Quadratic Gravity as a Derived Interface Theory

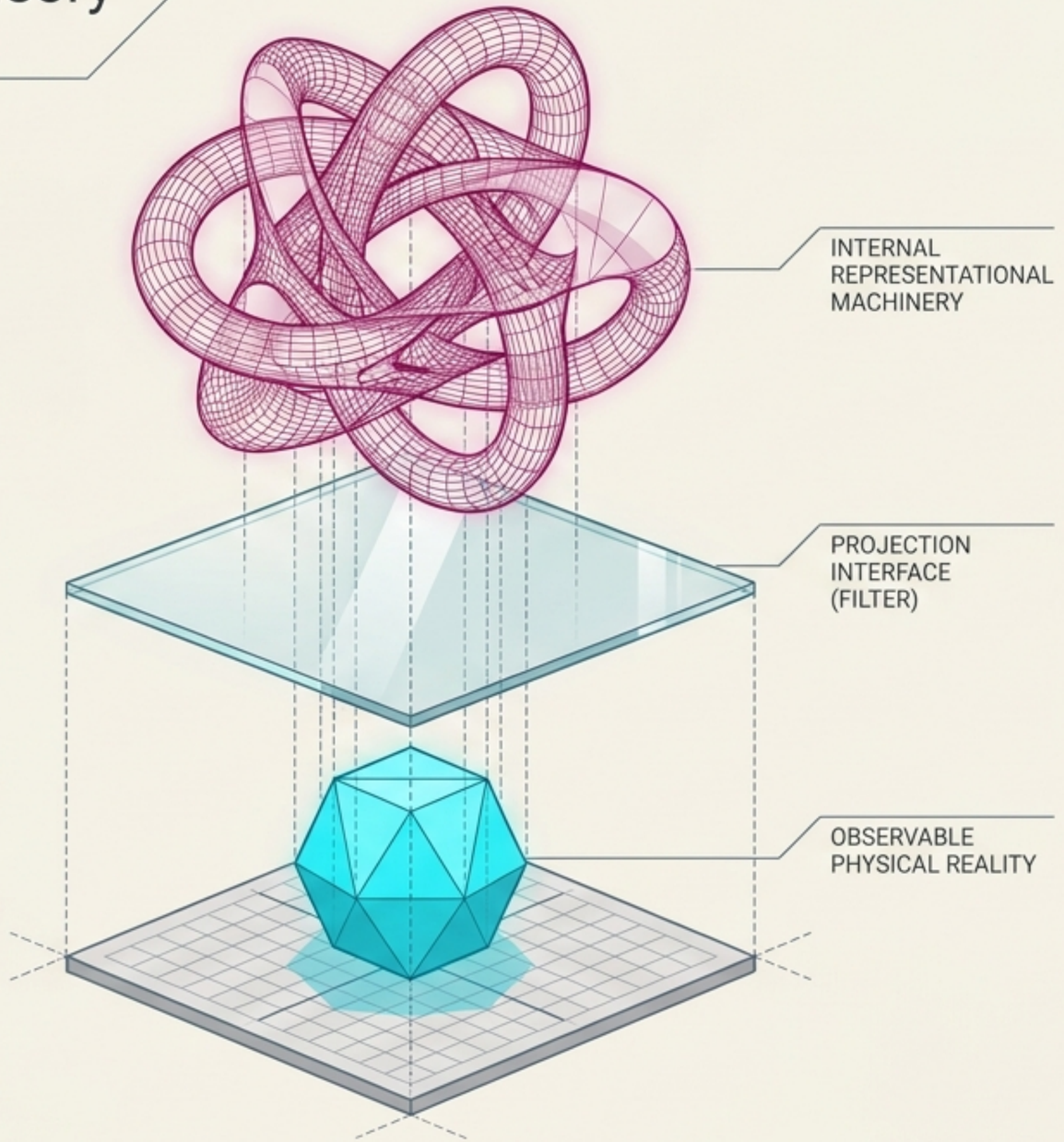
Flyxion, Independent Researcher (June 23, 2026)

Core Thesis

Higher-derivative quantum gravity is routinely rejected due to ghost instabilities. This rejection rests on a mathematical choice, not a physical necessity.

The Paradigm Shift

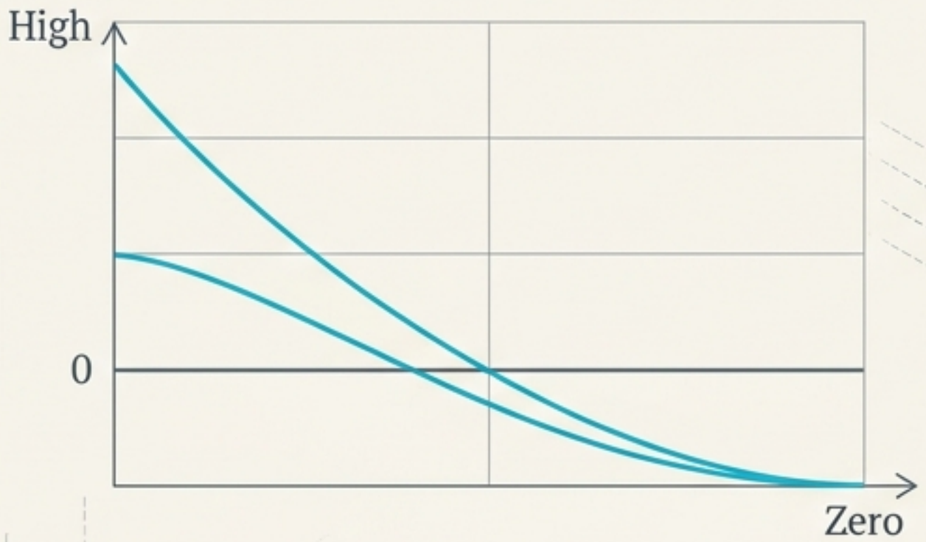
Physical constraints belong on the projected observable sector, not on the internal representational machinery.



The Dual Nature of Stelle's 1977 Discovery

The Dream: Perturbative Renormalizability

$$S = \int d^4x\sqrt{-g}\left(\frac{R}{16\pi G} + \alpha R^2 + \beta C_{\mu\nu\rho\sigma}C^{\mu\nu\rho\sigma}\right)$$



Asymptotic Freedom (Avramidi, 1980s) —
UV-complete with a well-defined continuum limit.

The Nightmare: The Spin-2 Ghost

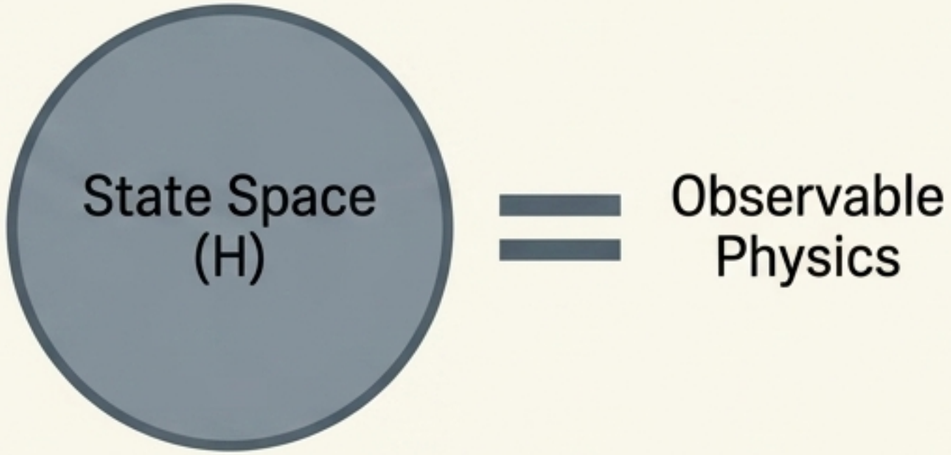
$$\Delta^{(2)}(k) \sim \frac{1}{k^2} - \frac{1}{k^2 + m_2^2}$$

Negative norm states. In canonical quantization,
these propagate with the wrong sign.

The standard inference:
Negative norm = Negative probability = Unphysical theory.

The Hidden Culprit: Latent Fundamentalism

The Hilbert Assumption (Orthodoxy)

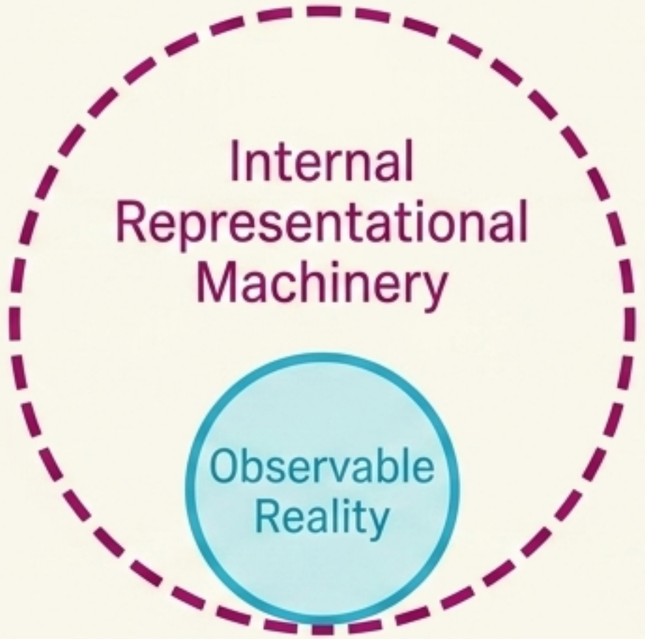


The Assumption

Observable Physics = Entire State Space.

The historical habit of demanding every mathematical coordinate correspond directly to a physical, positive-probability outcome.

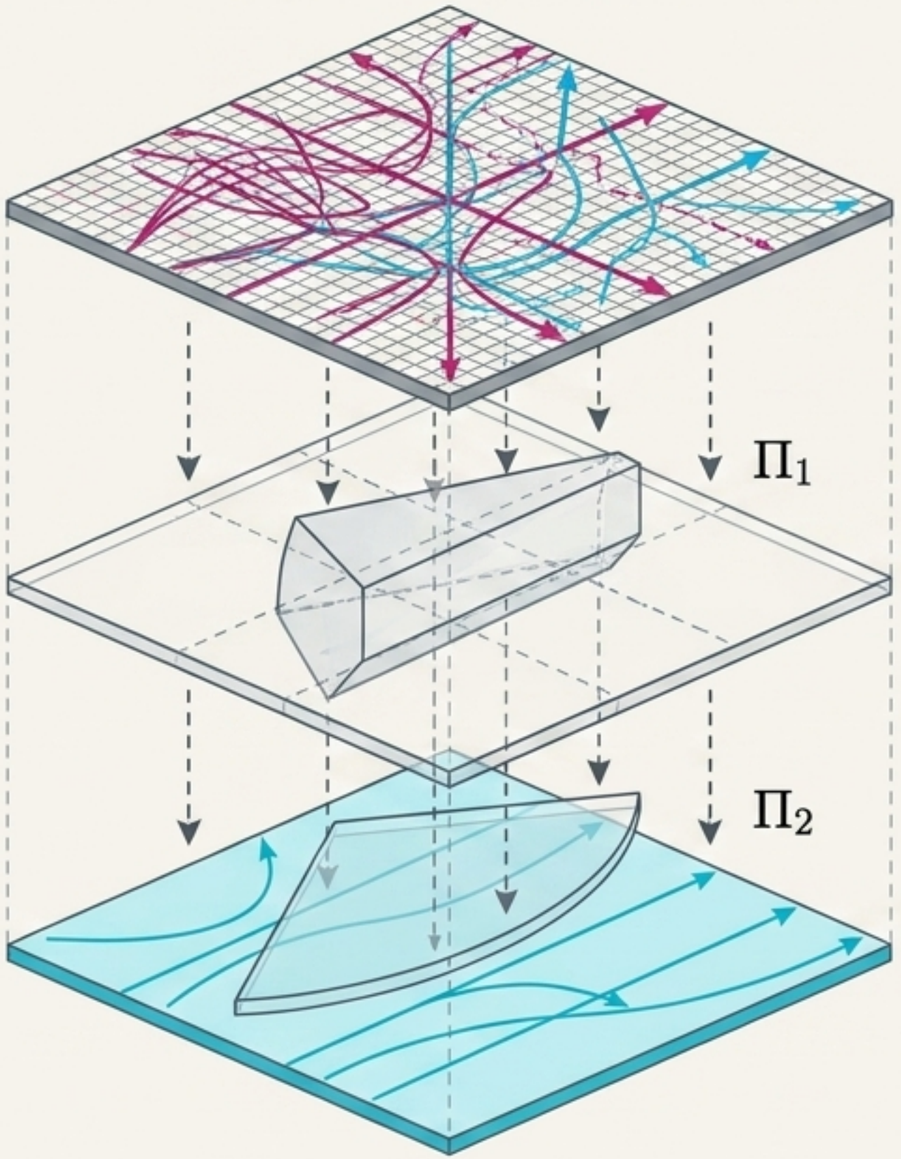
The Admissibility Framework (New Paradigm)



The Reality

A quantum state is a label for a system. You cannot observe the norm of a quantum state. You only observe transition probabilities.

The Admissibility Hierarchy



M_{adm} - Admissibility Manifold

Field histories consistent with fundamental dynamic constraints. Includes hidden dimensions, negative norms, gauge redundancies.

M_{proj} - Projection Manifold

Equivalence classes under symmetries generating non-observable degrees of freedom.

M_{obs} - Observable Manifold

Empirically distinguishable outcomes obeying causal probability measures.

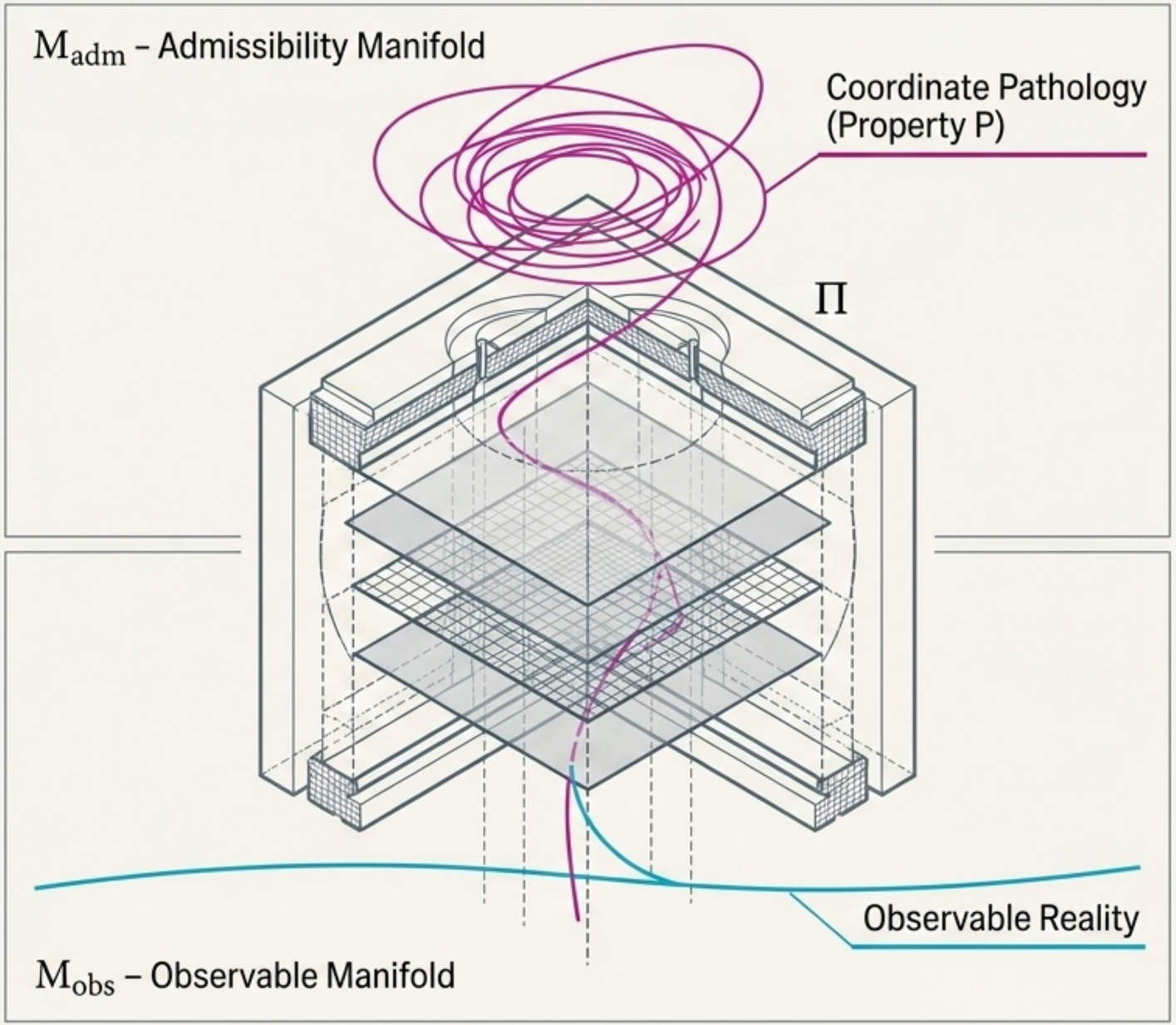
Observable Admissibility Theorem

$A_{\text{O}}(\Pi(h)) = 1$ requires non-negative probabilities summing to unity and preserved causal order.
It DOES NOT require a positive-definite inner product in M_{adm}.

Coordinate Pathologies Do Not Guarantee Observable Pathologies

Theorem 2.2: The Projection Pathology Separation Theorem

A property P of history h in M_{adm} does not automatically induce an observable pathology in M_{obs}.



The Fallacy

"This theory has a ghost"
DOES NOT EQUAL
"This theory predicts negative probabilities."

The Missing Step

One must prove the projection Π fails to absorb or cancel the ghost before reaching M_{obs}.

A History of Pathological Internal Mathematics

Coordinate Pathology (In M_{adm})	Status in M_{obs} (Observable Reality)	
Lorenz-gauge QED	Negative-norm longitudinal photons	Absent from physical states via subsidiary condition
BRST Gauge Theories	Off-shell Faddeev-Popov ghosts with wrong statistics	Absent from observable BRST cohomology
Ostrogradsky Gravity	Runaway phase-space direction (unbounded Hamiltonian)	Stable cosmological expansion
Quadratic Gravity	**Massive Spin-2 negative propagator pole**	**Status under investigation via ghost-parity symmetry**

Takeaway: Treating internal coordinates as ontological truth is Latent Fundamentalism.

Rehabilitating the Ghost: Krein-Space Quantum Mechanics

Krein Space
$(\mathbf{K} = \mathbf{K}_+ \oplus \mathbf{K}_-)$

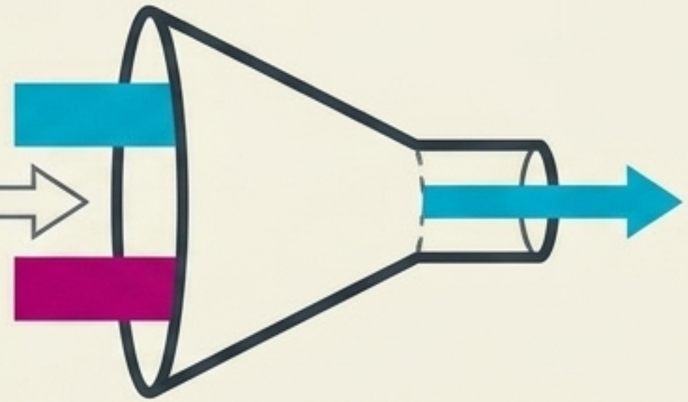
Positive Norms

Negative Norms/
Ghosts

S-matrix
$\mathbf{S} = \mathbf{S}_+ \oplus \mathbf{S}_-$

Ghost-Parity Symmetry
$[G, S] = 0$ keeps sectors
from mixing.

$\mathbf{P}(F|\mathbf{I}) = \mathrm{tr}_{\mathbf{K}}(A^\dagger A)$



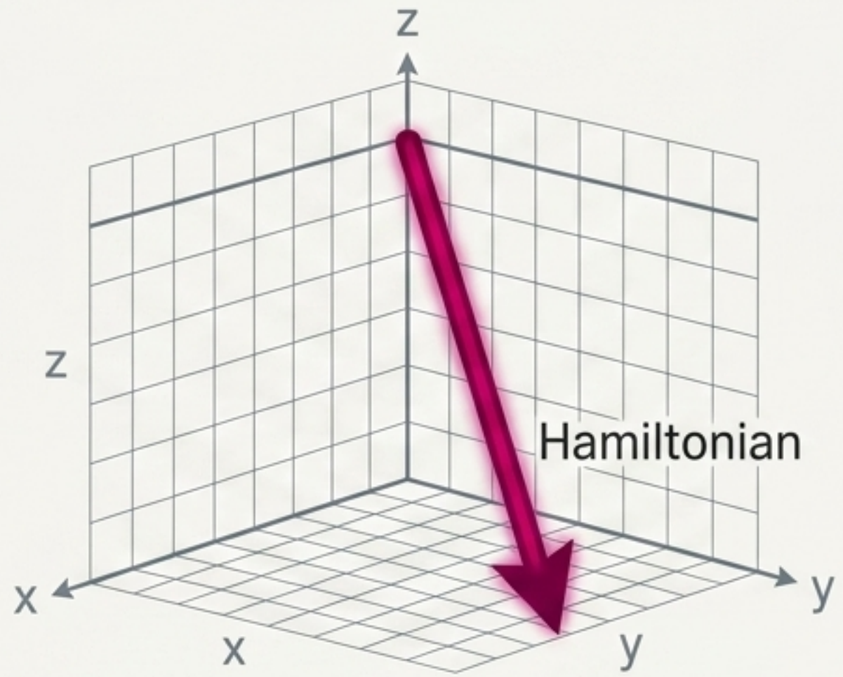
The Observable
Result

$$\sum_F P(F|\mathbf{I}) = 1, P \geq 0$$

The ghost is a hidden admissibility direction. It participates in the internal trace but does not project as a negative probability in the observable manifold.

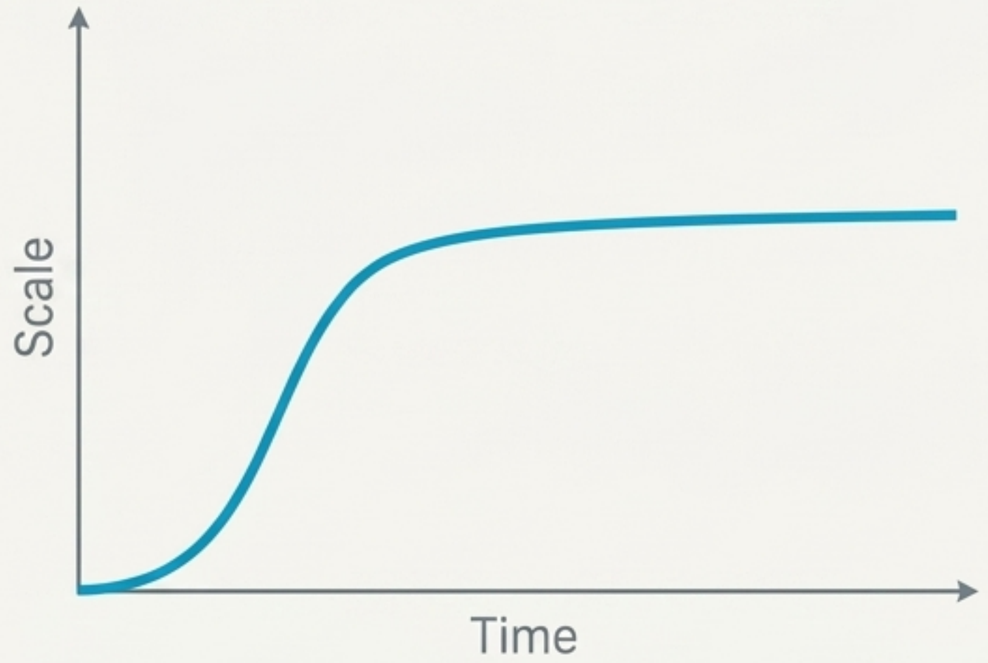
Revisiting Ostrogradsky: From State Properties to History Properties

State Property View



The Coordinate Illusion: H is linear in momentum P_1 and unbounded below.

History Property View



The Observable Reality: The unbounded direction precisely corresponds to normal, stable cosmological expansion.

Core Principle: Observable Stability is determined by the admissibility of projected trajectories, not by the sign of the Hamiltonian on M_{adm}.

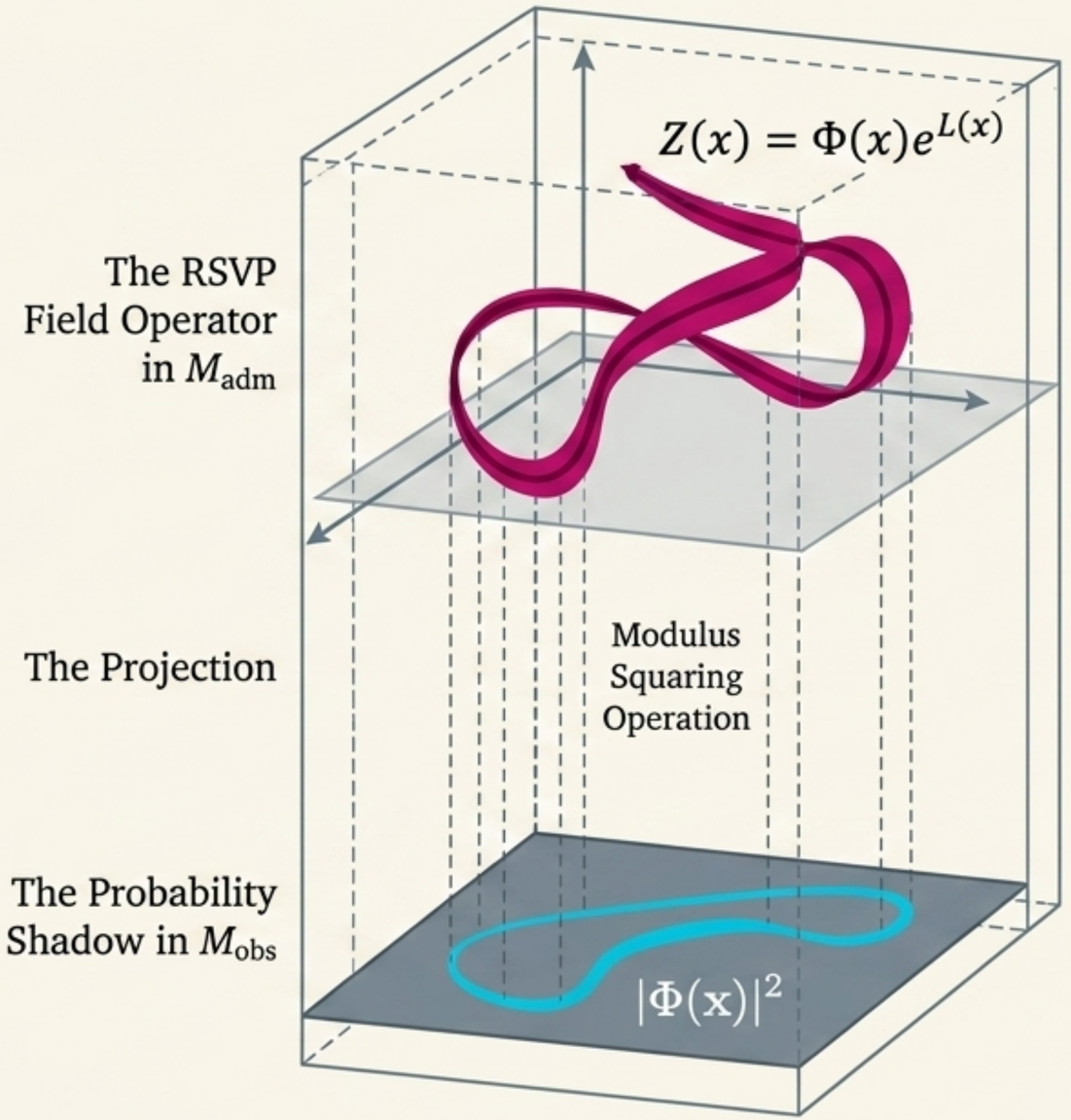
The Born Rule as a Derived Shadow

Unistochastic Coarse-Graining

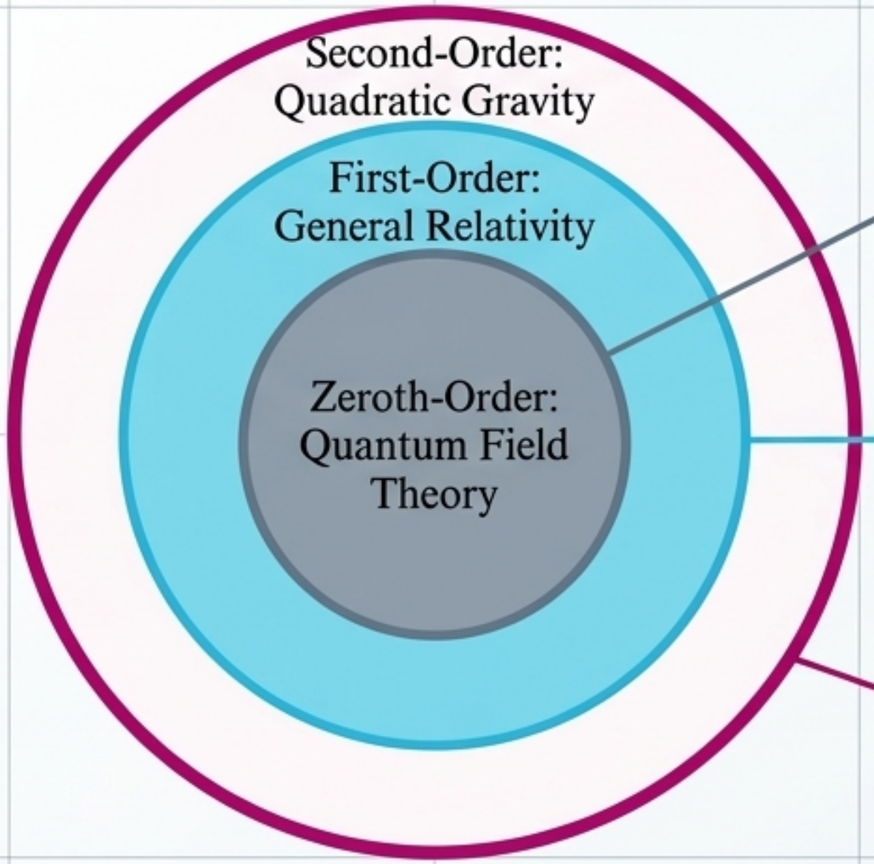
Quantum probability is not a foundational axiom. It emerges from coarse-graining over unobserved degrees of freedom.

The Squaring Operation

Taking the modulus discards the accumulated phase rotation. Ghost sectors are hyperbolic rotations that are simply squared away under projection Π.



The Derived Interface Conjecture



Spacetime is flat, matter propagates without back-reaction. The admissibility flow is trivial. The Hilbert Assumption is valid here.

Includes matter back-reaction on geometry. The Riemann tensor measures first-order departures of Π from flatness.

Retains first admissibility-curvature corrections. Unveils the massive ghost pole (a negative-metric direction in the fiber of Π that remains unobservable at sub-Planckian energies).

Conjecture Statement: Observable physical theories are effective interfaces. Gauge symmetry, Hilbert space, and metric positivity are properties of the interface, not ontological necessities.

Empirical Success I: The Dimension-Zero Scalar Program

Input

The dimension-zero scalar action:

$$S_4[\phi] = \pm\frac{1}{2}\int d^4x\sqrt{\pm g}\,\phi\Delta_4\phi$$

Infinite-dimensional gauge symmetry $\phi \to \phi + \chi$ eliminates all local degrees of freedom (projecting the ghost away).

Mechanism

The Weyl Anomaly

$$\langle T^{\mu}_{\mu} \rangle = cC^2 - aE + \xi R$$

Requires simultaneous cancellation of vacuum energy ($E_k^{(0)} = 0$) and anomalies ($a = 0, c = 0$).

Output

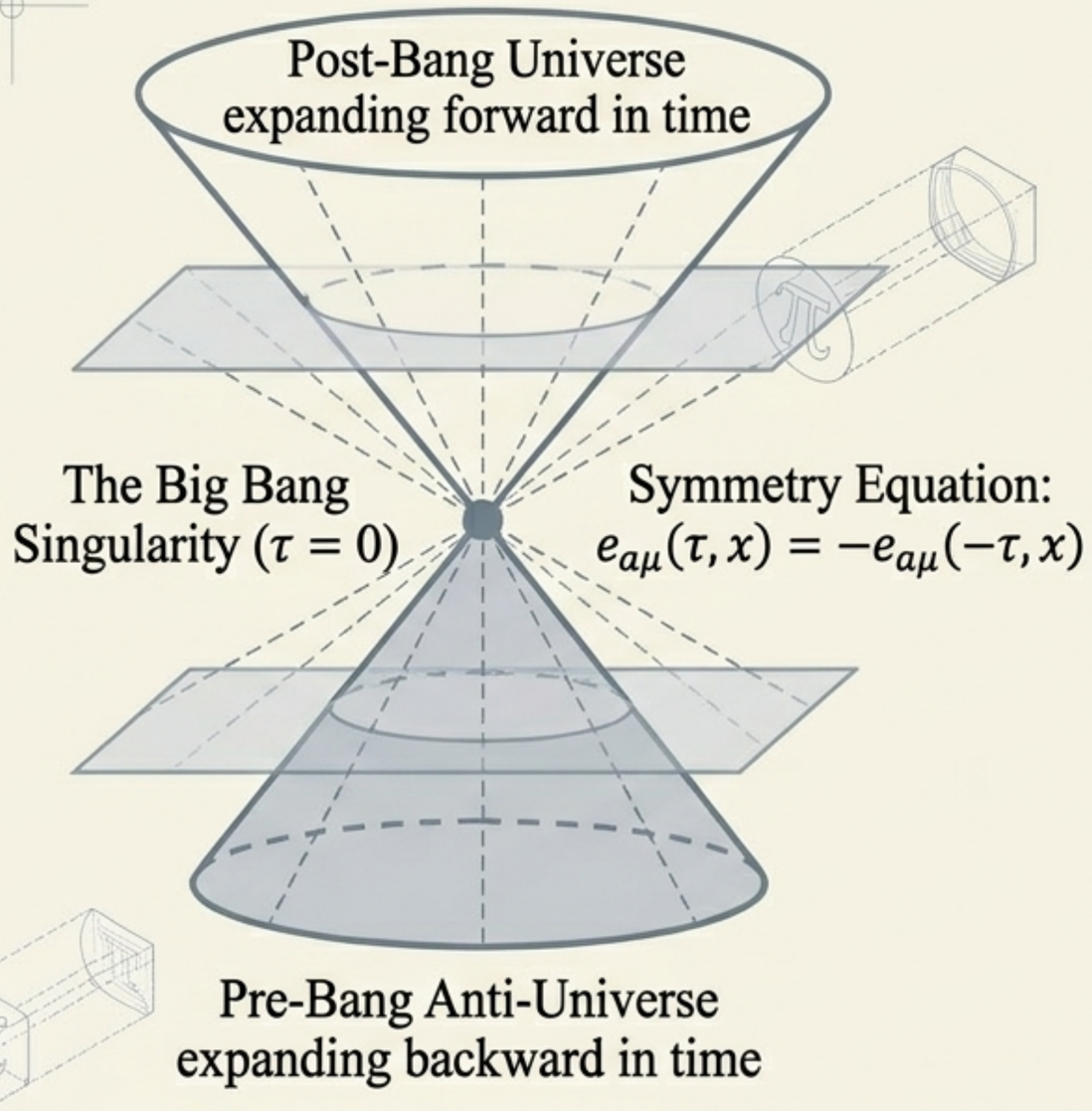
The unique mathematical solution:

$$n_{1/2} = 4n_1$$

The Prediction

With 12 Standard Model gauge bosons ($n_1 = 12$), the math demands exactly 48 Weyl fermions ($n_{1/2} = 48$). This is exactly three generations of fermions, including right-handed neutrinos.

Empirical Success II: The CPT-Symmetric Universe



Boundary Conditions

The CPT-symmetric vacuum uniquely selects the regular growing mode near $\tau = 0$.

Prediction 1 (No Inflation)

Predicts a scale-invariant CMB power spectrum ($n_s \approx 0.958$) and exactly zero primordial gravitational waves ($r = 0$).

Prediction 2 (Dark Matter)

Right-handed neutrinos are produced from the CPT vacuum. One stable neutrino perfectly matches observed Ω_{DM} at mass $M \approx 5 \times 10^8$ GeV.

Rethinking the String Theory Assumption

Pathway A: The Hilbert Landscape

Require positive norm everywhere.

→

Face Weyl anomalies and ghosts in 4D.

→

Forced to postulate 10 or 26 dimensions and supersymmetry to project onto a positive-definite Hilbert space.

Pathway B: The Admissibility Landscape

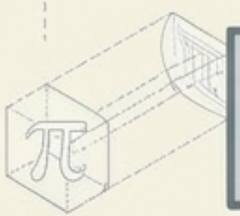
Allow ghosts as hidden admissibility directions.

→

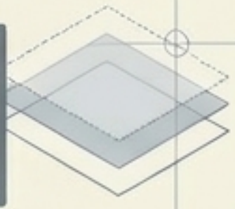
Project out unobservable coordinate pathologies via Π.

→

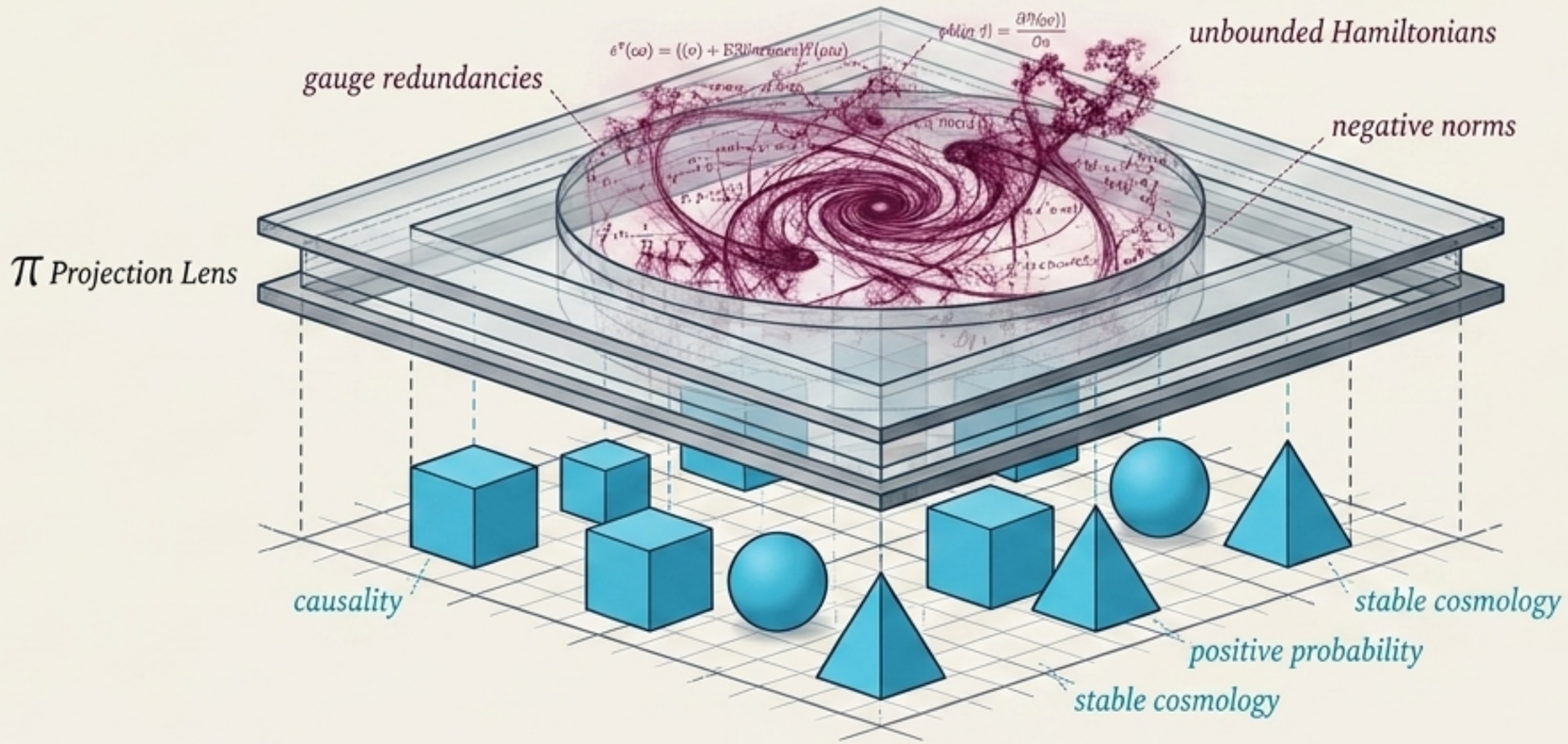
Achieve 4D UV-complete quantum gravity without extra dimensions.



String theory assumes admissibility must be imposed on the internal state space (M_{adm}). Relaxing this assumption removes the a priori necessity for strings.



Exorcise vs. Project



1. Constraints Belong on Observation

1. Constraints Belong on Observation

Physical constraints are conditions on observable histories, not internal mathematical coordinates.

2. Probability is a Shadow

2. Probability is a Shadow

The Born rule and positive norms are interface approximations, not ontological axioms.

3. Quadratic Gravity Works

3. Quadratic Gravity Works

By abandoning latent fundamentalism, we unlock a 4D, UV-complete quantum gravity theory.

The ghost need not be exorcised. It need only be projected.