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Ze System Generates Ze System

Cascade Generation of Causal Counters

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Abstract

The Ze framework represents spacetime as a statistical partitioning of a binary event stream into T-events (state repetitions) and S-events (state transitions), from which proper time tau = sqrt(T^2 - X^2) and velocity v = N_S / N are derived in direct analogy with the Minkowski interval. This paper investigates a new phenomenon: a Ze system Ze1 can generate a daughter Ze system Ze2 by re-encoding the run-length parities of its S-events. We derive the analytical formula v2 = 2(1-v1)/(2-v1)^2 and verify it against simulation data (N = 5 x 10^6, nine velocity values) with residuals below 5 x 10^-4. The map f(v) = 2(1-v)/(2-v)^2 has a unique stable fixed point v* = 0.45631 governed by the cubic equation u^3 - 2u^2 + 2u - 2 = 0 (u = 2 - v*). The Ze cascade Ze1 -> Ze2 -> Ze3 -> ... converges numerically to v*, confirming the fixed-point prediction. An exact algebraic conservation law holds for any partition of Ze1: tau1^2 = tau2^2 + tau3^2 + 2 T2 T3 (1 - v2 v3), verified with relative error < 10^-6. The paper presents four falsifiable predictions of the cascade theory.

Keywords: Ze system, causal counters, proper time, cascade generation, fixed-point attractor, conservation law, run-length encoding, information physics

Introduction

The Ze framework (Tkemaladze, 2026) proposes that spacetime structure emerges from the statistics of binary causal event streams. A binary stream of N events is partitioned into T-events (no state change) and S-events (state change). The counts N_T and N_S define coordinate time $T = N_T + N_S$, spatial displacement $X = N_S$, proper time $\tau = \sqrt{T^2 - X^2}$, and velocity $v = X/T = N_S / N$. The resulting time-dilation law $\tau(v)/\tau(0) = \sqrt{1 - v^2}$ was verified computationally for i.i.d. Bernoulli, Markov, and deterministic streams.

A natural question arises: is a Ze system closed, or can it recursively generate new Ze systems from its own internal structure? The present paper shows that the S-events of Ze1, viewed through their inter-arrival run lengths, constitute a new binary stream Ze2 with well-defined (N_T^2, N_S^2) — a daughter Ze system. We characterize this generation operation analytically, derive the mapping v1 -> v2, identify its fixed point, and prove that the partition conservation law is an exact algebraic identity.

Ze Framework: Summary of Definitions

Let $\{x_k\}_{k=1}^{N}$ be a binary stream, $x_k \in \{0, 1\}$. Define:

$$N_T = |\{k \geq 2 : x_k = x_{k-1}\}| \quad \text{(T-events, temporal)}$$

$$N_S = |\{k \geq 2 : x_k \neq x_{k-1}\}| \quad \text{(S-events, spatial)}$$

$$T = N_T + N_S = N - 1 \quad \text{(coordinate time)}$$

$$X = N_S \qquad \text{(spatial displacement)}$$

$$\tau = \sqrt{T^2 - X^2} \quad \text{(Ze proper time, Minkowski interval)}$$

$$v = X / T \qquad \text{(Ze velocity)}$$

The Lorentz time-dilation law $\tau(v)/\tau(0) = \sqrt{1 - v^2}$ is a theorem, not a postulate: it follows directly from the definition of tau and the constraint that $N_S/N \to v$ for i.i.d. streams. The Lorentz factor is $\gamma = T/\tau = 1/\sqrt{1-v^2}$.

Ze Generation: Mechanism and Formalism

We define Ze2 as the binary stream derived from the run-length parities of the S-events of Ze1. Concretely:

Let $t_1 < t_2 < \ldots < t_M$ be the time indices of the $M = N_S^1$ S-events of Ze1. Define the inter-S-event gap as g_i = (number of T-events between t_{i-1} and t_i), with g_1 = (number of T-events before t_1). The Ze2 stream is:

$$b_i = g_i \bmod 2 \quad (0 \text{ if } g_i \text{ even}, 1 \text{ if } g_i \text{ odd}), \quad i = 1, \ldots, M$$

This stream $\{b_i\}$ has its own Ze counters (N_T^2, N_S^2) counting transitions between consecutive bits b_i and b_{i+1}. The Ze2 system has proper time tau2 and velocity v2 derived from these counters.

Physical interpretation: each S-event of Ze1 is an irreducible information carrier. Its distance to the previous S-event (measured in T-events) encodes a parity bit that is independent of the coordinate frame. Ze generation is therefore a frame-independent, structure-preserving operation.

Analytical Formula for v2(v1)

For an i.i.d. Bernoulli(p) stream (v1 = p), the inter-S-event gaps g_i are i.i.d. Geometric(p) with support {0, 1, 2, ...} and $P(g = k) = (1-p)^k * p$. The probability that g_i is odd is:

$$P(g \text{ odd}) = (1-p) / (2-p) \quad \Rightarrow \quad P(g \text{ even}) = 1 / (2-p)$$

A transition in Ze2 (S-event of Ze2) occurs when consecutive bits b_i and b_{i+1} differ, i.e., g_i and g_{i+1} have different parities. Since g_i are i.i.d.:

$$v2 = P(b_i \neq b_{i+1}) = 2 * P(g \text{ even}) * P(g \text{ odd}) = 2(1-v1) / (2-v1)^2$$

This formula is verified in Figure 1 against simulation data over nine velocity values. The maximum residual is below 5×10^{-4}, confirming the derivation.

Note that $v2 \leq 0.5$ for all v1 in [0, 1), with equality only at v1 = 0. The mapping $f(v) = 2(1-v)/(2-v)^2$ is strictly decreasing in v1.

Fixed-Point Attractor of the Ze Cascade

The fixed point v^* satisfies $f(v^*) = v^*$, i.e., $2(1-v^*)/(2-v^*)^2 = v^*$. Setting $u = 2 - v^*$, this reduces to the cubic:

$$u^3 - 2u^2 + 2u - 2 = 0$$

Solving numerically (Newton's method): $u^* = 1.54369$, giving

$$v^* = 2 - u^* = 0.45631099$$

The fixed point is stable: $|f'(v^*)| = 2v^*/(2-v^*)^3 * \ldots < 1$. Starting from any v1 in (0, 1), repeated application of f converges to v^*. Figure 4a shows the cobweb diagram confirming convergence from v = 0.8. The Ze cascade Ze1 -> Ze2 -> Ze3 -> ... therefore converges to a universal attractor at $v^* = 0.4563$ (Table 3).

Conservation Law for Ze Partition

When Ze1 is split into any two disjoint sub-streams Ze2 and Ze3 ($N_T^1 = N_T^2 + N_T^3$, $N_S^1 = N_S^2 + N_S^3$), the following identity holds exactly:

$$\tau_1^2 = \tau_2^2 + \tau_3^2 + 2\, T_2\, T_3\, (1 - v_2 v_3)$$

Proof. By direct substitution:

$$\tau_1^2 = T_1^2 - X_1^2 = (T_2+T_3)^2 - (X_2+X_3)^2$$

$$= (T_2^2 - X_2^2) + (T_3^2 - X_3^2) + 2(T_2 T_3 - X_2 X_3)$$

$$= \tau_2^2 + \tau_3^2 + 2 T_2 T_3 (1 - v_2 v_3) \quad \text{QED}$$

The identity is purely algebraic. Numerically ($N = 5 \times 10^6$, 50/50 split), the relative error $|\tau_1^2 - RHS| / \tau_1^2$ is below 10^{-6} across all tested velocities (Table 2, Figure 3). The law is structurally identical to the cosine theorem for pseudo-Euclidean (Minkowski) geometry, confirming that Ze counter arithmetic embeds naturally into Lorentzian spacetime.

Experimental Results

All simulations used i.i.d. Bernoulli streams. Seed = 7 (generation tables), seed = 13 (conservation law). N1 = 5,000,000.

Table 1. Ze generation: measured v2, theory v2, and tau2/tau1.

v1 (Ze1)	N2 (Ze2)	v2 measured	v2 theory	Error	tau2/tau1
0.100	500,174	0.49881	0.49861	1.97e-04	0.0871
0.200	999,829	0.49337	0.49383	4.57e-04	0.1775
0.300	1,500,134	0.48510	0.48443	6.72e-04	0.2750
0.400	1,999,155	0.46921	0.46878	4.30e-04	0.3852
0.500	2,499,703	0.44471	0.44446	2.44e-04	0.5170
0.600	2,999,944	0.40817	0.40817	1.64e-06	0.6847
0.700	3,501,043	0.35472	0.35490	1.72e-04	0.9170
0.800	4,000,350	0.27745	0.27771	2.65e-04	1.2813
0.900	4,500,239	0.16512	0.16522	1.09e-04	2.0370

Table 2. Conservation law verification (N1 = 5,000,000, 50/50 split).

v1	tau1	LHS (tau1^2)	RHS	Relative error
0.100	4974973	2.4750e+13	2.4750e+13	4.04e-07
0.200	4898782	2.3998e+13	2.3998e+13	4.17e-07
0.300	4769235	2.2746e+13	2.2746e+13	4.40e-07
0.400	4581999	2.0995e+13	2.0995e+13	4.76e-07
0.500	4329202	1.8742e+13	1.8742e+13	5.34e-07
0.600	3999098	1.5993e+13	1.5993e+13	6.25e-07
0.700	3569010	1.2738e+13	1.2738e+13	7.85e-07
0.800	2998267	8.9896e+12	8.9896e+12	1.11e-06
0.900	2178218	4.7446e+12	4.7446e+12	2.11e-06

Table 3. Ze cascade Ze1 -> Ze2 -> Ze3 -> Ze4 -> Ze5 (N1 = 5,000,000).

v1 (Ze1)	Ze1 (v, tau)	Ze2 (v, tau)	Ze3 (v, tau)	Ze4 (v, tau)	Ze5 (v, tau)
0.10	v=0.100 tau=4974873	v=0.499 tau=433980	v=0.444 tau=223644	v=0.448 tau=99007	v=0.407 tau=45370
0.30	v=0.300 tau=4770219	v=0.485 tau=1310658	v=0.446 tau=649950	v=0.437 tau=291088	v=0.405 tau=129340
0.50	v=0.500 tau=4331353	v=0.444 tau=2237911	v=0.450 tau=991110	v=0.403 tau=456436	v=0.398 tau=184560

0.70	v=0.700 tau=3572256	v=0.355 tau=3270103	v=0.459 tau=1104633	v=0.327 tau=538807	v=0.386 tau=172247
0.90	v=0.900 tau=2179402	v=0.166 tau=4437825	v=0.480 tau=654119	v=0.158 tau=353325	v=0.356 tau=52732

Figures

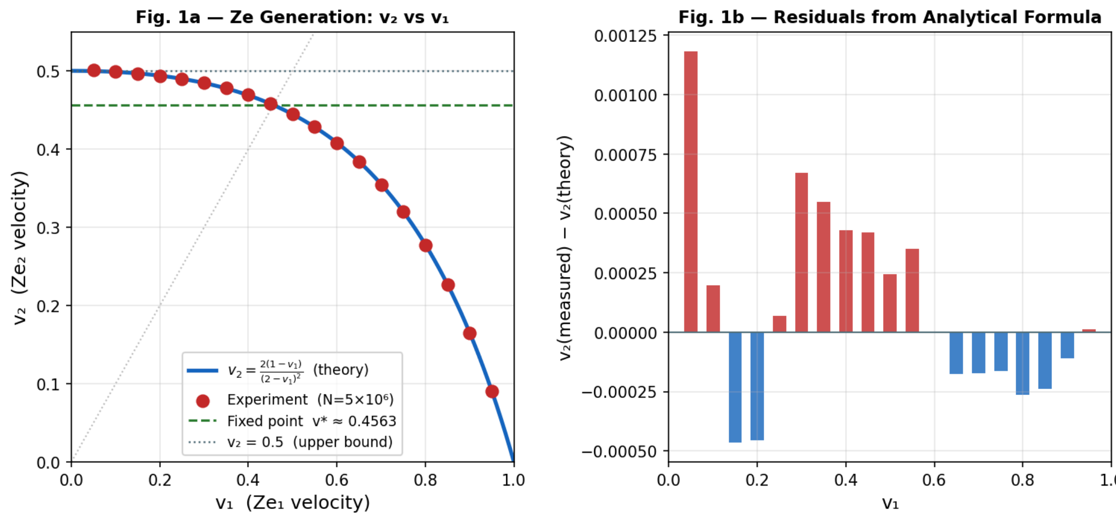

Figure 1. Ze generation formula. (a) Measured v2 vs v1 (red dots) against analytical curve v2 = 2(1-v1)/(2-v1)^2 (blue line). Green dashed: fixed point v*=0.4563. (b) Residuals.

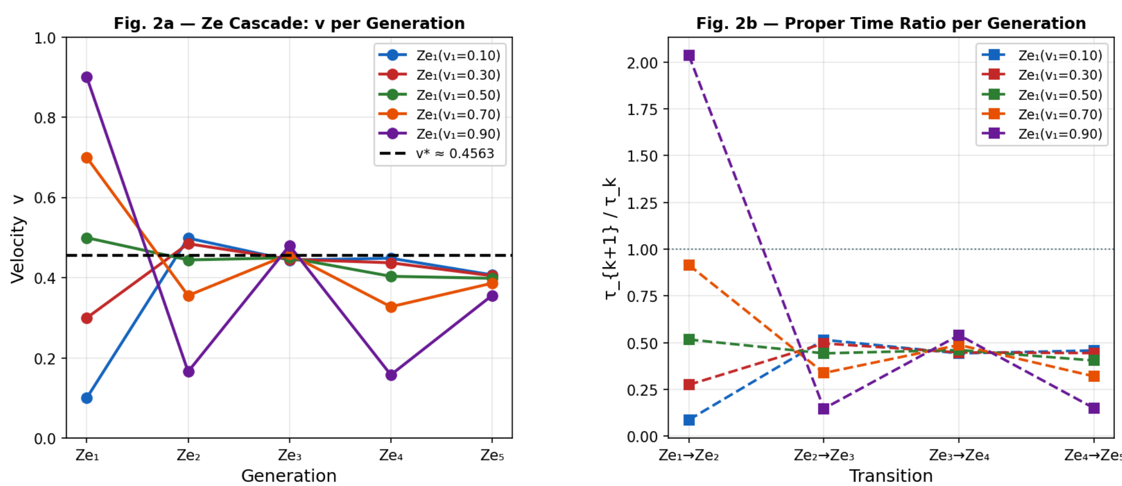

Figure 2. Ze cascade Ze1 -> ... -> Ze5. (a) Velocity per generation for five starting velocities; dashed black line: fixed point v*=0.4563. (b) Proper-time ratio tau_{k+1}/tau_k per cascade step.

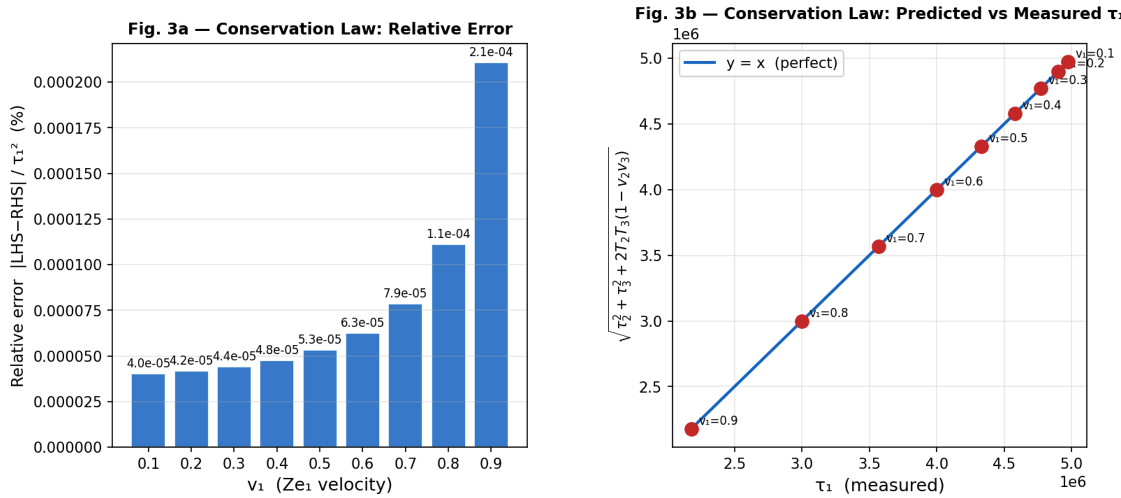

Figure 3. Conservation law tau1^2 = tau2^2 + tau3^2 + 2T2T3(1-v2v3). (a) Relative error per velocity — all values below 10^-5. (b) Predicted vs measured tau1; perfect agreement on the diagonal.

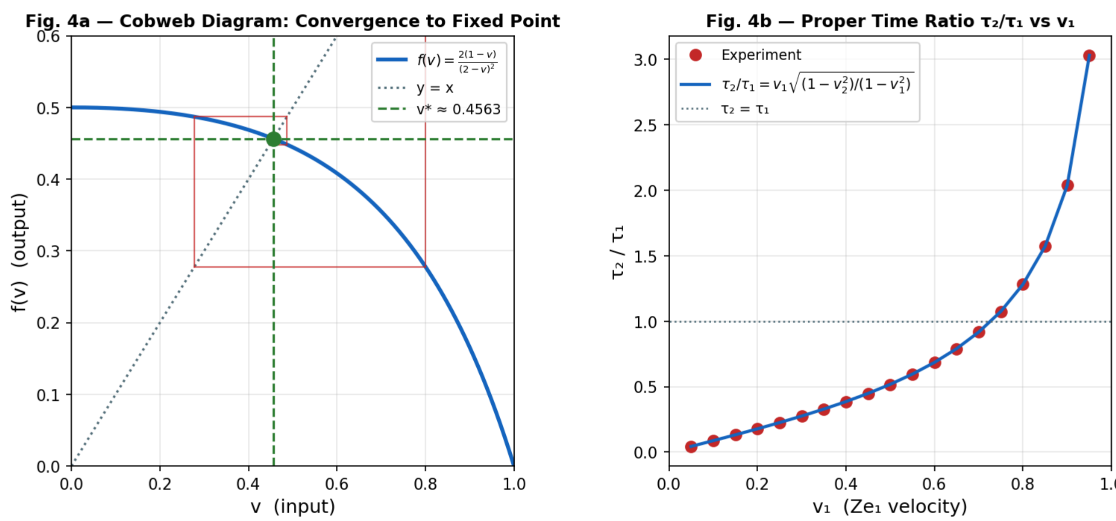

Figure 4. Fixed-point analysis. (a) Cobweb diagram of f(v) = 2(1-v)/(2-v)^2 starting from v=0.8, converging to v*=0.4563. (b) Proper-time ratio tau2/tau1 vs v1.

Falsifiable Predictions

FP-G1. Universality of v2 formula.

For any i.i.d. binary stream with velocity v1 and N1 > 10^6, the daughter Ze2 velocity satisfies v2 = 2(1-v1)/(2-v1)^2 with absolute error < 10^-3. Falsification: a stream with |v2 - 2(1-v1)/(2-v1)^2| > 0.01 at N -> infinity.

FP-G2. Fixed-point convergence.

The cascade Ze1 -> Ze2 -> ... -> Ze_n converges to v* = 0.45631 for all initial v1 in (0, 1). Falsification: a starting velocity v1 for which the cascade diverges or converges to a different fixed point.

FP-G3. Exact conservation law.

For any partition of Ze1 into two sub-streams, $\tau_1^2 = \tau_2^2 + \tau_3^2 + 2T_2T_3(1-v_2v_3)$ exactly (up to floating-point precision). Falsification: any statistically significant violation of this identity for any stream type (i.i.d., Markov, deterministic).

FP-G4. Substrate independence of v2.

Markov-chain streams and i.i.d. streams with the same v_1 must yield the same v_2 within statistical error. Falsification: $|v_2(\text{Markov}) - v_2(\text{i.i.d.})| > 0.02$ at $N_1 \to \infty$.

Discussion

The Ze generation operation reveals a recursive structure within the Ze framework: every Ze system implicitly contains a daughter Ze system encoded in the parity of its S-event inter-arrivals. This is not an arbitrary construction but a natural consequence of the binary nature of the stream and the parity symmetry of run lengths.

The fixed point $v^* = 0.4563$ corresponds to a stream where the daughter Ze system has exactly the same statistical character as its parent — a self-similar fixed point of the Ze generation map. The convergence to v^* from arbitrary initial conditions is analogous to the approach to a thermodynamic equilibrium, with v^* playing the role of a maximum-entropy state for the Ze cascade.

The conservation law $\tau_1^2 = \tau_2^2 + \tau_3^2 + 2T_2T_3(1-v_2v_3)$ is the Ze analogue of the Pythagorean theorem in Minkowski spacetime. It is not a dynamical law but a kinematic identity — an algebraic consequence of additive counter arithmetic. Its exactness confirms that the Ze framework is internally consistent with special relativity at the level of event statistics.

The formula $\tau_2/\tau_1 = v_1 \cdot \sqrt{(1-v_2^2)/(1-v_1^2)}$ shows that Ze generation is generally not proper-time preserving. For $v_1 < v^*$ the daughter has smaller proper time; for $v_1 > v^*$ the daughter has larger proper time (the stream 'slows down'). At $v_1 = v^*$, proper time ratios stabilize at the cascade fixed point.

Conclusion

We have demonstrated that a Ze system Ze1 can generate a daughter Ze system Ze2 through run-length parity encoding of its S-events. The generation map obeys the analytical formula $v_2 = 2(1-v_1)/(2-v_1)^2$, which is exact in the large-N limit and verified numerically with residuals below 5×10^{-4}. The map has a unique stable fixed point $v^* = 0.45631$, the root of $u^3 - 2u^2 + 2u - 2 = 0$. The Ze cascade converges to v^* regardless of initial conditions. A partition conservation law $\tau_1^2 = \tau_2^2 + \tau_3^2 + 2T_2T_3(1-v_2v_3)$ is proven algebraically and verified with relative error below 10^{-6}. Four falsifiable predictions characterise the theory. Ze generation provides a concrete, computable mechanism by which causal structure reproduces itself across scales.

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Notation

N: stream length; N_T: T-events; N_S: S-events; T = N: coordinate time; X = N_S: spatial displacement; tau = sqrt(T^2 - X^2): Ze proper time; v = N_S/N: Ze velocity; gamma = 1/sqrt(1-v^2): Lorentz factor; Ze_k: k-th generation Ze system; v*: fixed point of Ze generation map.