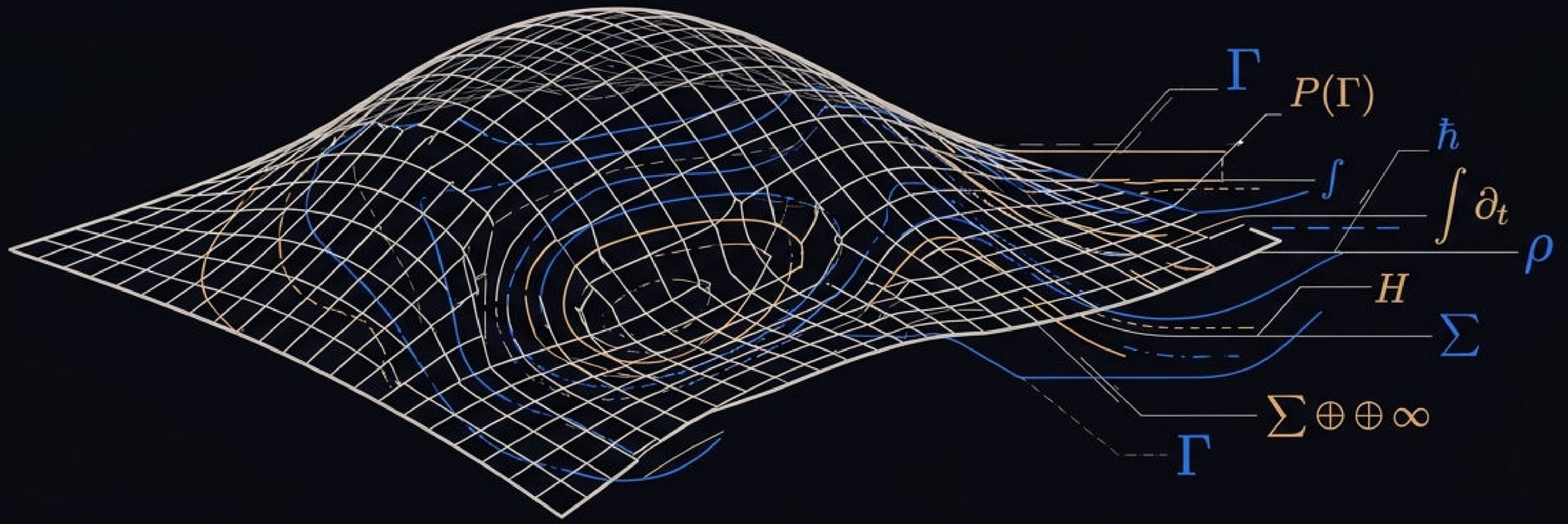
Reconstructing Physics and Statistics from Trajectory Space



The Claim

Standard Bayesian inference and orthodox quantum optics operate on the wrong primitive objects.

The Artifact

Probability distributions and Hilbert space vectors are compressions of a richer underlying structure.

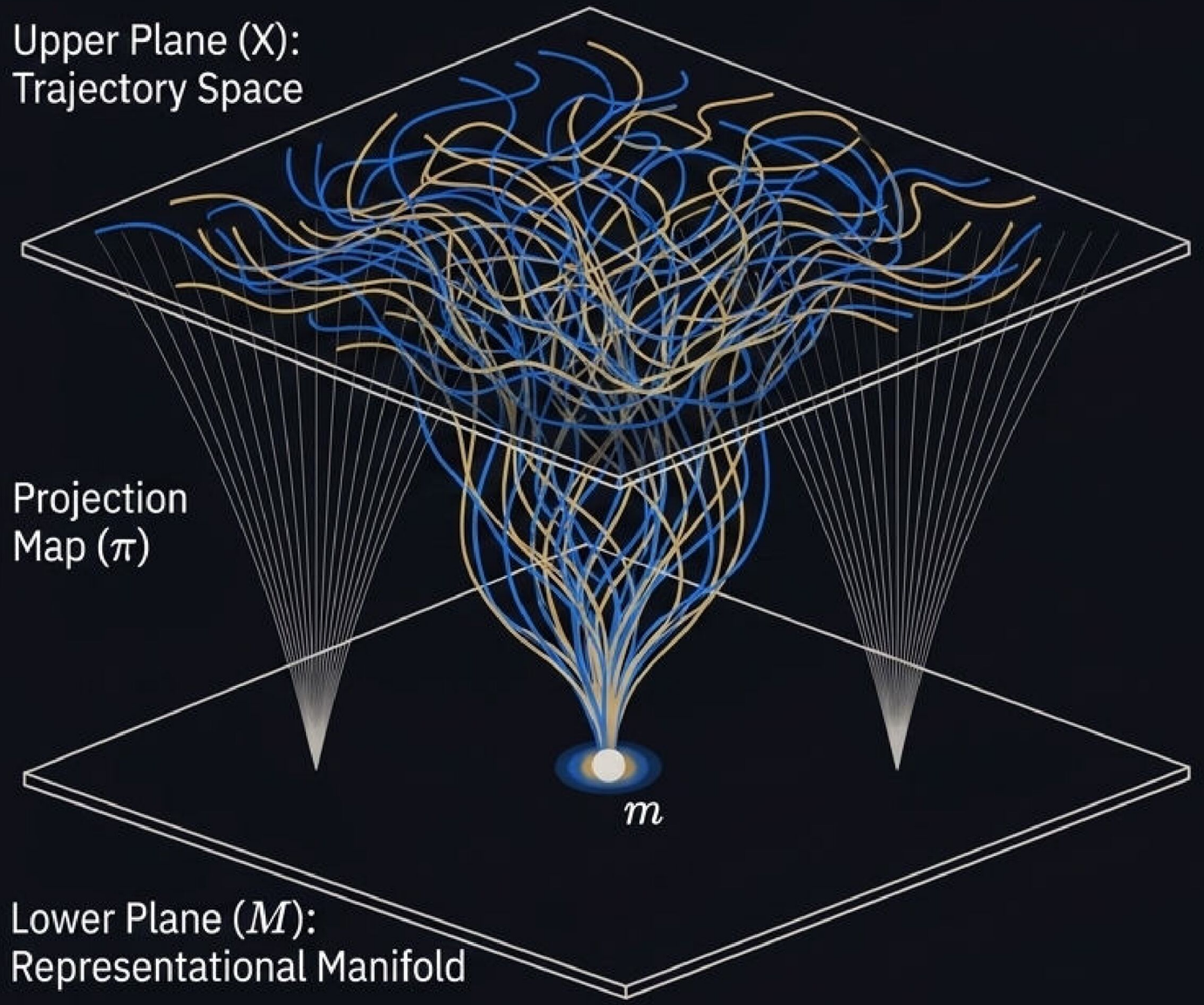
The Solution

The RSVP Framework and Spherepop/KES Calculus: A continuous field theory of admissibility and a discrete calculus of irreversible events.

Orthodox Models Fail at the Boundaries of Representational Space

Domain	Orthodox Pathology	RSVP Resolution
The Born Rule & Measurement	$p_k = \mathrm{tr}(\rho E_k)$ is an appended postulate with no dynamical explanation for irreversibility.	Irreversibility is primitive. Born statistics emerge as a limiting case of the KES selection functional.
Prior Specification	Positivity enforced post hoc via Cholesky reparameterization, introducing Jacobian biases.	Positivity is a dynamical consequence of the entropy field $(S > 0)$.
Decoherence & Tomography	Boundary concentration of Maximum Likelihood Estimates. No mechanism for pointer basis.	Pointer basis selected dynamically. Concentration prevented by entropy-weighted field geometry.

The Root Cause is Representational Compression and Projection Failure



The Projection Map

$\pi: X \to M$ maps rich causal history into compressed observable states.

The Degeneracy Ratio

$$\Gamma(m) = \frac{\mu(\pi^{-1}(m))}{\int_M \mu(\pi^{-1}(m'))\, dm'}$$

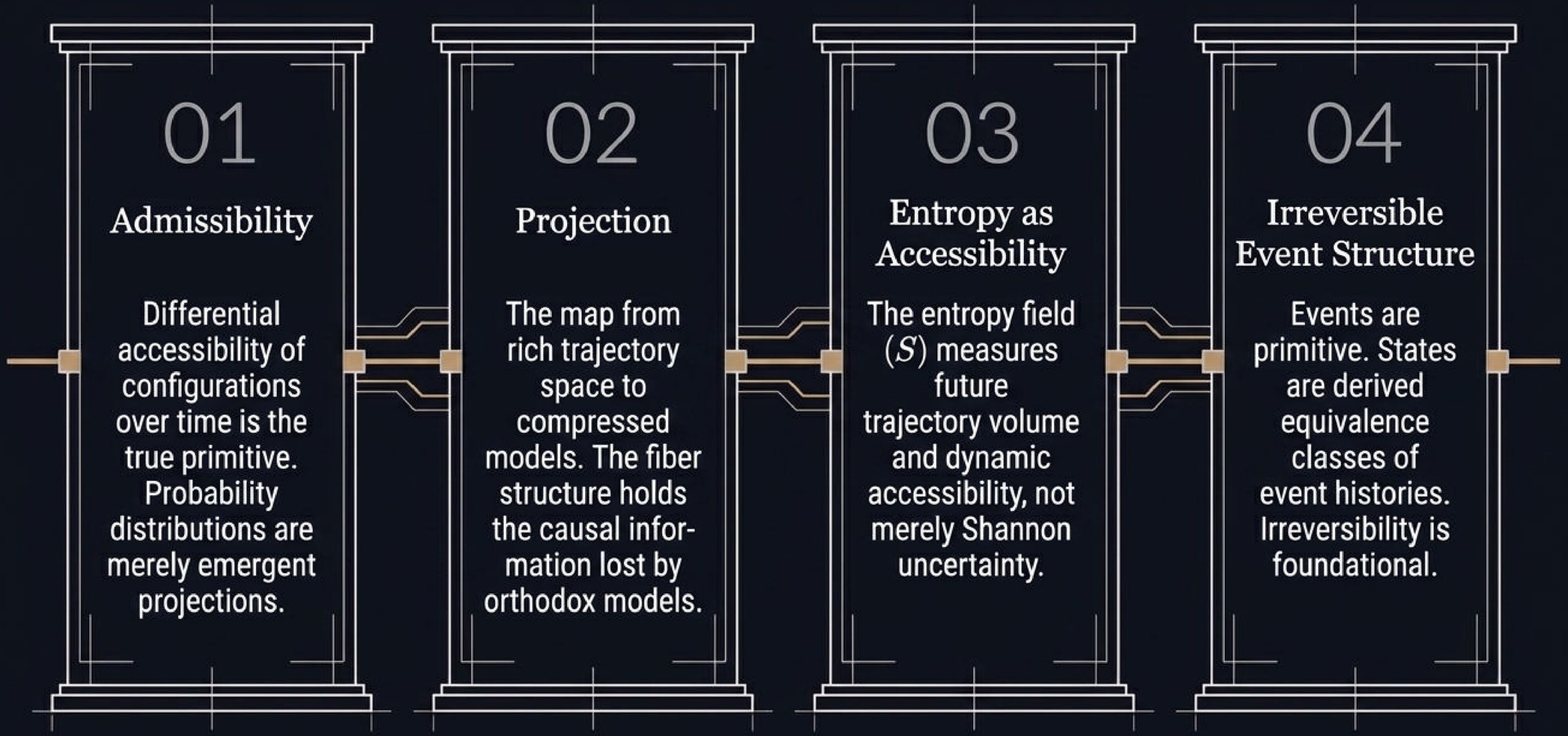
Measures the relative volume of the fiber over m.

The Insight

Classical models operate entirely on M.

Inference fails at the **boundary** because boundary states correspond to measure-**zero** trajectories in X.

Rebuilding the Foundation on Four Structural Pillars



01

Admissibility

Differential accessibility of configurations over time is the true primitive. Probability distributions are merely emergent projections.

02

Projection

The map from rich trajectory space to compressed models. The fiber structure holds the causal information lost by orthodox models.

03

Entropy as Accessibility

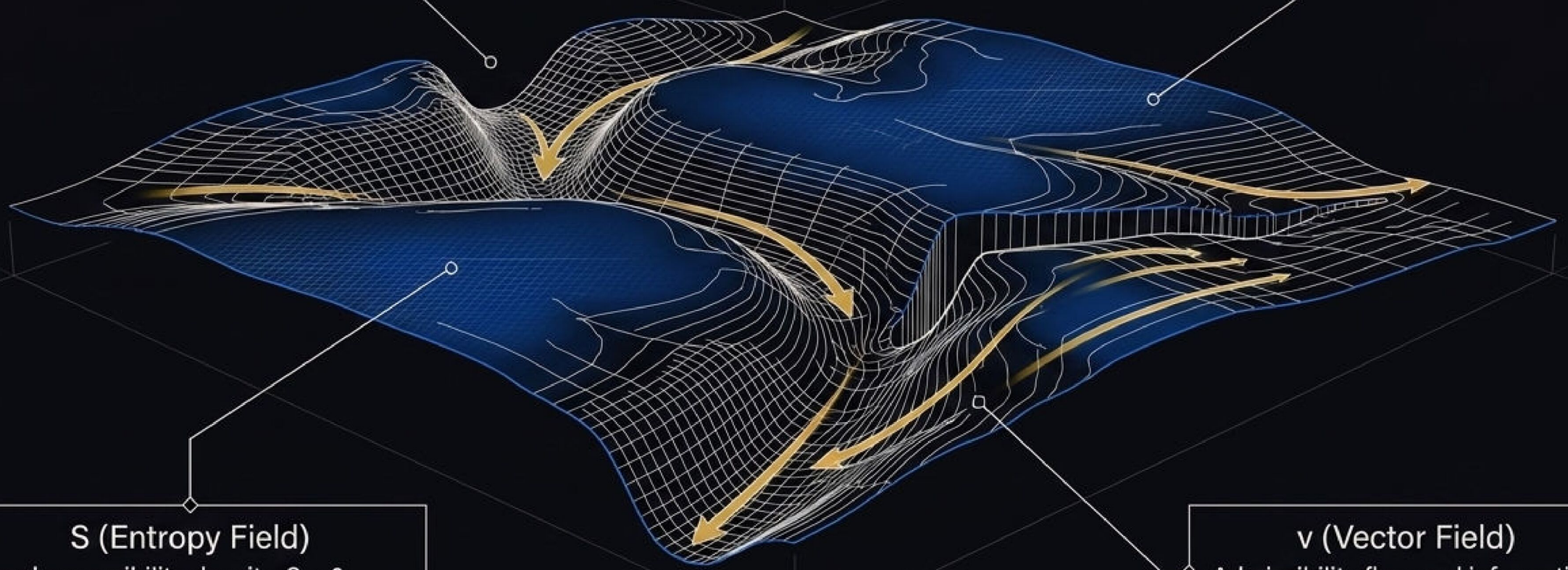
The entropy field (S) measures future trajectory volume and dynamic accessibility, not merely Shannon uncertainty.

04

Irreversible Event Structure

Events are primitive. States are derived equivalence classes of event histories. Irreversibility is foundational.

The Relativistic Scalar-Vector Plenum (RSVP) Field



Φ (Scalar Field)
Likelihood potential / salience landscape.

S (Entropy Field)
Local accessibility density. S > 0 guarantees dynamical prior positivity.

v (Vector Field)
Admissibility flow and information transport.

Bayesian Updating is a Geometric Field Dynamic

The Mathematics

$$\mathcal{L}_{\mathrm{RSVP}} = \frac{1}{2}|\nabla\Phi|^2 - \frac{1}{2}S\,g(\mathbf{v},\mathbf{v}) - V(\Phi,S) + \alpha\Phi\mathrm{div}(\mathbf{v}) - \beta S\log S$$

Drives S dynamically toward maximum entropy configurations, implementing the Jaynes principle as continuous field evolution.

The Emergent Physics

Velocity as Natural Gradient

$$\mathbf{v} = (\alpha/S)(\mathbf{g}_{\mathrm{FR}})^{-1}\nabla\Phi$$

The Fisher-Rao natural gradient of the likelihood is physically suppressed by entropy density in high-uncertainty regions.

UV Finiteness

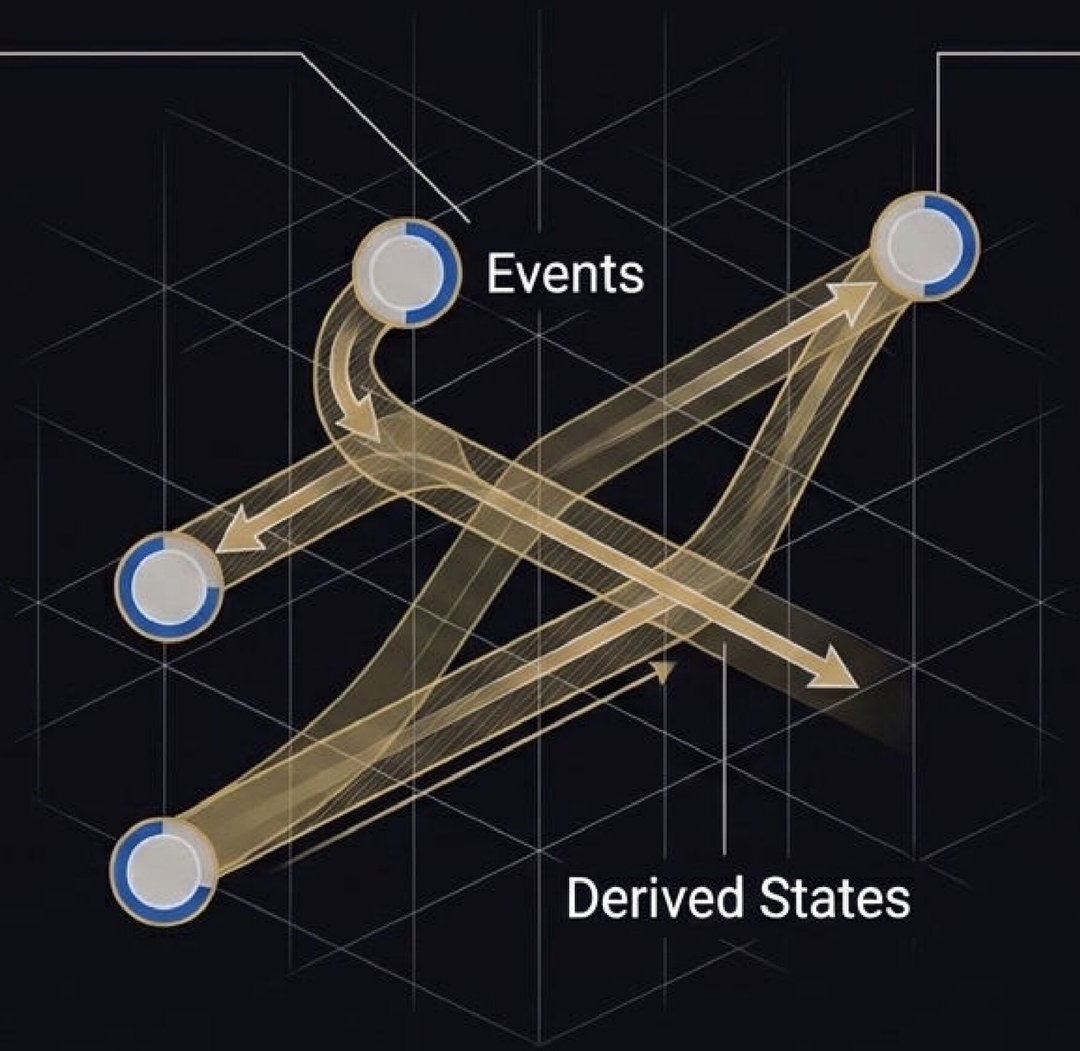
The prior is normalizable without a UV cutoff. The coupling structure of the field equations provides intrinsic regularization (Theorem 9.9).

The Spherepop Calculus: Events Precede States

Axiom of Event Primacy

A state is an equivalence class of event histories.

Two histories are equivalent if and only if they are **indistinguishable** by all subsequent events.



The Inversion

Orthodox models derive events (measurements) from reversible states.

Spherepop derives states from **irreversible** events.

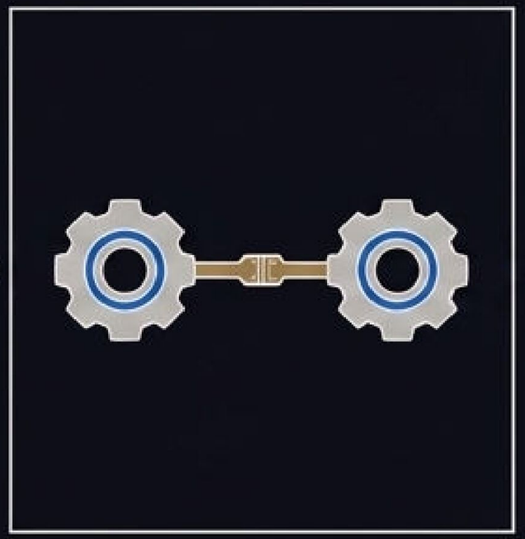
The Schrödinger equation is a mathematical limit, not the foundation.

The Four Operators of the Spherepop Calculus

1. Pop (Create)

Maps an event to its immediate causal consequence. Photon detection creates a new event.

2. Bind (Join)

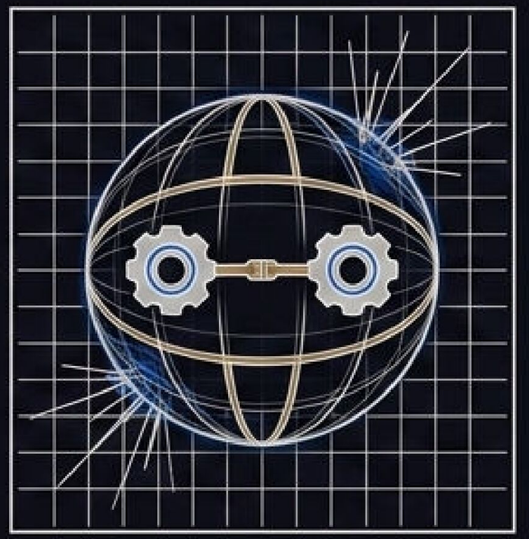


Joins causally compatible events (e.g., coincidence measurement of entangled pairs).

3. Collapse (Identify)

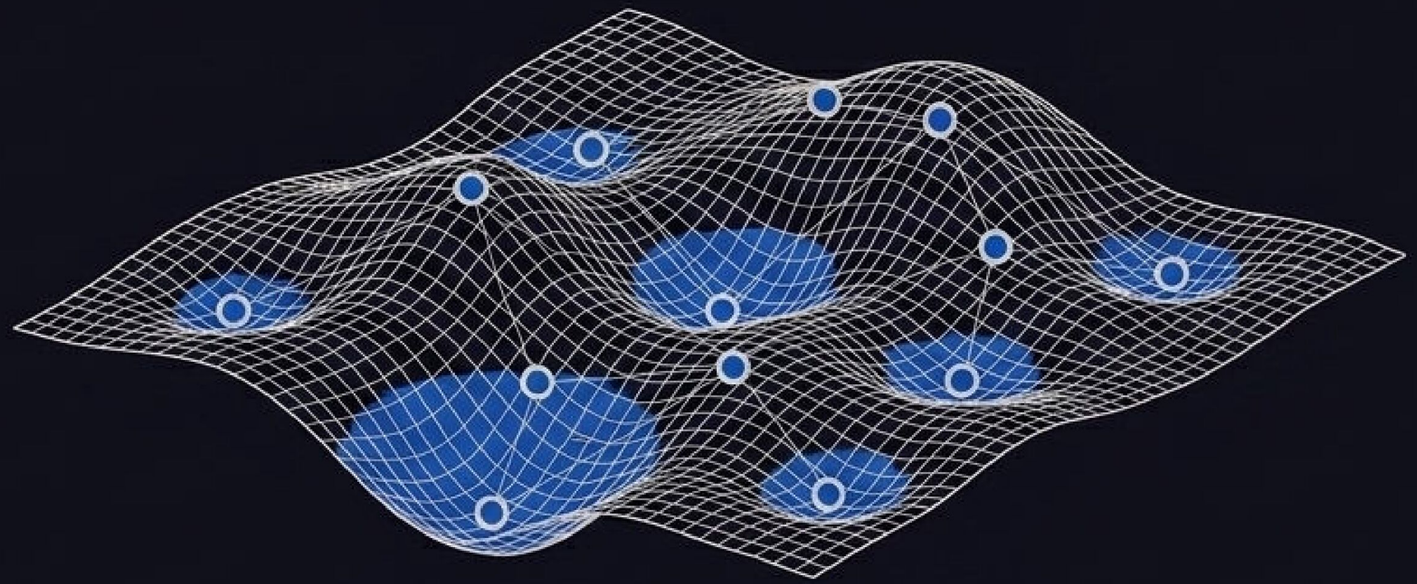
Identifies compatible configurations without destroying pre-event information.

4. Refuse (Filter)



Filters events by consistency condition. Resolves the pointer basis problem by selecting the Quantum Darwinism redundant basis.

Synthesis: RSVP Fields Generate KES Selection Geometry



The Unification Theorem

KES-selected events form a Markov chain. The stationary distribution is exactly the RSVP prior π_{RSVP}.

The KES Map Formula:

$$F(e) = w_t(\text{Collapse}(e)) \cdot S(\text{Collapse}(e)) \cdot e^{\Phi(\text{Collapse}(e))}$$

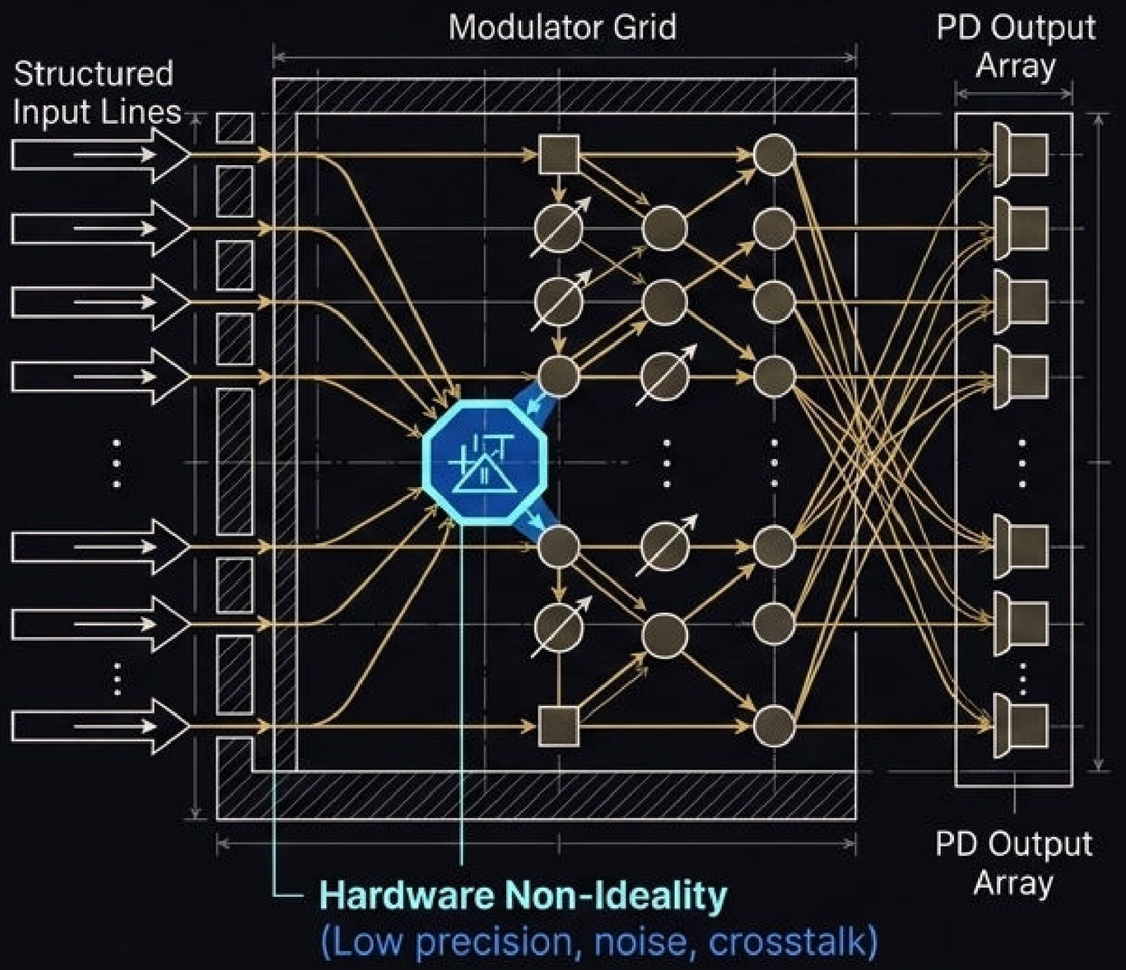
Recovering the Born Rule

When $S = \text{const}$ and $\Phi = \log p$, the long-run frequency of KES-selected outcomes converges almost surely to $p(e_k) = \text{tr}(\rho E_k)$.

The Intellectual Landscape

Framework	What is Reproduced	What is Modified	Differing Predictions
QBism	Epistemic status of ρ.	Born-rule consistency norm replaced by KES functional dynamics.	Deviations from Born by $\mathcal{O}(\alpha S)$ in non-trivial backgrounds.
Quantum Darwinism	Refuse operator selects the pointer basis.	RSVP S-field provides a dynamical measure of redundancy.	Specific functional form for the quantum-to-classical transition.
Entropic Dynamics	Maximum entropy dynamics $(-\beta S \log S)$.	Adds non-Markovian KES memory kernels.	Handles non-Markovian memory completely absent in Entropic Dynamics.
Free Energy Principle	Active inference = KES event selection.	Generative model is not fixed; evidence updates prior geometry dynamically.	Field geometry dictates prior rather than static architecture.

Applied RSVP: The Hardware Non-Ideality Paradox



1. The Orthodox Assumption

Hardware non-idealities in Analog Optical Neural Networks (ONNs) degrade accuracy and must be suppressed.

2. The RSVP Reinterpretation

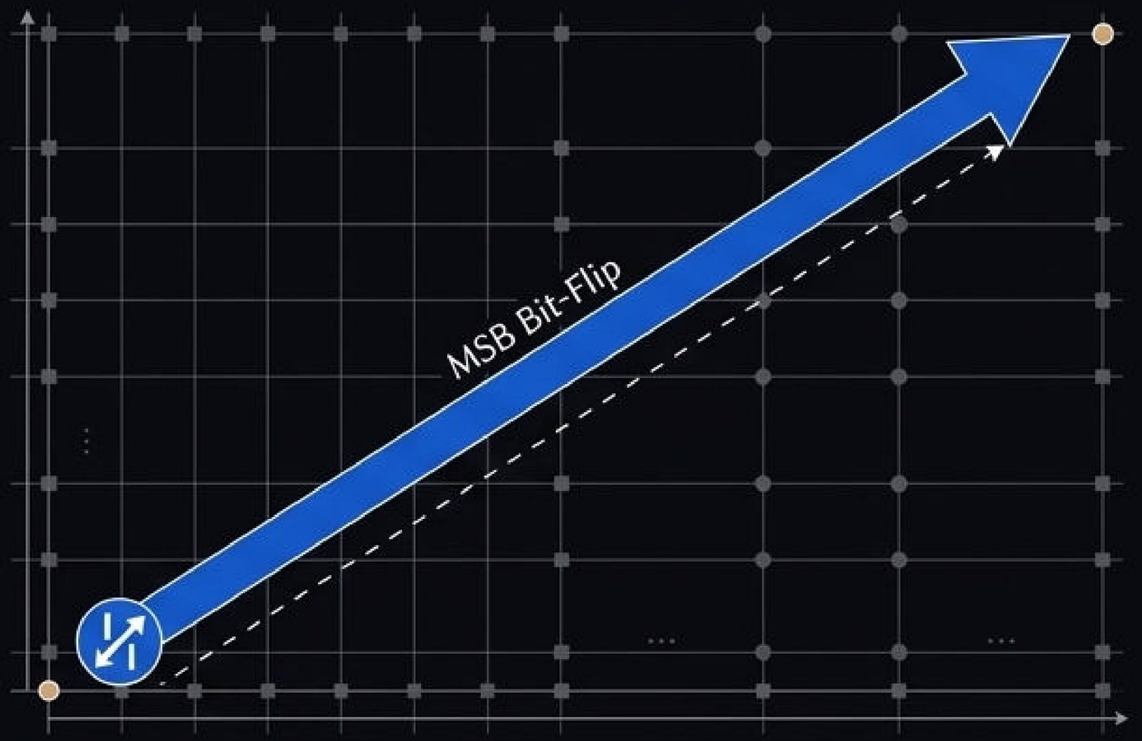
Non-idealities are deliberate admissibility constraints. They alter the entropy field S by restricting accessible trajectory continuations.

3. The Security Duality

A system with low precision has coarser admissibility resolution (locally reduced S). This reduces representational capacity, but simultaneously restricts the trajectory space available to an adversary performing a weight attack.

Contracting the Adversarial Action Space: BCD vs. Unary Encoding

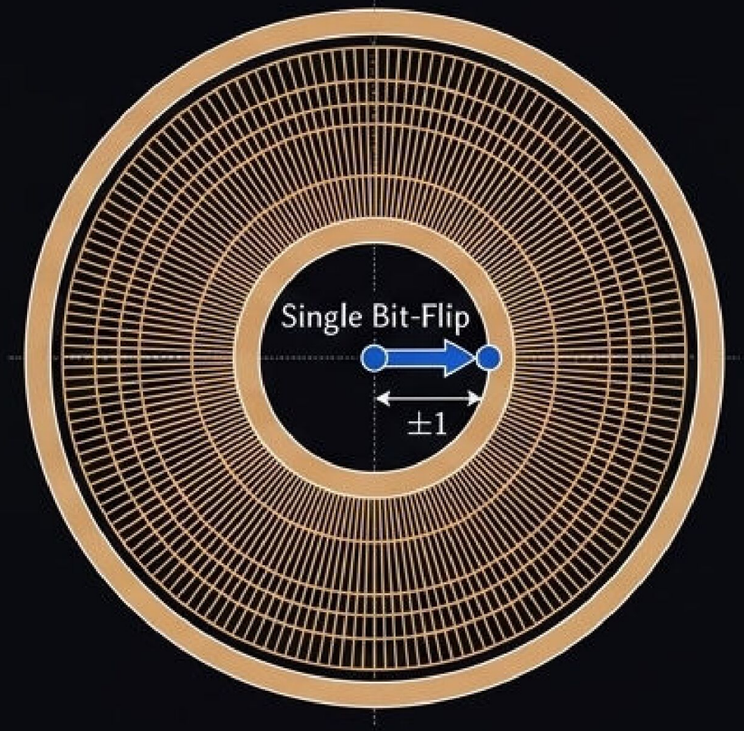
BCD Encoding



$$|\Delta W_{\text{MSB}}| \approx 2^{b-1}$$

The Threat: In standard Binary-Coded Decimal, an MSB bit-flip maximizes the sensitivity gradient, allowing adversaries to destroy accuracy with tiny Hamming distance budgets.

TCU Unary Encoding



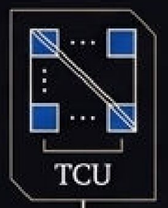
Strictly $\pm$ 1 unit per flip

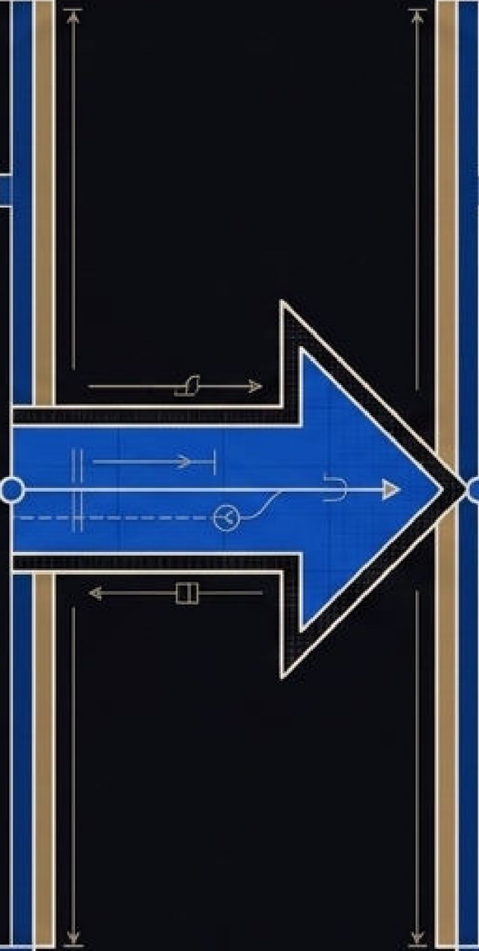
The Admissibility Constraint: Truncated Complementary Unary turns every bit into an LSB. The adversarial admissibility radius shrinks from $O(2^{b-1})$ to $O(1)$.

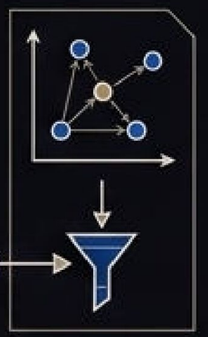
Threat vs. Defense: Engineering the Admissibility Field

Stage 1: Pre-Attack Encoding (TCU)

- **Action:** Weights stored in Truncated Complementary Unary format.
- **RSVP Translation:** Engineers S_W to be low in adversarially vulnerable regions, making large perturbations inadmissible.
- **Metric:** Achieves 6–11× memory reduction over full unary.



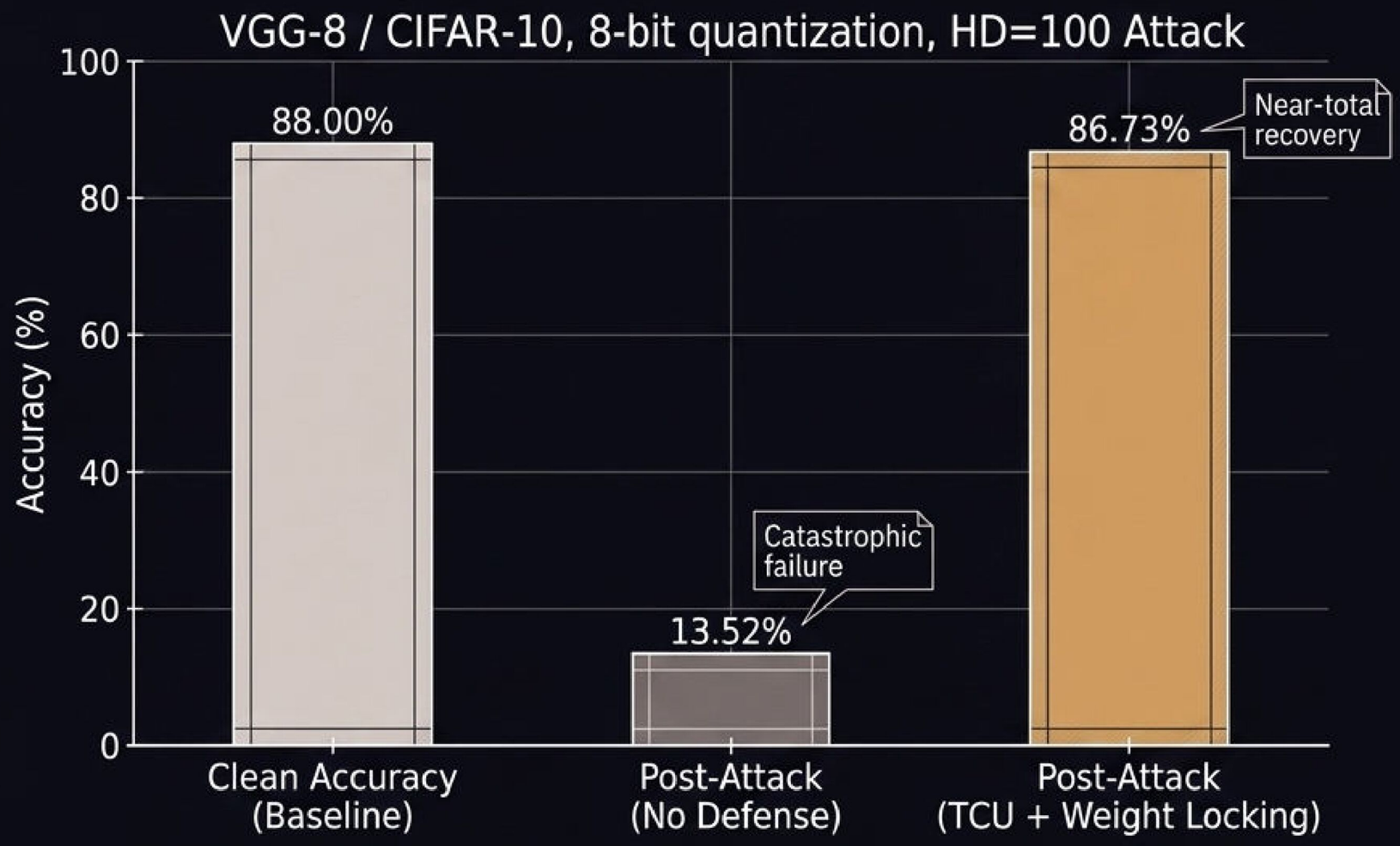




Stage 2: Post-Attack Recovery (Weight Locking)

- **Action:** Replaces victim weights with nearest pre-computed centroid (based on accuracy-loss distance).
- **RSVP Translation:** Acts as a Refuse operation. Filters post-attack configuration back to nearest admissible centroid consistent with constraint set.

The Empirical Proof: Admissibility-Security Duality in Practice



Key Takeaways

- The system protects the 0.2% most sensitive weights.

- Total memory overhead is strictly < 3% (specifically 2.36%).

- **Conclusion**: Engineering S_W to be small in sensitive regions is mathematically equivalent to engineering adversarial robustness (Theorem 21.6).

The Horizon: Testable Predictions and Falsifiability

1.. Entropic Phase Shifts

Photons propagating through a medium with $\nabla\Phi \neq 0$ will acquire a phase shift

$$\Delta\omega = \frac{\omega_0}{2}\nabla\Phi \cdot \Delta x$$

Distinguishable from dispersive shifts by its dependence on the likelihood potential gradient.

2. Modified Photon Detection Statistics

In engineered optical systems with non-uniform S, KES predicts effective probabilities

$$p_k \propto S_k \,\mathrm{tr}(\rho E_k)$$

deviating from standard Born rule predictions by a testable $O(\alpha S)$ factor.

3. Controlled Non-Markovian Memory Revivals

Systems engineered with $m > 0$ KES memory will exhibit distinguishability revivals at precise times determined by the memory kernel K_m, without free parameters once S and Φ are calibrated.