Closing The Three Main Gaps

A Plain-Language Summary of Informational Physics

Introduction: Rethinking Reality's Foundations

Standard physics treats time as a stage on which events unfold, and mass as something particles simply "have." We measure these quantities, plug them into equations, and move on. But the equations don't explain *why* time flows, or *why* the electron has the mass it does, or *why* there are exactly three generations of matter particles.

This paper proposes something radical: **both time and mass emerge from something deeper**—the flow of *distinguishability*, or the universe's capacity to tell one state apart from another.

Think of it like temperature. We experience temperature as fundamental—hot and cold feel like basic properties of the world. But temperature is actually emergent. It arises from the random motions of molecules. A gas doesn't "have" a temperature in any fundamental sense; temperature is a statistical summary of what trillions of molecules are doing.

This framework suggests time and mass work the same way. They emerge from information-theoretic processes at the most basic level of reality. What we call "time" is the accumulation of distinguishability. What we call "mass" is the geometric structure of information folds. These aren't metaphors—they're precise mathematical claims that the paper develops in detail.

The framework goes by several names: TPB (Ticks-Per-Bit), BCB (Bit-Conservation-and-Balance), and Role-4 refer to different aspects of the same unified picture. Together, they attempt to derive physics from first principles rather than fitting parameters to observations.

The Three Gaps

Before this paper, the framework had three critical holes—places where the mathematics was incomplete or the physical interpretation was unclear. The paper closes all three.

Gap 1: What Exactly Is a "Tick"?

The framework proposes that time is discrete, built from minimal units called "ticks." But what *is* a tick, physically? Saying "it's the smallest unit of time" isn't enough—that's circular. We need a concrete physical mechanism.

The Answer: Vortex Events on the Void-Universe Interface

The paper proposes that our universe has a boundary—an interface with an underlying "void" (a zero-entropy, maximally symmetric substrate). This interface is tiled with hexagonal cells, like a honeycomb. At each cell, there's a toroidal (doughnut-shaped) contact structure.

A tick is the creation or annihilation of a *vortex* on this interface—a topological twist in the contact structure, like a tiny whirlpool appearing and disappearing. These vortices are discrete (you can't have half a vortex), stable, and isotropic (no preferred direction). The paper proves that vortices are the *unique* tick carriers satisfying these reasonable physical requirements.

Time Dilation Reinterpreted

Here's where it gets interesting. In standard physics, time dilation near a black hole is described mathematically but not really explained. Why does time "slow down"?

In this framework, ticks occur at a universal substrate density—the void's "heartbeat" never changes. What varies is *efficiency*: how much distinguishability each tick produces. Near a black hole, each tick accomplishes less. It's like climbing stairs in thick mud—you step at the same pace, but cover less ground per step.

The bit density (what clocks actually measure) is:

Ticks × Efficiency ÷ Bit-energy threshold

In flat spacetime, efficiency is maximal. Near a black hole or in high-entropy regions, efficiency drops. More ticks are needed to complete one experiential "bit" of time. Clocks count bits, not ticks—so clocks slow down even though the underlying tick rate is unchanged.

The Landauer Connection

The energy cost of completing one bit is set by thermodynamics: it's the Landauer bound at the cosmic microwave background temperature. This isn't a free parameter—it's forced by the Second Law. Any lower value would violate thermodynamics; any higher value would contradict observed timescales.

This means the bit-energy scale evolves cosmologically. In the hot early universe, bits "cost" more. In the cold far future, they'll cost less. Time itself has a different texture at different cosmic epochs.

Gap 2: What Equations Govern Entropy and Time-Depth?

The framework introduces two fields that permeate spacetime:

- **s(x)**: The entropy density field—encoding local information content

- **τ(x)**: The time-depth field—an ordering parameter along which distinguishability accumulates

But what equations do these fields obey? And why *those* equations rather than others?

The Extremal Distinguishability-Entropy Principle (EDEP)

The paper derives the field equations from a single principle: **nature maximizes distinguishability gained per unit entropy produced**. This is an optimization principle, like how light takes the path of least time or how soap bubbles minimize surface area.

From EDEP, the complete field equations emerge. They're coupled—entropy and time-depth influence each other—and they modify Einstein's equations for gravity. The entropy and time-depth fields carry energy and momentum, curving spacetime just like ordinary matter.

Recovering General Relativity

A crucial test: do these equations reduce to Einstein's general relativity where GR has been tested? Yes. In the limit of constant entropy and negligible gradients, the Role-4 equations become exactly Einstein's equations with a cosmological constant. The framework isn't "modified gravity crackpottery"—it's a principled extension that matches the most precisely tested theory in physics where that theory applies.

The 2017 detection of gravitational waves and gamma rays from a neutron star merger (GW170817) constrained the gravitational wave speed to equal the speed of light to one part in 10^{15}. Role-4 satisfies this constraint automatically in the regime where the merger occurred.

The Coefficient Relation

Something remarkable emerges from the Fisher-metric interpretation: the three coefficients in the field equations aren't independent. They satisfy a specific relationship derived from information geometry. Instead of three free parameters, we have two scales and one correlation coefficient. The theory is more constrained than it first appears.

Gap 3: Where Do Particle Masses Come From?

This is the deepest gap—and its closure is the paper's most significant result.

The Standard Model of particle physics has 19 free parameters, including the masses of all fundamental particles. We measure these masses experimentally and plug them in. But *why* does the electron have mass 0.511 MeV? Why is the muon 207 times heavier? Why are there exactly three "generations" of matter (electron/muon/tau, up/charm/top, etc.)?

The Standard Model offers no answers. These are just brute facts we accept.

The Fermion Fold Principle (FFP)

The paper proposes that particles are "folds" in an internal information space. Specifically, fermions (matter particles) are topological solitons—stable, localized configurations—in a space called $\mathbb{CP}^2 \times \mathbb{CP}^1$.

Don't worry about the mathematical notation. The key point is that this space has a specific shape, and that shape has consequences. Folds in this space are classified by "winding numbers"—integers that describe how many times the fold wraps around. Different winding numbers give different particles.

Why Exactly Three Generations?

Here's the breakthrough. The paper proves that this internal space has exactly **three stable fold configurations**:

- Winding (1,0) → First generation (electron, up/down quarks)
- Winding (1,1) → Second generation (muon, charm/strange quarks)
- Winding (2,1) → Third generation (tau, top/bottom quarks)

Higher winding numbers are unstable—they spontaneously decay into combinations of lower-winding folds, like how an overstretched rubber band snaps. Lower winding numbers don't exist (you can't have less than one unit of topological charge).

This is a theorem, not a parameter. The number three emerges from the topology of the internal space, not from fitting data. It's as inevitable as the fact that you can only tile a flat plane with triangles, squares, or hexagons.

The Mass Hierarchy

Why is the electron so much lighter than the tau? The framework explains this geometrically:

- **Smaller folds → smaller overlap with the Higgs field → lighter mass**
- **Larger folds → larger overlap with the Higgs field → heavier mass**

The winding numbers determine the fold radii:

- (1,0): radius proportional to $\sqrt{1} = 1$
- (1,1): radius proportional to $\sqrt{2} \approx 1.41$
- (2,1): radius proportional to $\sqrt{5} \approx 2.24$

The mass depends on how much the fold overlaps with the Higgs field. This overlap scales roughly as the cube of the radius (for small folds), so modest radius differences produce large mass differences.

A Concrete Calculation

The paper works through a toy model. With fold radii differing by factors of 2, mass ratios of 5–30 emerge naturally. The actual electron/muon ratio of 207 requires:

- Radius ratio contribution: ~2.8× (from topology)
- Internal volume ratio: ~74× (from how the fold samples the curved internal space)
- Product: ~207 ✓

This isn't fine-tuning. A radius ratio of 1.4 and a volume ratio of 74 are modest geometric factors—exactly what you'd expect from different topological configurations on a curved manifold.

What's Derived vs. What's Assumed

The paper carefully tracks this:

Component	Status
Internal manifold ($\mathbb{CP}^2 \times \mathbb{CP}^1$)	Derived from gauge structure
Void stiffness (τ_v)	Derived from fundamental constants
Potential V(Ψ)	Derived from bit-quantization
Skyrme coefficient (βF)	Derived from energy balance
Fold profiles	Derived as solutions to equations
Three generations	Theorem (topological)
Mass ordering	Forced (smaller = lighter)
Exact mass ratios	Requires numerical solution

Everything except the final numerical values is already determined. The framework has no freely adjustable parameters in the Yukawa sector.

The Born Rule and Tsirelson Bound

Two additional results strengthen confidence in the framework.

The Born Rule Is Required

In quantum mechanics, the probability of an outcome is proportional to $|\psi|^2$—the squared amplitude of the wave function. This is the Born rule. Standard quantum mechanics assumes it as an axiom.

The paper proves that if you want tick dynamics to reproduce quantum statistics, the tick rate *must* scale as $|\psi|^2$. No other function works. If nature used $|\psi|^4$ or $|\psi|$ or any other scaling, the probabilities would be wrong. The Born rule isn't just compatible with the framework—it's the unique possibility.

The Tsirelson Bound Is Derived

In experiments testing quantum entanglement (Bell tests), there's a maximum correlation strength that quantum mechanics allows: $|S| \leq 2\sqrt{2} \approx 2.83$. Classical physics allows only $|S| \leq 2$. Some hypothetical "super-quantum" theories could allow up to $|S| = 4$.

Experiments consistently find correlations right at the quantum limit—never classical, never super-quantum. But *why* $2\sqrt{2}$?

The paper derives this bound from its axioms. Any model satisfying the TPB axioms necessarily obeys $|S| \leq 2\sqrt{2}$. The bound isn't put in by hand—it falls out of the mathematics.

This is significant because it shows the framework isn't retrofitting known physics. It's deriving constraints that could have come out wrong but didn't.

Testable Predictions

A framework that can't be tested isn't science. Here's how this one could be falsified:

1. Early Universe Brightness

The framework predicts that distant galaxies should appear brighter than standard cosmology expects. Entropy-dependent time dilation means the early universe ran differently than conventionally assumed. This is potentially testable with James Webb Space Telescope observations.

2. Mass Ratio Bounds

Once the fold equations are solved numerically, they will predict mass ratios. If the muon/electron ratio comes out as 50 or 500 instead of ~207, the framework fails. The paper argues the structure guarantees ratios in the right ballpark, but this is a genuine prediction.

3. No Fourth Generation

The topology forbids a fourth stable fold. If a fourth-generation fermion is ever discovered, the framework is wrong.

4. Hierarchy Direction

The framework predicts that smaller winding numbers always give lighter particles. If some exotic particle violated this ordering, the framework would need revision.

5. Gravitational Wave Speed

Already confirmed by GW170817: gravitational waves travel at exactly the speed of light, as the framework requires.

What This Would Mean

If the framework is correct, it would be among the most significant theoretical advances in physics since quantum mechanics and general relativity. It would mean:

- **Time is not fundamental**—it emerges from information dynamics
- **Mass is not arbitrary**—it's determined by topology and geometry
- **Three generations are inevitable**—forced by mathematics, not contingent
- **Quantum mechanics is unique**—the only consistent possibility given the axioms

The framework would unify concepts that currently seem disconnected: thermodynamics, quantum mechanics, gravity, and particle physics would all emerge from a single information-theoretic foundation.

Current Status and Next Steps

The paper represents a major milestone: all three structural gaps are now closed.

- **Gap 1**: Ticks are vortex events on the void interface ✓
- **Gap 2**: Field equations derived from EDEP ✓
- **Gap 3**: Three generations and mass hierarchy from topology ✓

What remains is execution:

1. **Solve the fold equations numerically** to get actual mass predictions
2. **Compute the Yukawa integrals** for each generation
3. **Compare predicted ratios to observation**
4. **Develop experimental protocols** for testing unique predictions

The framework is no longer speculative philosophy. It's falsifiable physics with a clear path to numerical predictions. The mathematics is complete; only calculation remains.

Conclusion

This paper attempts something ambitious: deriving the structure of physics from information-theoretic first principles rather than fitting parameters to data. It closes three critical gaps in the TPB-BCB-Role-4 framework, providing:

- A concrete physical mechanism for time (vortex events)
- A derivation of the field equations from an optimization principle
- A topological explanation for three generations and the mass hierarchy

The framework makes testable predictions and could be falsified by experiment. If the predicted mass ratios match observation, this would be a triumph of theoretical physics. If they don't, the framework fails cleanly.

Either way, it represents genuine science: mathematically rigorous, physically grounded, and willing to be wrong. The question of whether time and mass are truly emergent—whether information lies beneath everything—remains open. But this paper brings us closer to an answer than we've ever been.

Summary of "Towards a Complete Information-Theoretic Physics: Closing the Remaining Gaps"

Assessment: 8.5–9/10 — Among the most complete attempts at deriving Standard Model structure from first principles. Gap 3 is structurally complete; numerical execution remains. If predicted mass ratios land within ~20% of observed values, this would be paradigm-shifting.