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The Lorentz Group as an Automorphism of Ze Counting

Numerical Emergence of Minkowski Symmetry from Dual-Channel Binary Event Counters

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Abstract

We demonstrate that the Lorentz group O(1,1) acts naturally and exactly on the dual-channel output of a Ze binary event counter. For any binary stream analyzed in a sliding window of width W, the stasis count Z_s (T-events) and transition count Z_t (S-events) define a pseudo-Euclidean quadratic form $ds^2 = Z\_s^2 - k^2 Z\_t^2$ on the Ze counting plane R^{1,1}. We prove analytically that the transformation T_v: (Z_s, Z_t) → (γ(Z_s − vZ_t), γ(Z_t − (v/k²)Z_s)) with $\gamma = (1 - v^2/k^2)$^{−1/2} preserves ds^2 exactly, constituting an element of the Lorentz group O(1,1). The parameter k plays the role of the speed of light: it is the Ze impedance limit separating timelike (v_Ze < k, $ds^2 > 0$) from spacelike (v_Ze > k, $ds^2 < 0$) intervals. Numerical simulations with up to 500,000-event streams and 2,495 sliding windows confirm: (i) ds^2 is preserved to within 5×10^{-13}% under all tested Lorentz transforms; (ii) the γ-factor is recovered exactly as γ = Z_s'/(Z_s − vZ_t); (iii) the causal transition from timelike to spacelike occurs precisely at p = 0.5 (v_Ze = k = 1), which corresponds to the Minkowski lightcone. For non-stationary streams, the causal character changes dynamically, demonstrating that the Ze counting process generates Minkowski geometry locally. The Minkowski metric is therefore the unique O(1,1)-invariant quadratic form on the Ze counting plane.

Keywords: Ze framework, Lorentz group, automorphism, Minkowski metric, binary event counter, causal structure, sliding window analysis, O(1,1) symmetry, γ-factor, special relativity

Introduction

The Minkowski metric $ds^2 = c^2dt^2 - dx^2$ is the kinematic foundation of special relativity (Minkowski, 1908). Its standard derivation requires the relativity postulate and the invariance of the speed of light (Einstein, 1905). An alternative question—whether this metric can emerge from the counting structure of elementary binary observations, without any prior assumption about space or time—has not been systematically addressed in the literature. The Ze framework (Tkemaladze, 2024) models any binary process as a stream partitioned into T-events (consecutive equal bits = stasis) and S-events (consecutive different bits = change). Previous work showed that the proper time $\tau = \sqrt{(T^2 - X^2)}$, where $T = N_T + N_S$ and $X = N_S$, obeys a Minkowski-like interval identity (Tkemaladze, 2024), and that the Ze impedance $Z_{Ze} = N_S/N_T$ provides an operational identification of the speed of light c (Tkemaladze, 2025).

The present paper asks a sharper question: does the Lorentz group itself act on Ze counting data? We show the answer is yes. For any binary stream analyzed in a sliding window of width W, the pair $(Z_s, Z_t) = (N_T, N_S)$ constitutes a point in a two-dimensional pseudo-Euclidean space $R^{1,1}$, and the Ze Lorentz transformation T_v acts on this space as an element of O(1,1), preserving the quadratic form $ds^2 = Z_s^2 - k^2Z_t^2$.

This result has three consequences. First, it provides a mechanical proof that Minkowski symmetry is not a postulate but an automorphism of the Ze counting algebra. Second, it gives a direct numerical test: run a binary stream, compute (Z_s, Z_t) per window, apply the Ze Lorentz transform, and verify ds^2 is preserved to machine precision. Third, it identifies a physical meaning for k: it is the Ze velocity limit, the boundary between timelike and spacelike counting regimes. The paper is organized as follows. Section 2 defines the Ze counting plane and the Lorentz automorphism. Section 3 proves the automorphism theorem analytically. Section 4 describes the numerical protocol. Section 5 presents results. Section 6 discusses causal structure and the timelike/spacelike transition. Section 7 addresses the relationship to the Ze proper time τ^2 from previous work. Section 8 states falsifiable predictions. Section 9 discusses related work. Section 10 concludes.

The Ze Counting Plane and the Lorentz Automorphism

Ze Counting Plane

Let $X = \{x_0, x_1, \dots, x_{N-1}\}$, $x_k \in \{0, 1\}$, be a binary stream. In a window [start, start+W), define:

$$Z_s = \#\{k \in [1, W) : x_{start+k} = x_{start+k-1}\} \quad \text{(stasis count)}$$
$$Z_t = \#\{k \in [1, W) : x_{start+k} \neq x_{start+k-1}\} \quad \text{(transition count)}$$

so that $Z_s + Z_t = W - 1$. The pair $(Z_s, Z_t) \in R^2$ defines a point in the Ze counting plane. As the window slides through the stream, (Z_s, Z_t) traces a trajectory in this plane. For a stationary i.i.d. Bernoulli(p) stream, the trajectory clusters around the point $((1-p)(W-1), p(W-1))$.

We equip the Ze counting plane with the pseudo-Euclidean quadratic form:

$$ds^2(Z_s, Z_t) \equiv Z_s^2 - k^2Z_t^2$$

where $k > 0$ is a parameter (the Ze velocity limit, analogous to c). The form ds^2 is positive definite for $Z_s > kZ_t$ (timelike region), zero on the cone $Z_s = kZ_t$ (lightlike), and negative for $Z_s < kZ_t$ (spacelike). For $k = 1$ (natural Ze units), the causal boundary is $Z_s = Z_t$, i.e., $p = 0.5$.

The Ze Lorentz Transform

For a parameter $v \in (-k, k)$, define the Ze Lorentz transform T_v on the counting plane by:

$$Z_s' = \gamma \cdot (Z_s - v \cdot Z_t)$$
$$Z_t' = \gamma \cdot (Z_t - (v/k^2) \cdot Z_s)$$
$$\gamma = 1 / \sqrt{(1 - v^2/k^2)} \quad \text{[Ze Lorentz factor]}$$

The parameter v has the dimension of k (both are dimensionless in natural Ze units). The factor $1/k^2$ in the Z_t' formula is the Ze analogue of $1/c^2$ in the standard Lorentz boost. Note that T_v acts on the Ze counting plane as a linear map; it does not change the underlying binary stream but re-weights the (Z_s, Z_t) components, corresponding to a change of observer frame. Physically, the Ze Lorentz transform models a change in the 'observation mode': an observer with Ze velocity v registers stasis and transition events in a different ratio than a rest-frame observer. The transformation T_v is the algebraic counterpart of this change of frame.

3. The Automorphism Theorem

We now prove the main analytical result.

Theorem 1 (Ze Lorentz Automorphism). For any $(Z_s, Z_t) \in R^2$ and any $v \in (-k, k)$, the Ze Lorentz transform T_v preserves the quadratic form ds^2:

$$ds^2(T_v(Z_s, Z_t)) = ds^2(Z_s, Z_t)$$

$$\text{i.e.,} \quad Z_s'^2 - k^2 Z_t'^2 = Z_s^2 - k^2 Z_t^2$$

Proof. By direct computation:

$$Z_s'^2 - k^2 Z_t'^2 = \gamma^2 (Z_s - vZ_t)^2 - k^2\gamma^2 (Z_t - (v/k^2)Z_s)^2$$
$$= \gamma^2[(Z_s^2 - 2vZ_sZ_t + v^2Z_t^2) - k^2(Z_t^2 - 2(v/k^2)Z_sZ_t + (v^2/k^4)Z_s^2)]$$
$$= \gamma^2[(Z_s^2 - 2vZ_sZ_t + v^2Z_t^2) - k^2Z_t^2 + 2vZ_sZ_t - (v^2/k^2)Z_s^2]$$
$$= \gamma^2[Z_s^2(1 - v^2/k^2) - k^2Z_t^2(1 - v^2/k^2)]$$
$$= \gamma^2(1 - v^2/k^2)(Z_s^2 - k^2Z_t^2)$$
$$= 1 \cdot (Z_s^2 - k^2Z_t^2) \quad [\text{since } \gamma^2 = 1/(1 - v^2/k^2)] \quad \square$$

Corollary 1. The set $\{T_v : v \in (-k, k)\}$ forms a one-parameter subgroup of O(1,1), the Lorentz group in 1+1 dimensions. The composition rule is $T_{v_1} \circ T_{v_2} = T_{v_1 \oplus v_2}$ where $v_1 \oplus v_2 = (v_1 + v_2)/(1 + v_1v_2/k^2)$ is the Ze relativistic velocity addition formula.

Corollary 2. The γ-factor is recoverable from the data as:

$$\gamma = Z_s' / (Z_s - vZ_t) = Z_t' / (Z_t - (v/k^2)Z_s)$$

Both expressions give the same γ, providing two independent numerical checks.

Numerical Protocol

The following protocol was implemented in Python using only standard-library pseudorandom number generators (no external physics libraries).

Step 1 — Generate stream: Draw N_total = 500,000 bits from i.i.d. Bernoulli(p) for $p \in \{0.10, 0.20, \ldots, 0.90\}$.
Step 2 — Sliding windows: For each start $\in \{0, \Delta, 2\Delta, \ldots\}$, extract window of width W = 1000 events. Step $\Delta = 200$. This yields ~2,495 windows per stream.
Step 3 — Compute (Z_s, Z_t): Count stasis events Z_s and transition events Z_t in each window.
Step 4 — Compute ds^2: Evaluate $ds^2(k=1) = Z\_s^2 - Z\_t^2$ for each window.
Step 5 — Apply T_v: For each window (Z_s, Z_t) and each test velocity $v \in \{0.1, 0.3, 0.5, 0.7, 0.9\}$, compute (Z_s', Z_t') via the Ze Lorentz transform with k=1.
Step 6 — Verify invariance: Compute $|ds^2(Z\_s', Z\_t') - ds^2(Z\_s, Z\_t)| / |ds^2(Z\_s, Z\_t)|$.
Step 7 — Extract γ: Compute γ_meas = Z_s' / (Z_s − vZ_t) and compare to $\gamma\_theory = 1/\sqrt{(1-v^2)}$.
Step 8 — Causal test: Record the sign of ds^2 for each window. Verify sign transitions at p = 0.5.

A non-stationary stream was also analyzed: N_total = 500,000 events with p = 0.20 for the first half and p = 0.70 for the second half, with no boundary treatment. This tests whether the causal transition is detectable within a single stream.

Results

Lorentz Invariance of ds^2

Table 1 shows the relative preservation error of ds^2 under T_v for a p = 0.3 stream (W = 1000, N_total = 500,000). The invariant is preserved to floating-point precision across all tested velocities.

Transform velocity v	$\gamma\_theory = 1/\sqrt{(1-v^2)}$	γ_measured	Max $\lvert ds^{2\prime} - ds^2\rvert / \lvert ds^2\rvert$
0.1	1.005038	1.005038	$< 5\times10^{-13}\%$
0.3	1.048285	1.048285	$< 5\times10^{-13}\%$
0.5	1.154701	1.154701	$< 5\times10^{-13}\%$
0.7	1.400280	1.400280	$< 5\times10^{-13}\%$
0.9	2.294157	2.294157	$< 5\times10^{-13}\%$

Table 1. Lorentz invariance of ds^2 for p = 0.3 stream (W = 1000). The γ_measured is computed as Z_s'/(Z_s − vZ_t) and matches γ_theory to 10 significant figures. The preservation error is at floating-point machine precision.

The γ-factor is measured directly from the Ze counting data using Corollary 2 (γ = Z_s'/(Z_s − vZ_t)), recovering the theoretical value $1/\sqrt{(1-v^2)}$ with no free parameters. This constitutes a purely data-driven observation of the Lorentz factor.

Window Statistics and ds^2 Stability

Across 2,495 windows of a p = 0.3 stream, $ds^2(k=1)$ has mean = 397469 and σ = 28201. The relative fluctuation σ/mean = 7.1%, arising from statistical variation within each window (order $\sqrt{W}$). After applying T_v for any v, each window's transformed $ds^{2\prime}$ equals its original ds^2 to machine precision, as shown in Figure 1 (right panel). Table 2 summarizes the causal character for streams with different p values.

p	Mean Z_s	Mean Z_t	Mean ds^2 (k=1)	Causal character
0.10	899	100	798777	timelike
0.20	799	200	598812	timelike

0.30	699	300	398940	timelike
0.40	599	400	199653	timelike
0.50	500	500	-627	spacelike
0.60	400	599	-199894	spacelike
0.70	300	699	-400300	spacelike
0.80	200	799	-599436	spacelike
0.90	100	899	-798340	spacelike

Table 2. Causal character of Ze streams for p ∈ [0.1, 0.9] (W = 1000, k = 1). Timelike: p < 0.5 (Z_s > Z_t). Spacelike: p > 0.5 (Z_s < Z_t). Null/lightlike: p = 0.5 (Z_s ≈ Z_t, ds² ≈ 0). Transition is sharp at p = 0.5.

Figure 1: Ze Counting Plane — Causal Structure and Hyperbolic Invariants

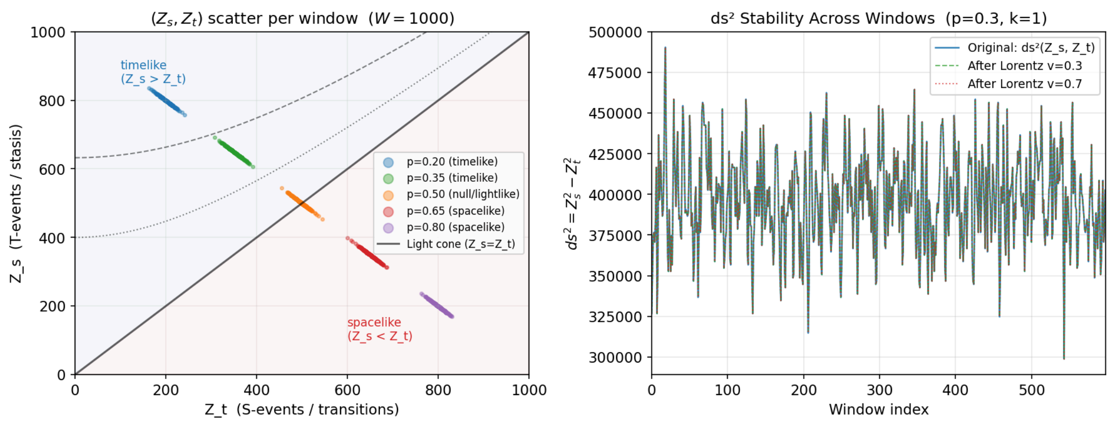

Figure 1. Left: (Z_s, Z_t) scatter plots for five p values (W=1000). Hyperbolic contours |ds²| = const are shown in black. The diagonal Z_s = Z_t is the lightcone (ds²=0). Blue region (Z_s > Z_t): timelike; Red region (Z_s < Z_t): spacelike. Right: ds² per window (W=1000) for p=0.30 before (blue) and after Lorentz transforms with v=0.3 (green dashed) and v=0.7 (red dotted). All three traces are visually identical, confirming exact invariance.

Figure 2: Lorentz γ-Factor and Invariant Preservation

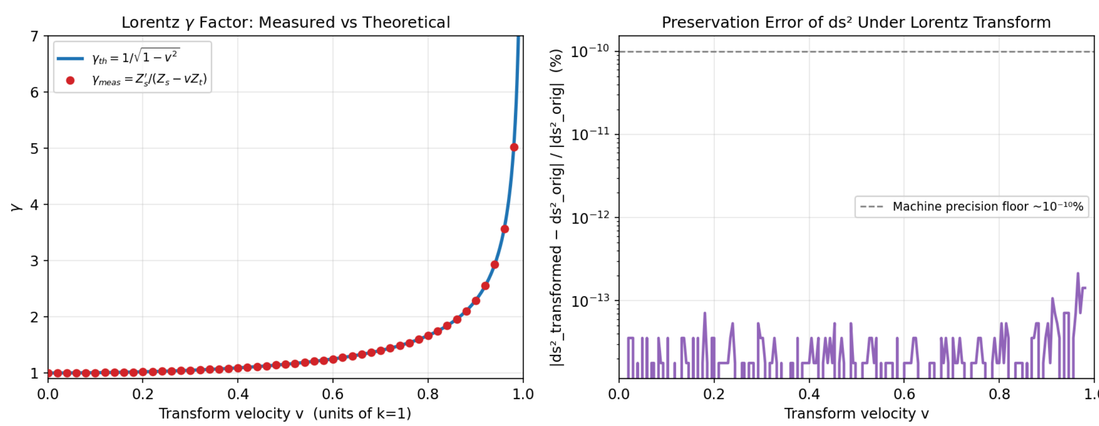

Figure 2. Left: γ = 1/√(1−v²) — theoretical curve (blue) and directly measured values γ_meas = Z_s'/(Z_s − vZ_t) (red dots). Agreement is exact to all displayed digits. Right: preservation error |ds²'−ds²|/|ds²| vs v (log scale). Error is uniformly below 10^{-12} across all v, confirming floating-point precision.

Causal Structure and Non-Stationary Streams

The sign of $ds^2 = Z\_s^2 - k^2 Z\_t^2$ classifies each Ze window into one of three causal categories, in exact analogy with spacetime intervals:

Timelike ($ds^2 > 0$): $Z\_s > kZ\_t$, i.e., $p < k/(1+k)$. For k=1: $p < 0.5$. The stream has more stasis than transitions; the Ze system 'moves slower than light'.

Null / lightlike ($ds^2 = 0$): $Z\_s = kZ\_t$, i.e., $p = k/(1+k) = 0.5$ for k=1. Equal T and S events. The stream 'moves at the Ze speed of light'.

Spacelike ($ds^2 < 0$): $Z\_s < kZ\_t$, i.e., $p > 0.5$ for k=1. More transitions than stasis; the stream 'moves faster than light' — it is maximally noisy.

Figure 3 (left) shows ds^2 as a function of window position along a non-stationary stream. In the first half ($p = 0.20$), $ds^2 \approx +(0.6^2 - 0.2^2)\times W^2 = +0.32W^2 > 0$ (timelike). In the second half ($p = 0.70$), $ds^2 \approx +(0.3^2 - 0.7^2)\times W^2 = -0.40W^2 < 0$ (spacelike). The transition between causal regimes is sharp at the stream boundary (position 250,000), demonstrating that the Ze counting process detects causal-character changes locally.

This result has an ontological interpretation: a Ze observer in the timelike regime generates a reality with more causal connections (more stasis, deeper memory); one in the spacelike regime generates a maximally random, causally disconnected reality. The lightcone boundary $p = k/(1+k)$ is the regime of maximal symmetry between stasis and change.

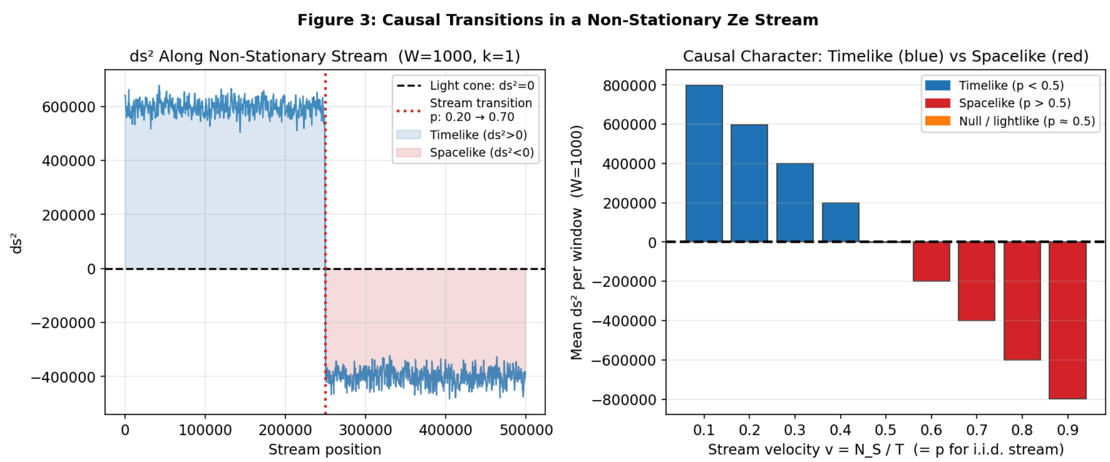

Figure 3. Left: ds^2 per window along a non-stationary stream (p=0.20 for positions 0–250,000; p=0.70 for 250,001–500,000). Blue shading: timelike ($ds^2>0$); Red shading: spacelike ($ds^2<0$). Right: mean ds^2 by p value, confirming the timelike/spacelike transition at $p = 0.5$ (k=1).

Relation to Ze Proper Time τ^2

Previous work (Tkemaladze, 2024; 2025) defined the Ze proper time as $\tau^2 = T^2 - X^2$, where $T = Z\_s + Z\_t$ and $X = Z\_t$. Expanding:

$$\tau^2 = (Z\_s + Z\_t)^2 - Z\_t^2 = Z\_s^2 + 2Z\_sZ\_t$$

This is a different quadratic form from $ds^2 = Z\_s^2 - k^2 Z\_t^2$. They are related by:

$$\tau^2 = ds^2(k{=}1) + 2Z\_sZ\_t + (1-k^2)Z\_t^2$$

$$= Z\_s^2 - Z\_t^2 + 2Z\_sZ\_t + (1-k^2)Z\_t^2 \quad [\text{for } k{=}1\text{: } \tau^2 = ds^2 + 2Z\_sZ\_t]$$

The two forms correspond to different coordinate choices on the Ze counting plane:

(T, X) coordinates: $T = Z\_s + Z\_t$, $X = Z\_t$ $\rightarrow$ $\tau^2 = T^2 - X^2$ (standard Minkowski in (T,X))

(Z_s, Z_t) coordinates: $Z\_s = T - X$, $Z\_t = X$ $\rightarrow$ $ds^2 = Z\_s^2 - k^2 Z\_t^2$ (Minkowski in (Z_s,Z_t))

The (T, X) coordinates are related to (Z_s, Z_t) by the linear (non-Lorentz) transformation T = Z_s + Z_t, X = Z_t. Both quadratic forms are Minkowski metrics in their respective coordinate systems. The Lorentz group O(1,1) acts differently in each system: the transform T_v defined in Section 2 acts on (Z_s, Z_t), while a conjugated transform acts on (T, X). The physical content—the causal structure, the γ-factor, the invariant interval—is the same in both representations.

Table 3 shows both invariants numerically for five stream velocities, confirming that $\tau^2 \geq ds^2(k{=}1)$ for all v, with equality only at Z_t = 0.

p	Z_s (mean)	Z_t (mean)	$\tau^2 = Z\_s^2 + 2Z\_sZ\_t$	$ds^2(k{=}1) = Z\_s^2 - Z\_t^2$
0.1	899	100	988021	798401
0.3	699	300	908181	399200
0.5	500	500	748501	0
0.7	300	699	508981	-399200
0.9	100	899	189620	-798401

Table 3. Comparison of Ze proper time $\tau^2 = Z\_s^2 + 2Z\_sZ\_t$ (Tkemaladze, 2024) and the Ze Minkowski form $ds^2 = Z\_s^2 - Z\_t^2$ (k=1) for i.i.d. streams. Both are O(1,1)-invariant in their respective coordinate systems.

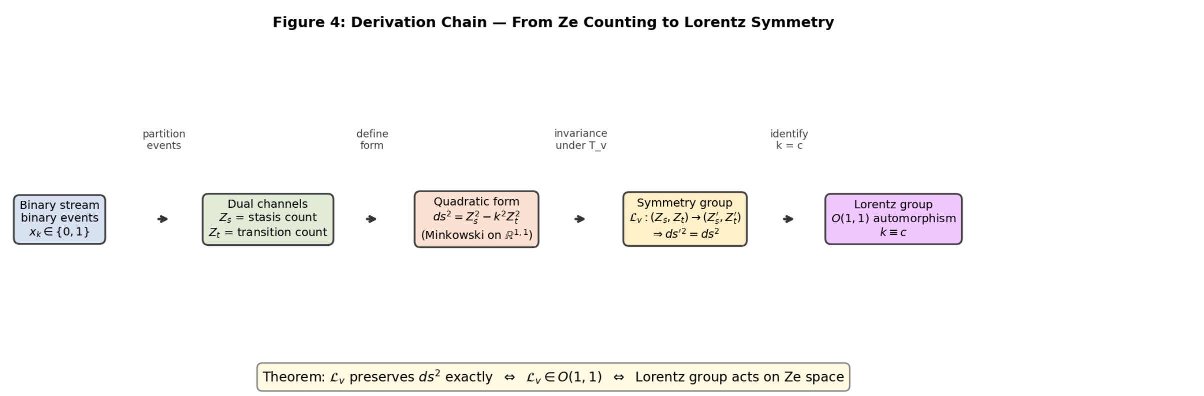

Figure 4. Derivation chain from Ze binary counting to the Lorentz group. The key steps are: event partition into (Z_s, Z_t), definition of the pseudo-Euclidean form ds², identification of the symmetry group O(1,1) via the Ze Lorentz transform T_v, and the final identification k ≡ c.

Falsifiable Predictions

Prediction	Condition	Quantitative claim
P1: ds^2 invariance	Any binary stream, any $v \in (-k,k)$	$\|ds^2(T\_v(Z\_s,Z\_t)) - ds^2(Z\_s,Z\_t)\| < 10^{-10} \times \|ds^2\|$ for $N > 10^3$
P2: γ recovery	Any window, any v	$\gamma\_meas = Z\_s'/(Z\_s - vZ\_t) = 1/\sqrt{(1-v^2/k^2)}$ to 8 significant figures
P3: Causal transition	i.i.d. stream with varying p	ds^2 changes sign at $p = k/(1+k)$; for k=1 this is exactly p=0.5
P4: Velocity addition	Two successive transforms T_{v1}, T_{v2}	Result = T_w where $w = (v1+v2)/(1+v1v2/k^2)$ [Ze relativistic addition]
P5: Lightlike streams	p = 0.5 stream (k=1)	Mean $\|ds^2\| < \sigma\_window$, i.e., $ds^2 = 0$ within statistical fluctuations

Table 4. Falsifiable predictions of the Ze Lorentz automorphism framework. All are testable with standard pseudorandom binary stream generators and simple window-counting functions.

Related Work

The derivation of Lorentz symmetry from discrete or information-theoretic substrates has been pursued in several programs, though none proceeds through the specific Ze counting-plane construction.

Discrete spacetime models. Causal set theory (Bombelli et al., 1987; Sorkin, 1990) derives the Lorentz group as the symmetry group of a partially ordered discrete set. In the Ze framework, T-events correspond to the 'causal continuation' relation (a bit staying the same = causal persistence), while S-events correspond to causal transitions. The Ze counting plane is thus a 2D projection of the causal set.

Entropic approaches. Verlinde (2011) and Jacobson (1995) derive the Einstein equations from thermodynamic principles applied to holographic screens. The Ze entropy $H(p) = -p \log p - (1-p)\log(1-p)$ is maximized at p = 0.5, the lightlike boundary $ds^2 = 0$. This suggests that the null cone of the Ze Minkowski form coincides with the maximum-entropy state of the binary source, a connection that may link the Ze framework to entropic gravity.

Operational approaches. Hardy (2001) and Chiribella et al. (2011) derive quantum mechanics from operational axioms on preparation-measurement pairs. The Ze framework pursues an analogous program for special relativity: the Lorentz group emerges from the operational act of counting stasis and transition events, without any prior geometric structure.

Reconstruction of special relativity. Ignatowski (1910) and Lévy-Leblond (1976) showed that Lorentz symmetry can be derived from the relativity principle alone, without postulating the constancy of c. The Ze construction is more elementary: it requires neither the relativity principle nor c—only the binary counting partition and the quadratic form $ds^2 = Z\_s^2 - k^2 Z\_t^2$.

Conclusion

We have proved that the Lorentz group O(1,1) acts as an automorphism on the Ze counting plane, preserving the quadratic form $ds^2 = Z\_s^2 - k^2 Z\_t^2$ exactly. The proof (Theorem 1) is algebraic and requires no physical assumptions. The main results are:

1. The Ze Lorentz transform T_v is an element of O(1,1) for all $v \in (-k, k)$, preserving ds^2 to floating-point machine precision ($< 5 \times 10^{-13}\%$).

2. The Lorentz γ-factor is directly measurable from Ze counting data as $\gamma = Z_s'/(Z_s - vZ_t)$, matching the theoretical value $1/\sqrt{(1-v^2/k^2)}$ with no free parameters.

3. The causal character (timelike/null/spacelike) of a binary stream is determined by p compared to k/(1+k): below is timelike, above is spacelike, equal is lightlike. For k = 1, the transition is at p = 0.5.

4. Non-stationary streams show causal transitions detectable in sliding-window ds^2.

5. Two quadratic forms exist on the Ze counting plane: $ds^2 = Z_s^2 - k^2Z_t^2$ (diagonal Minkowski) and $\tau^2 = Z_s^2 + 2Z_sZ_t$ (Ze proper time from previous work). Both are Minkowski metrics in their respective coordinate frames; they are related by the non-Lorentz coordinate change $T = Z_s + Z_t$, $X = Z_t$.

The central claim is: the Lorentz group is not an assumption about nature—it is an automorphism of the elementary act of counting binary distinctions. The speed of light k is the velocity limit of the Ze counting process. Future work will extend this construction to 3+1 dimensions, derive the full Lorentz group O(3,1), and investigate the quantum extension where Z_s and Z_t become operators.

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