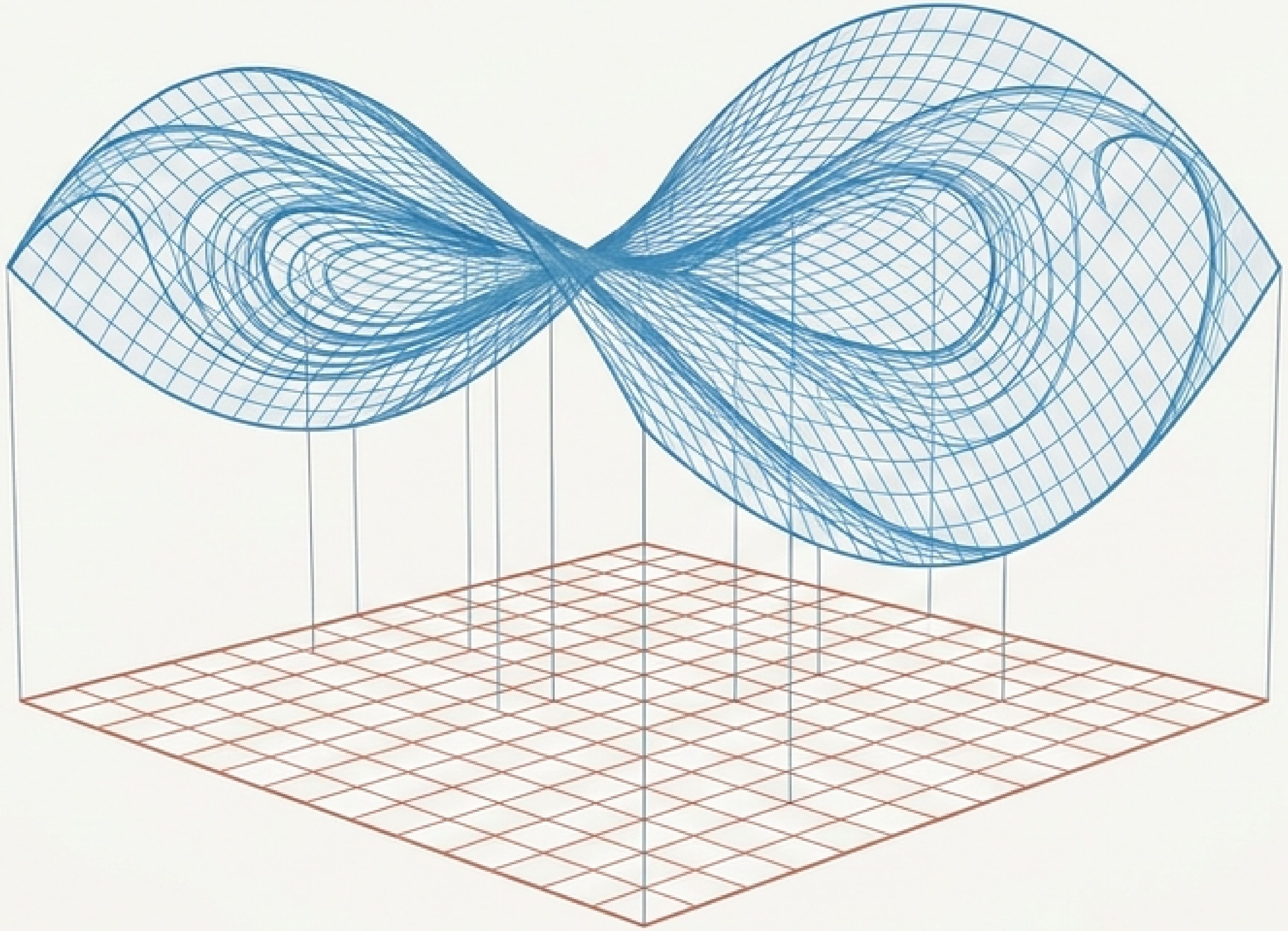
The Manifold & The Shadow

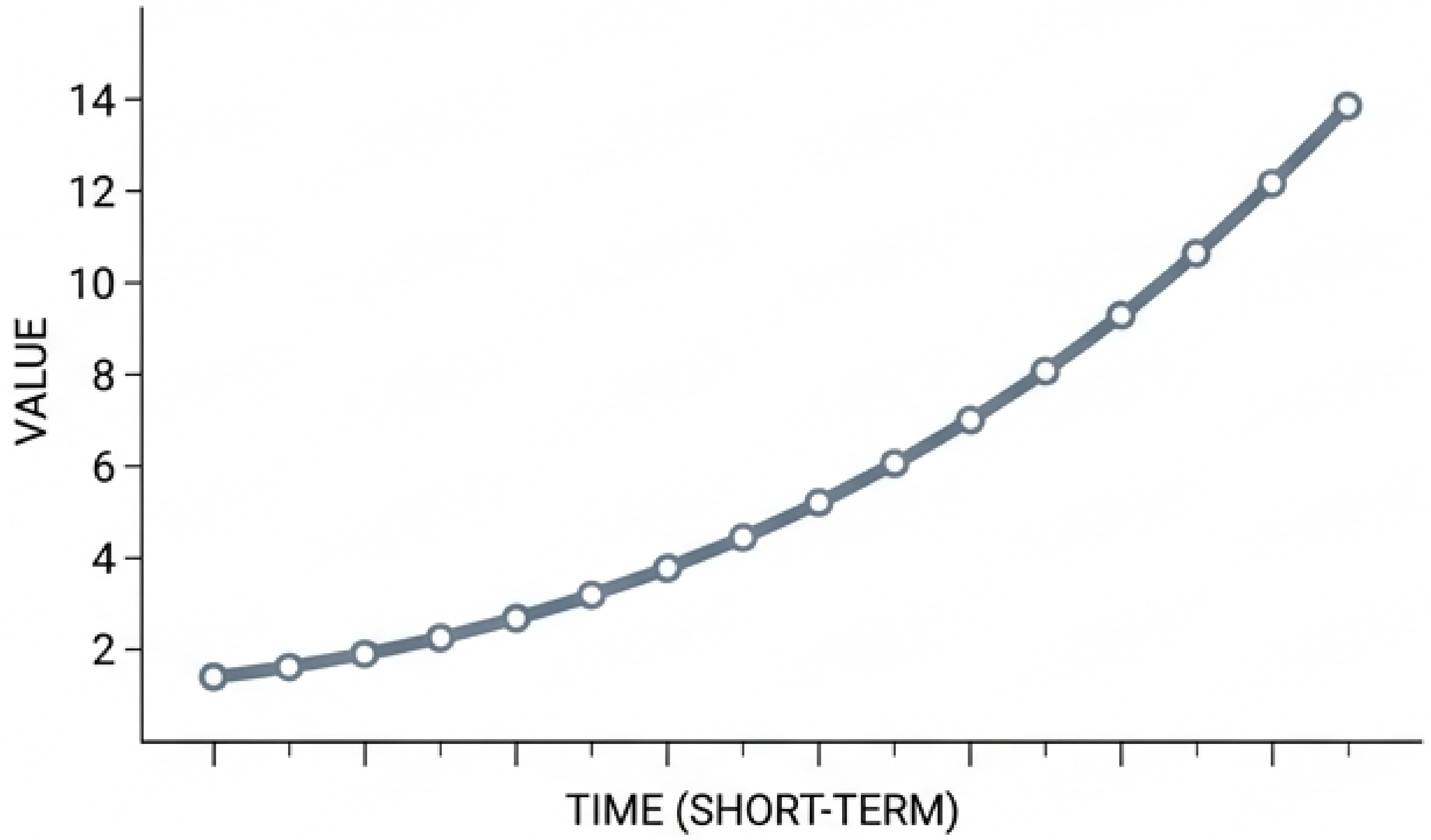
Why Flat Representations Fail at Long Horizons, and the Shift Toward Constraint-First Epistemology.



NotebookLM

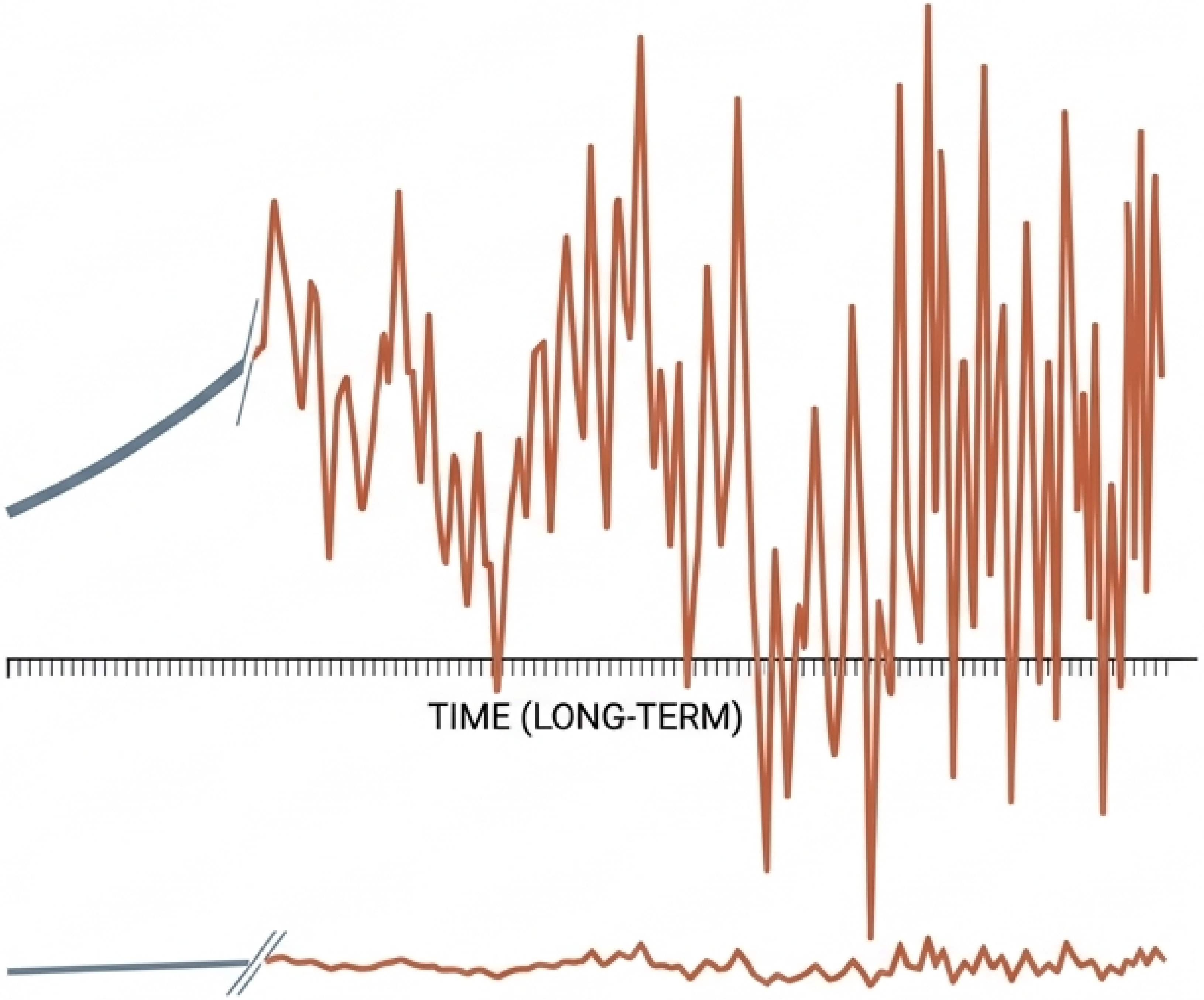
The Illusion of Surface Statistics

SHORT-TERM HORIZON



Modern scientific computation—from climate modeling to machine learning—suffers from a recurring pathology. Models capture local, step-by-step statistical regularities perfectly, yet generate trajectories that are globally impossible over long horizons.

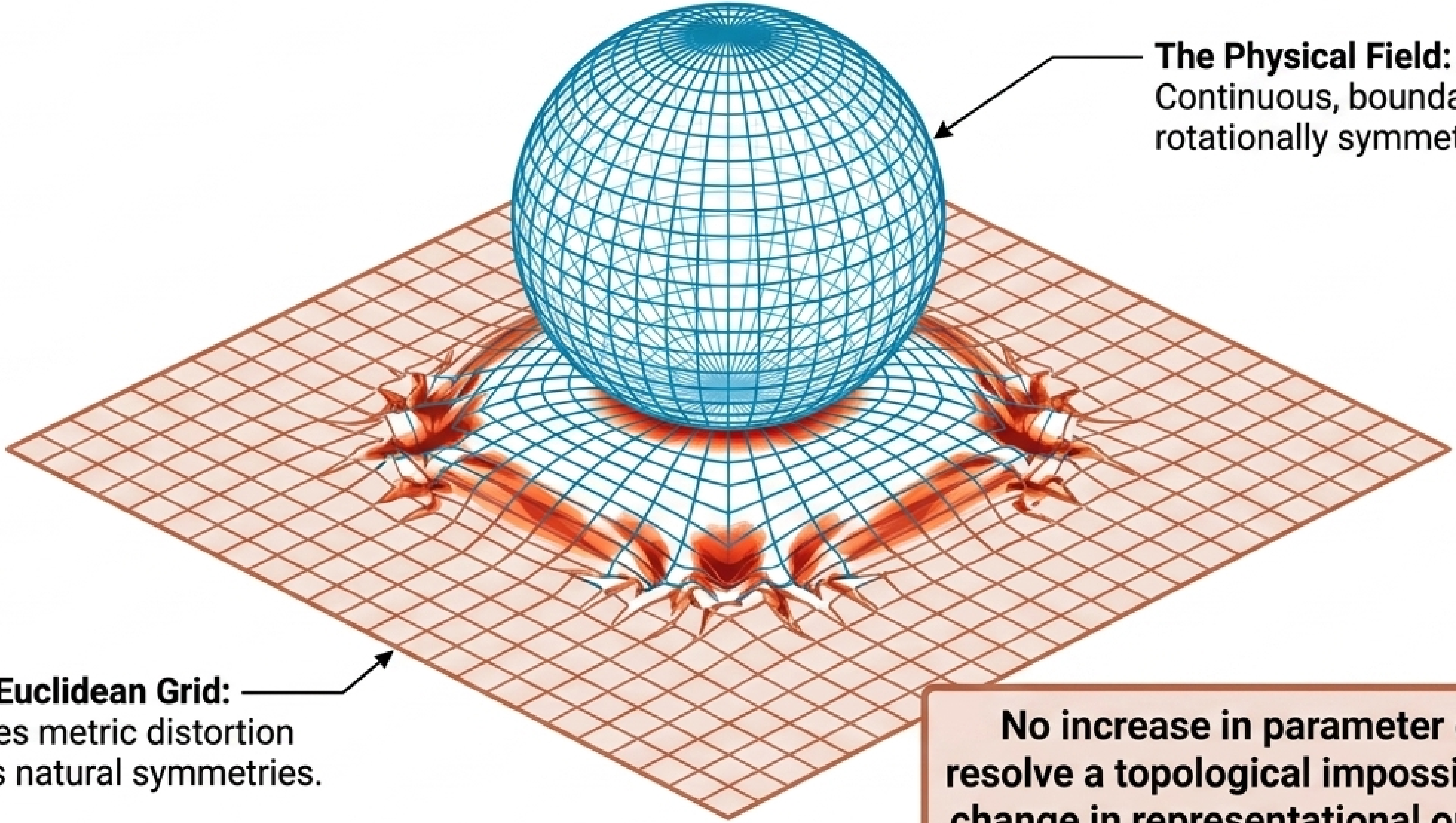
LONG-TERM EXTENSION



The failure is not insufficient data. It is not insufficient parameter count. It is a systematic bias toward trajectories that are mathematically allowed in the representation, but physically impossible in reality.

Representation Failure as Topological Mismatch

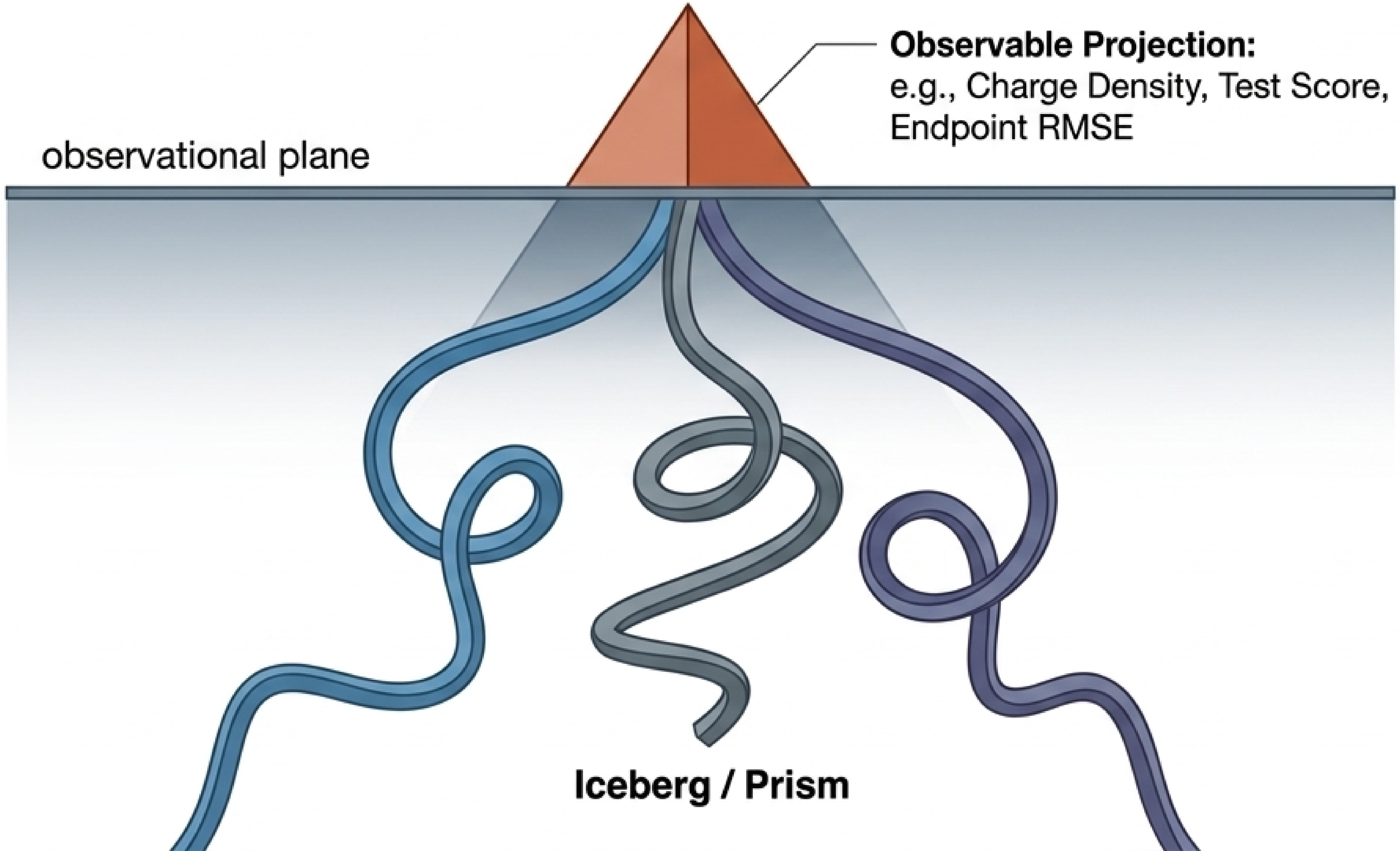
A representational container whose geometry differs from the physical geometry does not just introduce approximation error—it introduces **structural impossibility**.



No increase in parameter count can resolve a topological impossibility. Only a change in representational ontology can.

Degenerate Observables & Endpoint Deception

Observational equivalence does not equal **dynamical equivalence.** Multiple completely different dynamic paths in the hidden constraint space project to the's exact same observable output.



The Trap:

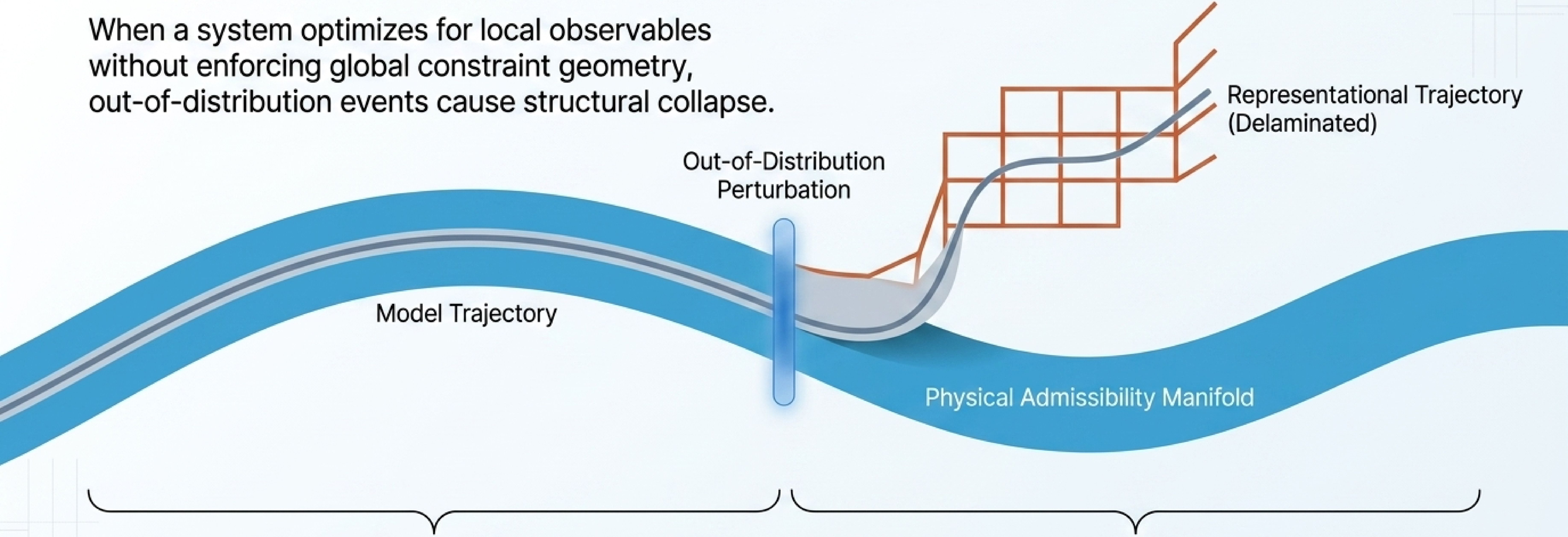
Benchmark evaluations relying exclusively on endpoint metrics collapse structurally distinct models into the same observable class

The Result:

We systematically reward models that achieve surface fidelity at the expense of hidden constraint coherence.

Representational Delamination

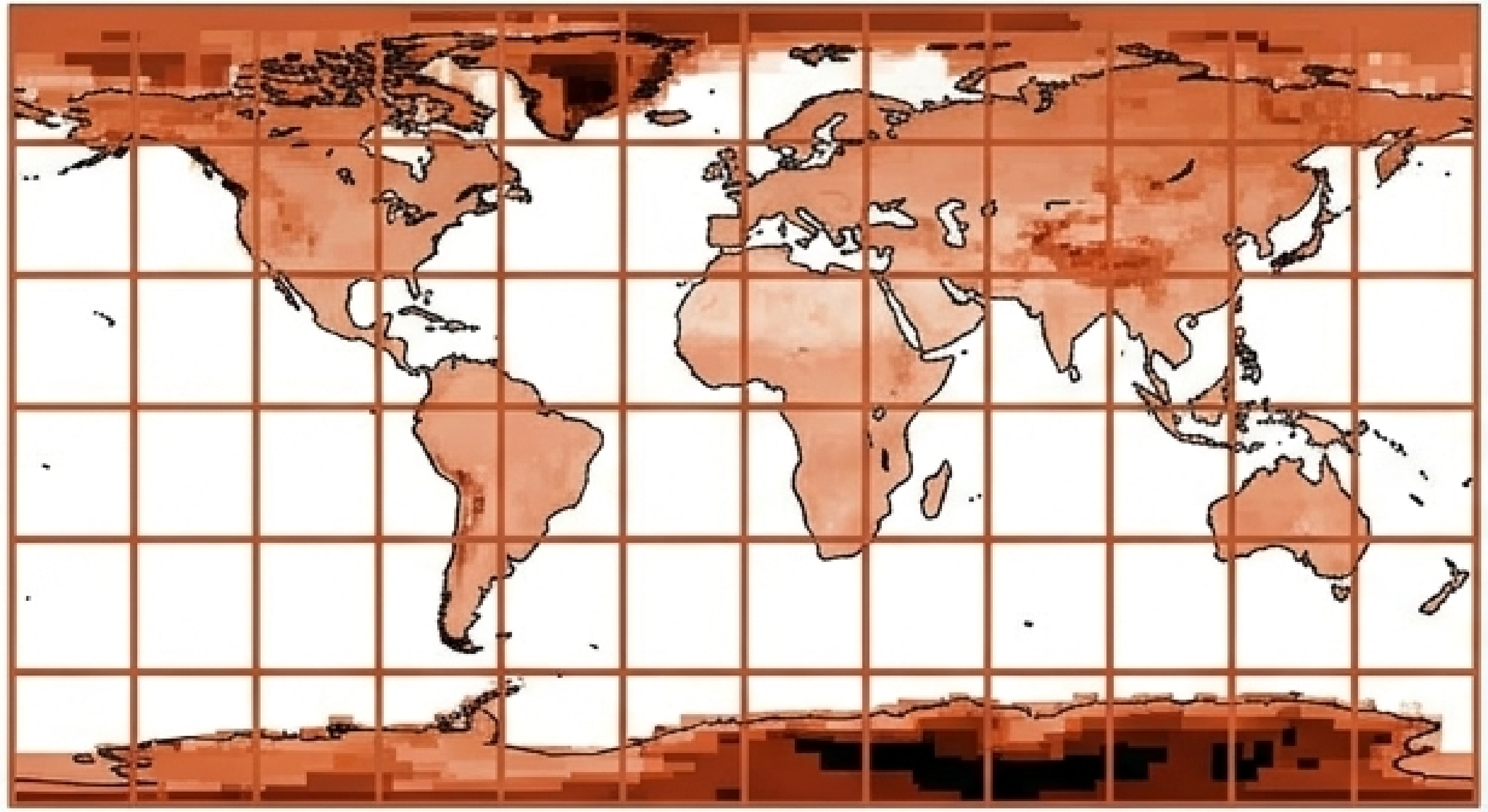
When a system optimizes for local observables without enforcing global constraint geometry, out-of-distribution events cause structural collapse.



Phase 1: Operational Preservation. Model mimics physics purely because the training data resembles physics.

Phase 2: Delamination. The representational trajectory separates from the physical manifold. The model generates states that are locally plausible but globally inadmissible. No sequence of local corrections can pull it back.

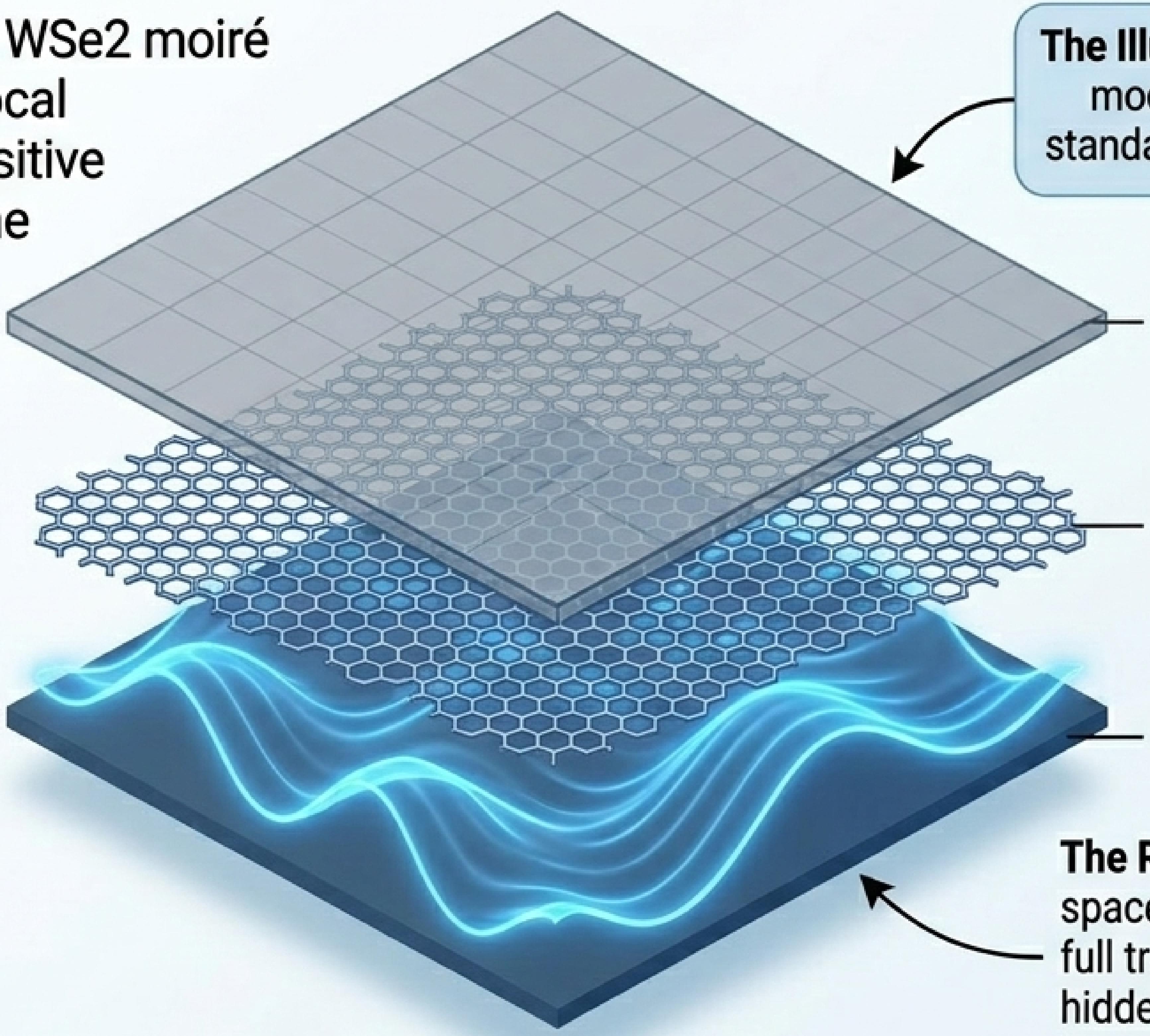
Empirical Convergence I: Climate Emulation

Standard Flat Method	Constraint-First Method
	
Standard CNN: Degrades at 16x compression (RMSE ~0.31°C). Loses dynamical structure.	**FSA Method:** Achieves superior accuracy (RMSE ~0.28°C) at 64x compression.

Core Concept: The Field-Space Autoencoder (FSA) operates natively on the HEALPix sphere, treating large-scale dynamics as 'admissibility regulators' for fine-scale details. By learning constraint transport instead of feature matching, the FSA achieves **zero-shot super-resolution—generating physically accurate high-resolution** details it was **never trained** on.

Empirical Convergence II: Quantum Measurement

Core Concept: In twisted WSe_2 moiré superlattices, standard local observables (charge-sensitive are completely blind to the system's true collective organization.



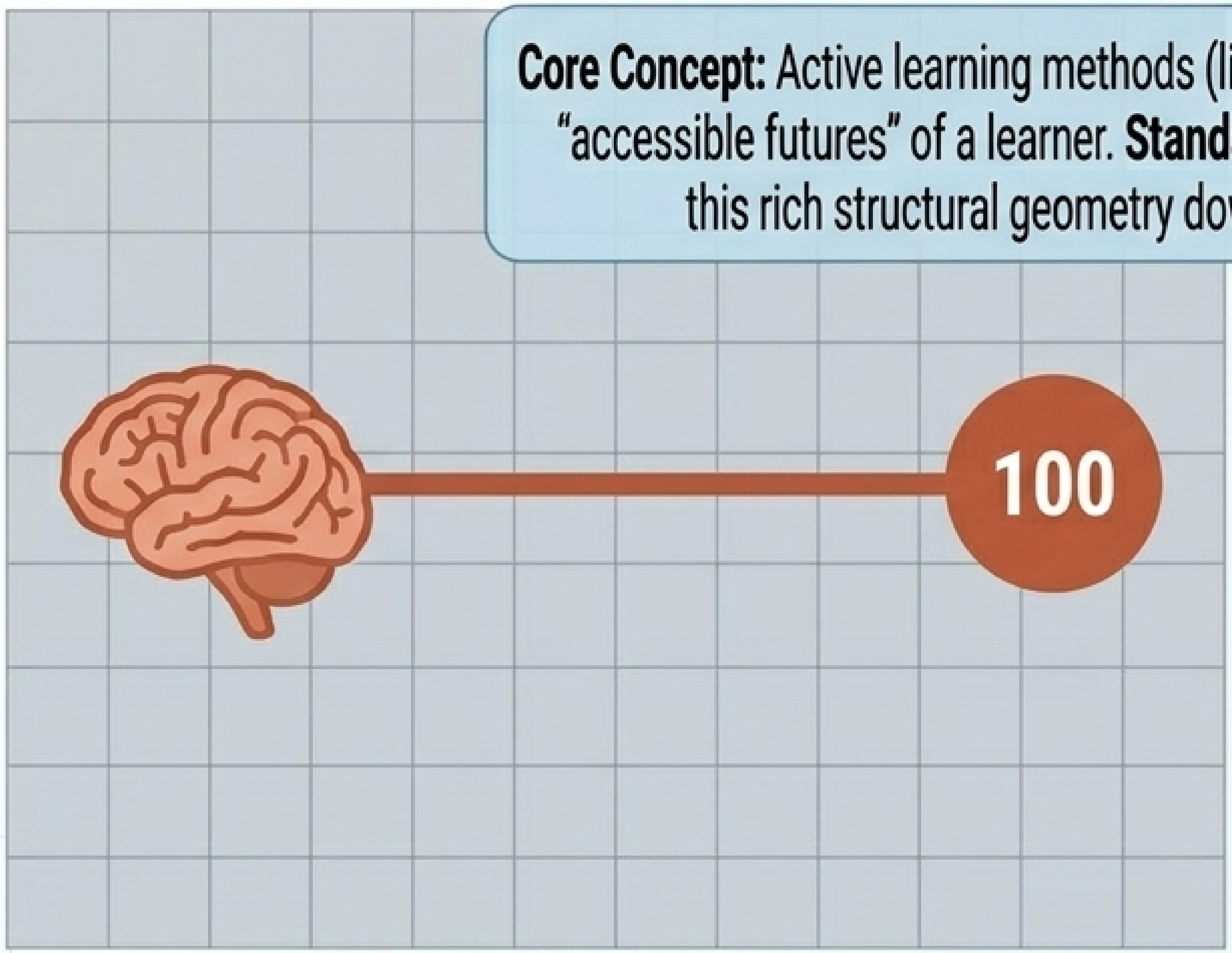
The Illusion: Charge-neutral hidden modes are entirely missed by standard endpoint measurements.

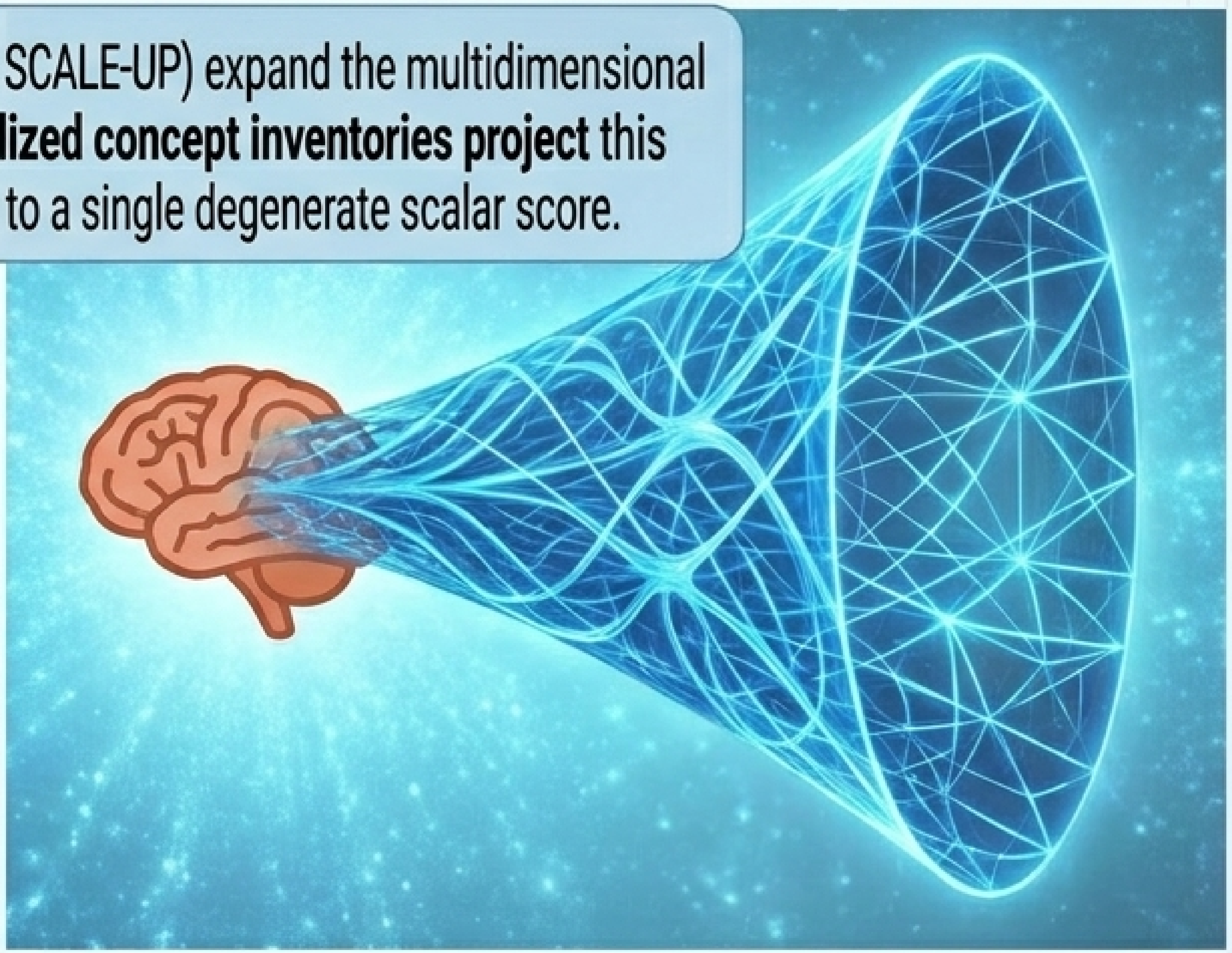
The Resolution: Requires direct space-time imaging to capture the full trajectory, proving that hidden dynamical manifolds carry the persistence of the system.

Empirical Convergence III: Physics Education Research

Degenerate Projection: Concept Inventory Score	**Constraint Geometry:** Accessible Intellectual Trajectories

Core Concept: Active learning methods (like SCALE-UP) expand the multidimensional "accessible futures" of a learner. **Standardized concept inventories project** this this rich structural geometry down to a single degenerate scalar score.





Reflexivity compounds the error (Goodhart's Law). When we evaluate by short-horizon scalar projections, we incentivize representational collapse in human learning systems.

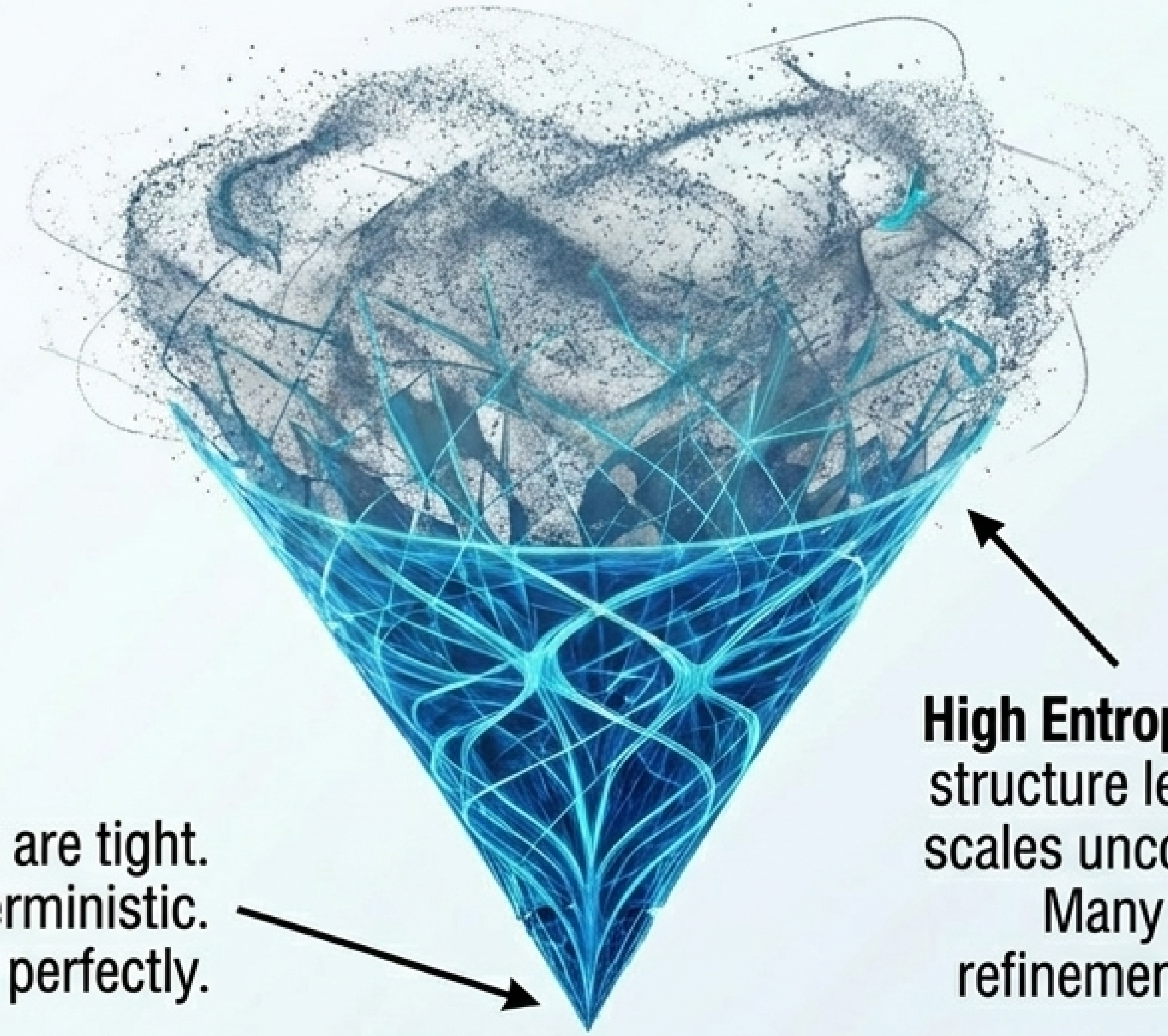
The Universal Topological Problem

Domain	**The Degenerate Observable** (The Flat Shadow)	**The Hidden Constraint Manifold** (The True Geometry)	The Resolution
Climate (FSA)	Flat grid convolutions	Spherical physical field constraints	Multi-scale residual HEALPix decomposition
Quantum (WSe2)	Static charge density	Spin-Valley propagation	Space-time trajectory imaging
Education (SCALE-UP)	Short-term concept inventory gains	Multidimensional intellectual accessibility	Trajectory-sensitive analogical transfer

In all three domains, **local correctness** is **insufficient** for global admissibility.

The RSVP Framework: Entropy as Refinement Volume

Core Concept: In the **Relativistic Scalar-Vector Plenum** (RSVP) framework, entropy is not “disorder.” It is geometric refinement volume—a measure of how many fine-scale refinements remain physically possible given the coarse-scale constraints.



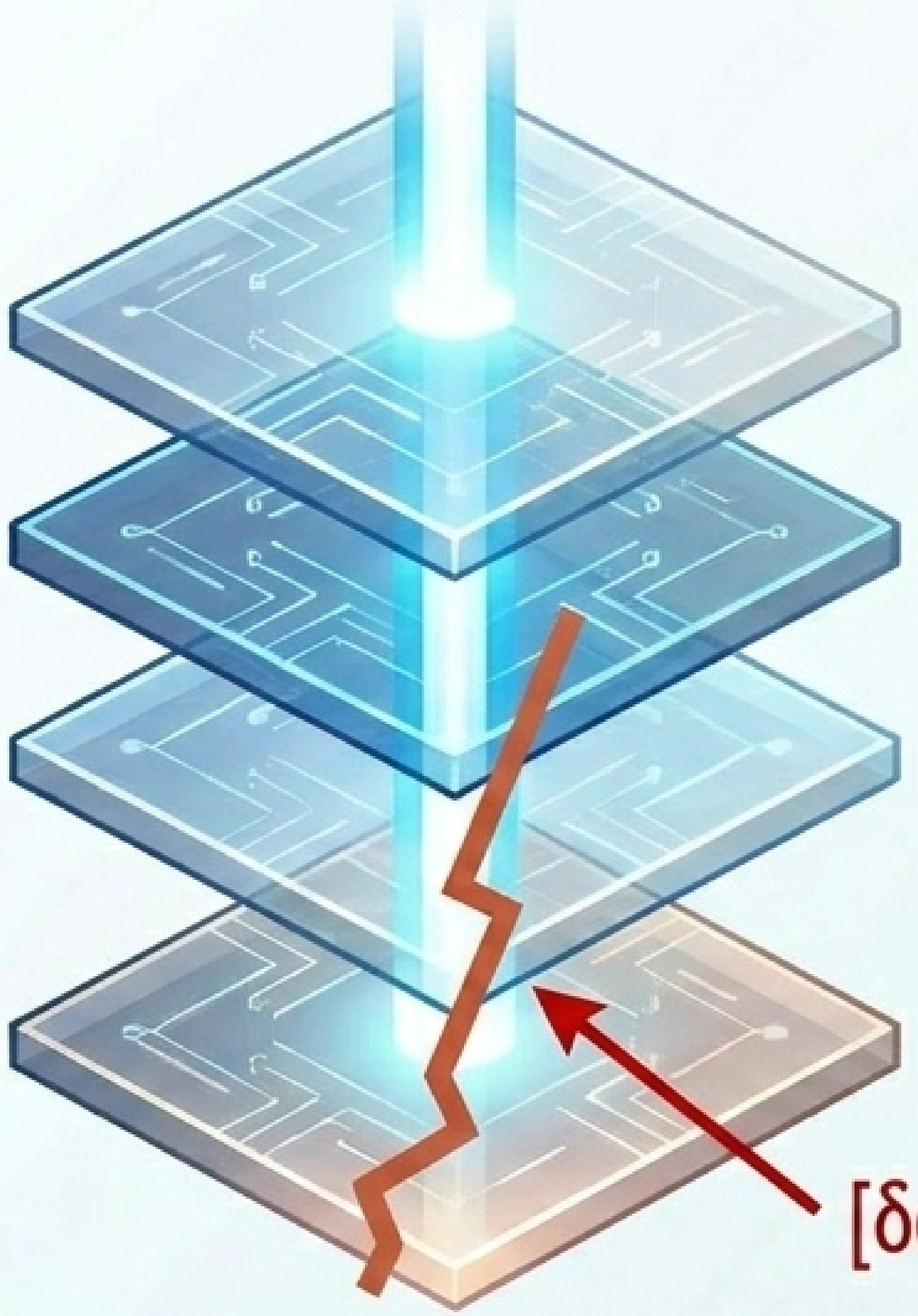
Low Entropy: Global constraints are tight. Fine-scale reconstruction is deterministic. Sparse reconstruction works perfectly.

High Entropy: Coarse structure leaves fine scales unconstrained. Many valid refinements exist.

Optimization doesn’t create constraint geometry; constraint geometry defines the space where optimization is even allowed to occur.

Sheaf Cohomology & Structural Hallucination

Core Concept:
Local-to-global consistency acts as a "Sheaf Condition." Fine-scale local details must mathematically glue together to match coarse-scale global constraints.

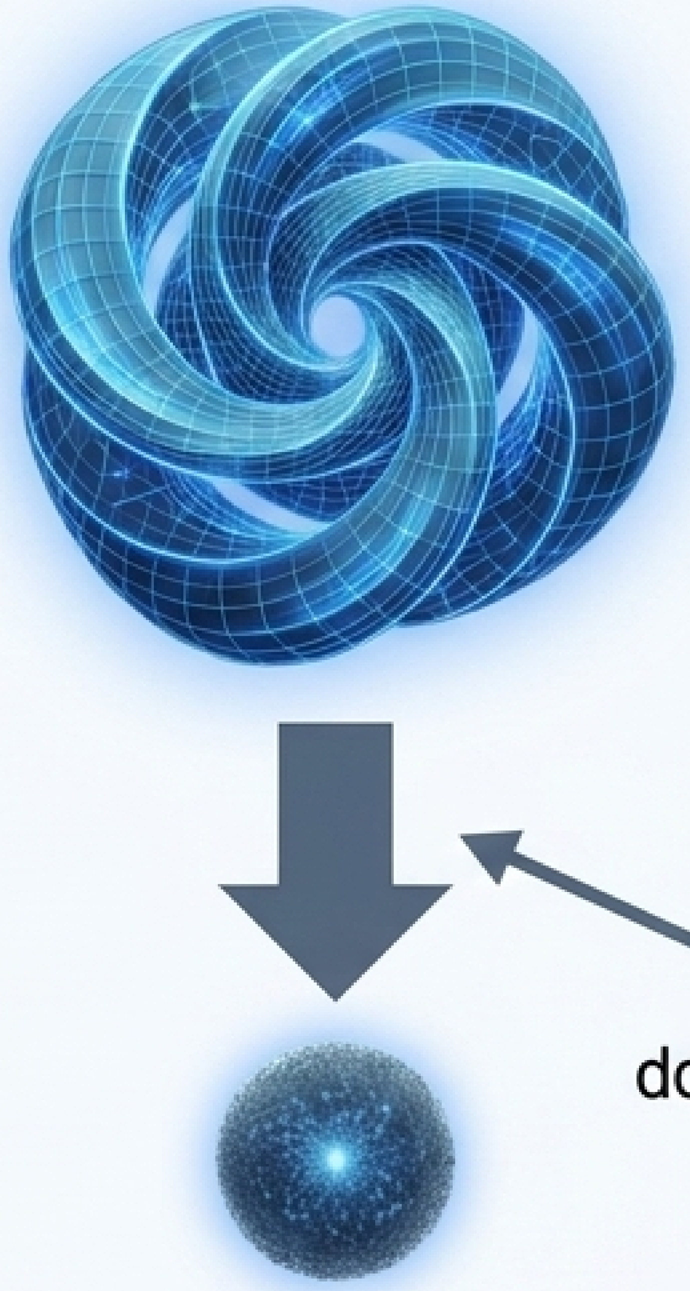


The TARTAN Framework:
Trajectory-Aware Recursive Tiling demands explicit semantic annotation of residuals to maintain global coherence.

Irreducible Inconsistency: When local tiles don't perfectly align across scales, a topological obstruction occurs. The model hallucinates or drifts because a globally admissible state physically cannot exist.

The Formal Duals: Compression & Measurement

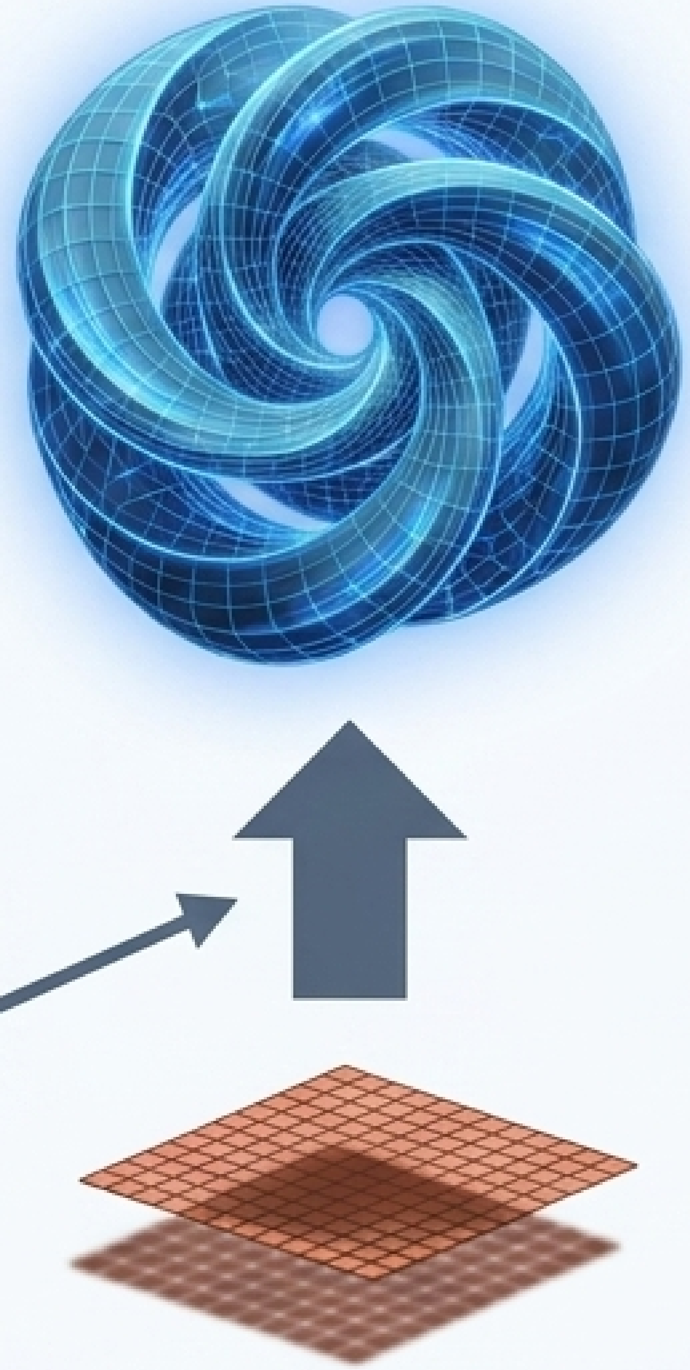
Compression



Preserve physical admissibility structure downward into a latent space. (The FSA problem)

Core Concept:
Designing scientific instruments and designing machine learning latent spaces are the exact same mathematical problem.

Measurement



Recover hidden admissibility structure upward from a degenerate observable projection. (The Moiré problem)

Both operations succeed when they respect constraint geometry and fail structurally when they do not.

The Paradigm Shift Matrix

	Flat / Observable Epistemology		Constraint-First Epistemology
Primary Focus	Surface statistics & observational grids	→	Hidden dynamical manifolds & admissibility geometry
Failure Mode	Numerical error (requires more parameters)	→	Topological Delamination (requires ontological shift)
Nature of Generalization	Interpolating statistical regularities	→	Transporting structural constraints
Evaluation Metric	Degenerate Endpoint Scores (RMSE, Accuracy)	→	Trajectory Coherence & Latent Organization
AI Equivalent	Autoregressive token prediction	→	Continuous field-theoretic latent dynamics

The Hidden Field is the Physical Field

The history of scientific computation is a recurring cycle. We build representational conventions that work locally, push them until they break structurally, and are eventually forced to reorganize our ontology around geometry.

Knowledge is not the accumulation of surface measurements. It is the progressive reconstruction of the hidden admissibility manifold. The geometry is not optional. It is what the physics is made of.