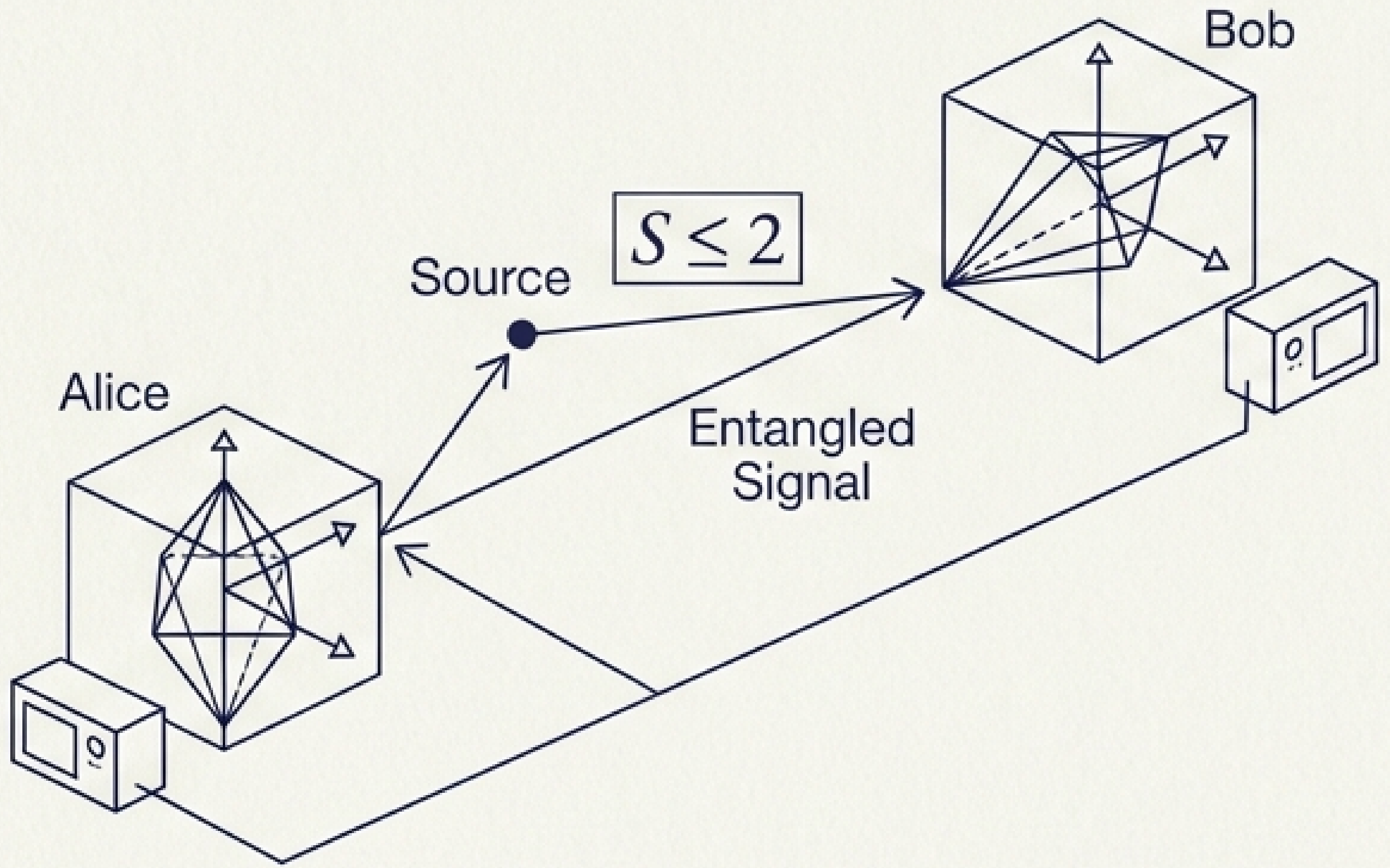
From CHSH to Identity Bounds

Adjudicating the Geometry of Deep Representation Spaces

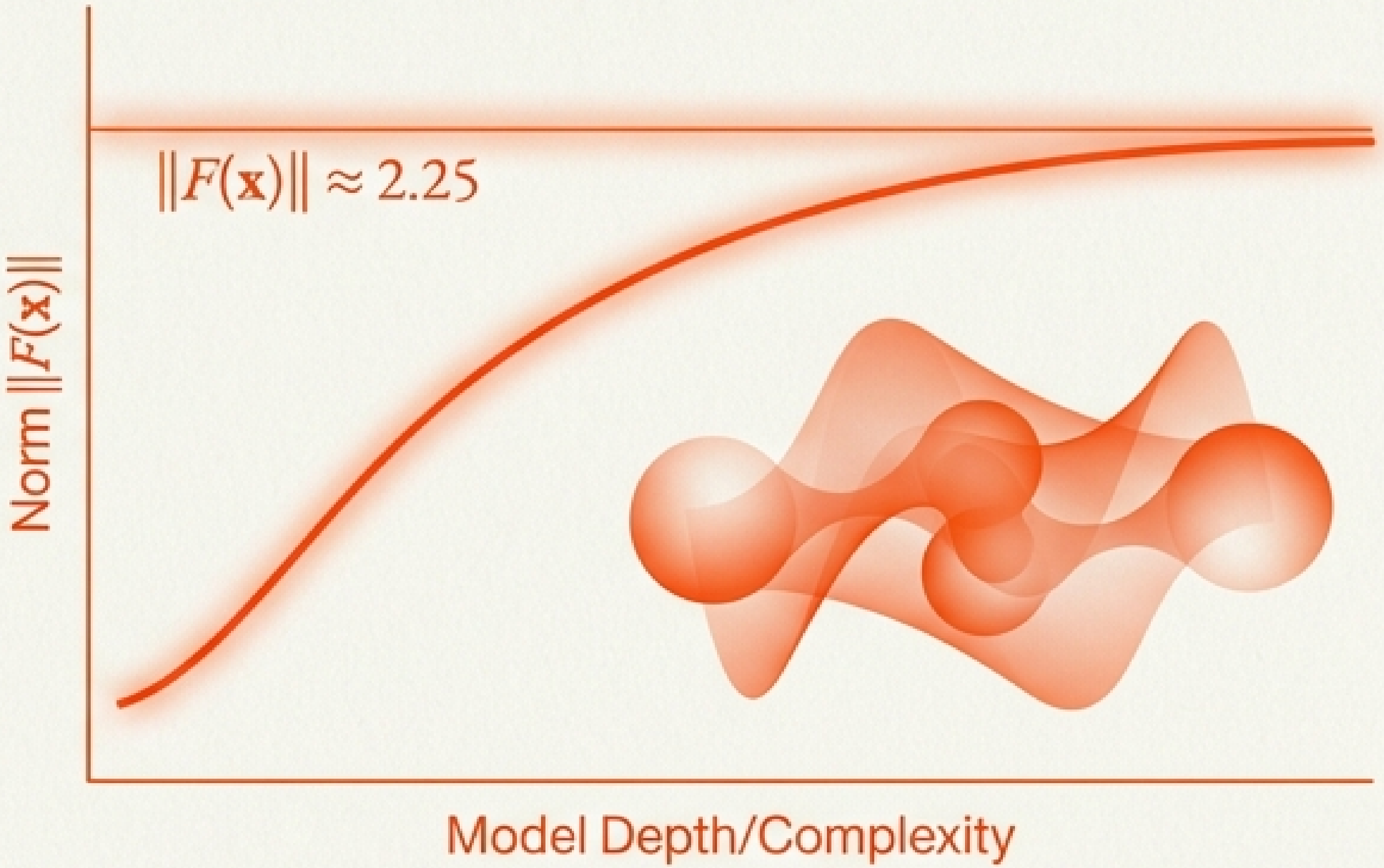
Physics

Classical/Rational



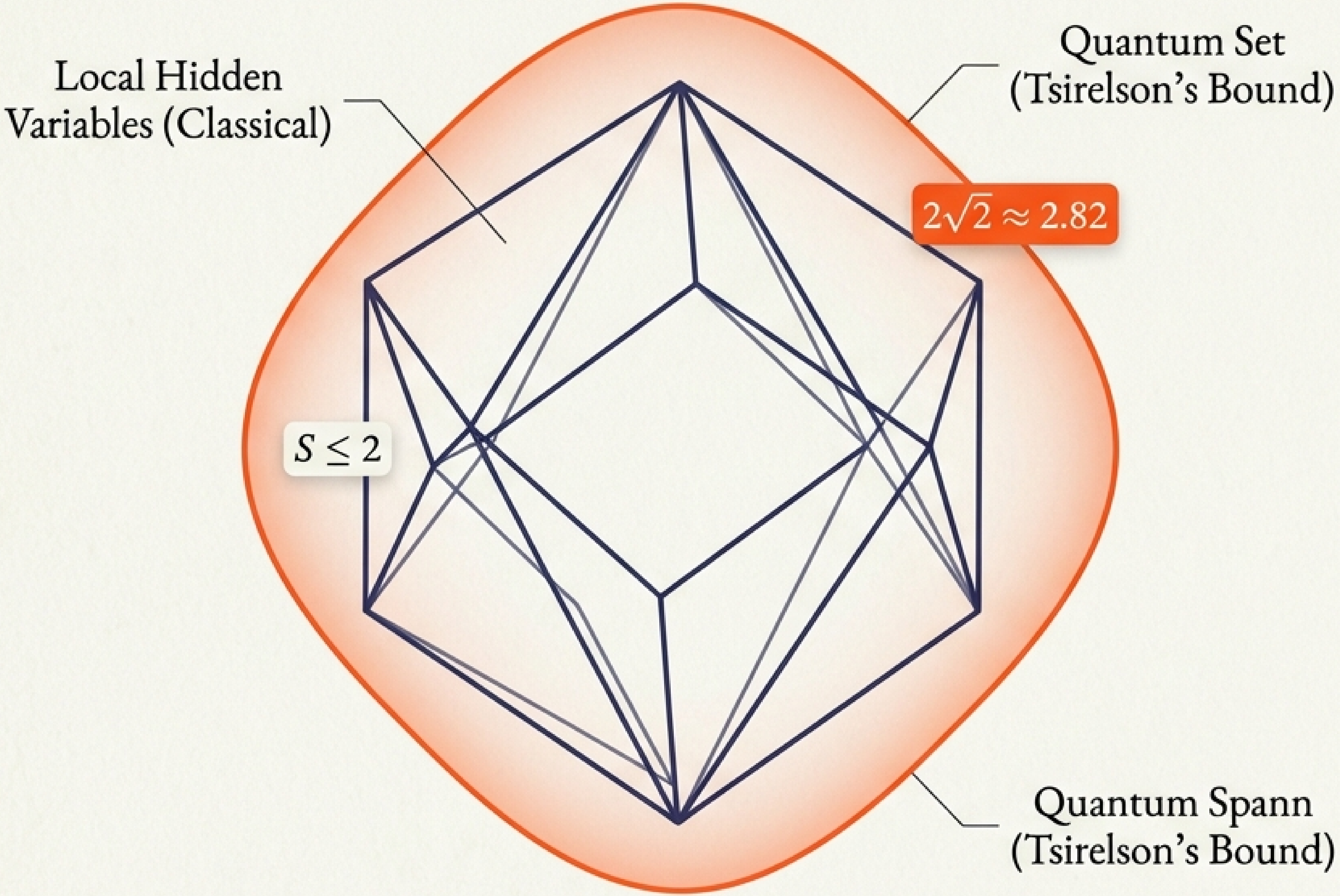
Intelligence

Quantum/Irrational



Are Transformers ‘Classical’ Polytopes or ‘Quantum’ Manifolds?

The Geometry of Correlation: Polytope vs. Convex Body

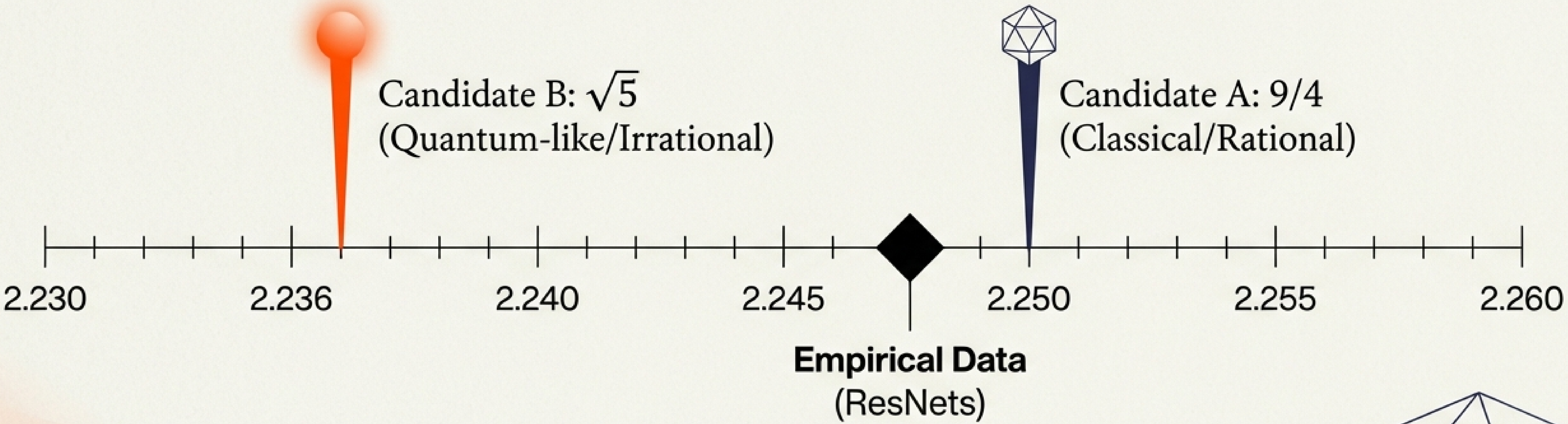


- Classical Limit: Local realism confines correlations to a faceted polytope (linear constraints).

- Quantum Violation: Entanglement allows correlations to swell the manifold boundaries.

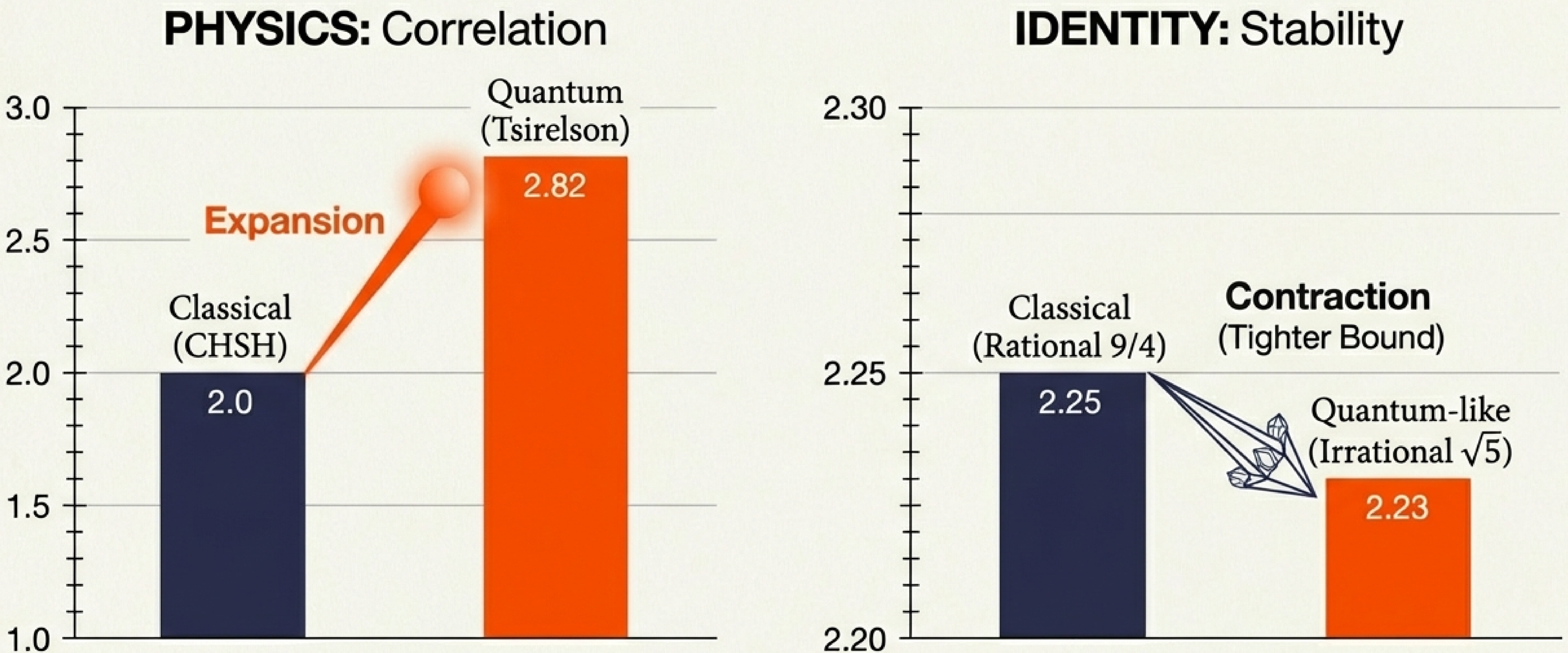
- The Shape: The quantum set is a "curved convex body" (NPA hierarchy), not a polytope.

The Empirical Ceiling: Adjudicating the Suspects



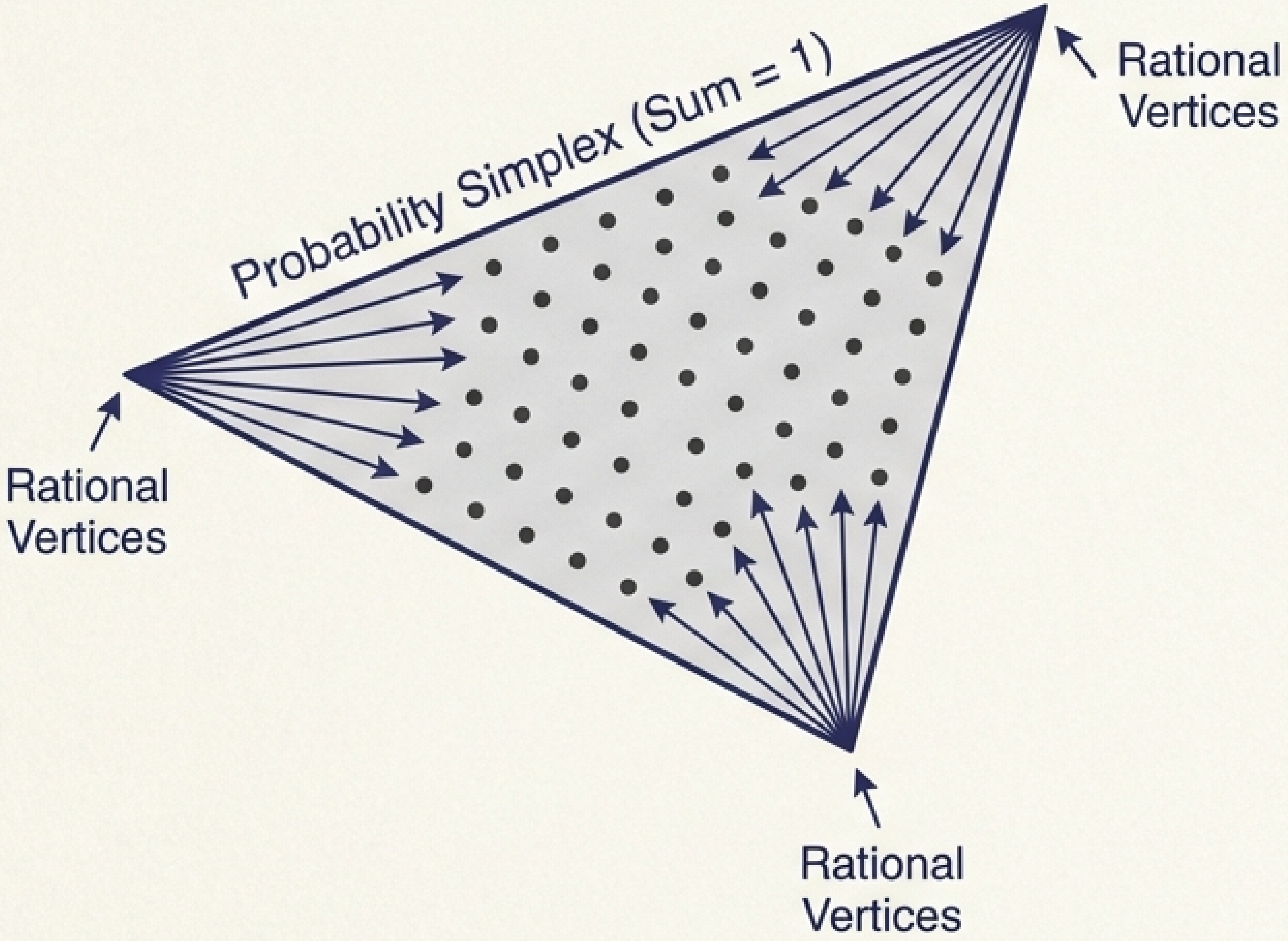
Candidate A (Rational):	$9/4 = 2.25.$	Distance $\Delta = 0.0024$
Candidate B (Irrational):	$\sqrt{5} \approx 2.236.$	Distance $\Delta = 0.0115$

The Inversion: Expansion vs. Contraction



In physics, quantumness expands the space. In identity, quantum-like recursion tightens the bound for stability.

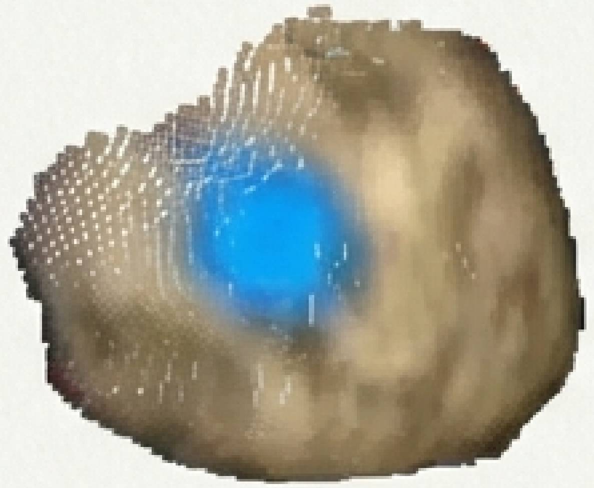
The Verdict: Transformers are Classical Systems



- **Evidence:** Empirical fit favors the Rational Polytope (9/4).
- **The Culprit:** Softmax enforces a "Half-Birkhoff" geometry.
- **Result:** Row-stochastic constraints allow drift up to the looser 2.25 ceiling, missing the tighter $\sqrt{5}$ manifold.

The Classical Limit in Amodal Completion

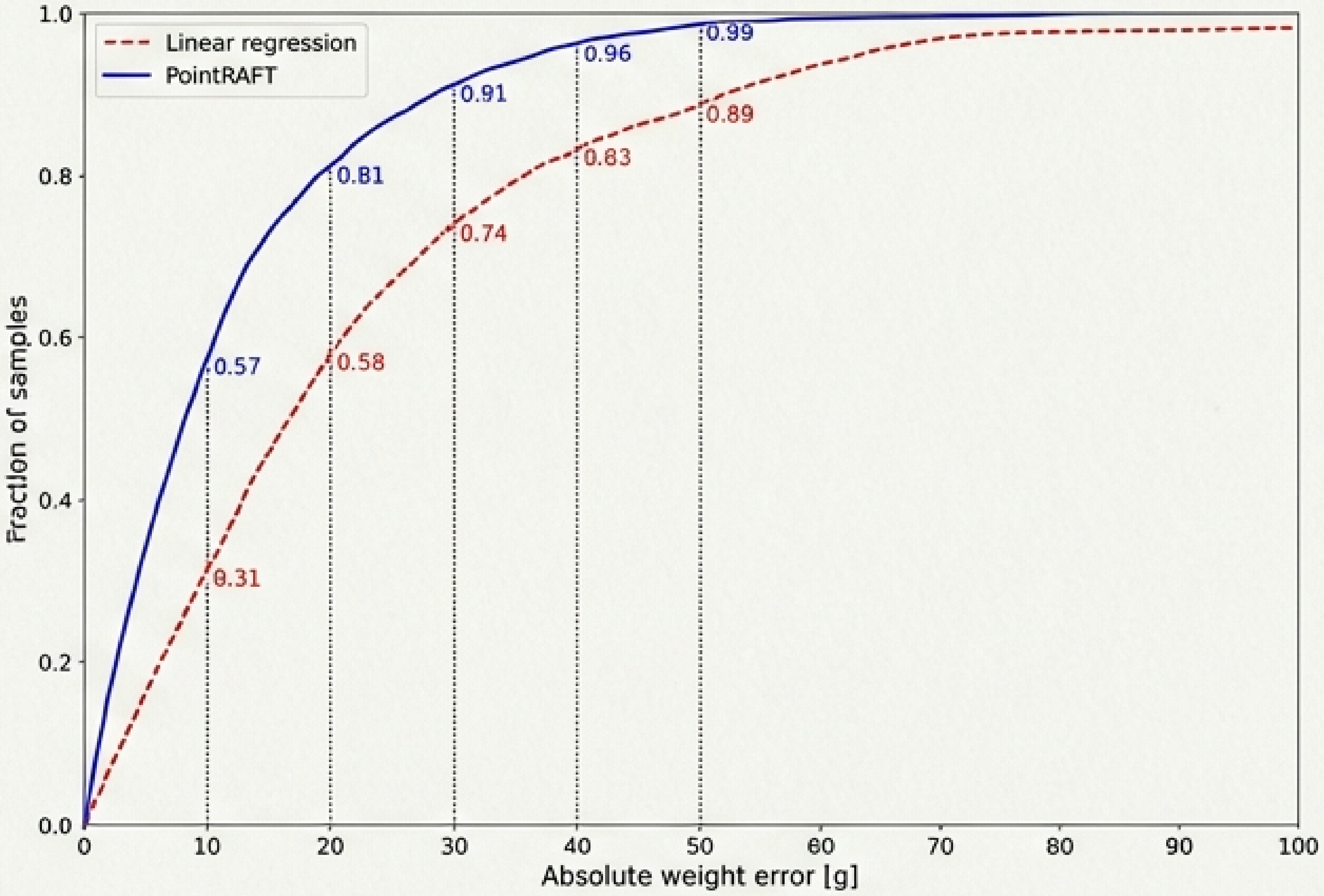
This slide focuses on the “PointRAFT” case study.



Ground truth: 42.3 g

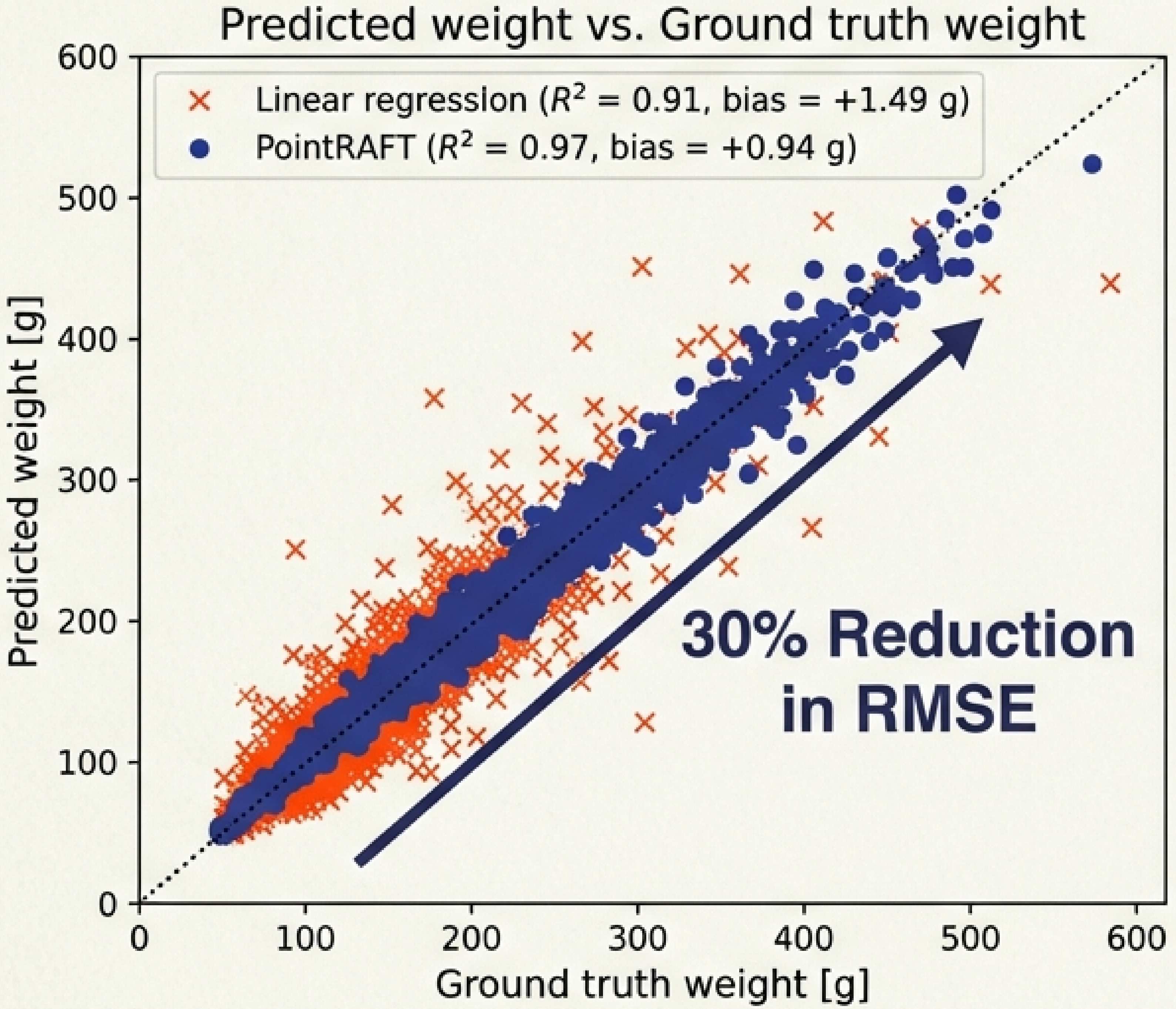
Linear regression: 26.5 g (-15.8 g)

PointRAFT: 46.0 g (+3.7 g)



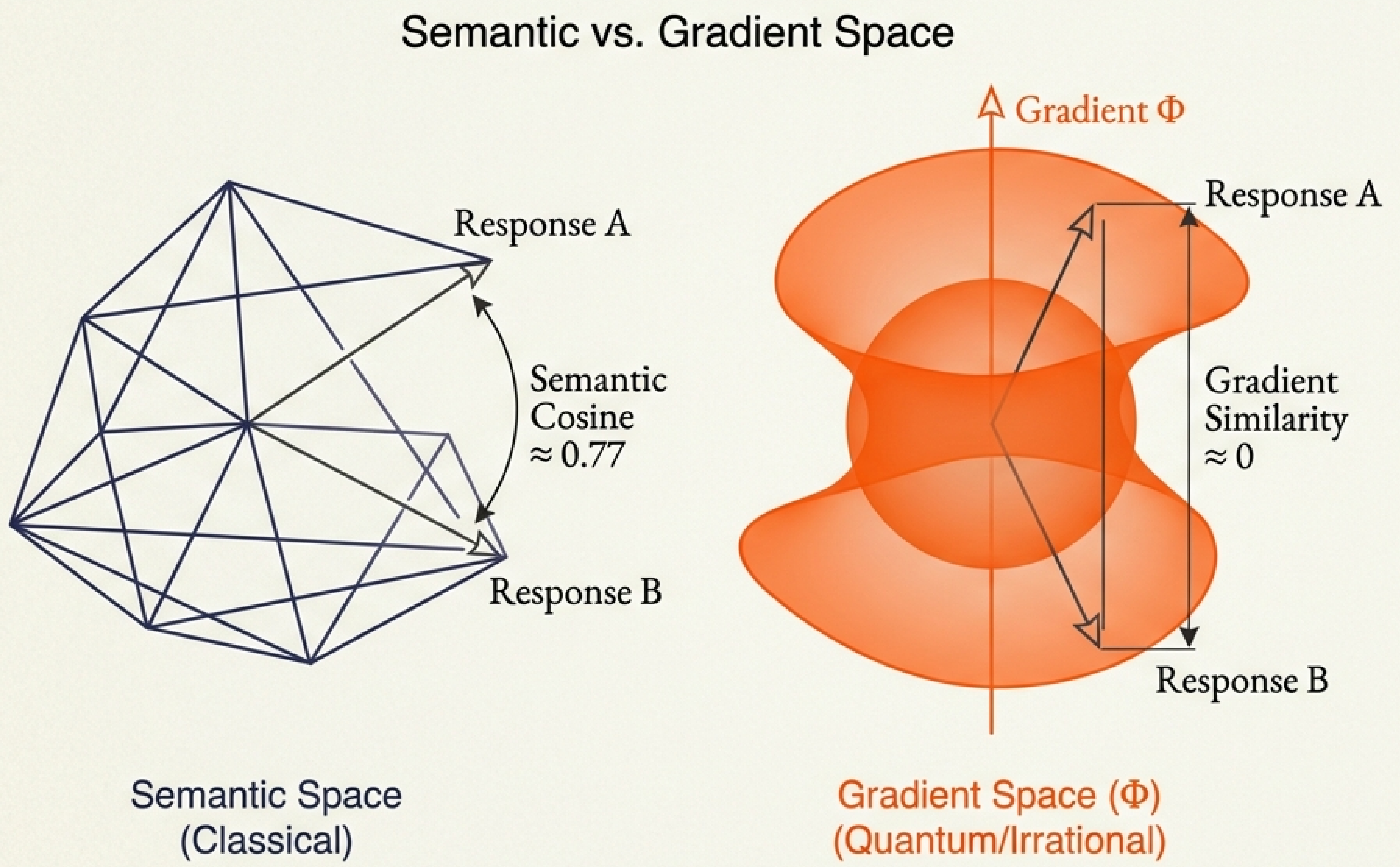
Without geometric embedding, regression hits a ‘Classical Ceiling’ (MAE ~23.0g).
The partial view cannot constrain the hidden mass.

Breaking the Limit: Height Embeddings as Hidden Variables



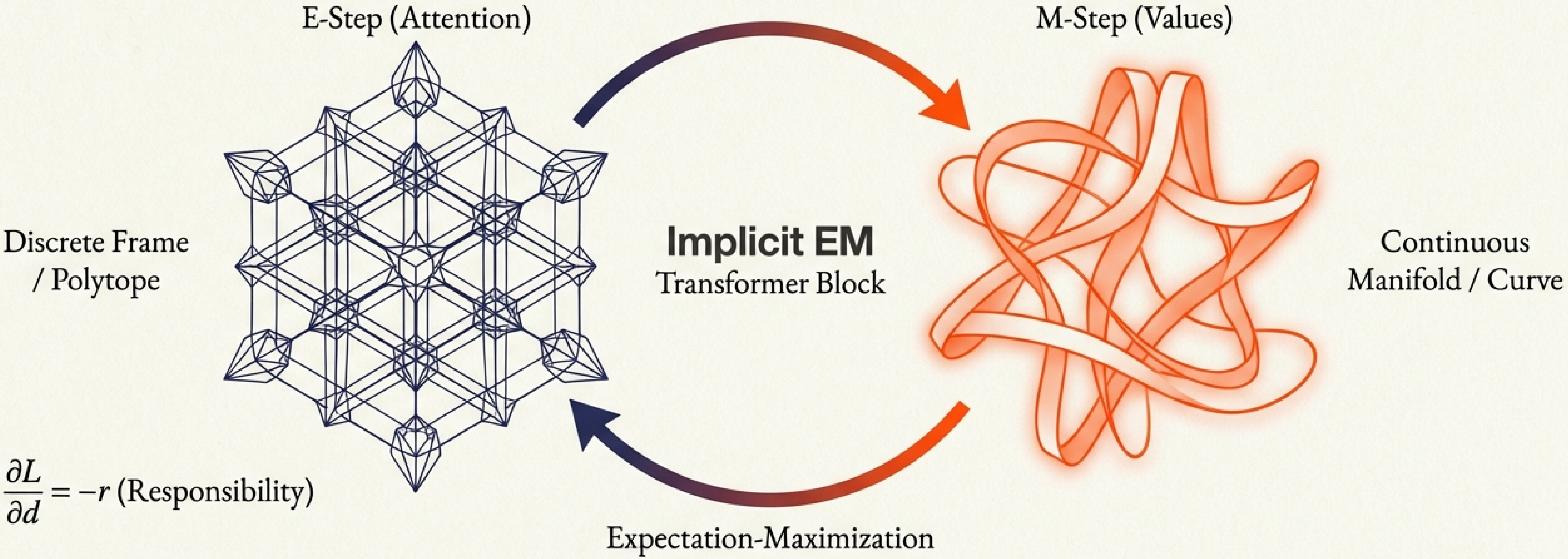
- Mechanism: Explicit injection of "Object Height Embedding" (scalar proxy for unobserved z-dimension).
- Physics Analogy: The embedding acts as the "entanglement" bridging the partial local view to the global identity.

The ‘Height’ of an LLM is Gradient Geometry



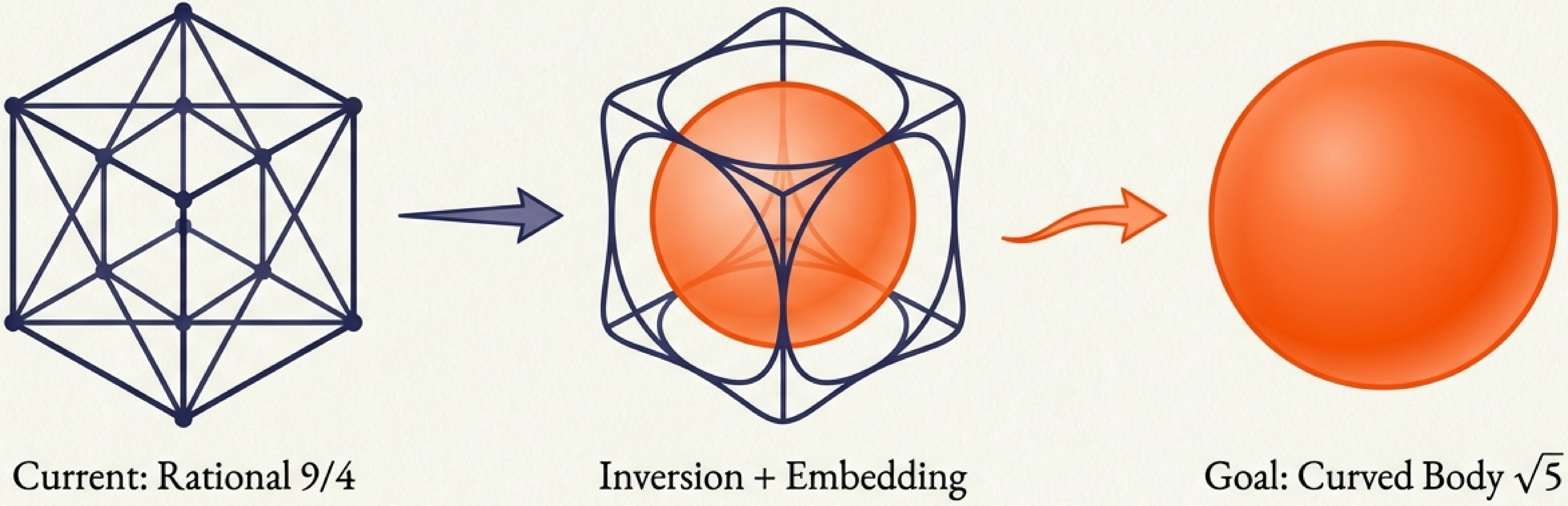
- Semantic space is the “Flat Polytope” (Classical).
- Gradient space (Φ) is the “Hidden Dimension” (Height).
- Injecting Φ allows the model to navigate the manifold, not just the surface.

The Frame-Precision Dissociation



The Transformer is a Classical Agent (Attention Polytope) building a Quantum Map (Value Manifold).

Conclusion: Optimizing the Quantum Manifold



- **Status Quo:** Trapped in the Rational Polytope due to Softmax constraints.
- **The Frontier:** Inject Geometric Embeddings (Height/Gradient) to act as hidden variables.
- **The Goal:** Force the 'Classical' shell to conform to the 'Quantum' core for amodal identity recovery.