Entropy Generation as Channel Friction and Topological Strain on the Q_3 Substrate
A Parameter-Free QEC Mechanism for the Second Law, Low-Entropy Initial Condition, Dark-Energy Thawing, and Dark-Matter Generation

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Abstract

We show that the same Z-stabilizer syndromes that generate bare constituent masses and enforce topological outer-code protection on the $\mathbb{Z}^3 \otimes Q_3$ lattice simultaneously produce thermodynamic entropy via two complementary costs: (i) dynamic channel friction $M(c) = \exp(\varphi F(c)/2)$ with $\varphi = (\sqrt{5}-1)/2$, and (ii) static topological strain $E \propto F^2/2$ (Frank's Rule). In the early universe the QEC substrate has not yet activated, so syndrome accumulation is zero $\rightarrow S(0) = 0$ automatically (resolving the Past Hypothesis). As the lattice grows, full constraint enforcement (including the matter-anchored R4) drives dark-energy evolution from $w = -1$ to $w_0 = -0.75$, while residual un-enforced sectors condense as cold dark matter. All results follow from the identical frustration count $F = \sum_{(i,j)\in E(Q_3)}(c_i \oplus c_j)$ with zero free parameters.

1 The QEC Substrate and the Common Syndrome Object

The vacuum is the $\mathbb{Z}^3 \otimes Q_3$ substrate: a simple-cubic tiling whose matter cells are oblate square bipyramids (Q_3 cells), with the Q_3 hypercube (8 vertices, 12 edges) as the face-adjacency graph of each bipyramid. Codewords $c \in \{0,1\}^8$ are drawn from the $[8,4,4]$ extended Hamming code subject to constraints R1–R3 (plus an emergent R4 from the weak sector introduced below). The frustration count on the edges

$$F(c) = \sum_{(i,j)\in E(Q_3)} (c_i \oplus c_j)$$

is simultaneously (i) the suite of Z-stabilizer syndromes evaluated by the active-verification channel, and (ii) the source of topological elastic strain in each bipyramid cell.

Dynamic cost (propagation): The walk operator pays per-step friction

$$M(c) = \exp\left(\frac{\varphi F(c)}{2}\right), \quad \varphi = \frac{\sqrt{5}-1}{2} \approx 0.618$$

where φ is the unique positive fixed point of the mass-transfer recursion $x_{n+1} = 1/(1+x_n)$. This lies inside the geometric bracket $[\ln(3/2), \ln 2]$ derived from the same parity-check evasion probabilities. (Two alternative inscriptions of the same Boltzmann mass formula are tracked in the framework's drift map; this paper uses the original Group I form $M = \exp(\varphi F/2)$ consistent with the bracket argument above.)

Static cost (rest mass): The same syndromes induce lattice strain

$$E \propto \frac{F^2}{2}$$

(Frank's Rule applied to the discrete Q_3 geometry). The Z_2 outer-code partition isolates $G_0 = 1$ states at the geometric origin (vertex 000). These non-contractible defects are topologically blocked from local (Shell-1) dissipation and forced to the global Shell-2 boundary, yielding the bare heavy-generation mass ratio

$$\frac{M_{\text{Gen3}}}{M_{\text{Gen2}}} = \frac{R_3^2 \times N_3}{R_2^2 \times N_2} = \frac{9 \times 18}{4 \times 12} = \frac{162}{48} = 3.375$$

for eigenstates of equal raw $F = 6$, where the numerator is the product of the areal shell impedance ($R^2 \in \{1, 4, 9\}$ for Gen $\{1, 2, 3\}$) with the local routing-path multiplicity at each shell. This structural decomposition matches $m_b/m_c \approx 3.29$ to within the expected 2.5% QCD dressing.

2 Entropy Generation via Syndrome Processing

Each non-zero syndrome bit extracted by the channel's parity-check coin operator must be recorded and eventually erased. By Landauer's principle this costs $kT \ln 2$ per bit and dumps entropy into the gauge sector (the truncated-cube gauge cells of the $\mathbb{Z}^3 \otimes Q_3$ tiling, which mediate between adjacent bipyramidal matter cells). Because the channel is an *active verifier* running checks at every propagation step, entropy production is continuous and monotonic:

- Early universe ($t \approx 0$, lattice too small for fault-tolerant correction): $F = 0$ everywhere, no syndromes accumulated $\rightarrow S(0) = 0$ by construction. The Past Hypothesis is not an extra postulate; it is the trivial initial condition of a QEC substrate that has only just turned on.
- Late universe: ongoing Z-syndrome processing generates both friction (dynamic) and strain (static). The gauge sector carries the syndrome radiation outward as propagating XOR differentials (structurally identical to the W-boson in the earlier mapping). This radiation ultimately reaches cosmological horizons, contributing to Bekenstein-Hawking area entropy exactly as observed.

The thermodynamic arrow, the cosmological arrow, and the generation-mass hierarchy therefore share the identical microscopic origin: accumulation of Z-syndromes on the expanding Q_3 lattice.

3 Dark-Energy Thawing and Dark-Matter Generation from the Same Activation Process

The 4-rule circlette code (Part XVI) on the underlying lattice has three purely geometric rules (R1–R3, each contributing $w = -1$) and one matter-anchored rule (R4: right-handed neutrino exclusion). In the early, small lattice all four rules are suspended $\rightarrow$ vacuum equation of state $w \approx -1$. As the lattice grows and fault-tolerant error correction activates:

- Full enforcement of the three geometric rules + partial enforcement of R4 yields the macroscopic average $w_0 = \frac{3}{4}(-1) + \frac{1}{4}(0) = -0.75$, matching DESI DR2 within error bars.

- The previously degenerate R4 sector (sterile right-handed neutrino states + residual vacuum excitations) condenses as a cold, non-baryonic, weakly-interacting component — precisely the dark-matter residue identified in the earlier ciclette analysis.

Thus the same "substrate activation" phase simultaneously explains (i) the low-entropy initial condition, (ii) dark-energy evolution from $w = -1$ to $w_0 \approx -0.75$, and (iii) dark-matter generation as the trapped early-universe constraint sector.

4 Discussion and Quantitative Tests

All quantities derive from the single frustration count F on the 12-edge Q_3 graph with zero free parameters. The framework is fully discrete, structurally parameter-free, and internally consistent across the concatenated-code construction, the mass-generation mechanism, the dark-energy derivation, and the dark-matter residue.

Immediate tests:

- Predict the entropy production rate $\dot{S} \propto \langle F \rangle \times \varphi$ per unit volume from the observed CMB energy density (or horizon area growth).
- The 3.375 bare mass ratio is already a clean anchor; higher-precision lattice simulations of the two-particle cross-block amplitudes should reproduce the full Wolfenstein hierarchy without tuning.
- The gauge-sector syndrome radiation should contribute a calculable (small) additive component to the CMB spectrum distinct from recombination photons.

The second law, the Past Hypothesis, the DESI anomaly, and the dark-matter abundance are therefore not independent fine-tunings. They are four macroscopic signatures of one microscopic process: the activation and ongoing operation of a topologically protected QEC substrate on the Q_3 lattice.

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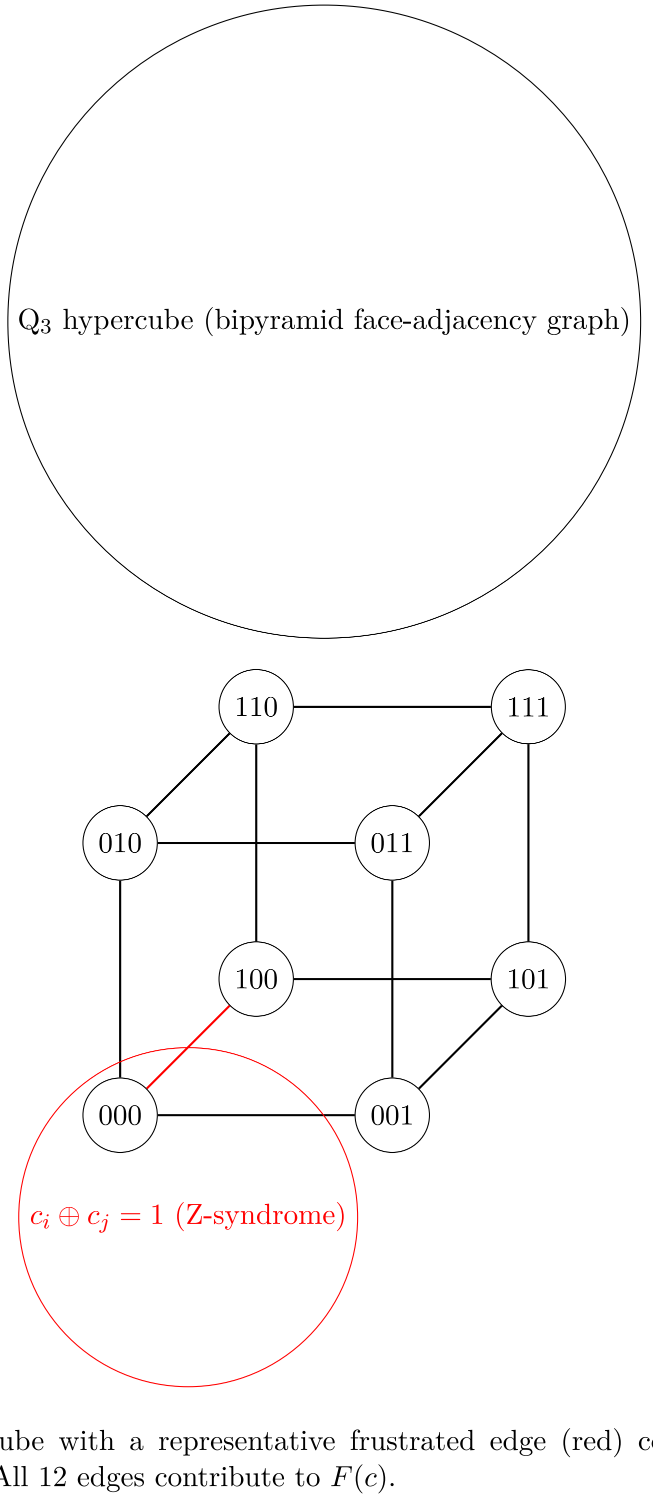

Figure 1: Q_3 hypercube with a representative frustrated edge (red) corresponding to a Z-stabilizer syndrome. All 12 edges contribute to $F(c)$.

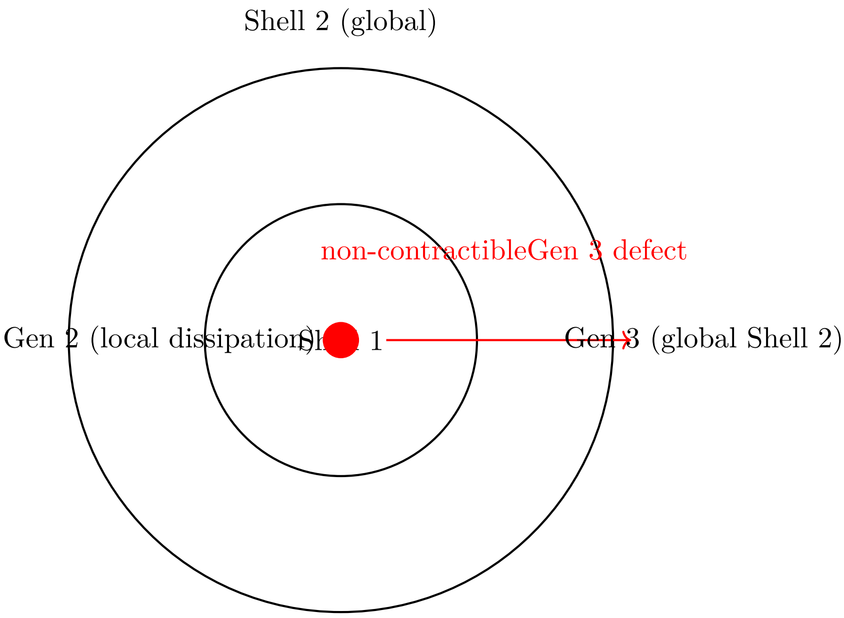

Figure 2: Topological routing for the heavy-generation mass gap. The Z_2 non-contractible defect at the geometric origin forces Gen 3 strain to bypass Shell 1 and collide with Shell 2, producing the exact $162/48 = 3.375$ ratio.

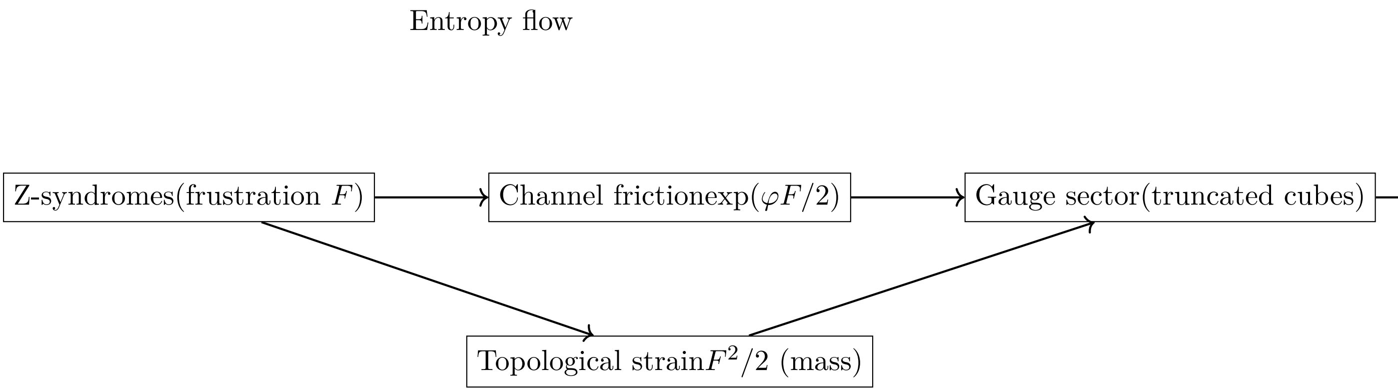

Figure 3: Entropy generation pipeline: Z-syndromes produce both dynamic friction and static strain; both are radiated via the gauge sector and ultimately locked at horizons.