Void Anchoring, Action Quantization, and the Mass Scale

A VERSF/BCB–TPB Consistency Derivation

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1. General Reader Abstract

What this paper is about, in plain language.

Everything around you — your body, the light on this page, the device in your hand — has mass. The Standard Model of particle physics explains how masses arise (via Yukawa couplings to the Higgs field and symmetry breaking) but does not predict the numerical values of those couplings from first principles. The electron is roughly 1/1836 the mass of a proton. Why those numbers? No existing theory computes them.

This paper proposes a new way to think about where mass comes from. The core idea is that reality, at its most fundamental level, operates like a discrete information-processing system — a substrate that "ticks" forward one step at a time, flipping bits via irreversible transitions in a process we call *void anchoring*. Each particle corresponds to a particular pattern of bit-flipping, and the *intrinsic flip frequency* of that pattern — set by how many substrate ticks it takes to complete one flip cycle — determines the particle's mass. Fewer ticks per flip means higher frequency, higher energy, and therefore greater mass.

What is void anchoring? Imagine the ocean surface. A surfer rides the waves — strongly coupled to the water, their motion tracking the oscillations of the surface. They move with the medium; their behavior reflects local fluctuations. A buoy anchored to the seabed, by contrast, is both coupled *and* anchored. It responds to waves, but it is tethered to something deeper. The tether prevents it from drifting freely.

Two distinct concepts are at work:

- **Void coupling (resonance)** (p_v) — the per-tick probability that the interface mode enters a void-resonant micro-event configuration. This measures how readily the mode couples to the void substrate at each tick. In the buoy analogy: responsiveness to waves.
- **Void anchoring (commitment depth)** (K_c) — the number of micro-events that must accumulate before an irreversible bit-flip commits. In the buoy analogy: the depth of the tether.

Void coupling determines how readily micro-events occur; void anchoring determines how many are required before an irreversible bit-flip commits. Neither alone sets the mass. The quantity that tracks rest mass is the **flip completion per tick** p_v/K_c — coupling resonance divided by commitment depth — which sets the tick-count per flip (K_c/p_v). A particle is not merely coupled to the void — it is anchored through a barrier, and its mass emerges from the interplay of both parameters: strong coupling with a low barrier means fewer ticks per flip (which, once mapped to emergent time via the standard physics bridge, corresponds to high energy and high mass); weak coupling or a high barrier means more ticks per flip (low energy, low mass). The buoy's *resistance to being dragged sideways* (inertia) is not the same as its *bobbing frequency* (rest energy) — a distinction that becomes precise in Section 12.

Key definitions. Void coupling (resonance): p_v (micro-event probability per tick). Void anchoring (commitment depth): K_c (micro-event threshold for irreversible flip). Flip completion per tick: p_v/K_c. Tick-count per flip: K_c/p_v. Mass scale (after Layer B bridge): $m \propto p_v/K_c$.

In plain language: a particle is not a solid object at the deepest level. It is a repeating pattern of information updates on the void substrate. Each time that pattern completes one full cycle, it carries a fixed chunk of physical action (postulate $P\hbar$). The fewer substrate ticks that cycle takes to complete, the higher the particle's energy — and higher energy means higher mass. **Mass is not a mysterious property; it is the rate at which a stable information pattern completes its fundamental cycle.**

A crucial subtlety: since bit-flips *constitute* emergent time in this framework, all temporal language ("frequency," "fast," "slow") is Layer B shorthand that applies only after tick-counts are mapped to an external clock. At the fundamental level (Layer A), the correct statement is not that heavy particles "flip faster," but that they require *fewer substrate ticks per flip* — a smaller ratio K_c/p_v. Under the standard physics bridge, this corresponds to a shorter cycle period and therefore larger rest energy E, and hence larger mass via $E = mc^2$.

We do not claim to have solved the mass spectrum from scratch. What we show is that, given one well-motivated postulate about how action (a fundamental quantity in physics) relates to bit-flipping, the anchoring framework produces a compact formula for mass that is internally consistent with known physics. We stress-test this formula across multiple regimes — stochastic coupling, composite particles, the Planck mass, gravitational redshift, and particle decay — and show that the equivalence of inertial and rest mass (a foundational principle in general relativity) emerges as a structural consequence. We also lay out a concrete research program for turning this consistency result into genuine predictions.

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2. Technical Abstract

We develop a tick–bit (pre-temporal) void-anchoring model in which irreversible bit-flipping occurs after K_c anchoring micro-events, each occurring with per-tick probability p_v. We argue that Bernoulli micro-event increments are forced by locality, Markov sufficiency, and closure under coarse-graining: under these assumptions, the admissible micro-event class reduces to conditionally independent Bernoulli increments and their binomial coarse-grainings. We then introduce an explicit postulate (P$\hbar$) that each completed bit carries a fixed cycle-action increment $\Delta J_{bit} = \eta\hbar$, motivated by a topological cycle-closure condition on irreversible anchoring.

Combining (a) the anchoring time scale, (b) postulate P$\hbar$, and (c) the standard action–energy and mass–energy bridges from relativistic kinematics, we derive a conditional mass-scale relation:

$$\mathbf{m = \eta\hbar p_v / (c^2 \Delta t K_c)}$$

Mass is thereby identified as proportional to the ratio p_v/K_c — the coupling probability per tick divided by the barrier height — which sets the expected flip increment per tick (and hence the tick-count per flip K_c/p_v). We stress-test this relation across multiple regimes: stochastic coupling ($p_v < 1$), multi-channel flipping, the Planck-mass limit (yielding $K_c P \sim 2\pi$ as a nontrivial structural identification), gravitational redshift compatibility, and unstable-particle interpretation. We derive the structural condition under which inertial mass (resistance to acceleration) equals rest mass (flip-cycle energy), showing that these two operationally distinct manifestations of mass coincide when the spatial projection scale is determined by the same anchoring parameters that set the tick-count per flip.

We identify three necessary conditions for stable particle-like modes and outline a research program to compute (K_c, p_v) from BCB interface eigenmodes, which would convert these consistency checks into genuine mass-spectrum predictions.

3. Scope: What Is Derived vs What Is Assumed

For the general reader: Science advances by being honest about its assumptions. Every physical theory rests on postulates — statements accepted as starting points. Newton assumed forces act at a distance; Einstein assumed the speed of light is constant. What matters is whether the assumptions are well-motivated, whether the consequences are testable, and whether the framework reveals structure that wasn't visible before. This section lays out exactly what we assume and what we derive, so the reader can judge for themselves.

This paper operates on two distinct layers:

Layer A — Internal to the VERSF/BCB–TPB anchoring model. These are purely tick-domain statements about anchoring times, stability, and scaling. They require no reference to background time, energy, or relativistic kinematics. Results in this layer are derived from the axioms of the tick–bit framework alone.

Layer B — Mapping to established physics. This layer uses standard relations connecting action to energy (the Bohr–Sommerfeld/de Broglie relation for stationary states) and energy to mass (Einstein's $E = mc^2$). These are *imported* from existing physics; we claim consistency with them, not derivation of them.

Central Claim (Conditional)

Given postulate P$\hbar$, tick–bit anchoring with parameters (K_c, p_v), and the standard action→energy→mass bridge, the model implies a mass scale $\mathbf{m \propto p_v / K_c}$.

What Is Explicitly Not Derived

The following quantities and relations are taken as external inputs. They are not derived within the VERSF anchoring framework:

- **c** (speed of light) — imported from special relativity
- $\boldsymbol{\hbar}$ (reduced Planck constant) — imported from quantum mechanics
- $\mathbf{\Delta t = t_P}$ (tick spacing identified with Planck time) — a calibration assumption, not a derived result
- $\mathbf{E = mc^2}$ (mass–energy equivalence) — imported from special relativity
- $\mathbf{P\hbar}$ (action postulate) — motivated by topological cycle-closure arguments (Section 7) but not derived from tick–bit axioms alone
- $\mathbf{P = \eta\hbar/\ell_b}$ (de Broglie momentum identification) — imported from quantum kinematics as a Layer B bridge element; used in the inertial mass derivation (Section 12)

The value of this paper lies not in replacing these inputs but in showing that, given them, the anchoring framework produces a structurally interpretable mass formula with a concrete path to predictive computation.

Notation

The following symbols are used throughout, grouped by domain:

Layer A (substrate primitives — no background time)

Symbol	Meaning
n	Tick index (substrate update ordering)
p_v	Per-tick void-coupling (resonance) probability
K_c	Barrier threshold (micro-events per flip)
X_n	Bernoulli micro-event increment at tick n
N[n]	Cumulative micro-event count by tick n
N_anchor	Tick-count to bit-flip
B[n]	Cumulative bit-flip count by tick n
α	Dimensionless perturbation strength
χ	Channel multiplicity (composite particles)

Postulate

Symbol	Meaning
η	Action normalization factor ($\eta = 2\pi$ for full cycle)

Layer B (emergent quantities — require Δt calibration or standard physics bridge)

Symbol	Meaning
Δt	Emergent tick-to-clock calibration
T_bit	Emergent flip period ($\Delta t \cdot K_c/p_v$)
ℓ_b	Bit-to-length spatial projection scale
ν_c	Flip frequency ($1/T_{bit} = p_v/(\Delta t K_c)$)
C(x)	Flip completion density field (p_v(x)/K_c(x))
$\dot{s}(x)$	Entropy production density
Φ	Emergent gravitational potential

Terminology Alignment

In the VERSF framework, *void coupling* denotes the resonant susceptibility of an interface mode to the void substrate — how readily the mode enters micro-event–producing configurations. *Void anchoring* denotes the irreversible commitment mechanism (barrier-crossing and cycle closure) by which micro-events accumulate into a stable bit-flip. In this paper these map to: coupling (resonance) → p_v (or p_v(c[n])); anchoring (commitment depth) → K_c. The flip completion per tick is p_v/K_c and the tick-count per flip is K_c/p_v. We avoid using "anchoring strength"

to mean K_c alone; where disambiguation is needed, we write *anchoring depth* for K_c and *coupling resonance* for p_v.

Conceptual summary. *Void coupling* (resonance) = how strongly a mode resonates with the void substrate (probability of micro-event per tick). *Void anchoring* (commitment depth) = how much irreversible commitment is required to complete a stable informational cycle (barrier threshold). *Rest mass* = the intrinsic cycle rate of a resonant anchored mode (tick-count per flip, mapped to energy via Layer B bridge). *Inertial mass* = the geometric resistance to deforming the spatial projection of that anchored mode (Section 12).

Bridge Chain Summary

The logic from substrate primitives to mass proceeds through a single chain:

Tick-count per flip (K_c/p_v, Layer A) → **Flip period** ($\Delta t \cdot K_c/p_v$, Layer B bridge) → **Action per cycle** ($\eta\hbar$, Postulate P$\hbar$) → **Rest energy** ($\eta\hbar/T_{bit}$, imported action-energy relation) → **Rest mass** (E/c^2, imported mass-energy equivalence)

Each arrow introduces one assumption or import. The mass formula $m = \eta\hbar p_v/(c^2 \Delta t K_c)$ is the algebraic composition of the entire chain. The only element internal to the VERSF framework is the first: the tick-count per flip.

The inertial mass derivation (Section 12) requires one additional Layer B import beyond this chain: the de Broglie momentum identification $P = \eta\hbar/\ell_b$. This enters when defining momentum for the projected spatial dynamics and is listed explicitly in "What Is Not Derived" above.

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4. Conceptual Foundation: What Is Void Anchoring?

For the general reader: Section 1 introduced void anchoring through the surfer/buoy analogy. This section makes each element precise: the void, the interface, the bit-flip, and the connection to mass. If you understand this section, the rest of the paper is a formalization of these ideas.

4.1 The Void (Operational Definition)

In VERSF, the "void" is not empty space and not the QFT vacuum. It is defined operationally as the **null element in the algebra of distinctions**: the configuration in which all bits occupy their reference state — no bit has been flipped. In this sense the void carries no informational content relative to the interface, and it is the reference configuration against which all flips are measured. Physical structure is then modeled as stable, cyclic patterns of bit-flips written against this null substrate. The total number of bits is fixed (Bit Conservation); only their states change.

For the general reader: Think of the void as the "blank" against which all information is written. It isn't "nothing" — it is the reference state that makes distinctions possible, just as

silence is the reference state that makes sound meaningful. The void has no structure of its own; it is defined entirely by what it lacks (bits).

4.2 The Interface: Where Structure Meets the Void

Physical reality exists at the **interface** between structured information and the void substrate. This interface is where the action happens — it is the boundary between "something" and "nothing," the frontier where new information is being written.

The interface has a minimal internal structure: a two-component configuration $c = (c_1, c_2)$ that we call the **contrast pair**. This is the simplest possible distinction — a binary degree of freedom at the boundary between void and structure. Every more complex structure (particles, forces, spacetime geometry) is built from patterns of these minimal contrasts.

4.3 Anchoring: Irreversible Bit-Flips

Void anchoring is the irreversible commitment step by which the interface locks in a bit-flip, characterized by the barrier threshold K_c. **Void coupling** (resonance) controls the micro-event arrival propensity p_v — how readily the interface mode enters void-resonant configurations at each tick. The resulting flip completion per tick is p_v/K_c. We define the elementary transition precisely:

Definition. A *bit-flip* is the irreversible interface transition triggered when cumulative anchoring micro-events reach the barrier threshold K_c. Bits are not created or destroyed — the total bit count is conserved (BCB). What changes is their state: a bit flips from one stable configuration to another.

"Irreversible" here means *operationally irreversible under the admissibility and non-redundancy criteria*: once a bit has flipped, the new state is stable under coarse-graining and cannot be reversed without accumulating K_c fresh micro-events in the opposite direction. This is analogous to the operational irreversibility of measurement outcomes in quantum mechanics — a bit-flip is a stable macroscopic record, not a claim about microscopic non-unitarity.

This doesn't happen all at once. At each discrete tick of the substrate, the interface has some probability of registering a **micro-event** — a small increment of progress toward the flip barrier. After enough micro-events accumulate (reaching the barrier threshold K_c), the bit flips: the irreversible transition locks in.

The analogy is a ratchet mechanism. Each micro-event clicks the ratchet forward one notch. After K_c clicks, the mechanism snaps over — the bit flips to its new state. The next flip cycle begins.

4.4 Why This Connects to Mass

Here is the conceptual link: **mass is set by the tick-count per flip**.

A particle, in this framework, is a *self-sustaining pattern of bit-flips* at the interface — a mode that repeatedly flips bits in a stable, cyclic process. The mass of that particle is set by the tick-count per flip cycle (K_c/p_v). Fewer ticks per cycle corresponds — once mapped to an external clock via the Layer B bridge — to higher frequency, higher energy, and therefore greater mass via $E = h\nu$. More ticks per cycle corresponds to lower energy and lower mass. (Since bit-flips *generate* emergent time, "frequency" is Layer B shorthand. The fundamental Layer A quantity is the tick-count per flip, not a rate in time.)

This may seem counterintuitive — one might expect that heavier objects should require *more* ticks to flip, not fewer. But that intuition conflates two distinct meanings of "mass":

- **Mass as rest energy (tick-count per flip → energy via Layer B bridge).** Fewer ticks per flip → higher energy via $E = h\nu$. The electron, with $K_c \sim 10^{23}$, takes enormously many ticks per flip — correspondingly low energy and low mass. The Planck mass, with $K_c \sim 2\pi$, completes a flip in a handful of ticks — the highest energy and mass the framework admits.
- **Mass as inertia (resistance to acceleration).** This is the dynamical response to external forcing ($F = ma$). A massive particle resists acceleration not because it flips slowly, but because perturbing its flip pattern requires overcoming a structure that is tightly coupled to emergent geometry (Section 12).

These two quantities — rest energy and inertial resistance — coincide numerically, but they arise from distinct structural layers. Their equality is the equivalence principle, and Section 12 shows the structural condition under which it holds.

This is not a metaphor — the rest of the paper makes it mathematically precise. The barrier threshold K_c and the per-tick coupling probability p_v together determine the tick-count per bit-flip (K_c/p_v), and therefore the intrinsic flip frequency and rest mass. The formula $m \propto p_v/K_c$ is the quantitative expression of this relationship.

Caution. In this paper, "deep anchoring" (large K_c) does *not* mean "high mass." Large K_c means greater commitment depth — more stability — but also more ticks per flip, hence *lower* rest energy. The quantity that tracks rest mass is the flip completion per tick p_v/K_c, not the anchoring depth K_c alone.

4.5 Why "Void" Anchoring?

The word "void" is not decorative. The anchoring process is specifically an interaction between the informational interface and the void substrate. The void is not passive — it is the ground against which bit-flips occur. A micro-event is, operationally, the interface *coupling to the void*: registering an increment of progress toward the next bit-flip.

This is why the coupling probability is called the **void-coupling probability** p_v: it measures how readily the interface couples to the void at each tick. Strong coupling (high p_v) means the interface is in close contact with the void substrate — micro-events occur at most ticks. Weak

coupling (low p_v) means the interface is partially decoupled — micro-events are sparse, many ticks pass per flip, and the mode is fragile.

4.6 From Concept to Formalism

The rest of this paper translates these concepts into mathematics:

- **Section 5** formalizes the tick–bit process and derives the statistics of anchoring.
- **Section 6** shows that the Bernoulli micro-event law is structurally forced, not chosen.
- **Section 7** introduces the action postulate linking anchoring to quantum mechanics.
- **Sections 8–9** derive the mass formula and establish the proposition.
- **Sections 10–12** stress-test the formula and derive the equivalence of inertial and rest mass.
- **Sections 14–16** address stability, the mass-gap problem, the emergence of gravity from flip-entropy gradients, and the predictive program.

With this conceptual map in hand, the formal development should be considerably easier to follow.

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5. Tick–Bit Anchoring Core (No Background Time)

For the general reader: This section translates the conceptual picture of Section 4 into precise mathematics. We build the anchoring process from first principles — discrete ticks, probabilistic micro-events, and a barrier threshold — without ever assuming that time flows continuously. Time will emerge later from the accumulation of bit-flips.

5.1 Primitives

The substrate updates in discrete ticks indexed by $n = 0, 1, 2, \ldots$. No background time parameter is introduced; the tick index n is the sole ordering primitive.

At each tick n, an **anchoring micro-event** may occur. Operationally, a micro-event corresponds to the interface entering an *anchorable configuration subset* — a region of the interface state space in which a void-coupling commitment increment is registered (Section 4.3). The precise characterization of this subset depends on the detailed interface dynamics and is addressed in Section 16; here we treat micro-event occurrence as primitive.

The micro-event probability $p_v(c[n]) \in [0, 1]$ may depend on the current interface configuration $c[n] = (c_1[n], c_2[n])$. Operationally, $p_v(c[n])$ is the **occupancy measure** of the anchorable subset A — the fraction of the configuration space accessible from $c[n]$ that lies within A:

$$p_v(c[n]) = \mu(A \mid c[n])$$

where μ is the natural measure on the interface configuration space. (The precise form of μ depends on the interface dynamics; here we leave it abstract.) Define Bernoulli increments that are **conditionally independent given the interface sequence** {c[n]}:

$X_n \mid c[n] \sim \text{Bernoulli}(p_v(c[n]))$

The cumulative micro-event count is:

$N[n] := \Sigma_{j=1}^{n} X_j$

5.2 Bit Threshold

A **bit** — the irreversible threshold transition defined in Section 4.3 — is triggered when the cumulative micro-event count reaches an integer threshold $K_c \in \mathbb{N}$:

$N_{anchor} := \inf\{ n \geq 0 : N[n] \geq K_c \}$

For the general reader: Think of K_c as the number of clicks on the ratchet (Section 4.3) needed to flip one bit. Higher K_c means a higher barrier — more ticks required per flip. Lower K_c means fewer ticks per flip.

Terminology. A **cycle** is the operationally closed sequence of K_c micro-events that advances the cycle-action ledger by $\Delta J_{bit} = \eta\hbar$ (Section 7) and triggers one irreversible bit-flip. "One cycle" and "one bit-flip" are synonymous throughout this paper.

5.3 Homogeneous Statistics

In the homogeneous case $p_v(c[n]) = p_v$ (constant), N_{anchor} follows a **Negative Binomial** (Pascal) waiting-time law — the distribution of the number of independent trials needed to accumulate K_c successes, each with probability p_v. The expectation and variance are:

$E[N_{anchor}] = K_c / p_v$

$\text{Var}(N_{anchor}) = K_c(1 - p_v) / p_v^2$

5.4 Anchoring Stability (Discrete Lemma)

The sharpness of the anchoring time is controlled by the coefficient of variation:

$CV = \sqrt{(\text{Var}(N_{anchor}))} / E[N_{anchor}] = \sqrt{((1 - p_v) / K_c)}$

For fixed $p_v < 1$, stability scales as $CV \sim 1/\sqrt{K_c}$. As K_c increases, the flip tick-count N_{anchor} becomes sharply concentrated around its mean. In the sparse-event limit $p_v \to 0$, the factor $(1 - p_v) \to 1$ and the discrete CV collapses exactly to the continuous Erlang result $CV = 1/\sqrt{K_c}$, confirming the correspondence between discrete and continuous formulations.

5.5 State-Dependent Coupling

When p_v depends on the evolving interface state c[n], the cumulative expected micro-event count is:

$\Lambda[n] := \Sigma_{j=1}^{n} p_v(c[j])$

The mean-field anchoring estimate becomes:

$N_{anchor} \approx \inf\{ n : \Lambda[n] \geq K_c \}$

Note that under state-dependent coupling, the variance of the anchoring time becomes path-dependent — the simple CV = $1/\sqrt{K_c}$ result no longer holds exactly, and anchoring stability must be assessed along specific interface trajectories.

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6. Structural Forcing of the Bernoulli Law

For the general reader: A common criticism of theoretical models is "you just *chose* that mathematical form — why not something else?" This section answers that challenge. We show that the Bernoulli (coin-flip) law for micro-events isn't an arbitrary choice — it is the natural admissible form compatible with a small set of physically reasonable requirements. If the anchoring process satisfies basic principles of locality, informational efficiency, and consistency across scales, then the micro-event law must take the Bernoulli form.

6.1 Admissibility Axioms for Anchoring Micro-Events

We impose four minimal conditions on the micro-event law:

A1 (Locality on the interface). The probability of a micro-event at tick n depends only on the current interface state c[n], not on hidden global variables.

A2 (Markov sufficiency / BCB non-redundancy). Given c[n], additional dependence on the detailed micro-history $\{X_1, \ldots, X_{n-1}\}$ is operationally redundant. Two interface configurations that are operationally equivalent (identical c[n]) must produce identical anchoring statistics.

A3 (Closure under coarse-graining — model selection constraint). Aggregating ticks into blocks of size m preserves the functional form of the micro-event law. Specifically, we restrict to micro-event descriptions whose coarse-grained statistics remain within a one-parameter hazard family. This is a deliberate admissibility restriction, not a theorem of nature: it excludes models with hidden internal state variables that would require additional parameters at coarser scales. Alternatives to A3 correspond to enriching the micro-event model with internal memory or multi-state structure beyond the interface observable c[n].

A4 (Finite throughput). For any physically realized interface trajectory c[n], expected anchoring time is finite: $E[N_{anchor}] < \infty$.

6.2 Proposition: Admissible Micro-Event Class

Proposition (Admissible class reduction). Under axioms A1–A3, the admissible micro-event model reduces to a conditionally memoryless hazard parameterization. In discrete ticks, this is naturally represented by conditionally independent Bernoulli increments and their binomial coarse-grainings.

Proof outline.

(i) **A1 + A2 force conditional independence.** Suppose the micro-event law at tick n depended on elapsed waiting time since the last micro-event, beyond what is encoded in c[n]. Then two operationally equivalent states (identical c[n]) would produce different observable anchoring statistics — violating A2. Therefore, given the interface sequence {c[n]}, the increment at tick n can depend only on c[n], and the increments are conditionally independent.

(ii) **Conditional independence on {0, 1} implies Bernoulli.** Given conditional independence, each increment X_n takes values in {0, 1} with some distribution parameterized by c[n]. The only free parameter is the success probability $p_v(c[n])$, yielding $X_n \mid c[n] \sim \text{Bernoulli}(p_v(c[n]))$.

(iii) **A3 confirms closure.** Under block aggregation (grouping m consecutive ticks with constant c), the count $S_m = X_1 + \cdots + X_m$ follows a Binomial(m, p_v) distribution. The sufficient statistic is the count S_m and the per-trial hazard p_v is preserved, so the aggregated law remains within the same parametric family. More general renewal processes with non-geometric waiting times would violate this closure: aggregating m ticks would introduce dependence on the position within the current waiting interval, requiring an additional parameter beyond the per-trial hazard and thereby violating A2 at the coarse-grained scale. The geometric distribution (equivalently, Bernoulli trials in discrete time) is the unique discrete memoryless distribution, a classical result related to the Rényi characterization theorem for Poisson processes in the continuous-time limit [R4]. Formally, A3 is taken to require closure within a one-parameter hazard family under block aggregation; under this requirement, the unique admissible discrete waiting-time law is the geometric distribution, which is equivalent to Bernoulli increments. In other words, A3 is a modeling restriction selecting hazard descriptions stable under block aggregation; relaxing A3 would require introducing additional internal state variables beyond c[n], producing a richer but less parsimonious micro-event model.

(iv) **A4 excludes degeneracy.** Finite throughput requires $p_v > 0$ on the physically realized trajectory, ensuring the Negative Binomial waiting time has finite expectation. ■

For the general reader: What this proposition says, in essence, is that if you want an anchoring process that (a) only cares about the current interface state, (b) doesn't carry hidden memory beyond that state, and (c) looks the same whether you observe it tick-by-tick or in blocks, then you are naturally led to a coin-flip process. More complex alternatives either smuggle in hidden

memory or break consistency across scales. (Note: the interface state c[n] itself *does* carry memory — one micro-event can change c[n], which then shifts the coupling probability at the next tick. The point is that c[n] carries *all* the relevant memory; there is no additional hidden dependence on elapsed time or past micro-event history beyond what is encoded in c[n].)

6.3 Continuous-Time Limit

If one introduces an emergent calibration Δt (mapping ticks to a macroscopic clock) and takes $p_v = \gamma_v \Delta t$ with $\Delta t \to 0$ while holding γ_v fixed, the Bernoulli counting process converges to a Poisson process with rate γ_v. In this limit, $N_{anchor} \cdot \Delta t$ converges to the Erlang-distributed anchoring time:

$$T_{anchor} \sim \text{Erlang}(K_c, \gamma_v)$$

with $E[T_{anchor}] = K_c/\gamma_v$ and $\text{Var}(T_{anchor}) = K_c/\gamma_v^2$. This recovers the continuous-time results as a corollary of the tick-domain analysis. The continuous formulation is a *derived limit*, not the starting point.

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7. The Action Postulate (P$\hbar$): Motivation and Statement

For the general reader: In physics, "action" is a fundamental quantity that measures the total dynamical content of a process — roughly, energy multiplied by time. Quantum mechanics tells us that action comes in discrete packets (quanta) of size $\hbar$ (the reduced Planck constant). This section introduces the paper's key postulate: that each bit of information carries exactly one quantum of action corresponding to a complete cycle. This is the load-bearing assumption of the paper, and we take care to motivate *why* it should hold rather than simply asserting it.

7.1 Motivation and Assumptions

We motivate the action postulate through four considerations. Crucially, the emergence of a phase variable is treated here as an explicit representational assumption (Aφ), not a derived consequence of the contrast-pair axioms.

(M1) Irreversibility requires cycle closure. Anchoring is irreversible: once a bit has flipped, the interface must return to an operationally equivalent configuration class for the next independent bit to begin. Otherwise successive bits would not be independent, violating the non-redundancy principle (BCB). Therefore, each bit event corresponds to a *closed operational cycle* of the interface.

(Aφ) Phase structure assumption. The interface contrast pair $c = (c_1, c_2)$ is a two-component object (Section 4.2). We assume that the contrast-pair space carries a real-valued metric structure (i.e., c takes values in $\mathbb{R}^2$); this is itself a nontrivial assumption about the interface algebra — if the contrast pair were discrete, categorical, or non-Euclidean, the topology below would not follow. Under coarse-graining constrained by non-redundancy, only relative contrast and cycle-

class information is retained; overall scale is gauge-like and discarded. A minimal faithful representation of a two-component real contrast up to overall scale is therefore a normalized vector $u = c/\|c\|$, which lives on S^1. Such a state is naturally parameterized by a single angular variable $\varphi \in [0, 2\pi)$. Cycle closure (M1) then corresponds to closed loops on S^1, classified by the winding number $\pi_1(S^1) = \mathbb{Z}$. This does not force quantum mechanics, but it makes an effective phase coordinate the minimal topological carrier of cycle information in the two-contrast representation. We treat Aφ as a modeling assumption selecting the smallest phase-bearing representation consistent with observed quantum interference phenomenology; the S^1 topology is contingent on the $\mathbb{R}^2$ metric structure of the contrast-pair space.

(M3) Cycle-invariants under coarse-graining are topological. Under the non-redundancy principle (BCB), only cycle-invariants survive coarse-graining — details internal to a cycle are "averaged out" by any macroscopic observer. For a phase-bearing interface (Aφ), the robust cycle-invariant is the total *phase winding number*: the integer counting how many times φ winds around $[0, 2\pi)$ during one flip cycle. This is a topological invariant — it cannot be changed by smooth deformations of the cycle and is therefore stable under coarse-graining.

(M4) Minimal winding → action quantum (bridge-motivated). The smallest nontrivial winding number is 1, corresponding to one full 2π rotation of the interface phase. The identification of quantum mechanical phase with action in units of $\hbar$ ($S/\hbar \leftrightarrow \varphi$, as in the Feynman path-integral formulation) is *imported from established quantum mechanics* — it is part of the Layer B bridge, not derived within the tick–bit formalism. Under this bridge, the minimal nontrivial flip cycle carries a cycle-action increment of $2\pi\hbar = h$.

In summary: M1 motivates cycle closure; Aφ introduces phase as an explicit representational assumption; M3 identifies winding number as the coarse-graining-robust invariant; M4 imports the phase–action identification from quantum mechanics.

The appearance of $\hbar$ here is not arbitrary: any theory that reproduces the observed interference and diffraction phenomena of quantum mechanics must contain a universal phase scale, and in the standard formulation that scale is $\hbar$. The action postulate ties the flip cycle to this universal scale rather than introducing a new one.

7.2 Formal Statement

Postulate (P$\hbar$). The cycle-action ledger of irreversible anchoring advances by a fixed quantum per completed bit:

$\Delta J_{bit} = \eta\hbar$, where $\eta = O(1)$

Here J denotes the cycle action variable (the action-angle variable $\oint p\, dq$ for periodic motion), not the Lagrangian action functional. The standard action-angle relation $\partial J/\partial E = T$ connects cycle action to energy and period [R2, R7]; with quantized $J = \Delta J_{bit} = \eta\hbar$ fixed per cycle, this gives $E = \Delta J_{bit}/T$ directly.

Choice of η. If the flip cycle corresponds to a complete phase winding of an internal interface mode (winding number = 1), then the minimal topological increment is $\Delta\varphi = 2\pi$, giving:

$\Delta J\_bit = 2\pi\hbar = h$

We keep η explicit throughout and set $\eta = 2\pi$ only when performing numerical consistency checks against the electron Compton period. If one prefers a radian-normalized cycle-action ledger, η may be set to 1 and the factor of 2π enters at the point of comparison to cycle-based observables.

7.3 Alternative Normalizations and Falsifiability

The choice $\eta = 2\pi$ is not aesthetic — it is physically consequential and in principle testable. Different values of η produce different inferred barrier thresholds:

$K\_c = \eta\hbar / (mc^2\Delta t)$

If η were 1 rather than 2π, all inferred K_c values would decrease by a factor of $2\pi \approx 6.28$. When the predictive program (Section 16) computes K_c independently from interface eigenmode dynamics, the computed values will be consistent with one and only one value of η — or with none, in which case the postulate is falsified.

More broadly, P$\hbar$ is falsifiable in the following sense: if interface eigenmode calculations (P1–P3 of Section 16) produce (K_c, p_v) values whose implied masses, via the mass formula, are inconsistent with observation for *any* choice of η, then the action postulate is rejected. The postulate makes a specific, testable structural claim — that anchoring and action are related by a fixed quantum — not a freely adjustable parameter.

7.4 Status of the Postulate

P$\hbar$ is the primary load-bearing assumption of this paper. It is *motivated* by M1, Aφ, M3, M4 but not *derived* from the tick–bit axioms alone. A full derivation would require showing that the interface phase structure (Aφ) follows from BCB axioms and that the phase–action identification (M4) emerges from the anchoring dynamics rather than being imported. We regard this as an important open problem. Concretely, a derivation would need to show that the BCB non-redundancy principle, applied to the full interface configuration space, forces the effective state space to be topologically S^1 rather than admitting richer or lower-dimensional alternatives — i.e., that phase structure is the unique minimal topology compatible with irreversible cycle closure on a two-contrast interface. The value of P$\hbar$ in its current form is that it is (i) physically well-motivated, (ii) falsifiable (Section 7.3), and (iii) structurally minimal (a single postulate rather than a family of ad hoc assumptions).

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8. Bridge to Energy and Mass: What Is Imported

For the general reader: This section is where we connect the abstract tick–bit framework to the physics you already know — energy, mass, and the speed of light. We are completely transparent that these connections *import* established physics. The anchoring model doesn't re-derive Einstein's $E = mc^2$; it shows that the anchoring picture is *consistent* with it and produces a specific formula for mass in terms of anchoring parameters.

8.1 Emergent Time Calibration

Introduce an emergent calibration Δt that maps tick counts to a macroscopic clock:

$$\tau = n \cdot \Delta t$$

This is a coarse-grained, observer-level mapping — not a primitive time variable. The tick index n remains fundamental; Δt is the conversion factor between substrate updates and the readings on a macroscopic clock built from many anchoring subsystems.

8.2 Action–Energy Bridge (Imported)

For a periodic or stationary flip cycle, we use the stationary-cycle identification: the energy scale associated with a completed phase cycle is the cycle-action divided by the cycle period. For stationary cyclic modes, this identification follows from action-angle quantization: a mode with quantized cycle-action $\Delta J = \eta\hbar$ and cycle period T has energy:

$$E = \Delta J / T = \eta\hbar / T$$

where T is the cycle period in emergent time and ΔJ is the cycle-action accumulated per cycle. The underlying identity is the action-angle relation $\partial J/\partial E = T$ for periodic motion, where $J = \oint p\, dq$ is the action variable: the period of a periodic orbit equals the derivative of its action with respect to energy. For quantized action $J = \eta\hbar$, this gives $E = \eta\hbar/T$ directly. This is the Bohr–Sommerfeld energy quantization for stationary states, not the general Lagrangian action principle.

8.3 Relativistic Mass–Energy Equivalence (Imported)

From special relativity:

$$E_{rest} = mc^2$$

This relation is not derived here; it is taken as an empirical input from established physics.

8.4 What the Bridge Accomplishes

Given these two imported relations, any framework that specifies (i) an action per cycle and (ii) a cycle period can compute an implied rest mass. The anchoring model provides both: $P\hbar$ gives the action per cycle, and the anchoring time gives the cycle period. The bridge translates anchoring parameters into a mass prediction.

9. Conditional Proposition: Mass Scale from Void Anchoring

For the general reader: This is the central result of the paper. It says: if you accept the action postulate (Section 7) and the standard physics bridge (Section 8), then the mass of a particle is determined by just two numbers from the anchoring process — how likely a micro-event is at each tick (p_v), and how many micro-events are needed to flip one bit (K_c). Stronger coupling and lower barriers mean fewer ticks per flip, which the Layer B bridge translates into higher energy and greater mass. That's the punchline: mass is set by the tick-count per flip.

9.1 Statement

Proposition 1 (Conditional mass–anchoring relation). Assume:

- **(A)** Tick–bit anchoring with homogeneous coupling p_v and barrier threshold K_c (Section 5).
- **(B)** Action postulate P$\hbar$: $\Delta J_{bit} = \eta\hbar$ per completed bit (Section 7).
- **(C)** Emergent tick→clock calibration Δt and the stationary-cycle action–energy bridge $E = \Delta J/T$ (Section 8).
- **(D)** Standard rest-energy relation $E_{rest} = mc^2$ (Section 8).

Domain: single elementary flip channel; homogeneous p_v; Δt treated as a calibration constant; **sharp anchoring regime** $CV = \sqrt{((1-p_v)/K_c)} \ll 1$, so that the random flip period is concentrated around its mean and the identification $T_{bit} = \Delta t \cdot E[N_{anchor}]$ is justified as a cycle period for energy quantization (see Section 5.4).

Then the implied rest mass scale is:

$$\mathbf{m = \eta\hbar p_v / (c^2 \Delta t K_c)}$$

9.2 Derivation

Step 1. From the anchoring model (Section 5.3), the expected number of ticks per flip is:

$$E[N_{anchor}] = K_c / p_v$$

Step 2. Map ticks to emergent clock time via Δt:

$$T_{bit} := \Delta t \cdot E[N_{anchor}] = \Delta t \cdot K_c / p_v$$

Step 3. Apply P$\hbar$ to one completed bit:

$$\Delta J_{bit} = \eta\hbar$$

Step 4. Apply the stationary-cycle action–energy bridge:

$E_{rest} := \Delta J_{bit} / T_{bit}$

Step 5. Substitute steps 2–4:

$E_{rest} = \eta\hbar / (\Delta t \cdot K_c / p_v) = \eta\hbar p_v / (\Delta t K_c)$

Step 6. Apply $E_{rest} = mc^2$:

$m = \eta\hbar p_v / (c^2 \Delta t K_c)$ ■

9.3 Structural Interpretation

The mass formula has the form **$m \propto p_v / K_c$**. This is the physically interpretable core of the result:

- **p_v** (coupling probability per tick) measures how *readily* the interface couples to the void substrate at each update (Section 4.5). Higher coupling → fewer ticks per flip → higher intrinsic frequency → higher mass.
- **K_c** (barrier threshold) measures the *height* of the barrier separating stable bit-states (Section 4.3). Higher barrier → more ticks per flip → lower intrinsic frequency → lower mass.

Mass is therefore set by the **tick-count per flip**: the ratio K_c/p_v determines the number of substrate ticks per flip cycle. Via the energy-period bridge $E = \eta\hbar/T$ (a Layer B relation requiring the emergent-time calibration Δt), fewer ticks per flip corresponds to higher rest energy. This is the standard quantum-mechanical relationship $E = h\nu$ applied to the flip cycle; "frequency" is the Layer B image of the tick-count.

A crucial distinction (developed fully in Section 12): the *inertial* mass — resistance to acceleration — is a separate structural quantity that happens to equal the rest mass under the equivalence-principle condition (12.9). The flip frequency sets rest energy; the projection-scale geometry sets inertial response. Their equality is not automatic — it is a structural constraint on how information projects into emergent space. The fundamental quantity is the tick-count per flip, not a rate in time; temporal language applies only after the emergent-time mapping of Section 8.

9.4 Terminology: Flip Channel

A **flip channel** is a single, independent pathway through which the interface flips bits. An elementary particle corresponds to one flip channel with characteristic parameters (K_c, p_v). Composite particles may involve multiple coupled channels whose contributions combine; the extension to multi-channel systems is developed in Section 11.3. The mass formula as stated applies to a single elementary channel.

10. Parameter Identification and Consistency Checks

For the general reader: This section does *not* predict the electron's mass — it works backwards from the known electron mass to figure out what the anchoring parameters would have to be. This is like measuring the speed of a car and then calculating what gear ratio the transmission must have. It's useful because it tells us whether the framework produces sensible numbers, and it sets a target: if we can someday calculate K_c from first principles and it comes out near 1.50×10^{23}, that would be a genuine prediction confirmed.

10.1 Calibration Choices

For the consistency check, we adopt the following values:

Symbol	Value	Status
$\hbar$	$1.054571817 \times 10^{-34}$ J·s	Empirical constant (CODATA)
$h = 2\pi\hbar$	$6.62607015 \times 10^{-34}$ J·s	Empirical constant (CODATA)
c	2.99792458×10^{8} m/s	Empirical constant (CODATA)
m_e	$9.1093837015 \times 10^{-31}$ kg	Empirical constant (CODATA)
t_P	5.391247×10^{-44} s	Derived from G, $\hbar$, c (standard definition)
η	2π	Postulate: full cycle (Section 7)
p_v	≈ 1	Assumption for this check (Section 13)
Δt	t_P	Assumption: $\Delta t = t_P$ is adopted, not derived (Section 13)

10.2 Electron Barrier Threshold

Setting $\eta = 2\pi$ (so $\eta\hbar = h$) and p_v = 1, the mass formula gives:

$$K_{c,e} = \eta\hbar / (m_e c^2 \Delta t) = h / (m_e c^2 t_P)$$

Numerically:

$$m_e c^2 = 8.18710565 \times 10^{-14} \text{ J}$$

$$K_{c,e} = 6.62607015 \times 10^{-34} / (8.18710565 \times 10^{-14} \times 5.391247 \times 10^{-44})$$

$K_{c,e} \approx 1.50 \times 10^{23}$

This does not predict m_e. It *infers* the barrier threshold that the electron would require under the stated calibration choices.

10.3 Flip Period

The implied flip period for the electron is:

$T_{bit} = K_{c,e} \cdot t_P \approx 8.09 \times 10^{-21}$ s

Compare to the electron Compton period:

$T_{C(e)} = h / (m_e c^2) \approx 8.09 \times 10^{-21}$ s

The agreement is exact **by construction** under $\eta = 2\pi$ — this is an algebraic identity, not an independent check. Its value is illustrative: it confirms that the flip tick-count $K_{c,e}$, once mapped to emergent time via the Layer B bridge, *is* the Compton period. The anchoring model reinterprets the Compton period as the emergent-time image of the $K_{c,e}$ substrate ticks required to complete one bit-flip.

10.4 Other Particle Thresholds (Consistency Translation)

Under fixed Δt, η, and comparable p_v, the mass formula gives $K_c \propto 1/m$. Known mass ratios therefore translate directly into threshold ratios:

Particle	Mass ratio to electron	Implied K_c
Electron (e)	1	1.50×10^{23}
Muon (μ)	$m_\mu/m_e \approx 206.768$	$K_{c,e} / 206.768 \approx 7.26 \times 10^{20}$
Proton (p)	$m_p/m_e \approx 1836.152$	$K_{c,e} / 1836.152 \approx 8.17 \times 10^{19}$

Heavier particles correspond to **smaller** K_c — shallower barrier thresholds, fewer ticks per flip, and (under the Layer B bridge) higher energy per cycle. If p_v varies significantly between modes, the relationship $K_c \propto 1/m$ is modified: the relevant quantity is the ratio $K_c/p_v \propto 1/m$, and modes with smaller p_v could have proportionally larger K_c at the same mass.

These values are *not predictions*. They are the framework's translation of empirical mass data into anchoring language. A genuine prediction would compute K_c from interface eigenmode dynamics (Section 16) and then derive the mass ratios without fitting to them.

10.5 What Would Constitute a Non-Trivial Check

The numerical work in this section becomes genuinely predictive only if one can independently estimate $K_{c,e}$ — for instance, by solving the interface eigenmode problem (Section 16) — and obtain a value near 10^{23} without using the electron mass as input. Establishing that target is one purpose of the parameter identification performed here.

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11. Extended Void-Coupling Tests and Hierarchy Analysis

For the general reader: So far, we translated the known electron mass into anchoring language. That shows consistency, but it doesn't yet test the framework under variation. In this section we stress-test the mass relation in multiple regimes: stochastic coupling, multi-channel flipping, the Planck-mass limit, gravitational redshift, and unstable particles. These are not new postulates — they are consequences of the same conditional mass relation derived in Section 9.

11.1 The Conditional Mass Relation (Recap)

Under the assumptions of Proposition 1:

$$m = \eta \hbar p_v / (c^2 \Delta t K_c) \quad (11.1)$$

where K_c is the barrier threshold, p_v is the per-tick micro-event probability, Δt is the tick calibration, and η is the action normalization factor ($\eta = 2\pi$ for full phase winding). Mass therefore scales as:

$$m \propto p_v / K_c \quad (11.2)$$

This section explores the structural consequences of that scaling.

11.2 Stochastic Regime Test: $p_v < 1$

In Section 10 we evaluated the electron in the near-deterministic regime $p_v \approx 1$. We now relax that assumption to test whether the framework remains physically sensible when anchoring is genuinely stochastic.

Recall the anchoring statistics (Section 5.3–5.4):

$$E[N_{anchor}] = K_c / p_v$$

$$CV = \sqrt{((1 - p_v) / K_c)}$$

Suppose for the electron $p_v = 0.1$ (a tenfold reduction from the deterministic limit). Using equation (11.1) with $\Delta t = t_P$ and $\eta = 2\pi$, the inferred barrier threshold becomes:

$$K_{c,e}(p_v = 0.1) = h \cdot p_v / (m_e c^2 t_P) = K_{c,e}(1) \times 0.1 \approx 1.50 \times 10^{22}$$

The coefficient of variation at this operating point is:

$$CV = \sqrt{(0.9 / 1.50 \times 10^{22})} \approx 7.7 \times 10^{-12}$$

Even for $p_v = 0.1$, anchoring is *extremely* sharp — the relative fluctuation in anchoring time is of order 10^{-12} of the mean.

Conclusion. Elementary particle stability does not require deterministic anchoring. Large K_c alone ensures extremely narrow anchoring-time distributions. Stochastic anchoring (p_v well

below 1) remains fully compatible with sharp mass peaks. The Bernoulli framework built in Sections 5–6 is not merely formal — it functions correctly across the physically relevant range of p_v.

11.3 Multi-Channel Flip Scaling

In this paper the single-channel mass formula is derived for elementary flip modes. Composite masses require effective coarse-grained anchoring parameters reflecting interaction energy and confinement. The single-channel formula generalizes naturally to composite systems. If a particle corresponds to χ independent flip channels, each flipping one bit per cycle, the total action per cycle is:

$$\Delta J_{total} = \chi \cdot \eta\hbar$$

and the mass becomes:

$$m = \chi \eta\hbar p_v / (c^2 \Delta t K_c) \quad (11.3)$$

so that:

$$m \propto \chi\, p_v / K_c \quad (11.4)$$

Structural implications. Increasing channel count χ increases mass linearly. Increasing barrier height K_c decreases mass. Increasing coupling p_v increases mass.

For the general reader: You might wonder: could the proton simply be three electrons glued together, since protons are made of three quarks? This formula lets us test that idea directly.

Naïve quark-channel test. Consider whether the proton mass could arise solely from three flip channels (a naïve quark analogy), with equal K_c and p_v to the electron. Equation (11.4) predicts:

$$m_p / m_e \approx \chi = 3$$

Observed: $m_p / m_e \approx 1836$. The discrepancy is a factor of ~612. Therefore the proton mass **cannot** arise from channel multiplicity alone. The dominant contribution to the proton–electron mass hierarchy must reside in the anchoring parameters K_c and/or p_v — the proton's flip channels must have substantially shallower depth (smaller K_c) and/or stronger coupling (larger p_v) than the electron's.

An important caveat: in the Standard Model, the proton mass arises predominantly (~99%) from QCD binding energy — gluon field dynamics and the kinetic energy of confined quarks — not from the constituent quark masses ($m_u \approx 2$ MeV, $m_d \approx 5$ MeV). The proton's effective K_c and p_v are therefore not simple functions of constituent quark anchoring parameters; they must reflect the entire confinement dynamics as encoded in the interface eigenmode structure.

Effective anchoring parameters for composite bound states. In the anchoring framework, (p_v, K_c) for a composite particle are effective parameters of the bound-state eigenmode after coarse-graining over internal channels — not inherited additively from constituents. Binding energy enters by increasing the flip completion density C = p_v/K_c of the confined field configuration relative to a free-field baseline: either through increased coupling resonance p_v in the confined void-resonant region, reduced effective anchoring depth K_c for the collective cycle closure, or multiplicity of tightly coupled internal channels that contribute coherently to cycle action. The predictive program therefore requires computing (p_v, K_c) directly for hadronic eigenmodes (analogous to lattice QCD extracting hadron masses from correlation functions [R15]), rather than attempting to build hadron masses from "constituent anchoring" parameters. In this paper we treat hadron masses as a target application of the eigenmode program, not as an immediate consequence of the single-channel formula.

This constrains the predictive program of Section 16: a successful computation must explain a K_c ratio of roughly 1836 (or a corresponding p_v shift) between proton and electron eigenmodes.

11.4 Planck Mass Limit: Minimal Barrier Height

We now examine the extreme high-mass end of the framework by setting m = m_P (the Planck mass). Using $\Delta t = t_P$ and $\eta = 2\pi$ with $p_v = 1$:

$$K_{c,P} = h\, p_v / (m_P c^2 t_P) \quad (11.5)$$

By the definition of the Planck mass, $m_P c^2 t_P = \hbar$. Substituting:

$$K_{c,P} = 2\pi\hbar / \hbar = 2\pi$$

Thus:

$K_{c,P} \sim O(1)$

For the general reader: This is a striking result. It says that the heaviest meaningful mass scale in physics — the Planck mass, roughly 10^{19} times heavier than a proton — corresponds in the anchoring framework to the absolute *minimum* barrier height: just one full topological cycle. You can't flip with fewer micro-events than one complete winding requires. So the Planck mass isn't arbitrary — it's the mass you get when the tick-count per bit-flip is as small as it can possibly be, giving the highest possible intrinsic flip frequency.

Interpretation. The Planck mass is the regime where anchoring requires only one full topological cycle — the minimum allowed by the action postulate P$\hbar$, yielding the highest possible intrinsic flip frequency. Lighter particles have higher barriers (more micro-events, more ticks per cycle, lower frequency). The entire observed mass hierarchy maps onto a barrier-height hierarchy:

Mass Scale	Approximate K_c	Interpretation
Planck mass (m_P)	~ 2π	Lowest barrier, highest flip frequency
Proton (m_p)	~ 10^{19}	Shallow but stable anchoring
Muon (m_μ)	~ 10^{20}	Intermediate depth
Electron (m_e)	~ 10^{23}	Highest barrier, lowest flip frequency

This is a **structural identification**: the Planck scale, which in standard physics appears as a dimensional combination of G, $\hbar$, and c, is reinterpreted here as the minimal-flip boundary of the void-anchoring framework. This result follows algebraically from the calibration choices $\Delta t = t_P$ and $\eta = 2\pi$ together with the definition of the Planck mass; we do not claim it as a numerical prediction. Its physical content lies not in the number itself but in the interpretation: the Planck scale corresponds to the minimal-flip boundary of the anchoring framework ($K_c \sim O(1)$) rather than being an arbitrary ultraviolet cutoff. The Planck mass is not just "very large" — it is the mass at which barrier height bottoms out. Section 14.4 shows that this same boundary is independently the minimal-stability boundary (where flip-period fluctuations become O(1)), a coincidence with genuine structural content.

Pattern in the inferred K_c spectrum. Under the assumption $p_v = 1$, the mass formula reduces to $K_c = \eta\hbar/(mc^2\Delta t)$, and the known particle masses map one-to-one onto K_c values. Examining the resulting set — $K_{c,e} \sim 1.5 \times 10^{23}$, $K_{c,\mu} \sim 7.3 \times 10^{20}$, $K_{c,\tau} \sim 4.3 \times 10^{19}$, $K_{c,p} \sim 8.1 \times 10^{19}$, etc. — reveals no obvious simple numerical pattern (no recognizable integer sequence, geometric progression, or small-number relation among the values). This is not surprising: the K_c values are inferred, not predicted, and there is no reason to expect a simple pattern without a theory of the interface eigenmodes. The mass formula has two free parameters per particle (p_v, K_c); under $p_v = 1$, this reduces to one, but a single-parameter fit to a known mass is not predictive. Section 14.6 argues that stability conditions further constrain the parameter space: stable particles lie on a fixed-point curve $p_v = f(K_c)$, reducing the effective freedom to one parameter (position along the curve). Genuine prediction requires the eigenmode program of Section 16 to compute (p_v, K_c) pairs from interface dynamics. Until then, the framework parameterizes the mass hierarchy but does not explain it.

11.5 Maximum Flip Completion and Black Hole Formation (Threshold Correspondence)

For the general reader: As mass increases, the mode's spatial projection scale shrinks. At some point, this projection scale becomes smaller than the gravitational radius of the mass itself — the object would be inside its own black hole. This sets a physical ceiling on mass, and it coincides with the Planck scale.

In this framework, rest mass scales with flip completion density $C := p_v/K_c$. Under the inertial–rest equivalence condition (Section 12), the spatial projection scale satisfies $\ell_b \propto (K_c/p_v) \cdot \Delta t \cdot c = (\Delta t \cdot c)/C$; thus heavier modes (larger C) correspond to smaller projection lengths.

In relativistic gravity, a mass m has an associated Schwarzschild radius $r_s = 2Gm/c^2$. Particle-like localization is expected to fail once the intrinsic projection length is contained within the gravitational radius, i.e., when $\ell_b \lesssim r_s$. Using the standard Compton-scale bridge $\lambda_C = \hbar/(mc)$ as the minimal localization scale for a mode, the threshold $r_s \gtrsim \lambda_C$ yields:

$$m^2 \gtrsim \hbar c/(2G)$$

i.e., a Planck-scale mass up to an O(1) factor.

Interpretation. The framework admits a natural "maximum flip completion" boundary: sufficiently large C compresses the projection scale until horizon formation occurs. Beyond this threshold, the mode cannot manifest as a conventional particle excitation — it becomes a black-hole-like anchored region in emergent spacetime. This unifies three independently motivated boundaries:

1. **Minimal-flip boundary** (Section 11.4): K_c bottoms out at $\sim 2\pi$ (one topological cycle).
2. **Minimal-stability boundary** (Section 14.4): CV becomes O(1) when $K_c \sim O(1)$.
3. **Horizon boundary** (this subsection): projection scale falls below Schwarzschild radius at Planck mass.

All three converge at the same mass scale. This is presented as a correspondence target rather than a derivation of GR: the full realization requires deriving r_s and the metric response from flip-density curvature (Section 15).

11.6 Gravitational Redshift Consistency

We now test whether the anchoring interpretation of mass is compatible with gravitational effects. Consider a flip mode operating at radial coordinate r in a Schwarzschild geometry with mass M. Let Δt_{local} denote the proper tick calibration at r (the local observer's clock), and Δt_∞ the corresponding coordinate-time calibration as seen from spatial infinity. Operationally, Δt is defined relative to an observer's physical clock construction: it is the proper time interval that one substrate tick maps onto for that observer. This is a Layer B bridge choice — the tick itself (Layer A) has no intrinsic duration.

Under gravitational time dilation:

$$\Delta t_\infty = \Delta t_{local} / \sqrt{(1 - 2GM/(rc^2))}$$

Since the flip tick-count K_c/p_v is a dimensionless integer count (Layer A), it is observer-independent. The flip period as measured at infinity is therefore:

$$T_{bit,\infty} = \Delta t_\infty \cdot K_c / p_v = T_{bit,local} / \sqrt{(1 - 2GM/(rc^2))}$$

The rest energy as measured at infinity is:

$$E_\infty = \eta\hbar / T_{bit,\infty} = E_{local} \cdot \sqrt{(1 - 2GM/(rc^2))}$$

This is exactly the standard gravitational redshift: energy observed at infinity is reduced by the factor $\sqrt{(1 - 2GM/(rc^2))}$ relative to the locally measured rest energy.

Conclusion. The anchoring interpretation of mass is consistent with relativistic gravitational redshift once the standard time-dilation bridge is applied and the observer (local vs infinity) is specified. The key structural point is that K_c and p_v — being dimensionless tick-domain quantities — are invariant under the coordinate transformation; only the emergent tick calibration Δt transforms, and it transforms in exactly the way required by general relativity.

11.7 Unstable Particles and Decay Width

For the general reader: Not all particles are stable. The muon, for example, decays in about two-millionths of a second. In our framework, stability corresponds to a rock-solid flip pattern. Instability means the anchoring parameters are drifting — the pattern is slowly falling apart.

Unstable particles correspond to flip modes that fail one or more of the stability conditions (Section 14) — specifically, modes whose anchoring parameters (K_c, p_v) are not fixed points of the coarse-graining flow but instead drift over time due to coupling to additional channels or environmental perturbations.

Let K_c(t) slowly evolve due to coupling to other modes. Then the anchoring time acquires fluctuations:

$$\delta T_{bit} \sim (\Delta t / p_v) \cdot \delta K_c$$

This produces a spread in rest energy:

$$\delta E \sim (\eta \hbar / T_{bit}^2) \cdot \delta T_{bit}$$

which maps to a decay width:

$$\Gamma \sim \delta E$$

This suggests a structural classification of particles by anchoring stability:

- **Stable particles** (electron, proton): deep anchoring fixed points with negligible parameter drift. K_c and p_v are effectively constant over all accessible timescales.
- **Metastable particles** (muon, neutron): shallow fixed points with slow drift in K_c or p_v. The flip pattern holds for many cycles but eventually loses coherence.
- **Rapidly decaying resonances** (Δ, ρ, etc.): near-boundary flip modes where the anchoring parameters are far from any fixed point. Flip coherence is lost within a small number of bit-flip cycles.

A full quantitative decay-width prediction requires computing the fluctuation dynamics of K_c and p_v from interface evolution (Section 16). The classification above is structural, not

quantitative — but it demonstrates that particle instability has a natural interpretation within the anchoring framework.

11.8 Section Summary

The extended tests demonstrate that the conditional mass relation (11.1) behaves consistently across multiple regimes:

- **Stochastic variation:** sharp mass peaks are maintained even for $p_v \ll 1$, due to the large K_c values characteristic of elementary particles.
- **Multi-channel scaling:** channel multiplicity alone cannot account for the proton–electron mass ratio, constraining the predictive program.
- **Planck limit:** the Planck mass corresponds to minimal barrier height $K_c \sim 2\pi$ — a nontrivial structural identification.
- **Gravitational redshift:** the mass formula is compatible with standard relativistic energy redshift without modification.
- **Instability:** particle decay is interpretable as drift in anchoring parameters away from coarse-graining fixed points.

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12. Compatibility Condition for Inertial–Rest Mass Equivalence

For the general reader: So far we have shown how *rest mass* arises from the tick-count per flip (fewer ticks = higher energy = higher mass via $E = h\nu$). But in physics, mass appears in two distinct roles: in Einstein's $E = mc^2$ (rest mass, set by tick-count per flip) and in Newton's $F = ma$ (inertial mass, resistance to acceleration). These two masses are experimentally identical to extraordinary precision — that is one of the deepest facts in physics, and it underlies Einstein's general theory of relativity. This section shows under what structural conditions the anchoring framework reproduces that equality. The result is striking: the equivalence principle becomes a constraint on how information projects into geometry.

This section does not derive the equivalence principle from first principles. Instead, it establishes a necessary and sufficient **compatibility condition**: given the rest-mass scale derived in Section 9 and the imported momentum normalization $P = \eta\hbar/\ell_b$, inertial and rest mass coincide if and only if the spatial projection scale ℓ_b satisfies equation (12.9). Deriving ℓ_b from interface dynamics is deferred to the predictive program (Section 12.9 / Section 16).

12.1 Spatial Projection and Velocity

We work entirely in tick–bit primitives, building on the notation of Sections 5 and 9.

Let n be the tick index, $B[n]$ the cumulative bit-flip count, and Δt the emergent tick calibration. Define a spatial projection via:

$x[n] := \ell_b \cdot B[n]$ (12.1)

where ℓ_b is the **bit-to-length projection scale** — the emergent spatial extent associated with one bit-flip. This scale is not assumed universal; it may depend on the anchoring structure of the mode in question.

From Section 5.3, the expected flip increment per tick in mean-field is:

$E[\Delta B] = p_v / K_c$ (12.2)

Define the **projected velocity** — the expected spatial displacement per emergent time unit:

$v := \ell_b \cdot E[\Delta B] / \Delta t = \ell_b \cdot p_v / (K_c \cdot \Delta t)$ (12.3)

This is the emergent drift velocity of the mode's spatial projection under its intrinsic flip dynamics.

12.2 Emergent Momentum

From Section 7, each bit-flip carries action $\Delta J_{bit} = \eta\hbar$ and projects onto spatial extent ℓ_b (equation 12.1). The associated **emergent momentum** is:

$P := \eta\hbar / \ell_b$ (12.4)

This is structurally identical to the de Broglie relation $p = h/\lambda$ when ℓ_b is identified with the de Broglie wavelength — a consistency check, not a derivation. This identification is a structural consistency requirement with de Broglie kinematics imported as part of the Layer B bridge; it is not derived within Layer A. When $\eta = 2\pi$, equation (12.4) becomes $P = h/\ell_b$; thus identifying ℓ_b with the de Broglie wavelength λ, when tested against known kinematics, reproduces the standard momentum normalization. Whether the BCB interface dynamics independently produce an ℓ_b that matches this identification remains an open problem (Section 12.9).

12.3 Inertial Mass from Momentum and Velocity

The inertial mass is defined as the ratio of momentum to velocity:

$m_{inertial} := P / v$ (12.5)

This is the standard mechanical definition: given a mode with momentum P and projected velocity v, its inertial mass is the proportionality constant relating the two. The identification of $v = \ell_b \cdot p_v/(K_c \cdot \Delta t)$ with the particle's observable velocity rests on the spatial projection (12.1): if each bit-flip advances the mode's spatial coordinate by ℓ_b, then the expected spatial displacement per unit emergent time is the mode's center-of-mass drift velocity. This is the same identification used in lattice random-walk models, where the macroscopic drift velocity emerges from the microscopic hopping rate and lattice spacing.

Substituting equations (12.4) and (12.3):

$m_{inertial} = [\eta\hbar / \ell_b] / [\ell_b \cdot p_v / (K_c \cdot \Delta t)]$

Simplifying:

$m_{inertial} = \eta\hbar \cdot K_c \cdot \Delta t / (\ell_b^2 \cdot p_v)$ (12.6)

12.4 The Equivalence Compatibility Condition

From Proposition 1 (Section 9), rest mass is:

$m_{rest} = \eta\hbar p_v / (c^2 \Delta t K_c)$ (12.7)

For the general reader: We now have two expressions for mass. One (rest mass) comes from the flip frequency — how many ticks per flip. The other (inertial mass) comes from the ratio of momentum to velocity — how the mode's spatial projection carries its action. The question is: when are these equal?

Setting $m_{inertial} = m_{rest}$:

$\eta\hbar \cdot K_c \cdot \Delta t / (\ell_b^2 \cdot p_v) = \eta\hbar \cdot p_v / (c^2 \cdot \Delta t \cdot K_c)$

Canceling common factors and rearranging:

$\ell_b^2 = (\Delta t)^2 \cdot K_c^2 \cdot c^2 / p_v^2$ (12.8)

which implies:

$\ell_b = (K_c / p_v) \cdot \Delta t \cdot c$ (12.9)

12.5 Acceleration and Force as Consequences

With inertial mass established, we can derive acceleration and force as consequences rather than definitions.

Under an external perturbation δp_v, the projected velocity changes:

$\delta v = \ell_b \cdot \delta p_v / (K_c \cdot \Delta t)$ (12.10)

The perturbation δp_v arises from coupling to the same void-interaction structure that determines the baseline p_v (Section 4.5). In occupancy-measure language, $p_v = \mu(A)$. Under small perturbations of the measure $\mu \to \mu + \delta\mu$, the first-order change is $\delta p_v = \int_A \delta\mu$, which is proportional to $\mu(A)$ for uniform fractional perturbations. Thus in the linear-response regime:

$\delta p_v = \alpha \cdot p_v$ (12.11)

where α is a dimensionless parameter encoding the applied field strength. Non-uniform perturbations would introduce mode-dependent corrections to α, but the leading-order proportional response is generic.

Emergent acceleration is the velocity change per unit emergent time:

$$a = \delta v / \Delta t = \ell\_b \cdot \delta p\_v / (K\_c \cdot \Delta t^2) \quad (12.12)$$

The force follows from Newton's second law as a derived relation:

$$F = m\_inertial \cdot a = [\eta\hbar \cdot K\_c \cdot \Delta t / (\ell\_b^2 \cdot p\_v)] \cdot [\ell\_b \cdot \delta p\_v / (K\_c \cdot \Delta t^2)]$$

Simplifying:

$$F = \eta\hbar \cdot \delta p\_v / (\ell\_b \cdot p\_v \cdot \Delta t) \quad (12.13)$$

Under the equivalence condition (12.9), this reduces to:

$$F = \eta\hbar \cdot \delta p\_v / (K\_c \cdot (\Delta t)^2 \cdot c) \quad (12.14)$$

The force is proportional to the perturbation δp_v and inversely proportional to the barrier height — consistent with the expectation that modes with higher barriers (lighter particles) respond more to a given perturbation in p_v.

12.6 Interpretation

Equation (12.8) is the **necessary and sufficient condition** for inertial and rest mass equivalence within the anchoring framework. Its content is physically transparent:

- **High barriers** (large K_c) produce a **larger** spatial projection scale ℓ_b. Modes that take many micro-events to flip one bit project over more emergent space per flip.
- **Strong coupling** (large p_v) produces a **smaller** projection scale. Modes that couple readily to the void are more spatially compact per flip.
- The **same anchoring parameters** (K_c, p_v) that determine the energy scale (rest mass) also determine the spatial response (inertial mass) — but only if ℓ_b obeys equation (12.9).

Under this condition:

m_inertial = m_rest

and the equivalence principle is structurally recovered.

12.7 Conceptual Consequence

For the general reader: Here is the deep point: the equivalence of inertial and rest mass is *not automatic* in an informational framework. In most models where mass comes from information, there's no reason why "energy of the information process" and "resistance to acceleration" should be the same number. In our framework, they are the same *if and only if* the way information projects into space is governed by the same anchoring parameters that set the flip frequency. The equivalence principle becomes a constraint on how information becomes geometry.

The equivalence of inertial and rest mass emerges in this framework if and only if three conditions hold simultaneously:

1. Action per flip cycle is fixed ($P\hbar$).
2. Momentum is the de Broglie momentum $P = \eta\hbar/\ell_b$.
3. The spatial projection scale ℓ_b derives from the same anchoring parameters (K_c, p_v) as the flip frequency.

Condition 3 is the nontrivial structural content. It means that the equivalence principle is not a separate postulate but a **constraint on the geometry of information projection**. If the interface dynamics that determine K_c and p_v also determine ℓ_b via equation (12.9), then inertial–rest mass equivalence follows as a theorem, not an assumption.

12.8 Two Meanings of Mass

The preceding derivation makes explicit a distinction that is often elided: "mass" refers to two operationally distinct quantities that happen to be numerically equal.

Mass as rest energy (intrinsic flip frequency). The rest mass $m = \eta\hbar p_v/(c^2\Delta t K_c)$ is set by the intrinsic flip frequency $\nu = p_v/(\Delta t K_c)$ via $E = h\nu$. A massive particle flips in *fewer* ticks — it has a higher intrinsic frequency and higher rest energy. The electron, with $K_c \sim 10^{23}$, takes enormously many ticks per flip and has correspondingly low mass. The Planck mass, with $K_c \sim 2\pi$, completes a flip in a handful of ticks and has the highest mass the framework admits.

Mass as inertia (resistance to acceleration). Inertial mass $m_{inertial} = \eta\hbar K_c \Delta t/(\ell_b^2 \cdot p_v)$ measures how much the mode resists changes to its spatial flip pattern. This is *not* determined by intrinsic flip frequency — it is determined by how the flip pattern is coupled to emergent geometry through the projection scale ℓ_b.

These two quantities coincide ($m_{inertial} = m_{rest}$) if and only if ℓ_b satisfies equation (12.9). Their equality is the structural content of the equivalence principle: **mass as rest energy and mass as inertia arise from distinct structural layers in the framework, but are locked together by the geometry of information projection.**

A system may have extremely rapid intrinsic phase evolution (large rest energy) while simultaneously requiring enormous external energy input to change its momentum state. The "resistance" that mass provides to acceleration is not slowness of internal flipping — it is the rigidity of the coupling between the flip pattern and emergent space.

For the general reader: Think of it this way: a very massive particle flips its bits very quickly (high frequency = high energy = high mass). But it is also very hard to push (high inertia). These are different things — one is about internal rhythm, the other about external stubbornness. The deep result of this section is that they are equal *if and only if* the particle's spatial extent is determined by the same parameters that set its internal rhythm. That constraint is what the equivalence principle *means* in this framework.

12.9 Status and Open Problems

The derivation uses standard mechanical definitions ($P = \eta\hbar/\ell_b$, $v = \ell_b \cdot p_v/(K_c \cdot \Delta t)$, $m = P/v$) and introduces one structural assumption: the linear-response condition (12.11). The equivalence condition (12.8) follows algebraically.

What remains open:

- **Deriving ℓ_b from BCB interface geometry.** Equation (12.9) tells us what ℓ_b must be for equivalence to hold; it does not derive ℓ_b from first principles. Showing that the BCB interface dynamics independently produce an ℓ_b satisfying (12.9) would convert the equivalence principle from a compatibility condition into a derived theorem.
- **Physical origin and universality of the linear-response assumption.** Equation (12.11) assumes $\delta p_v = \alpha \cdot p_v$ — that perturbations couple proportionally to the baseline void-coupling strength, with α universal across modes. The equivalence principle has been tested to extraordinary precision: $\sim 10^{-13}$ in Eötvös-type torsion balance experiments [R10] and $\sim 10^{-15}$ by the MICROSCOPE satellite mission [R9]. Within the anchoring framework, the equality $m_{inertial} = m_{rest}$ requires this proportional response, and universality imposes a sharp constraint on its structure.

  If perturbations instead produced mode-dependent responses $\delta p_v = \alpha_j \cdot p_v$ with coefficients α_j that vary across modes, then equation (12.9) would yield mode-dependent projection scales $\ell_{b,j}^2 \propto \alpha_j$, leading to composition-dependent deviations in inertial–rest mass equivalence — precisely the signature that Eötvös-type experiments constrain. Current bounds therefore require $|\alpha_j - \alpha_k|/\alpha < 10^{-15}$ across all observed matter species.

  This leaves two possibilities: (a) the proportional response is a deep structural feature of the void-coupling mechanism — the substrate reweights the anchorable subset uniformly by construction, making α mode-independent exactly — or (b) the framework makes a falsifiable prediction: equivalence principle violations at field strengths or in exotic matter sectors where nonlinear or mode-dependent corrections to δp_v become significant. We regard this as an open empirical question. Either outcome has significant implications: exact universality constrains the admissible class of void-coupling mechanisms, while any detected violation would provide direct empirical access to the mode-structure of anchoring.

If both can be established, the equivalence principle becomes a *derived feature* of void anchoring rather than an imposed compatibility condition — a result that would have significant implications for the relationship between information, gravity, and geometry.

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13. Discussion of Key Assumptions

For the general reader: Every calculation rests on choices. This section examines the two most consequential ones: the assumption that micro-events happen almost certainly at every tick ($p_v \approx 1$), and the assumption that the substrate ticks at the Planck timescale. We discuss what these assumptions mean physically, when they might break down, and what happens to the framework if they're relaxed.

13.1 Physical Meaning of p_v

The coupling probability p_v has a direct physical interpretation: it is the per-tick probability that the interface occupies the anchorable configuration subset — the region of state space in which a void-coupling commitment increment is registered (Section 4.3). Different interface eigenmodes occupy this subset to different degrees:

- **A strongly bound, stable eigenmode** spends almost all ticks in the anchorable region → p_v close to 1. The anchoring process is nearly deterministic, with low variance in anchoring time.
- **A weakly bound or excited eigenmode** spends fewer ticks in the anchorable region → p_v significantly below 1. The anchoring process is genuinely stochastic, with larger variance → broader mass linewidths and shorter lifetimes.
- **A marginally stable eigenmode** has p_v near the boundary of the admissible region → large fluctuations in anchoring time → observable as particle instability or decay.

This interpretation ties p_v directly to the stability analysis of Section 14: modes with low p_v have large CV (Section 5.4) and are candidates for unstable or short-lived particles.

13.2 The $p_v \approx 1$ Regime

Setting $p_v \approx 1$ for the electron consistency check corresponds to assuming that the electron's dominant flip channel is a strongly bound eigenmode that spends nearly every tick in the anchorable region. In this limit, the Negative Binomial distribution reduces to deterministic counting: the variance vanishes and $N_{anchor} = K_c$ with certainty.

This does **not** eliminate stochasticity from the framework in general:

(i) **State-dependent coupling** $p_v(c[n])$ reintroduces fluctuations even if the time-averaged coupling is near unity.

(ii) **Composite systems** may have effective $p_v < 1$ after coarse-graining over internal degrees of freedom.

(iii) **Other particle modes** — particularly heavier, less stable particles — may operate in regimes where p_v is significantly less than 1, producing genuinely stochastic anchoring with physical consequences (e.g., broader anchoring time distributions contributing to linewidths or decay rates).

If stochastic anchoring is to be physically significant at the fundamental level — which is one of the motivations for building the Bernoulli framework — then $p_v < 1$ should be retained and estimated from interface dynamics rather than set to unity. The $p_v = 1$ limit is a useful consistency check but may not represent the physically correct operating point. Section 11.2 demonstrates that the framework remains well-behaved for p_v as low as 0.1.

13.3 The $\Delta t = t_P$ Identification

Identifying the tick spacing with the Planck time is natural within VERSF (it identifies the substrate update rate with the Planck scale), but it is a substantive physical assumption — it asserts that the substrate operates at the shortest meaningful timescale in quantum gravity.

The framework can also be presented with Δt left symbolic. In that case, the mass formula becomes a relation among three unknowns (K_c, p_v, Δt) per particle, and empirical input — or a separate derivation of Δt from TPB/BCB substrate dynamics — is required to fix the tick scale. The choice $\Delta t = t_P$ is the simplest and most physically motivated identification, but it is separable from the rest of the derivation.

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14. Stability and the Mass-Gap Problem

For the general reader: One of the deepest puzzles in physics is why there are only a handful of stable elementary particles with specific masses, rather than a continuous smear of possible masses. This is called the "mass-gap problem." Our framework rephrases it in informational terms: why do only certain anchoring configurations produce stable, long-lived flip patterns? We don't solve this problem here, but we identify the precise conditions that a solution must satisfy — which is itself progress, because it tells us what to look for.

14.1 The Problem

The statement that "particles correspond to stable BCB interface eigenmodes" conceals a deep question: why should the set of stable modes be discrete with a gap (a minimum nonzero mass), rather than forming a continuum? This is the mass-gap problem expressed in anchoring language.

14.2 Necessary Stability Conditions

Within this anchoring framework, a stable particle-like mode must satisfy at minimum three conditions:

(S1) Bounded anchoring variance. The coefficient of variation $CV = \sqrt{((1 - p_v)/K_c)}$ must be sufficiently small over the mode's operating regime. Concretely, we require $CV < \varepsilon$ for some ε determined by observational constraints on mass stability. Modes with large CV produce broad anchoring-time distributions and would not appear as sharp mass peaks.

(S2) Self-consistency under coarse-graining (renormalization fixed-point condition). The mode's effective parameters (K_c, p_v) must remain within an admissible basin when ticks are aggregated into blocks of increasing size. Formally, this is a **renormalization group fixed-point condition**: the flow of (K_c, p_v) under block-spin–type coarse-graining must converge to a fixed point or limit cycle rather than running to an inadmissible boundary ($p_v \to 0$, $K_c \to 0$, or $K_c \to \infty$ without bound). The number of stable fixed points determines the number of particle species — and explaining why this number is finite is the core of the mass-gap problem in this language.

(S3) Non-redundant cycle closure. The mode must return to an operationally equivalent configuration class after a full flip cycle. Failure to close means successive "bits" are not independent — the mode either drifts (unstable) or produces redundant information that is eliminated under coarse-graining (not a genuine flip channel). This condition is the anchoring analogue of the quantization condition in Bohr–Sommerfeld theory: only closed orbits in configuration space produce stable states.

14.3 Connection to Sections 11.7 and 12

The stability classification of Section 11.7 (stable / metastable / resonance) maps directly onto S1–S3: stable particles satisfy all three conditions robustly, metastable particles satisfy them marginally (slow drift away from a near-fixed-point), and resonances fail S2 or S3 outright. The decay-width analysis of Section 11.7 is the dynamical consequence of departure from the fixed-point structure described by S2.

The inertial–rest mass equivalence of Section 12 adds a further stability requirement: the spatial projection scale ℓ_b must remain slaved to (K_c, p_v) via equation (12.9) throughout the mode's evolution. Modes for which ℓ_b decouples from anchoring parameters would exhibit a growing discrepancy between inertial and rest mass — a signature that is not observed for any known particle, suggesting that condition (12.9) is robustly satisfied in the physical regime.

14.4 The Planck Boundary as Minimal-Stability Boundary

Since $CV \sim 1/\sqrt{K_c}$ (Section 5.4), modes with small K_c have large relative fluctuations in their flip tick-count. For a mode to appear as a particle with a well-defined mass, its flip period must be sharply concentrated — otherwise the mode produces a broad continuum rather than a discrete mass peak. We formalize this as a critical stability threshold:

A mode is particle-like if CV < ε_c, where ε_c is the maximum relative fluctuation compatible with experimental mass resolution.

For the minimal topological cycle K_c = 2π (the Planck-mass mode from Section 11.4), CV ∼ 1/√(2π) ≈ 0.40, meaning the flip tick-count fluctuates by ~40% of its mean. Whether this constitutes a stable particle depends on ε_c. If ε_c ∼ 0.1 (10% relative width, comparable to broad resonances like the ρ meson), then K_c must exceed ~100 for stability, and the Planck-mass mode at K_c ∼ 2π is firmly excluded. If ε_c is more permissive, the boundary shifts, but the qualitative conclusion holds: the Planck-mass boundary is simultaneously the **minimal-flip boundary** (fewest micro-events per flip allowed by P$\hbar$) and the **minimal-stability boundary** (smallest K_c compatible with sharp anchoring).

The precise value of ε_c is an open empirical question tied to the interface dynamics. What is structurally robust is that *both* constraints — action quantization and anchoring stability — produce upper mass limits, and these limits coincide at the same scale (K_c of order unity). This coincidence is a structural consistency check on the framework, not a tuned result.

14.5 Path to Resolution

A full solution requires showing that conditions S1–S3, applied to the space of all possible interface configurations, admit only a finite or countable set of solutions. This is equivalent to showing that the joint fixed-point structure of the coarse-graining flow (S2) intersected with the cycle-closure constraint (S3) and the variance bound (S1) produces a discrete set. We treat this as an open problem and note that the mathematical structure is closely analogous to the problem of classifying stable orbits in Hamiltonian systems — a problem with a rich existing literature that may provide analytical tools.

14.6 Parameter Reduction: Why the Apparent Two-Parameter Freedom Is Not Physical

A common objection is that the mass relation m = η$\hbar$p_v/(c²ΔtK_c) contains two parameters (p_v, K_c) per particle, so any single mass could be fit by adjusting two numbers. This is true only if p_v and K_c are treated as independent knobs. In the anchoring framework they are not independent once the interface dynamics and the micro-event criterion are fixed. The "two-parameter freedom" is therefore best understood as an incomplete specification problem: we have not yet specified the interface rule tightly enough to compute the map (mode) ↦ (p_v, K_c).

We now state precisely how the freedom collapses.

14.6.1 p_v is a derived measure once the micro-event criterion is fixed. Let c[n] be the interface state and let micro-events be defined operationally by a resonance functional R(c) ∈ [0, 1], which measures void coupling (resonant susceptibility) of state c. Fix a threshold R* and define the anchorable subset:

A := { c : R(c) ≥ R* }

The micro-event indicator is $X_n = \mathbb{1}\{c[n] \in A\}$, and the coupling probability is:

$$p_v = E[X_n] = \int_A \rho(c)\, dc$$

where ρ is the stationary (invariant) measure induced by the interface dynamics for the mode under consideration. Once the interface update rule and $R(c)$ are specified, p_v is no longer a free parameter — it is a computed overlap of the mode's invariant measure with the resonance region A.

14.6.2 K_c is a derived cycle-closure count once phase/action bookkeeping is fixed. Under the phase-cycle assumption (Aφ), each micro-event advances the cycle coordinate by an increment determined by the interface dynamics. Define the accumulated winding variable:

$$W[n+1] = W[n] + X_n \cdot \Delta\varphi(c[n] \to c[n+1])$$

with cycle completion when $|W| \geq 2\pi$ (equivalently, when the action ledger reaches $\Delta J_{bit} = \eta\hbar$). The anchoring depth is then:

$$K_c = E[\ \#\{\text{micro-events per completed cycle}\}\ ]$$

Once the interface rule and the cycle-increment functional $\Delta\varphi(\cdot)$ (or $\delta J_{event}(\cdot)$) are fixed, K_c is not chosen — it is measured from the same dynamics that determine p_v.

14.6.3 The physical spectrum is the image of the dynamics, not the full (p_v, K_c) plane. The pair (p_v, K_c) is not an arbitrary point in $[0, 1] \times \mathbb{N}$. For a given interface rule and resonance functional R, each candidate eigenmode j induces a specific pair:

$$(p_v, K_c)_j = \left(\int_A \rho_j(c)\, dc,\ E_j[\#\{\text{micro-events per cycle}\}] \right)$$

The "allowed" parameter set is the image of the eigenmode map $M : j \mapsto (p_v, K_c)_j$. Even before coarse-graining constraints are imposed, M is typically low-dimensional because p_v and K_c are computed from the same underlying mode geometry.

14.6.4 Stability restricts the image further: only coarse-graining fixed points are particle-like. Stable particle-like modes are defined by the stability criteria S1–S3 (Section 14.2). Coarse-graining induces a renormalization map:

$$R : (p_v, K_c) \mapsto (p_v', K_c')$$

Particle-like modes correspond to fixed points (or limit cycles) of R — points where $(p_v, K_c) \approx R(p_v, K_c)$. This typically reduces the admissible set to a discrete collection of points (or a small number of one-dimensional branches). The "two-parameter freedom" is removed twice: first by the eigenmode map M, and again by the stability constraint R.

14.6.5 Off-manifold variation is not free: it corresponds to linewidth and decay. Modes that do not sit on the stable fixed-point set are not additional stable particles; they are unstable

excitations. Departures from fixed-point structure manifest as drift in effective anchoring parameters and therefore as a spread in cycle period and rest energy. Via the energy–period relation (Section 9), a spread δT in cycle period produces a rest-energy uncertainty $\delta E \sim E \cdot \delta T/T$, which maps onto the decay width Γ (Section 11.7). The apparent second degree of freedom is therefore the distance from stability, which corresponds to observable decay widths — not an arbitrary fitting handle.

14.6.6 What remains open. At present we have not computed M or R for a fully specified BCB interface rule. This is exactly the content of the predictive program (Section 16): once the interface dynamics and resonance functional are fixed, the theory predicts a discrete set of (p_v, K_c) pairs and therefore a discrete mass spectrum via $m \propto p_v/K_c$. Until that computation is performed, the framework parameterizes masses; it does not yet explain the observed spectrum from first principles.

14.7 Weak Scaling Constraint from Interface Scale Invariance

While Section 14.6 shows that (p_v, K_c) are not freely adjustable once the interface dynamics and resonance criterion are specified, one may still ask whether any structural relation between them can be derived prior to full eigenmode computation. In this subsection we show that a weak but nontrivial power-law constraint $p_v \propto K_c^{-\alpha}$ emerges naturally under a minimal scale-invariance assumption for the interface.

14.7.1 Coherence length and scale invariance. Assume that the interface dynamics admit an emergent coherence length ξ, measured in substrate units, characterizing the spatial extent over which the contrast-pair field remains phase-coherent. We require only: (i) the interface is statistically homogeneous; (ii) under coarse-graining by scale factor b, coherence rescales as $\xi \to b\xi$; (iii) the resonance (anchorable) condition is local in the interface field. No detailed microscopic model is required.

14.7.2 Scaling of p_v. Recall that $p_v = \int_A \rho(c)\, dc$ (Section 14.6.1). If coherent regions of size ξ tile the interface with approximate independence beyond that scale, the fraction of the interface in resonant configuration scales inversely with the number of independent coherent domains. In an interface of effective dimension d, the number of independent domains scales as ξ^{-d}, so:

$$p_v(\xi) \sim \xi^{-d}$$

This follows from statistical self-similarity under coarse-graining and does not depend on microscopic details.

14.7.3 Scaling of K_c. Under the phase-cycle assumption (Section 7), each micro-event advances the phase variable by an increment $\Delta\varphi_{event}$. For a mode of coherence length ξ, phase gradients scale inversely with domain size: $\Delta\varphi_{event}(\xi) \sim \xi^{-1}$. Larger coherent domains evolve more rigidly and accumulate phase more slowly per local resonant fluctuation. Since one full cycle requires total winding $\Delta\varphi = 2\pi$:

$$K_c(\xi) \sim 2\pi / \Delta\varphi_{event}(\xi) \sim \xi$$

Thus $\xi \sim K_c$: the coherence length and the anchoring depth are proportional.

14.7.4 Emergent power law. Eliminating ξ between $p_v(\xi) \sim \xi^{-d}$ and $K_c(\xi) \sim \xi$ yields:

$p_v \propto K_c^{-\alpha}$, where $\alpha := d$

This relation is not imposed; it follows from interface scale invariance and local resonance structure. The exponent equals the effective interface dimension.

14.7.5 Consequence for the mass relation. Substituting into $m \propto p_v/K_c$ gives:

$m \propto K_c^{-(\alpha+1)}$

Along a scale-invariant family of interface modes, the apparent two-parameter freedom collapses to a single effective degree of freedom parameterized by K_c, with mass scaling as a power law determined by the effective interface dimension. For a two-dimensional interface ($d = 2$): $m \propto K_c^{-3}$.

14.7.6 Status. This result does not derive the mass spectrum. It establishes: (i) p_v and K_c cannot vary independently under scale invariance; (ii) stable modes are expected to lie on a one-dimensional scaling manifold in (p_v, K_c) space; (iii) deviations from this manifold correspond naturally to instability and linewidth (Section 11.7, Section 14.6.5). Verification of the exponent α requires explicit simulation of the interface dynamics (Section 16.3). The scaling law therefore provides a concrete falsifiable target: if numerical interface models fail to exhibit a stable power-law relation between p_v and K_c, the scale-invariance hypothesis is invalid.

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15. Entropy Gradients and the Emergence of Gravity (Correspondence Target)

For the general reader: In this framework, mass is not a primitive property — it is set by the tick-count per flip (fewer ticks = higher energy = higher mass, once mapped through the Layer B bridge). Anchoring is irreversible, and irreversibility generates entropy. If the density of flip activity varies across space, that variation must affect how emergent space itself is structured. This section constructs a consistent mapping from flip density to a weak-field gravitational potential, and identifies the precise equations that a full derivation must target. We do not derive Einstein's field equations — this is a correspondence, not a derivation.

15.0 Relation to Entropic and Thermodynamic Gravity

The idea that gravity has an entropic or thermodynamic character has a substantial prior literature. Verlinde's entropic gravity program [R11] and Jacobson's thermodynamic derivation of the Einstein equations [R12] highlight both opportunities and challenges: reproducing the correct tensor structure, treating radiation-dominated regimes, and avoiding inconsistencies in

cosmology. More broadly, the anchoring framework belongs to the "it from bit" tradition initiated by Wheeler [R13], with connections to Bekenstein's entropy-area bound [R14] and Lloyd's computational capacity arguments [R16]. The present section does not claim to resolve these issues or to re-derive GR. Instead, we identify a correspondence target specific to the anchoring framework: spatial variation in flip completion density $C(x) = p_v(x)/K_c(x)$ induces variation in the projection scale $\ell_b(x)$, which can be interpreted as a metric component in a weak-field limit. A full comparison requires (i) constructing an emergent metric from ℓ_b and Δt, (ii) deriving geodesic motion from that metric, and (iii) showing that the resulting field equations match Einstein gravity (or a controlled modification) across matter and radiation sectors. We treat this as future work and include this section as a roadmap and consistency target rather than a completed derivation. The novelty relative to prior entropic gravity proposals lies in the specific microfoundation: discrete irreversible anchoring with a projection metric via ℓ_b, rather than postulated holographic screens or temperature fields. The role of the Unruh effect and local equilibrium assumptions in Jacobson's derivation has no direct analogue in the anchoring framework, which operates pre-thermally at the tick level; whether an Unruh-like structure emerges from tick-domain dynamics is an open question.

15.1 Mass as Flip-Entropy Density

From Proposition 1 (Section 9), the rest mass of a flip channel is:

$$m = \eta\hbar p_v / (c^2 \Delta t K_c) \quad (15.1)$$

Each completed flip cycle irreversibly flips one bit. Each bit increases thermodynamic entropy by:

$$\Delta S_{entropy} = k_B \ln 2 \quad (15.2)$$

where k_B is Boltzmann's constant. The entropy increment per cycle is therefore fixed; it is the number of cycles per unit emergent time (the flip frequency, a Layer B quantity) that determines the entropy production rate.

Define the flip frequency (Layer B — requires the emergent-time mapping $\tau = n\Delta t$):

$$\nu_c := 1/T_{bit} = p_v / (\Delta t K_c) \quad (15.3)$$

Then the entropy production rate per channel is:

$$\dot{S} = k_B \ln 2 \cdot \nu_c \quad (15.4)$$

Using equation (15.1), $mc^2 = \eta\hbar\nu_c$, so:

$$\mathbf{\dot{S} = (k_B \ln 2 / \eta\hbar) \cdot mc^2} \quad (15.5)$$

Mass is proportional to entropy production rate per flip channel. Mass density therefore corresponds to entropy-generation density. This is a structural identity within the framework, not

an additional assumption — it follows directly from the irreversibility of anchoring and the mass formula.

15.2 Spatial Flip Density

Let $\rho_m(x)$ denote mass density at emergent spatial position x. From equation (15.5):

$$\dot{s}(x) \propto \rho_m(x) \quad (15.6)$$

Regions of higher mass density are regions of higher irreversible flip activity. Define a **flip density field**:

$$C(x) := p_v(x) / K_c(x) \quad (15.7)$$

From equation (15.1):

$$\rho_m(x) \propto C(x) \quad (15.8)$$

Spatial gradients in mass correspond to spatial gradients in flip density.

15.3 Entropy Gradients and Effective Geometric Response

In statistical mechanics, entropy gradients generate effective forces ($F = T\nabla S$). We adopt an analogous structural statement within the anchoring framework: spatial gradients in flip-entropy density produce an effective geometric response.

The spatial projection scale ℓ_b is tied to barrier height by the inertial–rest mass equivalence condition (Section 12, equation 12.9):

$$\ell_b \propto (K_c / p_v) \cdot \Delta t \cdot c \quad (15.9)$$

Therefore:

$$\ell_b \propto 1 / C(x) \quad (15.10)$$

Regions of high flip density correspond to a compressed projection scale — each bit projects onto less emergent space. This is the anchoring analogue of spatial curvature: where flipping is dense, space is "compressed."

15.4 Emergent Gravitational Potential (Weak-Field Limit)

Define an emergent gravitational potential Φ via projection-scale variation in the weak-field regime:

$$\ell_b(x) = \ell_0 (1 + 2\Phi(x)/c^2) \quad (15.11)$$

where ℓ_0 is the projection scale at spatial infinity and $|\Phi| \ll c^2$. Variations in ℓ_b encode curvature.

Combining equations (15.10) and (15.11):

$$\nabla\Phi \propto -\nabla C(x) \quad (15.12)$$

Gravitational acceleration corresponds to flip-density gradients: matter falls toward regions of higher flip activity.

15.5 Poisson Equation Target

In Newtonian gravity:

$$\nabla^2\Phi = 4\pi G\rho_m \quad (15.13)$$

Using equation (15.8), the Poisson equation requires:

$$\nabla^2\Phi \propto C(x) \quad (15.14)$$

Important caveat. Equation (15.14) does *not* follow directly from (15.12). From $\nabla\Phi \propto -\nabla C$, taking the divergence gives $\nabla^2\Phi \propto -\nabla^2 C$, not $C(x)$. For $\nabla^2\Phi \propto C$ to hold, the relationship between the projection scale ℓ_b and the emergent metric must be nonlinear — specifically, the Laplacian of the metric component constructed from $1/\ell_b$ must be proportional to the source density, not to the Laplacian of C. This requires:

$$\nabla^2\Phi \sim \nabla\cdot\nabla(1/\ell_b) \propto \rho_m \quad (15.15)$$

which involves the second-order structure of the $\ell_b \rightarrow$ metric mapping that is not derived here. The Poisson structure is therefore a *target* for the emergent metric construction, not a consequence of the weak-field definitions alone. Deriving the precise proportionality constant (recovering $4\pi G$) requires specifying how ℓ_b enters the emergent metric tensor — a task deferred to future work.

Status: correspondence, not derivation. This section constructs a consistent structural mapping from flip density to an effective gravitational potential. It does not derive the Poisson equation from first principles — it identifies the equation the framework must reproduce and shows that the mapping has the correct qualitative structure. The correspondence becomes a derivation only when ℓ_b is shown to define a metric component and flip-density gradients are shown to produce geodesic acceleration.

15.6 Interpretation and Consistency

For the general reader: Here is the picture: mass generates entropy through irreversible anchoring. Where mass is concentrated, entropy production is concentrated. The spatial variation of this entropy production compresses the emergent spatial scale, which is what we experience as

gravitational curvature. Objects fall toward regions of higher flip density — that is, toward mass — because the geometry of emergent space is shaped by the density of informational commitment.

This section establishes a structural mapping:

- Anchoring irreversibility → entropy production (15.2)
- Entropy production rate ∝ mass density (15.5–15.6)
- Spatial entropy gradients → projection-scale gradients (15.10)
- Projection-scale gradients → curvature in weak-field limit (15.11–15.12)
- Curvature → gravitational acceleration (15.12–15.13)

This chain is consistent with the intrinsic mass formula (Section 9), the Planck minimal-flip boundary (Section 11.4), the inertial–rest equivalence condition (Section 12), and gravitational redshift compatibility (Section 11.6).

15.7 Status

This section does **not** derive Einstein's field equations. It establishes:

- A consistent weak-field correspondence between flip density and gravitational potential.
- A structural entropy–mass mapping that follows from the irreversibility of anchoring.
- A concrete target (equations 15.13–15.15) that a full derivation must reproduce.

A full gravity theory within VERSF requires: (i) constructing the emergent metric tensor from ℓ_b and Δt, (ii) deriving curvature tensors from flip-density gradients, and (iii) demonstrating that the resulting equations reduce to Einstein's equations (or a testable modification) in the appropriate limit. This remains an open research direction — but the structural correspondence established here identifies the path.

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16. Predictive Program: Computing K_c and p_v from Interface Dynamics

For the general reader: Everything up to this point has been about building the machinery — showing that *if* you know the anchoring parameters of a particle, you can compute its mass. The real prize is computing those parameters from scratch, without using any measured masses as input. This section outlines how that computation would work. It's a research program, not a completed calculation — but it's a concrete one with clearly defined steps.

16.1 Program Outline

To convert consistency checks into genuine predictions, one must compute K_c and p_v from the BCB/One-Fold interface model rather than inferring them from measured masses.

(P1) Define the anchoring observable. Construct an observable (or operator) on the interface configuration space that flags micro-events — i.e., identifies when the interface enters the anchorable configuration subset (Section 4.3). This requires a precise characterization of which interface states contribute to flip progress.

(P2) Compute per-mode parameters. For each candidate eigenmode j of the interface dynamics, compute:

- The per-tick micro-event probability $p_{v,j}$ from the mode's overlap with the anchorable configuration set (i.e., the fraction of ticks the mode spends in the anchorable region — see Section 13.1).
- The barrier threshold $K_{c,j}$ from the mode's phase-winding structure — specifically, the number of micro-events required to complete one full topological cycle (winding number = 1) of the interface phase.

(P3) Apply the mass formula. Insert $(K_{c,j}, p_{v,j})$ into the conditional mass relation:

$$m_j = \eta \hbar p_{v,j} / (c^2 \Delta t K_{c,j})$$

For multi-channel modes (Section 11.3), include the channel multiplicity χ_j.

(P4) Compare to observation. Compute mass ratios m_μ/m_e, m_p/m_e, etc. from the derived parameters and compare to measured values *without fitting those ratios*. Section 11.3 provides a specific constraint: the proton computation must explain a mass ratio of ~1836, which cannot arise from channel multiplicity alone.

(P5) Verify equivalence-principle consistency. For each stable eigenmode, compute the spatial projection scale ℓ_b from interface geometry and verify that it satisfies equation (12.9). Failure would indicate that the mode cannot support inertial–rest mass equivalence and is therefore not a viable particle candidate.

(P6) Recover gravitational coupling. Construct the emergent metric tensor from ℓ_b and Δt, derive the curvature produced by flip-density gradients (Section 15), and verify that the weak-field limit reproduces the Poisson equation $\nabla^2\Phi = 4\pi G\rho_m$ with the correct proportionality constant. This would determine G within the framework.

16.2 What "Computing p_v and K_c" Means Concretely

Steps P1–P2 above are abstract. Here we specify what the computation reduces to mathematically.

Computing p_v. Let the interface state at tick n be c[n] (the contrast pair), and let $A \subset C$ denote the *anchorable subset* — the region of interface configuration space where micro-event registration occurs (Section 4.3). If the interface dynamics admit a stationary distribution $\rho(c)$, then:

$p_v = \int_A \rho(c)\, dc$

In the book-consistent language: p_v (void coupling / resonance) is the fraction of ticks the mode's trajectory spends in states that resonate with the void substrate strongly enough to register a commitment micro-event. Computing p_v therefore reduces to two sub-problems: (i) computing the stationary measure $\rho(c)$ of the interface dynamics, and (ii) defining the anchorable subset A.

For a specific eigenmode j of the interface operator, this becomes:

$p_{v,j} = \int_A |\psi_j(c)|^2\, dc$

where ψ_j is the eigenmode's amplitude over configuration space — the mode's overlap with the anchorable region.

Computing K_c. Under $A\varphi$, each micro-event advances the interface phase φ by some increment $\Delta\varphi_{event}$. The barrier threshold is the expected number of micro-events required for one full topological winding ($\Delta\varphi = 2\pi$):

$K_c = 2\pi / E[\Delta\varphi_{event}]$

Equivalently, in action-ledger form: if each full cycle commits $\Delta J = \eta\hbar$ (postulate P$\hbar$) and each micro-event commits a computable action increment δJ_{event}, then:

$K_c = \eta\hbar / \delta J_{event}$

Computing K_c therefore reduces to computing the micro-event's mean contribution to phase advance (or equivalently, to cycle action).

Minimal computable model (toy but non-handwavy). To illustrate that (p_v, K_c) are genuinely computable quantities — not just symbols — consider a stochastic phase-oscillator on S^1:

$\varphi_{n+1} = \varphi_n + \delta + \sigma\xi_n \pmod{2\pi}$

where δ is the coherent phase advance per tick, σ the noise amplitude, and $\xi_n \sim N(0,1)$. Define the anchorable subset as a phase window $A = \{\varphi : |\varphi - \varphi^*| < \varepsilon\}$. If noise mixes phases sufficiently, $\rho(\varphi) \approx 1/(2\pi)$, giving:

$p_v \approx \varepsilon/\pi$

The conditional phase advance per micro-event is $E[\delta + \sigma\xi \mid \varphi \in A] \approx \delta$ (under symmetric noise), so:

$K_c \approx 2\pi/\delta$

The mass relation then becomes $m \propto p_v/K_c \approx \varepsilon\delta/(2\pi^2)$ — a computable prediction once ε and δ are derived from a specific BCB interface update rule. This is not the final theory, but it demonstrates that the program is mathematically well-posed: p_v is set by the size of the resonant window, K_c is set by the per-tick coherent phase advance, and mass emerges from their ratio.

From toy model to VERSF first principles. The path from the toy model to genuine predictions involves four refinements: (i) specifying the BCB interface as a concrete dynamical system; (ii) defining a measurable resonance functional on the interface; (iii) computing the phase/action increment per micro-event from the interface geometry; and (iv) simulating the interface to identify stable eigenmodes and measure their (p_v, K_c) directly. The following subsection carries out steps (i)–(iii) explicitly.

16.3 Minimal Computable Interface Model

We specify a concrete lattice dynamics from which p_v and K_c can be measured by simulation. This is not claimed as the final BCB interface — it is the smallest model that is local, has a well-defined stationary distribution, supports an operational resonance definition, and yields measurable (p_v, K_c).

State space. Let the interface be a periodic $L \times L$ lattice. At each site i, define a contrast vector $c_i[n] \in \mathbb{R}^2$ with phase $\varphi_i[n] = \mathrm{atan2}(c_{i,2}, c_{i,1})$.

Update rule. Local diffusion + noise (discrete-time Langevin):

$$c_i[n+1] = (1 - \lambda)\, c_i[n] + (\lambda/|N(i)|) \Sigma_{j \in N(i)}\, c_j[n] + \sigma\, \xi_i[n]$$

where $N(i)$ are nearest neighbors (4-neighborhood, periodic boundary), $0 < \lambda < 1$ controls spatial coupling (interface stiffness), $\xi_i[n] \sim N(0, I_2)$ i.i.d., and σ sets noise amplitude. This update is local (only neighbors contribute), Markov (depends only on current state), and stable under coarse-graining (diffusive linear dynamics are closed under block-averaging).

Resonance functional (void coupling). Define local phase coherence via the Kuramoto-style order parameter:

$$r_i[n] = \left| \left(1/|N(i)| \right) \Sigma_{j \in N(i)} \exp(i\varphi_j[n]) \right|$$

where $r_i \approx 1$ means locally phase-aligned (resonant/coherent) and $r_i \approx 0$ means disordered. The anchorable subset is $A = \{i : r_i[n] \geq r^*\}$ for a threshold $r^* \in (0, 1)$. The micro-event indicator is $X_i[n] = \mathbb{1}\{r_i[n] \geq r^*\}$. The coupling probability is then:

$$p_v = E[X_i[n]] \approx (1/(TL^2)) \Sigma_n \Sigma_i X_i[n]$$

This is literally the fraction of site-ticks in the resonant set — void coupling as resonance, measured from the simulation.

Phase winding (void anchoring). Track the accumulated phase advance during micro-events only:

$$W_i[n+1] = W_i[n] + X_i[n] \cdot \Delta\varphi_i[n]$$

where $\Delta\varphi_i[n] = \mathrm{wrap}(\varphi_i[n+1] - \varphi_i[n]) \in (-\pi, \pi]$. A cycle completes when $|W_i| \geq 2\pi$; at that point, W_i resets and a bit-flip commits. The anchoring depth is then:

$$K_c = E[\ \#\{\text{micro-events between consecutive } 2\pi \text{ windings}\}\ ]$$

measured by recording how many micro-events occur between windings, averaged across sites and time (after burn-in). This turns K_c into a *measured outcome of the phase dynamics*, not a chosen threshold — anchoring depth is how many resonant ratchet clicks it takes to close a full cycle.

Eigenmodes. The deterministic part of the update is linear: $c[n+1] = A\, c[n] + \sigma\xi[n]$, where A is the neighbor-averaging operator. Its eigenvectors are Fourier modes on the lattice. Exciting a particular wavevector k by initializing $c_i[0] = (\cos(k \cdot x_i), \sin(k \cdot x_i))$ and evolving under noise yields mode-specific coherence statistics → different p_v, different winding behavior → different K_c. Different modes produce different flip completion densities $C_j = p_{v,j}/K_{c,j}$, and therefore different mass scales.

Parameter scan. The first scan varies three parameters: λ (spatial coupling), σ (noise), r^* (resonance threshold). Qualitative expectations: higher λ → more local coherence → higher p_v; higher σ → more mixing but reduced coherence; higher r^* → stricter resonance → lower p_v. The structure of K_c — how phase evolves inside resonant states — is where mode-dependent mass ratios emerge.

What this achieves. A simulation of this model produces, for each mode k: a measured $p_{v,k}$, a measured $K_{c,k}$, and therefore a predicted mass ratio $m_k/m_{k'} = C_k/C_{k'}$ with no free parameters beyond the interface dynamics (λ, σ, r^*). Whether these ratios bear any relationship to observed particle mass ratios is the empirical test of the framework. If they do not — for any choice of (λ, σ, r^*) — the framework is falsified at the level of this minimal model.

16.4 What Success Looks Like

The program succeeds if step P4 reproduces known mass ratios to within the precision of the interface eigenmode calculation. Partial success — e.g., correctly ordering the mass hierarchy or predicting ratios to within an order of magnitude — would still constitute significant evidence for the framework. Failure to reproduce any observed mass pattern would indicate either that the interface dynamics are incorrectly specified or that the single-channel mass formula requires modification (e.g., multi-channel coupling for composite particles).

16.5 Relation to Existing Approaches

The structure of this program — classifying stable modes of a dynamical system and reading off physical observables from mode parameters — is analogous to lattice QCD computations of hadron masses [R15], where one solves a discretized field theory and extracts mass eigenvalues. The key difference is that the "field theory" here is the BCB interface dynamics on a tick–bit substrate rather than a gauge theory on a spacetime lattice. Whether this analogy is deep or superficial is itself an open question that the program's execution would resolve.

16.6 Near-Term Falsifiability Constraints

Even prior to executing the eigenmode computation program, the framework is constrained by existing observations:

(i) **Equivalence-principle universality.** Any coupling perturbation mechanism entering δp_v must be universal across ordinary matter at the 10^{-15} level [R9, R10] (Section 12.9), strongly restricting admissible void-coupling dynamics. Mode-dependent perturbation responses would produce composition-dependent deviations already excluded by experiment.

(ii) **Discrete mass spectrum.** Stable particle-like modes correspond to discrete coarse-graining fixed points in (p_v, K_c) space (Section 14), implying that isolated elementary rest masses should not form a continuous stable spectrum. Discovery of an elementary particle with continuously tunable rest mass (not composite) would contradict the fixed-point picture.

(iii) **Maximum mass from horizon formation.** Under the standard GR bridge, flip completion density beyond the Planck regime compresses the projection scale below the Schwarzschild radius (Section 11.5), precluding stable particle-like modes above the Planck mass. Observation of a stable elementary particle above m_P would require modifying either the framework or the GR bridge.

These are conditional but operationally testable constraints independent of completing the full eigenmode program.

16.7 Limitations

For the referee's convenience, we collect the principal limitations of the present work:

(a) No mass predicted from first principles. The mass formula $m = \eta\hbar p_v/(c^2 \Delta t K_c)$ expresses mass in terms of anchoring parameters, but no particle's (K_c, p_v) values are derived. The framework parameterizes the mass hierarchy; it does not yet explain it. Prediction requires executing the eigenmode program (P1–P4 above).

(b) Two free parameters per particle, reduced to one by stability. The mass formula has two parameters (p_v, K_c) per particle. Section 14.6 argues that stability conditions constrain stable modes to a one-dimensional fixed-point curve $p_v = f(K_c)$, reducing effective freedom to one parameter (with the off-curve displacement controlling decay width). However, this reduction is structural, not yet computed; the framework becomes fully predictive only when the eigenmode program (Section 16) determines f and the fixed-point locations.

(c) Composite-particle masses require coarse-grained eigenmode computation. The single-channel formula applies to elementary flip modes. Hadron masses, which arise predominantly from QCD binding energy, require computing effective (p_v, K_c) for the entire confined eigenmode (Section 11.3) — a substantially harder problem analogous to lattice QCD.

(d) Gravity section is a correspondence target only. Section 15 identifies the qualitative structure the framework must reproduce (Poisson equation, weak-field limit) but does not derive it. The chain from flip-density gradients to the Poisson equation requires a nonlinear $\ell_b \to$ metric mapping that is not constructed here (Section 15.5).

(e) Phase structure (Aφ) is assumed, not derived. The S^1 topology of the interface effective state space is a representational assumption contingent on the $\mathbb{R}^2$ metric structure of the contrast-pair space. Deriving it from BCB axioms remains open (Section 7.4).

These limitations define the research frontier. The contribution of this paper is the framework itself — a structurally consistent, physically interpretable parameterization of mass with a concrete path to prediction — not the predictions themselves.

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17. Conclusion

This paper establishes a conditional mass-scale formula within the VERSF/BCB–TPB void-anchoring framework, stress-tests it across multiple physical regimes, and derives the structural condition for inertial–rest mass equivalence. The result rests on three pillars:

Pillar 1 (Structural — Layer A). The tick–bit anchoring model, with Bernoulli micro-events reduced from locality, Markov sufficiency, and closure under coarse-graining, provides a mathematically rigorous foundation for irreversible bit-flipping. Anchoring times, stability, and scaling are derived without reference to background time.

Pillar 2 (Postulational). The action postulate P$\hbar$ — that each bit carries a fixed cycle-action quantum $\Delta J_{bit} = \eta\hbar$ — is motivated by topological cycle-closure requirements on irreversible anchoring but remains an explicit postulate awaiting deeper derivation. It is falsifiable through the predictive program (Section 16).

Pillar 3 (Bridge — Layer B). Standard action–energy and mass–energy relations from relativistic quantum mechanics translate the anchoring cycle into a rest-mass formula: $m = \eta\hbar p_v/(c^2 \Delta t K_c)$.

The extended analysis of Section 11 demonstrates that this formula behaves consistently under stochastic variation, multi-channel generalization, the Planck-mass limit (yielding $K_{c,P} \sim 2\pi$ as a nontrivial structural result), gravitational redshift, and unstable-particle interpretation. The mass hierarchy across twenty-three orders of magnitude — from the Planck mass to the electron — maps onto a barrier-height hierarchy from $K_c \sim 1$ to $K_c \sim 10^{23}$.

Section 12 establishes that the equivalence of inertial and rest mass — a foundational principle in general relativity — is recovered within the anchoring framework under a single structural condition: the spatial projection scale ℓ_b must be determined by the same anchoring parameters (K_c, p_v) that set the tick-count per flip. The equivalence principle thereby becomes a constraint on how information projects into emergent geometry, rather than a separate postulate.

Section 15 extends this geometric thread by constructing a consistent mapping from mass density to flip-entropy density and from spatial flip-density gradients to projection-scale curvature, whose weak-field limit targets the structure of the Newtonian Poisson equation. Gravity, in this framework, would be the geometric response of emergent space to flip-entropy gradients — a structural correspondence that identifies a concrete target for a full derivation of Einstein's field equations from anchoring dynamics.

The resulting framework identifies mass as set by the **tick-count per flip** — determined by the ratio of coupling strength to barrier height. It reinterprets the Compton period as the emergent-time image of the substrate tick-count per bit-flip, translates the mass spectrum problem into an eigenmode computation on the BCB interface, and identifies three necessary conditions (S1–S3) for stable particle-like modes. Mass as rest energy (tick-count per flip mapped to energy via the Layer B bridge) and mass as inertia (resistance to acceleration) coincide numerically but arise from distinct structural layers — their equality is the structural content of the equivalence principle (Section 12.8).

What this paper does *not* do is predict any particle mass from first principles. That achievement requires executing the research program of Section 16: computing (K_c, p_v) from interface dynamics and verifying the equivalence-principle condition (12.9) from interface geometry. Until then, the contribution is a new, physically interpretable, and mathematically consistent parameterization of the mass scale — together with a concrete roadmap for turning consistency into prediction.

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