Mean

A tick occurs only when both channels have completed an event. From the budget principle, the internal share R is the ratio of the effective tick rate to the rest rate:

$$R = \frac{f_{\text{eff}}}{f_0}. \tag{8}$$

Using (4) and (5), $R = \sqrt{1 - \beta^2}$. From (7), the product of the channel rates is

$$f_{\text{fwd}} f_{\text{bwd}} = f_0^2 (1 - \beta^2) = f_0^2 R^2.$$

Combining with (8) gives

$$f_{\text{eff}}^2 = f_{\text{fwd}} f_{\text{bwd}} \quad \Rightarrow \quad \boxed{f_{\text{eff}} = \sqrt{f_{\text{fwd}} f_{\text{bwd}}}}. \tag{9}$$

Thus the geometric mean emerges directly from the budget principle and the linear bias model, without additional assumptions.

7 The Lorentz Factor and Length Contraction

7.1 Time Dilation

The tick duration in the moving frame is $T_{\text{moving}} = 1/f_{\text{eff}}$, while in the rest frame $T_{\text{rest}} = 1/f_0$. Therefore,

$$\frac{T_{\text{moving}}}{T_{\text{rest}}} = \frac{f_0}{f_{\text{eff}}} = \frac{1}{\sqrt{1 - \beta^2}} = \frac{1}{\sqrt{1 - v^2/c^2}} \equiv \gamma(v). \tag{10}$$

This is the standard Lorentz factor for time dilation.

7.2 Length Contraction

Using the same operational framework, length contraction follows directly. In the rest frame, the length of a rod is $L_0 = N L_{\text{step}}$. In a frame moving with speed v, the time for the rod to pass a fixed point is $\Delta t' = L'/v$. This time interval is dilated: $\Delta t' = \gamma \Delta t$, where $\Delta t = L_0/v$ is the time in the rest frame. Hence

$$\frac{L'}{v} = \gamma \frac{L_0}{v} \quad \Rightarrow \quad L' = \frac{L_0}{\gamma}. \tag{11}$$

Thus the model reproduces both time dilation and length contraction.

8 Limitations

The model has several limitations that should be acknowledged:

- The budget principle $k^2 + R^2 = 1$ is a postulate, not derived from deeper principles. Its quadratic form is motivated by axis neutrality, but a more fundamental justification is lacking.

- The linear bias model (7) is a first-order approximation; higher-order terms could modify the Lorentz factor and might be constrained by precision experiments.
- The model addresses only time dilation and length contraction; it does not explicitly derive the relativity of simultaneity or the full Lorentz transformation, although the consistency of (10) and (11) suggests that the full transformation can be obtained.
- The connection to other physical phenomena (e.g., the Casimir effect, the layered electron model) remains speculative and is not developed here.
- All numerical constants (c, m_e) are taken from experiment; the model does not predict them.

These limitations indicate that the model is phenomenological rather than fundamental. Its value lies in providing a simple counting picture for the origin of relativistic effects.

9 Conclusion and Outlook

We have presented a phenomenological two-channel model that reproduces the Lorentz factor from operational definitions, a postulated budget principle, and elementary symmetry arguments. The derivation is self-contained and does not rely on spacetime geometry. The model offers a complementary perspective on time dilation (and length contraction), highlighting their possible origin in a fixed per-tick capacity shared between two independent channels.

Future work could explore higher-order corrections to the linear bias model, attempt to derive the budget principle from a more fundamental theory (e.g., information-theoretic conservation laws), or extend the framework to include the full Lorentz transformation and its implications for quantum theory. Connections to specific physical systems, such as the layered electron model, remain speculative but may be worth pursuing.

References

[1] Bell, J.S. (1976). *Speakable and Unspeakable in Quantum Mechanics*. Cambridge University Press.

[2] Penrose, R. (2004). *The Road to Reality*. Jonathan Cape.

[3] 't Hooft, G. (2014). The Cellular Automaton Interpretation of Quantum Mechanics. arXiv:1405.1548.