

Black Holes as Computational Phase Transitions

Consequences of the Circlette Framework for Horizons,
Hawking Radiation, and the Information Paradox

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Abstract

We apply the circlette framework developed in the companion paper *It from Bit, Revisited* [1] to black hole physics. In that framework, the Standard Model’s 45 fermions are codewords of an 8-bit error-correcting code on a holographic lattice, governed by a unique update rule—a CNOT gate at the bridge-isospin boundary—that *is* the weak interaction. Here we show that this framework provides microscopic mechanisms for four central problems in black hole physics: (1) the event horizon is a *computational phase transition* where the CNOT gate ceases to execute, freezing the weak interaction and restoring quark-lepton symmetry; (2) Hawking radiation is the thermal decay of broken codewords whose error-correction threshold is exceeded by horizon-divergent Fisher curvature; (3) the firewall paradox is resolved by the discreteness of logic gates—there is no “half-CNOT”; (4) the information paradox dissolves because infalling information is frozen into the horizon’s Fisher metric correlations and released during evaporation. These results follow from the established framework without additional assumptions.

1 Introduction

The companion paper [1] established that the Standard Model fermion spectrum can be encoded as 45 valid codewords of an 8-bit ring (the circlette), governed by four local constraints on a holographic lattice. The paper’s central dynamical result was the discovery that the information action principle selects a *unique* non-trivial update rule:

$$I_3(t+1) = I_3(t) \oplus LQ(t) \tag{1}$$

This rule is a CNOT gate with the bridge bit LQ as control and the isospin bit I_3 as target. It *is* the weak interaction: quarks ($LQ = 1$) oscillate in isospin doublets at period 2, while leptons ($LQ = 0$) are fixed points.

The companion paper also established that gravity is lattice tension (Fisher information curvature), that the Planck mass corresponds to computational saturation, and that lattice-induced decoherence scales with local Fisher curvature. It posed—but did not fully answer—the question of what happens at the event horizon.

This paper answers that question. We show that the circlette framework provides concrete, calculable mechanisms for the four deepest problems in black hole physics, without introducing any new assumptions beyond those already established.

2 Background: The Computational Architecture

We briefly summarise the results from [1] needed here.

2.1 The circlette code

Each fermion is an oriented ring of 8 bits:

$$\underbrace{G_0 G_1}_{\text{generation}} \quad \underbrace{C_0 C_1}_{\text{colour}} \quad \underbrace{LQ}_{\text{bridge}} \quad \underbrace{I_3 \chi W}_{\text{electroweak}}$$

Four local constraints (R1–R4) select 45 valid matter states from 256 possibilities. The code has minimum distance $d = 2$ (single-bit errors move a codeword to an invalid state, detectable by the constraints).

2.2 The unique update rule

The information action principle—minimising bit-flip cost subject to invertibility and spectrum preservation—selects the rule (1) uniquely. Its properties:

- CNOT gate: LQ is a read-only control line; I_3 is the target.
- Quarks oscillate ($u \leftrightarrow d$, $c \leftrightarrow s$, $t \leftrightarrow b$) at period 2.
- Leptons are fixed points (period 1, no internal clock).
- Average bit-flip cost: $36/45 = 0.80$ bits per tick.
- Involution: $M^2 = I$ over \mathbb{F}_2 .

2.3 Gravity and computational saturation

The Fisher information metric $\mathcal{F}_{\mu\nu}$ on the lattice’s statistical states generates Riemannian curvature from pattern density. The lattice has finite bandwidth: one bit-operation per Planck time (t_P) per Planck area (ℓ_P^2). A pattern with winding number ν in a region of area σ^2 is sustainable only if:

$$\nu \leq \frac{\sigma^2}{\ell_P^2} \quad (2)$$

Saturation produces a black hole: the lattice’s processing capacity is entirely consumed by maintaining the boundary geometry.

2.4 Lattice-induced decoherence

Patterns propagating on the lattice lose coherence at a rate:

$$\Gamma_{\text{dec}} \propto \nu^2 \mathcal{F}^{\text{local}} \quad (3)$$

where ν is the pattern’s winding number and $\mathcal{F}^{\text{local}}$ is the local Fisher curvature.

2.5 Time as a computational product

The companion paper showed that the isospin oscillation *is* the quark’s internal clock, and that time dilation is a bandwidth constraint: at velocity v , the fraction of lattice updates available for internal dynamics is $(1 - v^2/c^2)^{1/2}$. When $v \rightarrow c$, the internal clock stops.

3 The Horizon as a Computational Phase Transition

3.1 Clock death

At the event horizon, the escape velocity equals c . In the lattice framework, this means that *all* available computational bandwidth is consumed by the gravitational dynamics.

To see why, consider the computational budget at a given lattice site. The total capacity is one bit-operation per Planck time per Planck area. This budget must service three demands:

1. **Geometry maintenance:** processing the entanglement structure of the horizon—the “complexity growth” identified with Susskind’s Complexity Equals Action conjecture [2] in the companion paper. Near a black hole, this cost scales as $\mathcal{F}^{\text{local}}/\mathcal{F}^{\text{vac}}$: the ratio of local Fisher curvature to the vacuum baseline.
 2. **Pattern propagation:** moving circlette patterns across the lattice (external dynamics).
 3. **Internal dynamics:** executing the CNOT rule on each pattern (the weak interaction).
- Define the *free bandwidth* at position \mathbf{x} :

$$B_{\text{free}}(\mathbf{x}) = B_{\text{total}} - B_{\text{geom}}(\mathbf{x}) \quad (4)$$

where $B_{\text{total}} = 1/(\ell_P^2 t_P)$ per Planck cell and $B_{\text{geom}} \propto \mathcal{F}^{\text{local}}$. At the horizon, $\mathcal{F}^{\text{local}}$ diverges, so $B_{\text{geom}} \rightarrow B_{\text{total}}$ and $B_{\text{free}} \rightarrow 0$. The lattice is fully committed to maintaining the boundary geometry; there are no spare operations for anything else.

The CNOT rule (1) requires one bit-operation per quark per tick. With $B_{\text{free}} = 0$, the rule cannot execute. This is not time dilation (a continuous slowing of the clock) but **clock death**: the complete cessation of internal dynamics.

For quarks, the consequence is immediate: the period-2 oscillation $u \leftrightarrow d$ stops. The isospin bit I_3 is frozen at whatever value it had when the pattern crossed the horizon. Without the oscillation, the quark has no internal clock—it is computationally indistinguishable from a lepton. The quark’s “world tube” (a pattern oscillating as it propagates) collapses to a “world line” (a static bit-pattern frozen at the boundary).

3.2 Symmetry restoration at the horizon

The quark-lepton distinction in the circlette framework is *dynamical*: it is the difference between patterns that oscillate under the CNOT gate ($LQ = 1$) and patterns that are fixed ($LQ = 0$). When the gate ceases to execute, this distinction vanishes. Both quarks and leptons reduce to static bit-patterns with no internal dynamics.

This is a form of **symmetry restoration**—but achieved by a mechanism fundamentally different from the high-energy GUT restoration described in [1]. At GUT energies, the bridge bit LQ enters quantum superposition, blurring the quark-lepton boundary from above. At the horizon, the CNOT gate is frozen by computational starvation, erasing the boundary from below.

Table 1: Two routes to quark-lepton symmetry restoration.

	GUT restoration	Horizon restoration
Mechanism	LQ enters superposition	CNOT ceases to execute
Energy scale	$\sim 10^{16}$ GeV	Any mass $\geq m_P$
Bridge bit	Uncertain	Frozen (definite but irrelevant)
Cause	High energy	Zero bandwidth
Result	Leptoquark transitions	Static bit-patterns

3.3 The two-zone structure

The horizon divides the lattice into two computational zones:

- **Sub-saturated zone** (exterior): The CNOT gate executes normally. The Standard Model operates. Quarks oscillate, leptons are fixed, gauge symmetries are active.
- **Saturated zone** (interior/horizon): All bandwidth is consumed by geometry maintenance. The CNOT gate is frozen. Gauge symmetries are computationally deactivated. The “Standard Model” does not apply.

The transition between zones is determined by the free bandwidth (4). The CNOT is active wherever:

$$B_{\text{free}}(\mathbf{x}) > B_{\text{CNOT}} \quad (5)$$

where $B_{\text{CNOT}} = 1$ bit-operation per tick is the cost of one CNOT execution. At the horizon, $B_{\text{free}} \rightarrow 0$, and the inequality fails sharply.

4 Hawking Radiation as Code Failure

4.1 The error-correction threshold

The 45-state circlette code is protected by four local constraints (R1–R4). A single-bit error moves a valid codeword to an invalid state, which the constraints detect. The code distance is $d = 2$: the code can *detect* single-bit errors but cannot correct them without additional redundancy from the lattice environment.

In the bulk (far from horizons), the lattice-induced decoherence rate Γ_{dec} is low, and the code maintains its integrity over cosmological timescales. But decoherence scales with Fisher curvature (3), and near the horizon, $\mathcal{F}^{\text{local}}$ diverges.

4.2 The failure mechanism

Define the *code integrity condition*: a circlette pattern maintains its identity as a valid Standard Model fermion as long as:

$$\Gamma_{\text{dec}} < \Gamma_{\text{code}} \quad (6)$$

where Γ_{code} is the error-correction rate—the speed at which the lattice environment restores corrupted bits to valid codewords. In the vicinity of the horizon:

1. $\Gamma_{\text{dec}} \propto \nu^2 \mathcal{F}^{\text{local}} \rightarrow \infty$ as $\mathcal{F}^{\text{local}}$ diverges.
2. $\Gamma_{\text{code}} \rightarrow 0$ as computational bandwidth is consumed by geometry.

At some radius $r_{\text{code}} > r_H$ (slightly outside the classical horizon), the code integrity condition (6) fails. Beyond this point, circlette patterns disintegrate: their constraint structure (R1–R4) can no longer be maintained against the decoherence pressure.

4.3 Thermal radiation from broken codewords

The disintegration of a circlette releases its 8 bits back into the lattice as unconstrained noise. This noise is **thermal**, but the mechanism requires care to state precisely.

In standard quantum field theory, Hawking radiation is thermal because of the Bogoliubov transformation between the vacuum states defined by freely-falling and static observers. In the lattice framework, the corresponding mechanism is as follows. The code failure at r_{code} is a *stochastic* process: the decoherence (3) is driven by random fluctuations of the lattice vacuum state (the residual Fisher noise at \mathcal{F}^{vac}), amplified by the divergent local curvature. Each individual code failure is unpredictable—which bit fails first, which constraint breaks—but the *statistics* of many failures are determined entirely by the local Fisher curvature, not by the identity of the failing circlette.

This pattern-blindness is the lattice analogue of the Bogoliubov transformation: the vacuum fluctuations that trigger code failure are thermal with respect to the accelerated (static) observer at temperature:

$$T_H = \frac{\hbar a}{2\pi c k_B} \quad (7)$$

where a is the surface gravity. In the lattice framework, a is the gradient of the Fisher curvature at the horizon—the rate at which the computational pressure changes with position. The thermal spectrum emerges not because the radiation is “born thermal” but because the *noise source*

(vacuum lattice fluctuations near the horizon) has a thermal distribution as seen by external observers.

4.4 The Bekenstein-Hawking entropy

The entropy of the black hole is:

$$S = \frac{A}{4\ell_P^2} \quad (8)$$

In the circlette framework, this has a direct interpretation: the horizon area A , measured in Planck units, counts the number of independent bit-operations per tick that maintain the horizon geometry. Each Planck-area cell contributes one bit of entropy—the minimum information required for causal connectivity. The Bekenstein-Hawking formula is not a semiclassical approximation but the *literal bit-count* of the horizon’s computational capacity.

When a circlette falls through the horizon, its 8 bits do not vanish into a volume; they are *projected onto the boundary*. The infalling pattern’s information is “plastered” onto the horizon surface, increasing the area by $\Delta A \sim 8\ell_P^2$ (one Planck area per bit). This is the microscopic mechanism behind the Bekenstein bound: the maximum entropy of a bounded region is determined by the number of bits that can be plastered onto its surface, not the number that can be packed into its volume.

This “plastering” is not merely consistent with the holographic principle—it *is* the holographic principle, given a concrete physical mechanism. Holography is not a mathematical duality between a bulk theory and a boundary theory; it is a literal description of how the lattice stores information when computational resources are saturated. The bulk pattern (the circlette) is decomposed into boundary data (the horizon bits) because the interior has no spare bandwidth to maintain the pattern’s structure. The holographic principle is a consequence of finite computational throughput.

5 The Computational Firewall

5.1 The paradox

The firewall paradox [3] asks whether an observer falling through the horizon encounters a singular surface (a “firewall”) or a smooth vacuum. In standard physics, the paradox arises from conflicting requirements of unitarity, the equivalence principle, and the no-cloning theorem.

5.2 Resolution via discrete logic

The companion paper posed this as a question about computational phase transitions [1]: does the update rule admit a smooth transition from sub-saturated to saturated computation?

The CNOT rule provides a definitive answer: **no**. A logic gate is either executing or not. There is no “half-CNOT.” The XOR operation $I_3 \oplus LQ$ either flips the isospin bit or it does not—there is no continuous interpolation between the two states.

This creates a sharp computational boundary at the radius where $B(\mathbf{x}) = B_{\text{CNOT}}$. Inside this boundary, the weak interaction is off. Outside, it is on. The transition is discrete.

5.3 A “silent firewall”

This is a firewall, but not of the kind envisioned by AMPS. It is not a wall of high-energy quanta; it is a wall of **computational silence**—a boundary where the Standard Model’s gauge symmetries are deactivated because the logic gates that implement them have no bandwidth to execute.

5.4 Complementarity and the equivalence principle

A sharp computational boundary appears to violate the equivalence principle: a freely-falling observer should notice nothing special at the horizon. The resolution lies in the observer-dependence of the bandwidth budget.

For an **external** (static) observer, the lattice updates at position r are split between geometry maintenance and pattern dynamics, with $B_{\text{free}} \rightarrow 0$ at r_H . The CNOT gate visibly freezes; the quark’s oscillation stops; the crossing takes infinite time.

For an **infalling** observer, the situation is different. The freely-falling frame is, by definition, the frame in which the lattice is locally undistorted—the local Fisher curvature is removed by the coordinate transformation to free-fall (this is the computational equivalence principle of the companion paper). In this frame, the local bandwidth budget is not saturated, because the “geometry cost” that consumes bandwidth for the static observer is precisely the gravitational field that the freely-falling observer does not experience. The infalling observer’s CNOT gate continues to execute; the quark continues to oscillate; the horizon crossing is uneventful.

The two descriptions are complementary, not contradictory: the external observer sees the computation freeze at the horizon; the internal observer sees it continue until the singularity (where the lattice genuinely saturates in *every* frame). This is black hole complementarity [4], but derived from the computational architecture rather than postulated. The equivalence principle is preserved because “free fall = locally unsaturated lattice” is a mathematical identity in the Fisher-metric formulation.

6 The Information Paradox Dissolved

6.1 The paradox restated

The black hole information paradox asks: when a black hole evaporates completely via Hawking radiation, what happens to the information about the quantum states that fell in? If the radiation is exactly thermal, the information is destroyed, violating unitarity.

6.2 Information is pattern structure

In the circlette framework, “information” is not an abstract quantity but the concrete pattern structure of the code: the 8 bits of each circlette, the correlations between nearby patterns, and the Fisher metric’s encoding of these correlations.

When a circlette falls into a black hole, three things happen to its information:

1. **The 6 environment bits** ($G_0, G_1, C_0, C_1, \chi, W$) are absorbed into the horizon’s bit-count, increasing the horizon area and hence the Bekenstein-Hawking entropy. These bits become part of the horizon’s computational budget.
2. **The CNOT dynamics** ($I_3 \oplus LQ$) are frozen by computational saturation. The isospin oscillation stops, but the *state* of I_3 and LQ at the moment of freezing is preserved—it is encoded in the frozen pattern at the horizon.
3. **The correlations** between the infalling circlette’s bits and the bits of circlettes that remain outside are preserved in the Fisher metric’s off-diagonal terms at the horizon. These correlations are not destroyed; they are *frozen* into the horizon geometry.

6.3 The Page curve

The Page curve [5] describes the entropy of Hawking radiation as a function of time: it rises initially (as the black hole absorbs information faster than it radiates), reaches a maximum at the “Page time,” and then decreases as the black hole shrinks and releases its stored correlations.

In the circlette framework, the Page curve has a direct computational interpretation:

- **Early phase** (entropy rising): New circlettes are falling in faster than old correlations are being released. The horizon’s bit-count grows. Each infalling pattern adds ~ 8 bits to the horizon.
- **Page time**: The rate of information absorption equals the rate of correlation release via Hawking radiation.
- **Late phase** (entropy falling): The black hole is shrinking. The frozen Fisher correlations at the horizon are being released as the computational budget contracts. The radiation in this phase is *not* thermal—it carries the correlations that were frozen in, restoring unitarity.

The information is never destroyed. It is frozen into the horizon’s Fisher geometry during absorption and thawed during evaporation. The total process is unitary because the underlying lattice dynamics (the CNOT rule and the lattice propagation) are reversible ($M^2 = I$).

6.4 Why the radiation appears thermal

During the early phase, the released bits are drawn from the horizon’s generic computational budget—they are the “maintenance noise” of the saturated lattice, carrying no specific correlation with the infalling patterns. This noise *is* thermal because it is pattern-blind (Section 4).

During the late phase, the released bits include the frozen correlations. An observer who collected *all* the radiation (early and late) would recover the full information content of the infalling matter. An observer who collected only the early radiation would see a thermal spectrum—not because information was destroyed, but because the correlated portion had not yet been released.

7 Predictions

The framework yields several testable predictions specific to black hole physics:

1. **Weak interaction cessation at horizons**: Near a black hole, the effective weak coupling should decrease as a function of the local Fisher curvature, reaching zero at the horizon. This modifies the rate of β decay and neutrino interactions in strong gravitational fields.
2. **Code failure radius**: The radius r_{code} at which circlette patterns disintegrate is *outside* the classical horizon r_H , determined by the condition $\Gamma_{\text{dec}} = \Gamma_{\text{code}}$. For a Schwarzschild black hole of mass M , the gap scales as:

$$r_{\text{code}} - r_H \sim \ell_P \left(\frac{m_P}{M} \right)^{1/2} \quad (9)$$

For stellar-mass black holes ($M \sim 10M_\odot$), this gap is negligible ($\sim 10^{-24}$ m). But for micro black holes near the Planck mass, the gap becomes comparable to r_H itself—the code failure zone extends well beyond the classical horizon, and the “black hole” is better described as a naked zone of code failure. This is a distinctive signature of the lattice framework: micro black holes near m_P should radiate *non-thermally*, because the code failure is global (all circlettes fail simultaneously) rather than local (individual patterns failing stochastically at the horizon).

3. **Non-thermal late radiation**: The Hawking radiation from an evaporating black hole should deviate from a thermal spectrum in the late stages, carrying correlations that restore unitarity. In the lattice framework, the deviation onset is set by the code distance: the radiation becomes non-thermal when the horizon’s bit-count drops below the threshold needed to maintain frozen correlations in the Fisher metric. This may differ from the standard Page time (half the initial entropy) by a factor depending on the code distance $d = 2$ of the circlette code. This is the “smoking gun” prediction of the framework: the onset of non-thermal radiation is calculable from the code’s error-correction properties.

4. **Symmetry restoration signature:** If the horizon restores quark-lepton symmetry, the Hawking radiation from a black hole that absorbed primarily baryonic matter should contain equal numbers of leptons and quarks (as free particles, not bound in hadrons), since the distinction is erased at the horizon.
5. **Discrete horizon structure:** The transition from active to frozen CNOT should produce a discrete “step” in the effective weak coupling as a function of radius, rather than a continuous fade. This step is at the Planck scale and not directly observable, but may leave imprints in the spectrum of Hawking radiation via quantum corrections.
6. **Minimum black hole mass and micro black hole instability:** The smallest possible black hole must be massive enough to saturate the CNOT gate of at least one circlette pattern, setting a minimum mass of order m_P . Below this threshold, the lattice cannot sustain a horizon. But the framework predicts something stronger: micro black holes with mass $M \sim m_P$ are *qualitatively different* from large black holes. Their code failure radius r_{code} exceeds r_H , meaning the entire object is a zone of code failure with no well-defined horizon. Such objects should decay in a “burst” (all circlettes failing within $\sim t_P$) rather than the slow thermal evaporation of large black holes. This burst would produce a characteristic non-thermal spectrum of decay products—a potential observable signature in high-energy collision experiments or primordial black hole searches.

8 Relationship to Existing Approaches

8.1 Comparison with the standard framework

The circlette framework does not contradict the standard results of Hawking [6] and Bekenstein [7]. Rather, it provides a *microscopic mechanism* for each:

Table 2: Standard results and their circlette mechanisms.

Standard result	Circlette mechanism
$S = A/4\ell_P^2$	Literal bit-count of horizon’s computational capacity
$T_H = \hbar a/2\pi c k_B$	Gradient of Fisher curvature at the horizon
Thermal radiation	Pattern-blind decoherence of broken code-words
Unitarity of evaporation	Reversibility of lattice rule ($M^2 = I$)

8.2 Relationship to Susskind’s Complexity Equals Action

The companion paper [1] identified the information action S_I with Susskind’s computational complexity [2]. In the black hole context, this identification becomes concrete: the “complexity growth” inside the black hole *is* the lattice’s ongoing bit-processing to maintain the horizon geometry, at a rate of $A/4\ell_P^2$ operations per tick. The linear growth of complexity with time is the steady accumulation of these operations.

8.3 Relationship to ’t Hooft’s cellular automaton

’t Hooft’s cellular automaton interpretation [8] proposes that quantum mechanics emerges from deterministic, discrete dynamics at the Planck scale. The circlette framework is a specific realisation of this programme, with the added feature that the automaton’s rule is *uniquely determined*

by the information action principle. The black hole results of this paper show that the automaton naturally produces horizons, thermal radiation, and unitary evaporation without additional assumptions.

9 Discussion

The central insight of this paper is that the circlette framework’s discrete, computational architecture provides *natural* resolutions to problems that are paradoxical in the continuous framework.

The firewall paradox arises because continuous field theory permits questions about “what happens at the horizon” that presuppose smooth interpolation. In the lattice framework, the horizon is a computational phase transition: the CNOT gate either executes or it does not. The paradox dissolves because the question “is the horizon smooth or singular?” is replaced by “does the gate have bandwidth?”—and the answer is simply no.

The information paradox arises because continuous field theory cannot track individual bits through a thermal process. In the lattice framework, every bit is accounted for: 8 bits per circlette, frozen into the horizon’s Fisher geometry, released during evaporation. The process is unitary because the underlying rule is an involution ($M^2 = I$).

The thermality of Hawking radiation arises because continuous field theory computes a Bogoliubov transformation between vacuum states. In the lattice framework, thermality arises because the decoherence that breaks codewords is pattern-blind: it depends only on the local Fisher curvature, not on the identity of the pattern being broken.

These are not *ad hoc* explanations. They follow directly from the framework established in the companion paper, using only the unique update rule, the Fisher metric, and the computational saturation bound. No new physics is introduced.

The framework suggests that the deepest problems in quantum gravity—the nature of horizons, the fate of information, the origin of black hole thermodynamics—are not problems of quantum field theory on curved spacetime but problems of *computation on a finite-bandwidth lattice*. The resolution is not a new theory but a new substrate: a lattice of bits, governed by a single CNOT gate, whose computational limits are the horizons, whose noise is the radiation, and whose reversibility is the unitarity.

10 Conclusion

We have shown that the circlette framework—an 8-bit error-correcting code on a holographic lattice, governed by the unique CNOT rule $I_3 \oplus LQ$ —provides microscopic mechanisms for the four central problems of black hole physics:

1. The event horizon is a computational phase transition where the CNOT gate ceases to execute, freezing the weak interaction and restoring quark-lepton symmetry.
2. Hawking radiation is the thermal decay of broken codewords whose error-correction threshold is exceeded by horizon-divergent Fisher curvature.
3. The firewall is “silent”—a wall of computational silence, not of fire—resolved by the discreteness of logic gates.
4. The information paradox dissolves: information is frozen into the horizon’s Fisher geometry during absorption and released during evaporation, with unitarity guaranteed by the rule’s involutory structure.

These results require no assumptions beyond the companion paper. The same rule that gives us the weak interaction, parity violation, CKM mixing, and time dilation also gives us horizons, radiation, and information preservation. The black hole is not a separate problem; it is the same computation, pushed to its limit.

Perhaps the most experimentally distinctive prediction is the behaviour of micro black holes near the Planck mass. In the standard framework, all black holes evaporate thermally. In the

circlette framework, micro black holes with $M \sim m_P$ have no well-defined horizon: their code failure radius exceeds the classical Schwarzschild radius, and they decay in a non-thermal “burst” as all circlette patterns fail simultaneously. This burst spectrum—calculable from the code distance and the Fisher curvature profile—would be a direct signature of the discrete computational substrate, distinguishable from the thermal Hawking spectrum in any future observation of primordial black hole evaporation or high-energy collision remnants.

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