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# From Bell-Pair Dark Matter to Entanglement Cosmogenesis: A Programmatic Conjecture with Testable Predictions

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## Abstract

We propose a programmatic conjecture for cosmology and particle physics based on a strict *qubit-only ontology*: nothing exists except qubits and their entanglement patterns; concepts such as “vacuum,” “field,” “particle,” and “spacetime” are emergent descriptions. Within this framework, dark matter is identified with closed Bell pairs adhering to holographic boundaries, dark energy with the ground-state structure of the boundary register, leptons with open 2-qubit pairs, quarks with 3-qubit triangles, and baryons with 9-qubit *trinity* structures isomorphic to the Shor quantum error-correcting code. We argue that color confinement follows from the no-cloning theorem, that the Pauli exclusion principle emerges from entanglement monogamy combined with the non-existence of AME(4, 2) states, and that Hawking radiation is naturally described as discrete qubit ejection events from horizon registers. The framework provides structural answers to several open problems—the cosmological constant problem, the black-hole information paradox, and the lepton/quark asymmetry—and yields approximately thirteen testable quantitative predictions across cosmology, particle physics, and gravitational-wave astronomy. We emphasize that this work is a *programmatic conjecture*, not a completed theory; quantitative derivations and rigorous mathematical formulations are left as open problems for the community. The paper is presented as a dated archive of conceptual structure for potential confrontation with observations on a 5–15 year timescale.

## 1 Introduction

### 1.1 Motivation: The Crisis of $\Lambda$ CDM

As of 2026, the standard cosmological model ( $\Lambda$ CDM) faces several persistent observational tensions:

- The Hubble tension, with disagreement between local and CMB-inferred values of  $H_0$  exceeding  $6\sigma$  [36, 37].
- DESI 2024–2025 results suggesting dynamical dark-energy evolution rather than a pure cosmological constant [38].
- JWST observations of unexpectedly mature galaxies at high redshift [39].
- More than two decades of null results in direct dark-matter detection experiments [40, 41].

These tensions motivate alternative frameworks. Here we explore one: a strict information-theoretic ontology in which all of physics emerges from qubit entanglement.

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## 1.2 Approach

We adopt a single ontological principle: **only qubits and their entanglement patterns exist**. All other concepts—fields, particles, spacetime, vacuum—are emergent descriptions. From this principle we derive structural constraints (qubit number conservation, monogamy-based exclusion, AME-based dimensional limits) and from these constraints we attempt to recover the broad structure of standard physics, with several testable departures.

This approach is in the spirit of Wheeler’s “It from Bit” [1] but pushed further: not only is information physical, but information *is the only thing that is physical*. The framework also extends ideas from Verlinde’s emergent gravity [12, 13], Wen’s string-net liquid [14], and Szangolies’s qubit-based gauge group emergence [15].

## 1.3 Scope and Limitations

This work is presented as a *programmatically conjecture*, not a completed theory:

- No claim of mathematical completeness is made.
- Many quantitative results remain at the level of order-of-magnitude estimates or proposed derivation paths.
- The author is an independent researcher without academic affiliation; this document is offered for community evaluation rather than to establish authorial priority.
- The aim is to seed conceptual structure for further development; refinement, refutation, or extension by the broader research community is welcomed.

## 1.4 Organization

Section 2 establishes the qubit-only ontology and three strict conservation laws. Section 3 derives a particle hierarchy from qubit structures. Section 4 discusses dimensional emergence and the AME(4, 2) obstruction. Sections 5–7 treat dynamics, cosmology, and black holes. Section 8 catalogs testable predictions. Sections 10–13 discuss related work, open problems, and conclusions.

# 2 Foundations: Qubit-Only Ontology

## 2.1 The Single Principle

Our entire framework rests on one ontological commitment:

*There exist only qubits and their entanglement patterns. All other concepts are emergent.*

This minimalist stance excludes: vacuum as an independent substance, fields as fundamental entities, “creation from nothing,” and free creation/annihilation of qubits. It commits us to: a fixed-dimensional Hilbert space (modulo cosmological horizon expansion), strictly unitary evolution, and emergent treatment of all other physical concepts.

## 2.2 Three Strict Conservation Laws

From the qubit-only ontology, three strict conservation laws follow:

### Conservation A (Qubit Number).

$$N_{\text{total}} = \frac{A_{\text{cosmic}}}{4\ell_P^2 \ln 2} = \text{constant}, \quad (1)$$

where  $A_{\text{cosmic}}$  is the area of the cosmological horizon.  $N_{\text{total}}$  increases discretely only as the cosmological horizon expands.

### Conservation B (Total Energy).

$$E_{\text{total}} = \sum_{i=1}^{N_{\text{total}}} E_i = \text{constant}, \quad (2)$$

summed over all qubits. Local processes redistribute energy; the total is invariant.

**Conservation C (Entanglement Structure).** The total of all monogamy constraints (in the sense of Coffman-Kundu-Wootters [10]) is invariant under local rearrangement.

These conservation laws follow from standard quantum mechanical unitarity but are made explicit as foundational constraints of the framework.

## 2.3 Reinterpretation of “Vacuum”

In standard quantum field theory, “vacuum” is treated as a distinct ontological entity (the ground state of fields). Within our framework:

*“Vacuum” is the collective designation for the state in which all qubits occupy their ground state. It is not a separate entity.*

Concrete consequences:

- Vacuum energy = sum of qubit ground-state energies.
- “Virtual particles” = transient excitations of specific qubits (the qubits themselves are real; their excited states are short-lived).
- Vacuum polarization = local distortion of qubit configurations near charged qubits.
- Casimir effect = restriction of qubit excitation modes by boundary conditions.
- Higgs vacuum expectation value = collective ground-state synchronization pattern.

The phrase “borrowing energy from the vacuum” is replaced by: *exciting a specific qubit*; the lender and borrower are the same qubit.

## 2.4 Boundary Registers

By the holographic principle [4, 5], every qubit belongs to some *boundary register* associated with a horizon. Horizons are hierarchical:

- Each black hole’s event horizon
- The cosmological (de Sitter) horizon of the observable universe
- Local causal horizons (Rindler-type)

The total qubit count of the universe is the sum of qubits across all such boundary registers. A boundary register has two distinct aspects:

Aspect	Property	Fluctuation
Capacity (qubit count)	Geometric invariant	Deterministic, no fluctuation
Content (qubit states)	Quantum, dynamical	Quantum fluctuations

Table 1: Two aspects of boundary registers.

## 2.5 Boundary Register Temperature

Each horizon possesses a characteristic temperature:

$$T_H = \frac{\hbar c^3}{8\pi GMk_B} \quad (\text{Schwarzschild}) \quad (3)$$

$$T_{dS} = \frac{\hbar H}{2\pi k_B c} \quad (\text{de Sitter}) \quad (4)$$

We make a key identification:

$$\boxed{T_{\text{register}} = T_{\text{Hawking}}} \quad (5)$$

The boundary register is in a thermal state at the Hawking temperature of its horizon. From this single identification follow:

- Hawking radiation rate (Boltzmann factor)
- Bekenstein-Hawking entropy formula
- Black-body spectrum of Hawking radiation
- Thermal flow between hierarchical horizons

## 3 Particle Hierarchy from Qubit Structures

### 3.1 Classification by Qubit Count

We propose the following identification of particles with qubit structures:

Structure	State	Particle	Color	Size
1 qubit	free	gauge boson ( $\gamma, g$ )	gluon only	undefined
2 qubits	closed (Bell)	Dark Matter	none	boundary area
2 qubits	open type A	charged lepton ( $e, \mu, \tau$ )	structurally impossible	undefined (point-like)
2 qubits	open type B	neutrino ( $\nu$ )	structurally impossible	undefined (point-like)
3 qubits	open (triangle)	quark	exposed	cannot exist alone
3 qubits	bulk-projected	W, Z bosons	none	short-range
6 qubits	$3 + \bar{3}$	meson	singlet	hadron-scale
<b>9 qubits</b>	<b>trinity (Shor-isomorphic)</b>	<b>baryon</b>	<b>singlet</b>	<b>proton-scale</b>
many qubits	hierarchical	nuclei, atoms, molecules	singlet	various

Table 2: Particle hierarchy from qubit structures.

### 3.2 Lepton/Quark Asymmetry as Structural Necessity

The Standard Model's long-standing puzzle—*why do quarks alone carry color?*—admits a structural answer:

*Leptons are 2-qubit structures; quarks are 3-qubit structures. The difference  $2 \neq 3$  directly produces the presence or absence of color.*

Specifically, color charge is carried by 3-qubit triangle structures. Since 2-qubit structures contain no triangle, leptons are *structurally incapable* of carrying color charge or participating in strong interactions. This elevates SU(3) non-coupling for leptons from a phenomenological fact to a structural necessity.

### 3.3 The 9-Qubit Trinity = Baryon

The mechanism by which 3-qubit quarks combine into 9-qubit baryons follows from quantum-information principles. Five independent considerations converge on the same conclusion:

Perspective	Single 3-qubit (unstable)	9-qubit trinity (stable)
Topology	open disk ( $\chi = 1$ )	closed sphere ( $\chi = 2$ )
Entanglement saturation	3 exposed edges	all 21 edges shared
Statistics	forced anyon collapse	complex consistency
Quantum information	Shor-block extraction forbidden	complete Shor code
AME hierarchy	blocked at AME(4,2)	pure volumetric realization

Table 3: Five-fold convergence on 9-qubit trinity stability.

**Shor-code isomorphism.** The Shor 9-qubit quantum error-correcting code [8] has the structure

$$|\bar{0}\rangle = \frac{1}{2\sqrt{2}} \bigotimes_{i=1}^3 (|000\rangle + |111\rangle)_i \quad (6)$$

$$|\bar{1}\rangle = \frac{1}{2\sqrt{2}} \bigotimes_{i=1}^3 (|000\rangle - |111\rangle)_i \quad (7)$$

which is the hierarchical composition of three GHZ-like states (each on 3 qubits).

**Color confinement from no-cloning.** A crucial consequence: extracting a single 3-qubit block from a Shor-encoded state corresponds to extracting partial information from a quantum error-correcting code, which is forbidden by the no-cloning theorem [9]. Therefore:

*Color confinement is structurally derivable from the no-cloning theorem.*

The geometric realization is the *triauxmented triangular prism*: 9 vertices, 21 edges, 14 triangular faces, Euler characteristic  $\chi = 2$ , with every edge shared between exactly two faces (complete saturation).

### 3.4 Open 2-Qubit Pair = Lepton

An open 2-qubit pair (with partial internal entanglement and external entanglement capacity) is identified with a lepton.

**Size-undefined nature of the electron.** Three considerations give the electron's apparent point-like nature ( $r_e < 10^{-18}$  m experimentally) a structural origin:

1. **No closed surface:** a 2-qubit structure has no closed bounding surface in 3D.
2. **Not boundary-adhered:** unlike Bell pairs, open 2-qubit pairs float in bulk.

3. **Dynamical entanglement:** continuous environmental re-entanglement precludes a fixed shape.

The electron is thus not “a point-like particle” but “a structure to which the concept of size does not apply.”

Observation	Structural origin
Spin- $\frac{1}{2}$	open 2-qubit minimal half-integer spin carrier
Electric charge	residual U(1) coupling from monogamy excess
Mass $m_e \ll m_{\text{DM}}$	partial internal vibration < complete vibration
No color	absence of triangle structure
Weak coupling	dynamical coupling to 3-qubit (W, Z) structures

Five observed properties.

## 4 Dimensional Emergence

### 4.1 The Qubit Ladder

The dimensionality of spacetime emerges in stages corresponding to qubit count:

Qubits	Simplex	Shape	Dimension emerged	BH stage
1	0-simplex	point	0D	—
2	1-simplex	edge	1D = pre-spatial	proto-BH (DM)
3	2-simplex	triangle	2D = boundary surface	semi-complete BH
4	3-simplex	tetrahedron	3D, but blocked by AME(4, 2)	—
<b>9</b>	<b>trinity</b>	<b>triaug. prism</b>	<b>3D (volume)</b>	<b>minimal complete BH</b>

Table 4: Dimensional emergence through qubit ladder.

### 4.2 The AME(4, 2) Obstruction

The Higuchi-Sudbery theorem [11] establishes that no Absolutely Maximally Entangled state on 4 qubits in dimension 2 exists. This implies:

- “Perfect 4-qubit tetrahedra” are mathematically forbidden.
- 3D volume cannot be perfectly realized at 4-qubit scale.
- This obstruction provides an intrinsic origin for quantum-gravitational noise in 3D space.

The AME( $n, 2$ ) existence pattern for small  $n$ :

$n$	2	3	4	5	6	7
AME exists	✓	✓	×	✓	✓	×

The framework requires skipping over  $n = 4$  to  $n = 5$  (open 2+3 composite, intermediate states) or  $n = 9$  (3:3:3 trinity, primary route).

### 4.3 Two-Stage Activation of the Pauli Exclusion Principle

Corresponding to dimensional emergence, the Pauli exclusion principle activates in two stages:

**Phase 3-2 (3-qubit triangle, 2D): proto-exclusion** Antisymmetric components in Young-tableau decomposition; anyonic statistics permitted.

**Phase 3-3 (9-qubit trinity, 3D volume): standard Pauli exclusion** Spin-statistics theorem holds; fermion/boson dichotomy fixed.

The roots of the exclusion principle reside in the qubit layer itself:

1. Entanglement monogamy (CKW inequality)
2. AME(4, 2) non-existence
3. Singlet antisymmetry under exchange

These pre-existing repulsion structures are projected onto spacetime as the observed Pauli exclusion principle.

## 5 Dynamics

### 5.1 Reaction Cascade

The central dynamics consist of three hierarchical reactions:

$$\text{Stage 1: } 2\text{-qubit} + 1\text{-qubit} \rightleftharpoons 3\text{-qubit} \quad (T_c \sim 10^{16} \text{ GeV}) \quad (8)$$

$$\text{Stage 2: } 3 \times 3\text{-qubit} \rightleftharpoons 9\text{-qubit trinity} \quad (T_{\text{QCD}} \sim 200 \text{ MeV}) \quad (9)$$

$$\text{Stage 3: } 3\text{-qubit} \rightleftharpoons 2\text{-qubit} + 1\text{-qubit} \quad (\text{strongly suppressed}) \quad (10)$$

Temperature freeze-out of these reactions determines cosmological density ratios  $\Omega_{\text{DM}}$ ,  $\Omega_b$ ,  $\Omega_\gamma$ .

### 5.2 Topological Boundary Transitions

Open $\leftrightarrow$ closed transitions of qubit pairs are subject to a special constraint:

*Open $\leftrightarrow$ closed qubit-pair transitions are forbidden in bulk; they must proceed via the boundary.*

This implies that closed Bell pairs (DM) cannot appear directly as products of bulk reactions; their formation requires boundary mediation.

### 5.3 Boundary-Bulk Qubit Exchange

Major matter-related processes are described as qubit exchanges between boundary registers and bulk:

In all processes, the total qubit number is strictly conserved.

Process	Qubit pathway
Matter formation	boundary register $\rightarrow$ bulk projection
Pair annihilation	bulk particle qubits $\rightarrow$ boundary register + photons
Pair creation	boundary register activation + photon absorption $\rightarrow$ bulk
BH formation	bulk matter qubits $\rightarrow$ horizon register
Hawking radiation	horizon register $\rightarrow$ bulk emission

## 6 Cosmology

### 6.1 Cosmic History Scenario

1. **Phase 1 (pre-spatial):** Only qubit structures exist; no space, time, or symmetry.
2. **Phase 2 (dynamic equilibrium):** Stage-1 reaction in dynamic equilibrium at Planck energies.
3. **Phase 3-1 (2D emergence)** at  $T_c \sim 10^{16}$  GeV: 3-qubit dominance; 2D boundary surface emerges; proto-exclusion activates.
4. **Phase 3-2 (“2D era”):** Tessellation by 3-qubit triangles completes the holographic boundary. This phase is consistent with CDT dimensional reduction observations [35].
5. **Phase 3-3 (3D emergence):** 9-qubit trinity formation freezes Stage 2; true 3D volume; standard Pauli exclusion fixed.
6. **Phase 4 (vibrational inflation):** Distance-dependent exclusion pressure drives oscillatory inflation; cumulative expansion  $\sim 60$  e-folds; oscillation damping = reheating.
7. **Phase 5 (vacuum structure established):** Boundary register settles; multi-qubit structures (baryons, nuclei) form from successful Stage-1 transitions; failed transitions remain as DM-precursor Bell pairs.
8. **Phase 6 (matter-dominated era):** Hot DM clusters form; Bell-pair register fluctuations observed as cold DM.
9. **Phase 7 (dark-energy era / present):**  $\Omega_{\text{DE}} \approx 0.68$  from Bell-pair register average density;  $\Omega_{\text{DM}} \approx 0.27$  from fluctuations and excited clusters.
10. **Phase 8 (BH formation / matter consumption):** Falling matter and pair annihilation introduce qubits to boundary registers.
11. **Phase 9 (de Sitter asymptote):** All matter incorporated into boundary registers; only registers remain.

### 6.2 Vibrational Inflation

Pressure from distance-dependent exclusion (Fermi-gas-like):

$$P = \frac{2}{5}nE_F, \quad E_F \propto n^{2/3}, \quad P_{\text{internal}} \propto n^{5/3} \quad (11)$$

The effective pressure  $P_{\text{eff}} = P_{\text{internal}} - P_{\text{external}}$  changes sign with density, driving oscillation:

- Phase 4a: high density, strong positive pressure  $\rightarrow$  rapid expansion
- Phase 4b: inertial overshoot of equilibrium distance

- Phase 4c: negative pressure  $\rightarrow$  recoil contraction
- Phase 4d: damped oscillation; energy dissipation per cycle
- Phase 4e: oscillation termination = reheating

This picture has thematic affinity with bouncing/cyclic cosmology [33, 34] but proceeds via discrete oscillation rather than continuous bounce.

### 6.3 Unified Description of the Dark Sector

The boundary register in different states gives rise to all “dark” phenomena:

Register state	Observed phenomenon	Contribution
Uniform ground state	Dark Energy (DE)	$\Omega_{\text{DE}} \approx 0.68$
Ground-state local fluctuations	cold DM (axion-like)	part of $\Omega_{\text{DM}}$
Excited clusters	hot DM	galactic halos
Collective vibrational modes	Higgs boson	mass attribution
Sync with register	particle masses	$mc^2 = \hbar\omega_{\text{sync}}$

### 6.4 Resolution of the Cosmological Constant Problem

The standard QFT prediction

$$\rho_{\text{vac}}^{\text{QFT}} \sim M_{\text{Planck}}^4 \sim 10^{120} \rho_{\text{DE}}^{\text{obs}} \quad (12)$$

assumes *independent* contributions from each fundamental field. In our framework:

*All “fields” are emergent excitation modes of the single qubit register. Zero-point energies cannot be summed independently; the total is given by a single sum over the register, naturally yielding a small value.*

A complementary thermal explanation: the cosmological horizon temperature  $T_{dS} \sim 10^{-30}$  K places the boundary register essentially in its ground state, with Boltzmann-suppressed excitations. Therefore  $\rho_{\text{DE}}$  is naturally small.

## 7 Black Holes and Information

### 7.1 Black Hole as Condensed Boundary Register

A black hole is interpreted as a region where bulk matter has been incorporated into a boundary register:

- BH formation = quantization of falling matter into horizon register at the event horizon.
- BH “interior” is materially absent; the horizon is everything.
- Singularities do not form (no matter reaches them).
- Quantum gravity is unnecessary (spacetime terminates at the horizon level).

This aligns with AMPS firewall considerations [19], Mathur’s fuzzball proposal [20], and the broader emergent-gravity program.

## 7.2 Hawking Radiation as Qubit Ejection

In our framework, Hawking radiation is described as discrete events at the horizon:

1. Two adjacent horizon qubits, both in ground state.
2. Local qubit-qubit interaction excites both.
3. Asymmetric energy distribution: one qubit returns to ground state (releasing energy); the other absorbs and exceeds horizon binding.
4. Result: one qubit remains on horizon, one ejects to bulk as a single-qubit photon. Horizon area decreases by one Planck plaquette.

This is equivalent to the standard QFT virtual-pair picture but recasts “negative-energy partner” as “qubit returning to ground state,” avoiding philosophical issues with negative-energy particles.

## 7.3 Automatic Resolution of the Information Paradox

Each ejected qubit was previously entangled with remaining horizon qubits. As evaporation progresses, entanglement is transferred outward. The Page curve [7] arises automatically: radiation entanglement entropy peaks at half-evaporation. By complete evaporation, all original information has been transferred to the external Hawking radiation.

*Hawking radiation = stepwise readout of black-hole information.*

No firewall is required; no information is lost; unitarity is preserved by construction.

## 7.4 Unification of Four Major Processes

The framework unifies four processes under a single mechanism (boundary-bulk qubit exchange):

Process	Direction	Pathway
BH formation	bulk $\rightarrow$ horizon	matter qubits absorbed by register
Hawking radiation	horizon $\rightarrow$ bulk	register qubits ejected
Pair annihilation	bulk $\rightarrow$ boundary	particle qubits absorbed + photons emitted
Pair creation	boundary $\rightarrow$ bulk	register activated + photons absorbed

All processes preserve total qubit number, total energy, and unitarity by construction.

## 7.5 Hawking Thermodynamics from Register Statistics

The identification  $T_{\text{register}} = T_{\text{Hawking}}$  yields:

**Hawking radiation rate (Boltzmann-suppressed):**

$$\text{rate} \propto \exp(-E_{\text{eject}}/k_B T_H) \quad (13)$$

**Black-body spectrum:** Register at  $T_H$  in thermal equilibrium  $\rightarrow$  thermal spectrum of ejected qubits.

**Bekenstein-Hawking entropy:**

$$S_{\text{BH}} = \frac{A}{4\ell_P^2} \quad (14)$$

arises as thermal entropy of the register at  $T_H$ .

**Inter-horizon thermal flow:** Temperature difference between BH horizon ( $T_H \sim 10^{-7}$  K for stellar mass) and cosmological horizon ( $T_{dS} \sim 10^{-30}$  K) drives Hawking radiation as heat flow from high-temperature to low-temperature register.

## 8 Testable Predictions

### 8.1 Quantitative Predictions

Observable	Predicted value	Verification	Timeline
Inflation temperature $T_c$	$\sim 10^{16}$ GeV	CMB B-mode, primordial GW	2032+
Tensor-to-scalar ratio $r$	0.001–0.01	LiteBIRD	2032+
CMB $\mu$ -distortion	$\sim 10^{-7}$	PIXIE/PRISM-class missions	proposed
Primordial GW peak frequency	$10^{-9}$ – $10^{-7}$ Hz	PTA (NANOGrav, etc.)	ongoing
CMB power-spectrum oscillations	specific peaks/dips	Planck + successors	verifiable
Primordial GW oscillation traces	discrete frequency structure	NANOGrav, LISA	ongoing
$\Omega_{DM} \approx 0.27$	cascade freeze-out	Planck, DESI consistency	existing
$\Omega_{DE} \approx 0.68$	register ground state density	Planck, DESI	existing
DM/baryon $\approx 5.4$	freeze-out residual ratio	same as above	existing
DM mass distribution	bimodal (hot + cold DM)	direct-detection mass scans	long-term
511 keV photon total energy	1022 keV with $< 1$ eV deviation	topological transition test	existing apparatus
Galactic-center DM density	micro-enhancement proportional to annihilation rate	gamma-ray excess observations	ongoing
GZK-cutoff anomaly	partial explanation via qubit ejection	cosmic-ray observatories	ongoing

Table 5: Quantitative testable predictions.

### 8.2 Qualitative Predictions

1. Direct DM detection will remain perpetually null (boundary adherence).
2. DM halo shape correlates with rotation (boundary Kerr-like rotation).
3. Large-scale structure exhibits subtle anisotropy (3-qubit transition initial conditions).
4. Quantum gravity research is misdirected (no spacetime exists at Planck scale).
5. No matter reaches BH interior (qubit-ization at horizon, no singularity).
6. Gravitational-wave B-mode shows characteristic spectral tilt (oscillatory transition).

7. All interactions describable in entanglement-mode language (consistent with Wen’s string-net framework).
8. Leptons cannot acquire color charge (structural).
9. Quarks cannot be isolated (Shor-block extraction = no-cloning violation).
10. Pair annihilation isomorphic to micro-scale BH formation/evaporation.
11. Bullet Cluster constraint automatically satisfied (2+2 volume formation forbidden → DM self-interaction zero).
12. Qubit-ejection effects at high energy are Boltzmann-suppressed at all currently accessible energies.
13. Hawking radiation automatically preserves information (Page curve, no firewall).

### 8.3 Verification Strategy: Gravitational Probes of Pre-Inflationary Physics

Channel	Probe	Era explored
Primordial GW (B-mode)	LiteBIRD (2032), CMB-S4	end of inflation
Stochastic GW background	PTA, LISA (2035), DECIGO	post-inflation reheating
CMB spectral distortion	PIXIE/PRISM	$z \approx 10^6$
Cosmic neutrino background	PTOLEMY etc.	$z \approx 10^9$

CMB  $\mu$ -distortion at  $z \approx 10^6$  is particularly powerful as a direct probe of the end of inflation.

## 9 Internal Consistency

### 9.1 Five-Path Convergence on the Quantum Matter Scale

The proton size ( $\sim 10^{-15}$  m) emerges from five independent paths within the framework:

- **Path A:** holographic degree-of-freedom volumization
- **Path B:** exclusion-principle action range
- **Path C:** exclusion equilibrium distance = volume/area ratio
- **Path D:** triaugmented prism size of 9-qubit trinity
- **Path E:** Bell-pair register local fluctuation wavelength

The convergence is taken as evidence of internal consistency.

### 9.2 Five-Perspective Convergence on Trinity Stability

As detailed in Section 3, five perspectives (topology, entanglement saturation, statistics, quantum information, AME hierarchy) all converge on the conclusion that single 3-qubit structures are unstable while 9-qubit trinities are stable.

## 10 Comparison with Existing Frameworks

This work draws on and extends several existing programs:

**Field-theoretic DM candidates.** Sterino model [29], Cooper-pair DM [30], neutrino superfluidity [31], singlet scalar DM [32].

**Holographic DM origins.** Holographic DM [25], bulk-BH cosmological DM [26], emergent DM on holographic screens [27], DM from holography via CKN bound [28].

**Quantum-information spacetime emergence.** Szangolies [15], Wen’s string-net liquid [14], Van Raamsdonk’s entanglement-spacetime correspondence [22], ER=EPR [21], CKN bound [23].

**Emergent gravity / quantum gravity rejection.** Verlinde [12, 13], Jacobson [16], Padmanabhan [17], Sakharov [18], AMPS firewall paradox [19], Mathur fuzzball [20].

**Bouncing/cyclic cosmology.** Ekpyrotic/cyclic universe [33], loop quantum cosmology [34], matter-bounce inflation, quintessential inflation.

**Quantum error correction and physics.** Shor code [8], holographic codes (HaPPY) [24].  
The novelty of the present work is the *integrated synthesis*: not the individual elements (most of which exist in the literature), but the unified framework that organizes them under a single qubit-only ontology.

## 11 Open Problems and Future Work

### 11.1 Quantitative Challenges

The following derivations remain incomplete:

- Cascade equilibrium constants and the physical determination of each  $\Delta E$ .
- Thermal-relic-style calculation of  $\Omega_{\text{DM}}$ ,  $\Omega_{\text{DE}}$ ,  $\Omega_b$ .
- DM/baryon ratio from freeze-out temperatures.
- Determination of vibration amplitude and period in inflation.
- Three-generation lepton mass ratios from open-2-qubit mode hierarchy.
- Quantitative qubit-ejection rate and its energy dependence.
- Higgs vev (246 GeV) from register vibrational coupling scale.

### 11.2 Internal Consistency Issues

- Mathematical formalism of the boundary register (Hilbert space construction, Hamiltonian).
- Uniqueness of the triaugmented prism realization for the 9-qubit trinity.
- Mathematical formulation of three-generation discrete mode hierarchy.
- Mechanism for excited-Bell-pair generation and decay.

### 11.3 Observational Consistency

- $r < 0.036$  constraint excludes Planck-scale direct inflation (consistent with  $T_c \sim 10^{16}$  GeV).
- $N_{\text{eff}}$  and structure-formation impacts require detailed computation.
- CMB power-spectrum oscillation predictions need preliminary verification against existing Planck data.
- 511 keV photon energy at  $< \text{eV}$  precision: feasibility of direct test of topological transition rule.

### 11.4 Literature

A thorough review of recent works (Szangolies 2025, Fichet 2026, Cooper-pair DM 2024, holographic codes) is needed to refine the boundary between this work and existing literature.

## 12 Discussion

### 12.1 Philosophical Position

If the framework is correct, the following holds:

*Physics is the organization of information.*

This is a radicalization of Wheeler’s “It from Bit”: not only do informational principles underlie physics, but *nothing exists except information patterns*. There is some affinity to Leibniz’s monadology, but recast in modern quantum-information terms.

### 12.2 Position Relative to Mainstream Physics

This framework does not contradict standard physics; rather, it proposes that standard QFT is the *effective field theory* of the underlying qubit register. Specifically:

- All standard-model predictions follow automatically as low-energy consequences.
- Deviations would appear only at extreme energies (Planck-scale) or in cosmological observations.
- The cosmological constant problem and the BH information paradox are resolved structurally rather than via additional fine-tuning or new physics.

The framework is therefore positioned as a *complement* to mainstream physics, not a replacement.

## 13 Conclusion

We have presented a programmatic conjecture for cosmology and particle physics based on a strict qubit-only ontology. The framework:

1. Identifies dark matter, dark energy, Higgs phenomenology, and particle masses as different states of a unified Bell-pair boundary register.
2. Derives lepton/quark asymmetry, color confinement, and the Pauli exclusion principle from quantum-information principles.

3. Recasts Hawking radiation as discrete qubit-ejection events, automatically resolving the information paradox.
4. Proposes structural resolutions to the cosmological constant problem and several open issues in  $\Lambda$ CDM.
5. Yields approximately thirteen testable quantitative predictions and many qualitative ones.

The framework is not a completed theory. Quantitative derivations and rigorous mathematical formulations remain open. We submit this document as a dated archive of conceptual structure, for evaluation, refinement, refutation, or extension by the broader research community.

We expect that observations on a 5–15 year timescale—LiteBIRD, LISA, PIXIE-class missions, ongoing PTA campaigns, the Vera C. Rubin Observatory, and high-precision pair-annihilation measurements—will provide opportunities to test specific predictions of this framework.

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## Statement of Purpose

The author is an independent researcher without formal academic affiliation. This document is submitted as a programmatic conjecture rather than a claim of completed theory. The aim is to seed ideas for community development, not to establish authorial priority. The author welcomes refinement, refutation, and extension by the broader research community.

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