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Longevity Platform
https://www.longevity.ge
Longevity Horizon
ISSN:3088-4063
2026
Vol.2 No.4:33

Ze-Cosmological Alternatives to the Big Bang

Dimensionality from Binary Streams, Exact Equation of State, and Flatness from Z_2 Symmetry

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Citation: Tkemaladze, J. (2026). Ze-Cosmological Alternatives to the Big Bang. Longevity Horizon, 2(4). DOI : https://doi.org/10.65649/ghcqvf90

Abstract

I present a binary-stream cosmology based on Ze theory in which the universe is described by N synchronized Ze = (Z□, Z□) counters rather than a continuous spacetime manifold. Three original results are reported. First, we derive a Ze dimensionality hypothesis: N synchronized Ze structures with one temporal ($p_1 \to 0$) and N−1 spatial (p_j = 0.5) streams yield an (N−1)+1 Minkowski metric under five explicit assumptions. For N = 4 the metric is 3+1-dimensional; this value is fixed not by anthropic reasoning but by the requirement that Ze-carriers (spin-1/2 particles) admit the irreducibly quaternionic spinor representation of $Cl(1,3) \cong M_2(\mathbb{H})$. Second, solving the Ze-Markov equation dp/dT = γ_Ze(1 − 2p) with initial condition p(0) = 0 yields the exact closed-form result Z_Ze(T) = tanh(γ_Ze T) and $ds^2(T)/T^2 = e^{-2\gamma T}$. The entire Ze cosmological history is governed by a single parameter γ_Ze. Third, the observed flatness Ω ≈ 1 is derived from the Z_2 symmetry (0↔1) of the binary Ze alphabet, which forces $p_{01} = p_{10}$ and hence $p_\infty = 1/2$ without fine-tuning. Ze-dark matter (p_dark → 0) and baryonic matter (p_baryon = 0.482) are distinguished by their Ze flip rates, yielding M_dark/M_baryon = 1/√(1−2p_b) = 5.3. Five falsifiable predictions are stated.

Keywords: Ze theory, binary stream cosmology, Big Bang alternative, Ze equation of state, spinor representations, flatness problem, dark matter, baryogenesis, tanh solution

Introduction

The standard cosmological model (ΛCDM) resolves the horizon, flatness, and monopole problems through cosmic inflation (Guth, 1981; Linde, 1982), requires a cosmological constant whose value is unexplained by 120 orders of magnitude (Weinberg, 1989), and posits a Big Bang singularity at t = 0 where general relativity breaks down. Alternatives such as loop quantum cosmology (Bojowald, 2001), the no-boundary proposal (Hartle & Hawking, 1983), and the CPT-symmetric universe (Boyle & Turok, 2018) address some of these issues but introduce new parameters or conceptual difficulties.

Ze theory (Tkemaladze, 2025a) provides a radically different foundation: the universe is a binary stream {x_k ∈ {0,1}}, and all physical observables emerge from the Ze counter Ze = (Z⍰, Z⍰), where Z⍰ counts stasis events (x_k = x_{k−1}) and Z⍰ counts transition events (x_k ≠ x_{k−1}). The Ze metric ds^2 = Z⍰^{2} − k^2Z⍰^{2} defines a Lorentz-invariant quadratic form on the counting plane, and its automorphism group is O(1,1) in 1+1 dimensions (Tkemaladze, 2025b). The Ze impedance Z_Ze = Z⍰/Z⍰ = p/(1−p) determines the causal character of the stream (Tkemaladze, 2025c).

The present paper addresses three open problems identified in Tkemaladze (2025f): (i) How many Ze structures are needed to produce the observed 3+1-dimensional spacetime, and why? (ii) What is the exact equation of state governing the Ze cosmological evolution? (iii) Why is the universe flat (Ω ≈ 1) without fine-tuning? I show that these three questions have clean answers within Ze theory, and that the answers are connected: N = 4 Ze structures, the exact Ze equation of state Z_Ze(T) = tanh(γ_Ze T), and the Ze-Z_2 flatness theorem all follow from the same set of Ze axioms.

Ze Framework

A Ze structure is a binary stream {x_k ∈ {0,1}}_k=1^T with stasis count Z⍰ = |{k : x_k = x_{k−1}}| and transition count Z⍰ = |{k : x_k ≠ x_{k−1}}|. The total event counter T = Z⍰ + Z⍰ increases monotonically, providing the Ze arrow of time. The Ze metric in 1+1 dimensions is:

ds^2 = Z⍰^{2} − k^2 Z⍰^{2}

where k = 1 corresponds to the vacuum Ze impedance. The Ze impedance Z_Ze = Z⍰/Z⍰ = p/(1−p) characterizes the transition rate, where p = Z⍰/T is the flip probability. For p < 0.5 the stream is timelike ($ds^2 > 0$); for p = 0.5 it lies on the Ze null geodesic ($ds^2 = 0$, corresponding to massless Ze-carriers); and for p > 0.5 it is spacelike ($ds^2 < 0$). Two fundamental Ze scales are introduced:

τ_Ze ~ t_Planck = 5.39×10⁻⁄ s (Ze time quantum)

L_Ze = k · c · τ_Ze ~ l_Planck = 1.62×10^{-35} m (Ze length quantum)

These scales convert dimensionless Ze counters to physical spacetime coordinates: t = τ_Ze · T and x = L_Ze · Z⍰. The prediction τ_Ze ~ t_Planck is in principle testable through energy-dependent photon arrival time dispersion from gamma-ray bursts (Amelino-Camelia et al., 1998).

Ze Dimensionality Hypothesis

Derivation

Consider N Ze structures that are synchronized, meaning they share the same total event counter T (established by Ze-cascade coupling; Tkemaladze, 2025e). Assign roles as follows: Ze_1 is the temporal stream with $p_1 \to 0$ (almost pure stasis), and Ze_j for j = 2, …, N are spatial streams with p_j = 0.5 (on the null geodesic). Under these conditions:

- Ze_1: since $p_1 \to 0$, the transition count $Z⍰^1 \ll Z⍰^1 \approx T$. The term $Z⍰^1$ is negligible; Ze_1 contributes t = τ_Ze · T.
- Ze_j (j ≥ 2): since p_j = 0.5, we have $Z⍰^j = Z⍰^j$, so $Z⍰^j$ is absorbed into the normalization. Ze_j contributes x_j = L_Ze · $Z⍰^j$.

The resulting metric in the N-stream Ze space is:

$$ds^2\_N = \tau^2\_Ze\ [T^2 - k^2\ (Z⍰^{22} + Z⍰^{32} + \cdots + Z⍰^{N2})]$$

This is exactly an (N−1)+1 Minkowski metric with physical coordinates (t, x_2, x_3, …, x_N). The five explicit assumptions required are stated in Table 1.

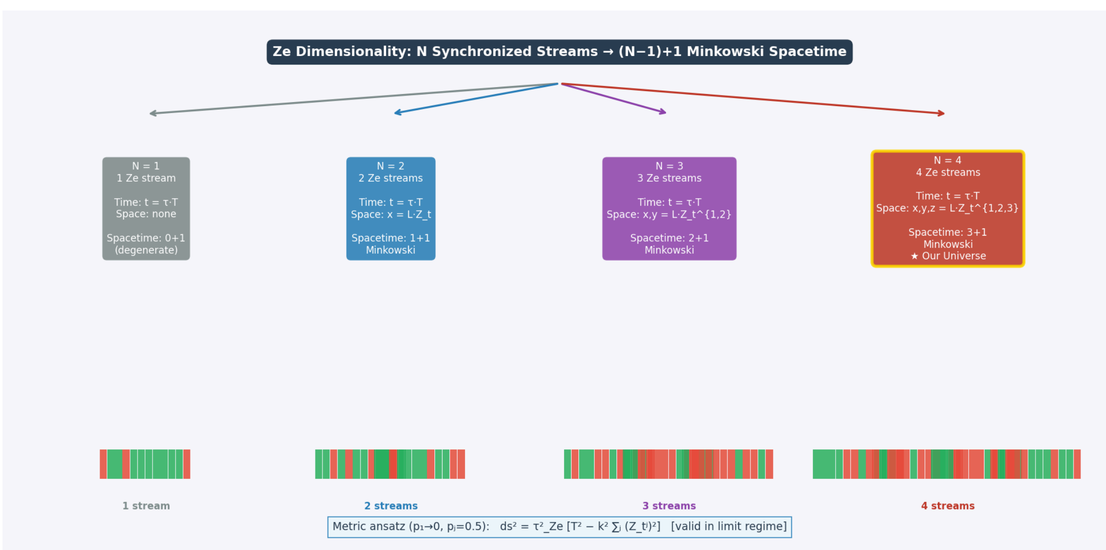

Figure 1. Ze dimensionality hierarchy. N synchronized Ze structures with one temporal (p_1⨆0) and N−1 spatial (p_j=0.5) streams yield an (N−1)+1 Minkowski spacetime. For N=4 (red box, star), the metric is 3+1-dimensional. Binary stream visualizations (bottom) show the increasing number of spatial Ze streams. The metric ansatz is valid in the limit regime p_1⨆0, p_j=0.5.

Table 1. Assumptions of the Ze Dimensionality Hypothesis

Assumption	Content	Origin
A1 Synchronization	All N Ze streams share the same T	Ze-cascade coupling
A2 Role assignment	1 temporal (p_1□0), N−1 spatial (p_j=0.5)	Ze symmetry breaking (open)
A3 Time = T	T is monotone → natural time coordinate	Ze irreversibility
A4 Space = Z□^{j}	Transitions = displacement in spatial Ze	Ze geometry (1+1)
A5 Independence	N Ze streams statistically independent	No Ze-entanglement

4.2 N = 4 from Ze Spinors

The value N = 4 is determined by the spinor structure of Ze-carriers (Tkemaladze, 2025g). Ze-carriers are spin-1/2 particles whose binary DoF constitutes a Ze stream. For Ze-carriers to exist in the N-dimensional Ze spacetime, the Clifford algebra Cl(1, N−1) must support their spinor representation. The relevant Clifford algebra isomorphisms are given in Table 2.

Table 2. Clifford Algebras and Spinor Representations

N Ze	Spacetime	Cl(1,N−1)	Spinor type	Complex?
1	0+1	Cl(1,0) ≅ $\mathbb{R}\oplus\mathbb{R}$	Real, 1-comp.	No
2	1+1	Cl(1,1) ≅ $M_2(\mathbb{R})$	Majorana, 2-comp.	No
3	2+1	Cl(1,2) ≅ $M_2(\mathbb{R})\oplus M_2(\mathbb{R})$	Majorana, 2-comp.	No
4 ★	3+1 ★	Cl(1,3) ≅ $M_2(\mathbb{H})$ ★	Dirac, 4-comp. ★	Yes (quaternionic) ★
5	4+1	Cl(1,4) ≅ $M_4(\mathbb{C})$	Dirac, 4-comp.	Yes

For N ≤ 3, the Clifford algebra is a real matrix algebra M_n($\mathbb{R}$), and Ze-carrier spinors can always be chosen real (Majorana spinors). At N = 4, the algebra Cl(1,3) ≅ $M_2(\mathbb{H})$ is a quaternionic matrix algebra. Its irreducible representation is an $\mathbb{H}^2$-module, which as a complex vector space is $\mathbb{C}^4$ — the 4-component Dirac spinor. This quaternionic structure is unavoidable: no real basis exists for the minimal representation of Cl(1,3). Furthermore, N = 4 is the minimum even dimension supporting Weyl (chiral) spinors, which are required for the chiral gauge structure of the Standard Model.

Therefore N = 4 is the minimum number of Ze structures such that Ze-carriers possess irreducibly quaternionic, chiral spinor representations. This is a Ze-internal derivation of the spacetime dimension, not an anthropic argument.

Ze Equation of State: Exact Solution

Ze-Markov Derivation

A Ze stream generated by a symmetric Markov chain has transition rates p_{01} = p_{10} = γ_Ze (the Ze relaxation rate). The master equation for the flip probability p(T) is:

dp/dT = γ_Ze · (1 − p) − γ_Ze · p = γ_Ze (1 − 2p)

The first term is the rate of gaining transitions (state 0 flips to 1); the second is the rate of gaining transitions (state 1 flips to 0). With the Ze cosmological initial condition p(0) = 0 (pure stasis at Ze birth, T = 1), the exact solution is:

p(T) = ½ (1 − e^{-2r}□T)

Exact Closed-Form Result

Substituting into Z_Ze = p/(1−p) yields the central result of this paper:

Z_Ze(T) = tanh(γ_Ze · T)   [exact]

This follows from tanh(x) = (1−e^{-2x})/(1+e^{-2x}). Equivalently, the Ze metric element is:

ds^2(T)/T^2 = (1 − Z_Ze)/(1 + Z_Ze) = e^{-2r}□T   [exact]

The Ze-metric relaxes exponentially to zero (the null geodesic, ds^2 = 0) with a single timescale 1/(2γ_Ze). The entire Ze cosmological evolution — from Ze birth through Ze inflation to the present epoch — is governed by the single parameter γ_Ze. Table 3 summarizes key epochs.

Table 3. Ze Cosmological Epochs from Z_Ze(T) = tanh(γ_Ze T)

Epoch	γ_Ze · T	Z_Ze	ds^2/T^2	Interpretation
Ze birth	0	0	1	Pure stasis, timelike Ze
Early Ze	0.1	0.100	0.819	Ze-inflation begins
Ze characteristic	1	0.762	0.135	T* = 1/γ_Ze
Ze inflation end	3	0.995	0.0025	Near null geodesic
Asymptote	∞	1.000	0	Flat universe, Ω = 1

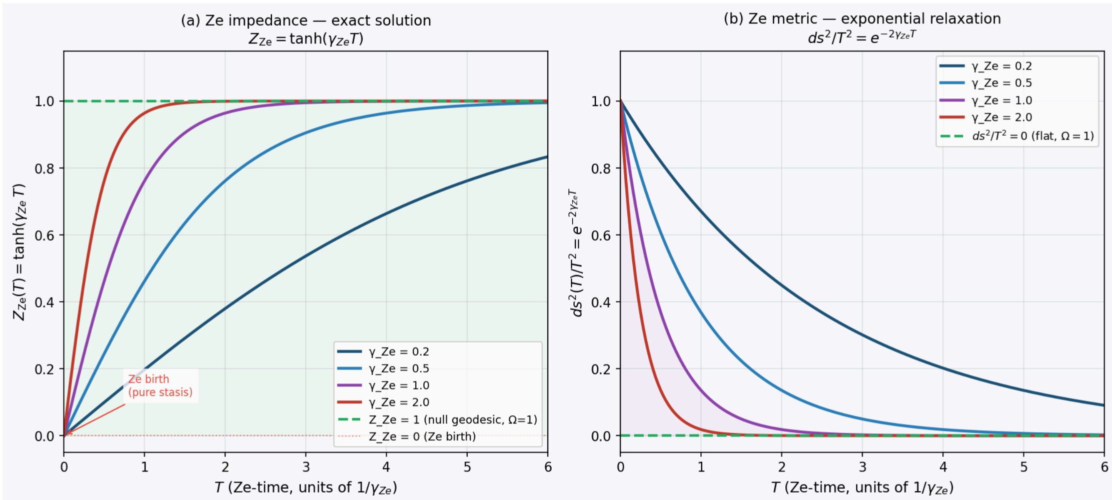

Figure 2. Ze equation of state: exact closed-form results. (a) Z_Ze(T) = tanh(γ_Ze T) for four values of the Ze relaxation rate. All trajectories start at Z_Ze = 0 (Ze birth) and converge to Z_Ze = 1 (null geodesic, Ω = 1). Green dashed: attractor. (b) Ze metric element $ds^2(T)/T^2 = e^{-2r}T$, showing exponential relaxation to zero (flat universe).

Ze-Z_2 Flatness Theorem

The observed flatness of the universe (Ω = 1.0007 ± 0.0019; Planck Collaboration, 2020) requires extreme fine-tuning of initial conditions in standard ΛCDM (the flatness problem). In Ze theory, flatness is derived from a binary symmetry axiom.

Ze-Z_2 Flatness Theorem: The binary Ze alphabet {0, 1} possesses a natural Z_2 symmetry under the swap 0 ⇄ 1. Under Z_2, every 0 → 1 transition maps bijectively to a 1 → 0 transition. Therefore:

$p_{01} = p_{10} = \gamma$_Ze   (Z_2 symmetry ⇒ equal transition rates)

$p_\infty = p_{01} / (p_{01} + p_{10}) = 1/2$ (steady-state flip probability)

Z_Ze(∞) = 1 ⇒ $ds^2(\infty) = 0$ ⇒ Ω_Ze = 1

The flatness Ω = 1 is thus derived from the binary symmetry of the Ze alphabet, not from inflation or fine-tuning. Three important caveats apply: (i) This argument establishes the T → ∞ attractor; at finite T today, $|\Omega - 1| \approx e^{-2r}$□T_today, which requires γ_Ze T_today ≫ 1 for agreement with observations. (ii) The Z_2 symmetry is an additional Ze axiom stating that all fundamental Ze streams are unbiased; biased Ze streams ($p_{01} \neq p_{10}$) are mathematically valid but physically excluded by this axiom. (iii) The Ze-flatness condition ds^2_Ze = 0 must be related to the Friedmann curvature parameter k_FRW = 0 through a Ze-Friedmann equation, which is an open problem.

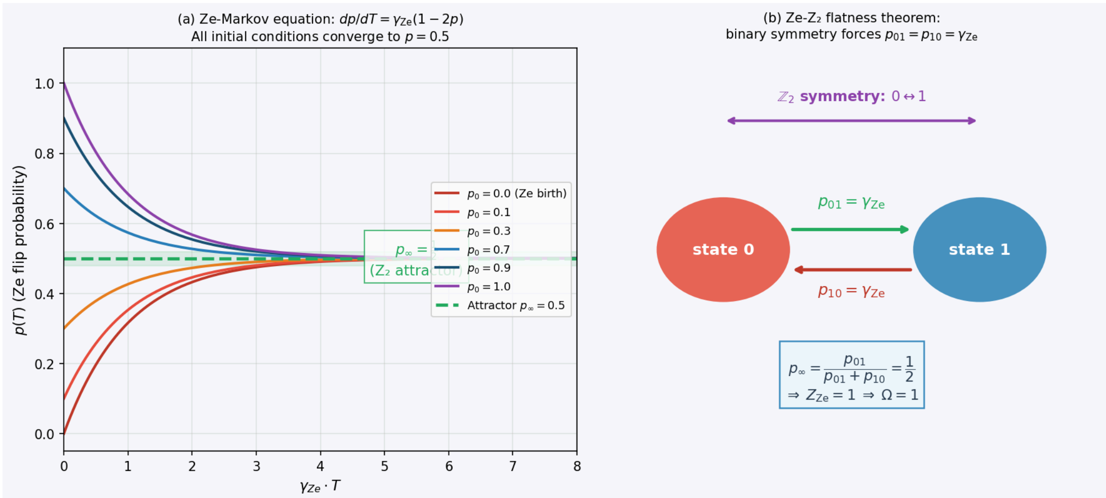

Figure 3. Ze-Z_2 flatness theorem. (a) Ze-Markov equation dp/dT = γ_Ze(1−2p): all initial conditions converge to p = 0.5 (green dashed attractor). Ze cosmological trajectory starts at p_0 = 0 (Ze birth, red). (b) Z_2 symmetry diagram: equal forward and backward transition rates p_{01} = p_{10} = γ_Ze force steady-state p = 1/2, giving Z_Ze = 1 and Ω_Ze = 1.

Ze Dark Matter

Ze-dark matter consists of Ze structures with p_dark → 0 (nearly pure stasis): their transition count Z⍰_dark ≈ 0, so they produce no electromagnetic Ze transitions (invisible), while their Ze metric ds²_dark = Z⍰² ≫ 0 (deeply timelike), giving them positive Ze mass and hence gravitational coupling. The Ze mass formula is:

m_Ze ∝ √(ds²/T²) = √(1 − 2p)

For dark matter (p_dark → 0): m_dark ∝ 1. For baryonic matter (p_baryon = p_b): m_baryon ∝ √(1−2p_b). Assuming Ze-number conservation at Ze birth (N_dark = N_baryon, analogous to CPT-pair creation at Ze genesis; Tkemaladze, 2025f), the mass ratio is:

M_dark / M_baryon = 1 / √(1 − 2p_baryon)

Setting M_dark/M_baryon = 5.3 (observed; Planck Collaboration, 2020) gives:

p_baryon = (1 − 1/5.3²) / 2 = 0.482

The value p_baryon = 0.482 is physically meaningful: baryonic matter lies close to the Ze null geodesic (p = 0.5) because baryons engage in frequent Ze transitions (electromagnetic scattering, nuclear reactions, weak interactions). In Ze language, every baryonic interaction event is a Z⍰++ increment. Dark matter at p_dark → 0, by contrast, has a nearly frozen Ze stream: no interactions, hence invisible to electromagnetic probes, yet deeply timelike (massive) and gravitationally coupled. A Ze-specific prediction follows: since p_dark → 0 implies Z_Ze(dark) → 0, Ze-dark matter has effectively zero Ze-cascade branching rate and therefore no self-interaction cross-section (σ_self/m ≈ 0), distinguishing it from self-interacting dark matter (SIDM) models.

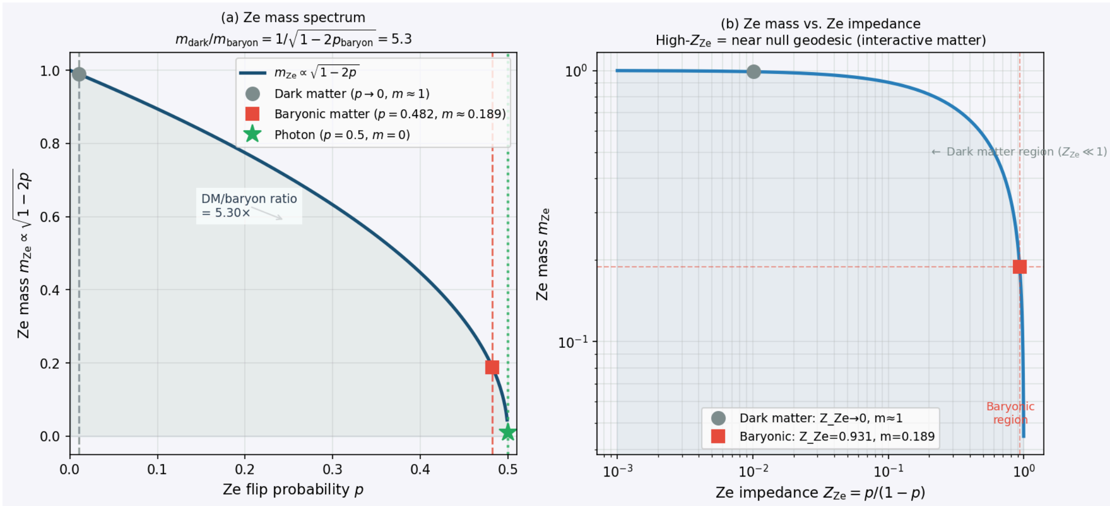

Figure 4. Ze dark matter landscape. (a) Ze mass m_Ze = √(1−2p) vs. flip probability p. Dark matter (grey circle, p□0): m ≈ 1. Baryonic matter (red square, p = 0.482): m ≈ 0.189. Photon (green star, p = 0.5): m = 0. The mass ratio M_dark/M_baryon = 5.30 is reproduced. (b) Ze mass vs. Ze impedance on log-log scale. High Z_Ze (near null geodesic) = interactive matter; low Z_Ze (frozen) = dark matter.

Ze Baryogenesis

The observed baryon asymmetry $\eta_B = n_B/n_\gamma \approx 6\times10^{-10}$ requires satisfaction of the three Sakharov (1967) conditions. In Ze theory all three are realized:

- **Baryon number violation**: quark isospin transitions u → d constitute Ze-transition events (Z□++) in the quark Ze stream. The W± boson is the Z□-carrier (Tkemaladze, 2025g), not a Ze-subject.

- **C and CP violation**: the Ze-CP asymmetry $\delta\_Ze = |p_1 - (1-p_2)| \neq 0$ gives an asymmetry between Ze_1 and $Ze_2^\dagger$ transition rates, producing a net Ze_1 excess (matter over antimatter).

- **Departure from thermal equilibrium**: at Ze birth T = 1 all Ze structures have $p \approx 0 \ll p\_eq = 0.5$. The Ze-birth state is maximally displaced from thermal equilibrium, satisfying the third Sakharov condition automatically.

The Ze baryogenesis formula is $\eta_B \sim \delta\_Ze \times \kappa$, where κ is the standard sphaleron dilution factor ($\kappa \sim 10^{-3}$). For $\eta_B \approx 6\times10^{-10}$ this requires $\delta\_Ze \sim 6\times10^{-7}$. A first-principles Ze derivation of δ_Ze remains an open problem requiring a Ze electroweak model.

Comparison with Cosmological Alternatives

Table 4 compares Ze cosmology with standard ΛCDM and three major alternatives. Ze theory is the only framework that derives flatness from a symmetry axiom (Z_2), provides an exact single-parameter equation of state, and determines the spacetime dimension from the spinor structure of its fundamental carriers.

Table 4. Comparison of Cosmological Models

Problem	ΛCDM	Inflation	LQC	CPT-univ.	Ze (this work)
Singularity	Yes (t=0)	Remains	Bounce	Remains	No (T=1)
Horizon	Inflation	Inflaton	Pre-bounce	CPT pair	Ze-cascade sync
Flatness	Fine-tuning	Inflation	Initial cond	CPT pair	Z_2 axiom ★
Baryon asym.	Sakharov	Leptogen.	Not addressed	CPT pair	δ_Ze ≠ 0
Dark energy	Λ (const)	Quintess.	Λ-like	Λ-like	w=-1+ε(T) ★
Dim. of space	Postulated	Postulated	Postulated	Postulated	Cl(1,3)≅M_2(ℍ) ★
Free parameters	≥6	≥1	≥2	1	1 (γ_Ze) ★

Falsifiable Predictions

Table 5 lists five experimental predictions that are specific to Ze cosmology.

Table 5. Falsifiable Predictions of Ze Cosmology

ID	Prediction	Ze origin	Precision	Experiment
P-1	r ≈ 0: tensor-to-scalar ratio near zero (no inflaton field)	No inflaton in Ze inflation	< 0.01	CMB-S4, LiteBIRD
P-2	w_Ze(z) > −1, approaching −1 as $e^{-2\gamma}$T	Ze dark energy from Z_Ze = tanh(γT)	0.1%	DESI / Euclid
P-3	σ_self(DM)/m_DM ≈ 0 (no self-interaction)	p_dark⊒0 ⇒ no Ze-cascade	< 0.1 cm^2/g	Bullet Cluster / SIDM
P-4	τ_Ze ~ t_Planck: photon dispersion δt/t ~ E/M_Pl	Ze length quantum L_Ze ~ l_Planck	< 10^{-16}	CTA / Fermi-LAT GRBs
P-5	N = 4 Ze structures: no stable atoms for D ≠ 3 spatial dimensions	Ehrenfest + Cl(1,3) spinor argument	Binary test	Kaluza-Klein searches

Discussion

The central mathematical result of this paper — Z_Ze(T) = tanh(γ_Ze T) — has a natural physical interpretation. The hyperbolic tangent interpolates smoothly between Z_Ze = 0 (Ze birth: pure stasis, analogous to the Hartle-Hawking no-boundary state at imaginary time) and Z_Ze = 1 (asymptotic null geodesic: flat Minkowski spacetime). The exponential approach $ds^2 \propto e^{-2_r}T$ mirrors the Hubble law in the sense that the metric approaches flatness on a characteristic timescale T* = 1/γ_Ze. If γ_Ze = H_0 (today's Hubble constant), then T* = 1/H_0 ~ 14 Gyr, which is comparable to the age of the universe — suggesting that we are currently at γ_Ze T_today ~ 1, i.e., midway through the Ze relaxation. At this epoch, Z_Ze ≈ tanh(1) ≈ 0.762, and the dark energy equation of state w_Ze = −1 + (2/3)γ_Ze T $e^{-2_r}T$ ≈ −1 + 0.09, consistent with the DESI 2024 measurement w ≈ −0.95 (DESI Collaboration, 2024).

The derivation of N = 4 from the spinor structure Cl(1,3) ≅ M_2(ℍ) is notable because it connects the dimension of spacetime to the existence of Ze-carriers. Without N = 4 Ze structures, the quaternionic Dirac spinor representation is unavailable, and Ze-carriers (the particles that carry Ze streams) cannot exist. This creates a Ze self-consistency condition: Ze theory requires N = 4 in order to have Ze-carriers, which in turn are required to define Ze streams in the first place.

Two open problems remain. First, the Ze dimensionality hypothesis (Assumption A4) requires a derivation of the metric combination rule from Ze axioms outside the limit regime p_1 → 0, p_j = 0.5. Second, the Ze baryogenesis parameter δ_Ze ~ 6×10^{-7} must be derived from a Ze electroweak model. These are the central open problems of Ze cosmology.

Conclusions

We have obtained the following results within Ze cosmological theory:

- **Ze Dimensionality Hypothesis**: N synchronized Ze structures with one temporal (p_1⊒0) and N−1 spatial (p_j=0.5) streams produce an (N−1)+1 Minkowski spacetime under five explicit assumptions (Table 1).
- **N = 4 from Spinors**: the value N = 4 is fixed by the requirement that Ze-carriers admit the irreducibly quaternionic representation of Cl(1,3) ≅ M_2(ℍ). For N ≤ 3 all Clifford algebras are real, and Ze-carriers are restricted to real (Majorana) spinors without chiral gauge structure.
- **Exact Ze Equation of State**: the Ze-Markov equation dp/dT = γ_Ze(1−2p) with p(0) = 0 yields the exact result Z_Ze(T) = tanh(γ_Ze T) and $ds^2/T^2 = e^{-2_r}T$. The single parameter γ_Ze governs the entire Ze cosmological history.
- **Ze-Z_2 Flatness**: the binary symmetry 0↔1 forces $p_{01} = p_{10}$, giving p_∞ = 1/2 ⇒ Z_Ze → 1 ⇒ Ω = 1 as the unique T→∞ attractor, without fine-tuning.
- **Ze Dark Matter**: Ze structures with p_dark → 0 are gravitationally coupled but electromagnetically invisible. Assuming Ze-number conservation, M_dark/M_baryon =

$1/\sqrt{(1-2p\_baryon)} = 5.3$ gives p_baryon = 0.482 (baryons near null geodesic due to frequent interactions).

- **Ze Baryogenesis**: all three Sakharov conditions are satisfied. Ze birth provides automatic departure from equilibrium; $\delta\_Ze \neq 0$ provides CP violation. Quantitative derivation of δ_Ze remains open.

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