The Spaciotemporal Vortex Model: Toward a Physically Grounded Framework for Cyclic Time and Energy Transitions

Jeremy Erich Resch

March 30, 2025

Abstract

The Spaciotemporal Vortex Model (SVM) offers a physically grounded framework in that time is reinterpreted as a layered fourth spatial dimension. Temporal evolution results from energy transitions between discrete temporal layers. Unlike conventional cosmological models, that treat time as a continuous linear axis and fail to address the low-entropy initial state, arrow of time, or dark phenomena, SVM introduces a novel mechanism: gravitational resistance to inter-layer transitions. This reinterpretation provides a thermodynamically coherent basis for cyclic cosmological dynamics, entropy management, and information encoding via curvature. The model derives formal evolution laws, thermodynamic couplings, and quantization paths, offering multiple empirical implications for entropy collapse, dark energy behavior, and curvature-entropy correspondence.

1 Introduction

Contemporary cosmological models based on General Relativity conceptualize time as a linear, continuous dimension, fundamentally distinct from space. However, they leave unresolved several foundational problems:

In the Spaciotemporal Vortex Model, time is not considered as an independent parameter but as a fourth spatial dimension composed of discrete layers. Each layer represents a distinct state of the universe, and the progression through these layers gives rise to the perception of a unidirectional flow of time.

- The origin of the arrow of time,
- The mechanism behind the universe's extremely low initial entropy,
- The nature of dark matter and dark energy,
- The inability to naturally implement cyclic or entropy-resetting cosmologies.

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Let $f(\Delta E_n(x)) := \alpha\,\nabla^2 \Delta E_n(x)$ with α a dimensionless scaling factor. The temporal layer transition becomes:

$$S_{n+1}(x) = S_n(x) + \alpha \nabla^2 \Delta E_n(x)$$

Where ∇^2 introduces spatial locality and diffusion-like behavior. If $[\Delta E] = \mathrm{J/m^3}$, then:

$$[f(\Delta E)] = \mathrm{J/m^5} \quad \Rightarrow \quad [S_{n+1}] = [S_n] + \mathrm{J/m^5}$$

Symbol Analysis

Symbol	Meaning	Unit/Type	Consistent?
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π_n	Transition momentum	Energy per layer	Yes
T_n	Temperature in layer	[K]	Yes
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2 Quantum Thermodynamic Extension

To extend the spaciotemporal model toward a quantum thermodynamic formalism, we promote the classical variables to operators:

$$\hat{S}_n, \quad \hat{\pi}_n, \quad [\hat{S}_n, \hat{\pi}_n] = i\hbar$$

The discrete action becomes a quantum path sum over all possible layer evolutions:

$$Z = \sum_{\text{paths}} e^{-A[S]/\hbar}$$

Including quantum fluctuations of entropy and temperature:

$$Z = \int \mathcal{D}S \, \mathcal{D}T \, \mathcal{D}Q \, e^{-\sum_n L(S_n, T_n, Q_n)/\hbar}$$

This formulation allows for a quantum statistical interpretation of interlayer dynamics, where temporal evolution reflects probabilistic thermal behavior.

3 Information Geometry

We define a Riemannian metric over the thermodynamic layer state space $\Omega_n := \{S_n, \pi_n, T_n, Q_n\}$ using curvature of the free energy $F(S_n)$:

$$g_{ab} = \partial_a \partial_b F(S_n)$$

In terms of statistical physics, this corresponds to:

$$g_{ab} = -\partial_a \partial_b \log Z$$

The metric captures fluctuations and geodesic paths in the thermodynamic manifold. The curvature R of this manifold may be interpreted as encoding gravitational analogues in the SVM framework.

4 Conclusion and Outlook

The Spaciotemporal Vortex Model (SVM) provides a physically motivated and mathematically consistent alternative to conventional cosmological models by redefining time as a layered spatial dimension. This ontological shift allows energy and entropy to evolve along discrete temporal transitions, that are interpreted as physical processes rather than abstract parameters.

Empirical Priorities

Key avenues for future empirical investigation include:

- Detection of entropy-curvature correlations in the CMB.
- Searching for discrete imprints or ”layer scars” in gravitational wave spectra.
- Investigating temperature fluctuations tied to quantum entropy effects.

Computational Tasks

We aim to simulate:

- Layered state evolutions using finite-difference or finite-element methods.
- Entropy dispersion as geometric diffusion in Ω_n.
- Free energy landscapes and curvature-induced state changes.

Theoretical Development

Future refinements of the model will involve:

- Tensorial formulations of g_{ab} with curvature invariants.
- Deriving gravitational field equations based on thermodynamic conjugates.
- Incorporating black hole boundary layers as entropy flux gates.

SVM proposes a coherent language that bridges thermodynamic irreversibility,

5 Visualization of Layer Dynamics

6 Model Comparison

We compare the Spaciotemporal Vortex Model (SVM) with several major cyclic or quantum cosmological frameworks.

SVM dist

A Appendix: Mathematical and Computational Details

A.1 Discrete Action Derivation

We start from the discrete action:

$$A = \sum_n \left[\frac{1}{2} (\partial_n S)^2 - V(S_n) \right]$$

Applying the discrete Euler-Lagrange principle:

$$\frac{\partial L}{\partial S_n} - \Delta \left(\frac{\partial L}{\partial (\Delta S_n)} \right) = 0$$

Leads to:

$$S_{n+1} - 2S_n + S_{n-1} = -\frac{\partial V}{\partial S_n}$$

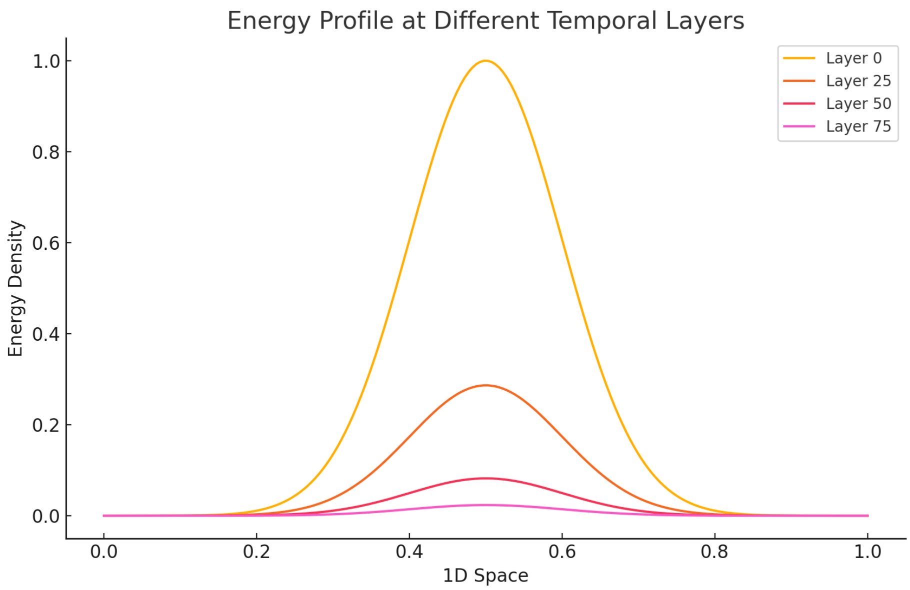

Figure 1: SVM Figure 1

Figure 2: Energy profiles across temporal layers. Each curve represents the energy density distribution at a given discrete temporal layer.

Model	**Time Structure**	**Spacetime**	**Entropy Reset**	**Cyclicity**	**Thermodynamics**	**Quantum Gravity**
SVM	Layered, spatialized	Discrete 4D vortex	Yes, via collapse	Yes	Explicitly coupled	Formal extension via $\hat{S}_n$
CCC	Conformal time loops	Classical, conformally rescaled	Yes, via conformal scaling	Yes	Not primary	Implicit (Penrose conjecture)
LQC	Bounce at Planck density	Quantized FLRW geometry	Yes, via bounce	Yes	Emergent from field quantization	Canonical loop quantization
CDT	Time-like slicing	Triangulated discrete spacetime	No explicit reset	No	Not considered	Emergent from path integral
Ekpyrotic	Cyclic brane collisions	Higher-dimensional	Partial (via brane tension)	Yes	Weakly integrated	String/M-theory inspired
Steady-State	Infinite, linear	Continuous expansion	No	No	Violates entropy increase	Classical only

Table 1: Comparison of key features across several cyclic and quantum cosmological models.

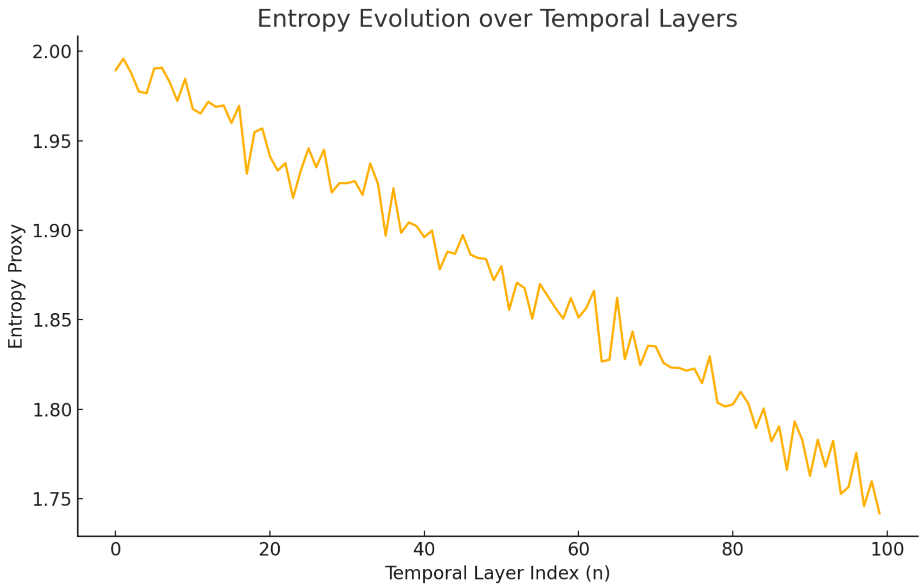

Figure 3: SVM Figure 2

Figure 4: Entropy evolution as a function of temporal layer index n. The slight decrease simulates entropic decay modulated by stochastic noise.

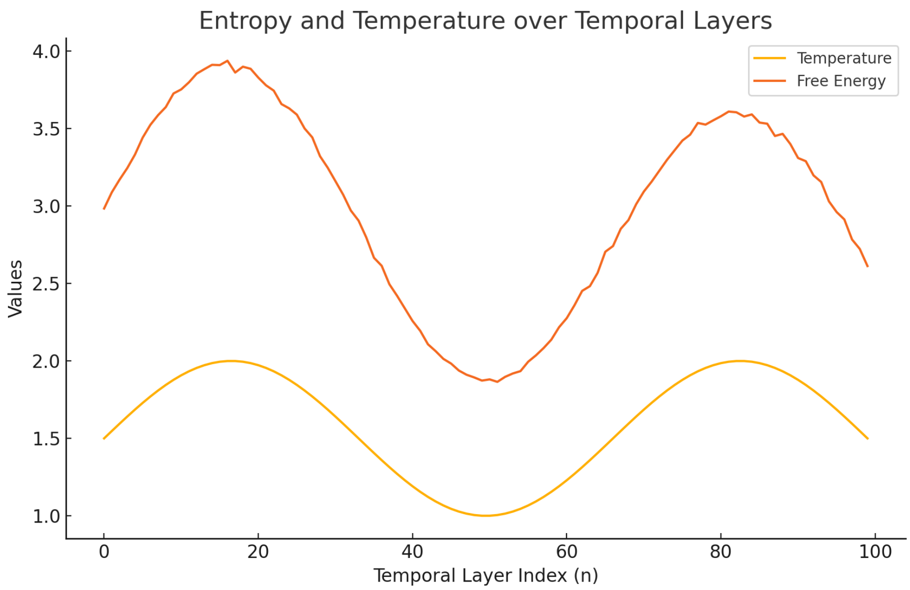

Figure 5: SVM Figure 3

Figure 6: Comparison of simulated temperature and free energy over time. Fluctuations are synthetic but reflect thermodynamic oscillations.

A.2 Numerical Integration Scheme

To simulate energy and entropy dispersion across layers:

- Discretize spatial domain using $x_i = i\Delta x$

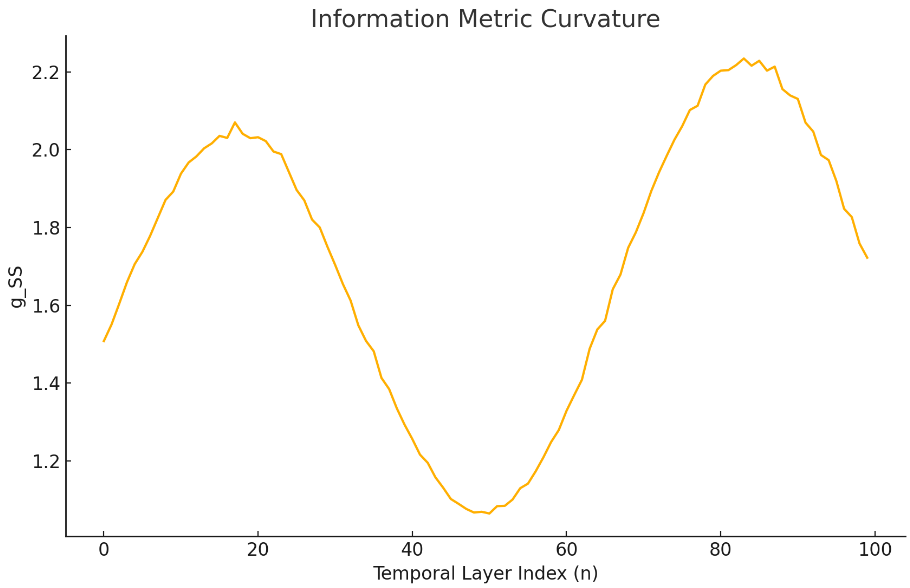

Figure 7: SVM Figure 4

Figure 8: Information metric curvature g_{SS} derived from synthetic entropy and temperature series.

- Time evolution: $S_{n+1}(x_i) = S_n(x_i) + f(\Delta E_n(x_i))$
- Use centered finite differences for ∇^2:

$$\nabla^2 E_n(x_i) \approx \frac{E_n(x_{i+1}) - 2E_n(x_i) + E_n(x_{i-1})}{\Delta x^2}$$

A.3 Thermodynamic Relations

Recall:

$$\begin{aligned} Q_n &= c_v T_n \\ F(S_n) &= S_n T_n \\ g_{ab} &= \partial_a \partial_b F(S_n) \\ \Delta S_n &= \frac{\Delta Q_n}{T_n} + \sigma_n \geq 0 \end{aligned}$$

This structure forms a thermal-geometric space where entropy, temperature, and curvature are coevolving.

B Discrete Spatial Layers

We define a 4-dimensional space S^4 that includes the three spatial dimensions x, y, z and a fourth spatial dimension t_s representing discrete "time-layers".

Formally, the at a given layer n can be described by:

$$U_n = \{(x, y, z, t_s) \mid t_s = n, n \in \mathbb{Z}\} \tag{1}$$

Each layer U_n contains a complete spatial distribution of energy $E_n(x, y, z)$.

C Energy Transition Between Layers

The transition between layers U_n to U_{n+1} is governed by the transfer of energy. We postulate an energy transition operator T, defined as:

$$T : U_n \to U_{n+1}, \quad T(E_n) = E_{n+1} \tag{2}$$

Energy conservation across layers is given by:

$$\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \int \tag{3}$$

D Cyclic Collapse and Reinitialization of Interactive Spacetime

At the critical timestep $n_{\text{crit}} = 2\tau \cdot 10^{40}$, the expansion of the universe reaches a scale at that all known fundamental interactions become ineffective. The average distance between particles $r(n) \sim \sqrt{n/(2\tau)}$ exceeds the maximum effective range $d_{\text{interact}} \sim 10^{20}\ell_P$.

This initiates a phase of entropic stagnation: energy becomes non-interactive and falls backward through the fourth spatial dimension. Compression through shrinking temporal hypersurfaces eventually reconverges all energy at the singularity-like point $[X, Y, Z, T] = [0, 0, 0, 0]$.

Interaction is reactivated when the radius satisfies:

$$I(n) = \frac{1}{1 + \exp\left(-\alpha(d_{\text{interact}} - \sqrt{n/(2\tau)})\right)}$$

with $\alpha \sim 10^{18}$, describing a Planck-scale transition.

The interactive energy field re-activates and explosively expands, constituting the next Big Bang.

We model this using a tensor field:

$$\mathcal{I}_{\mu\nu}(x, n) = I(n) \cdot \rho(x, n) \cdot g_{\mu\nu}$$

and modified field equations:

$$G_{\mu\nu} = \kappa \mathcal{I}_{\mu\nu}$$

See Figures 12, 10, 13.

E Physical Parameterization in SI Units

The spaciotemporal vortex model is grounded in Planck-scale discretization, allowing translation into SI units:

- Planck Time: $t_P = 5.39 \times 10^{-44}\,\text{s}$
- Planck Length: $\ell_P = 1.62 \times 10^{-35}\,\text{m}$
- Planck Energy: $E_P = 1.96 \times 10^{9}\,\text{J}$
- Planck Energy Density: $\rho_P = 4.63 \times 10^{113}\,\text{J/m}^3$

At the critical timestep $n_{\text{crit}} \approx 2 \cdot 10^{40}$, the model yields:

- Radius: $r(n_{\text{crit}}) \approx 1.62 \times 10^{-15}\,\text{m}$

- Elapsed time: $t(n_{\text{crit}}) \approx 1.08 \times 10^{-3}\,\text{s}$

As $r(n) \to \ell_P$, energy density converges toward:

$$\rho(n) \to \frac{E_P}{\ell_P^3} \approx 4.63 \times 10^{113}\,\text{J/m}^3$$

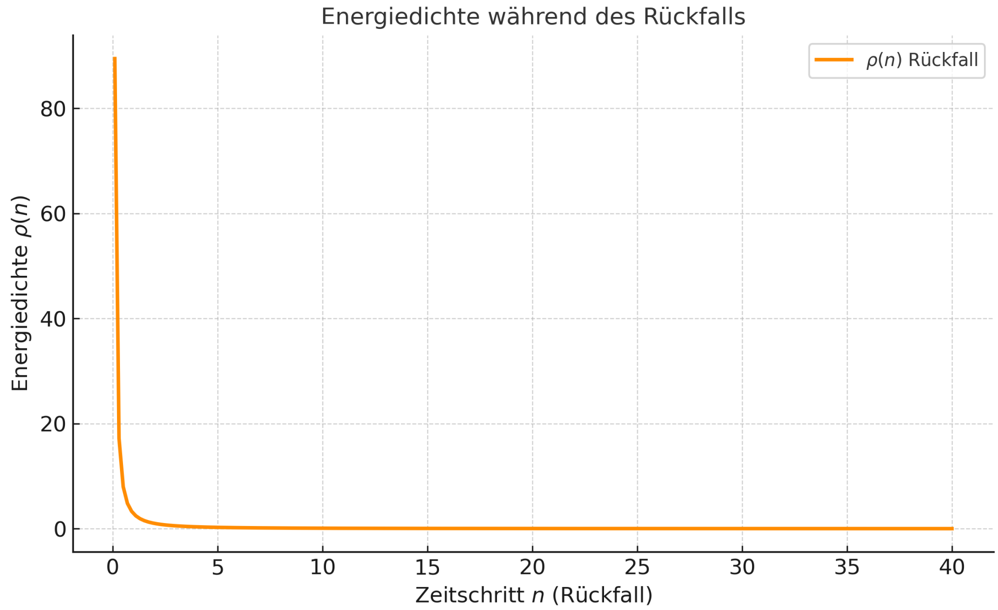

Figure 9: SVM Figure 5

Figure 10: Energy density increase during the recollapse phase approaching Planck-scale compression.

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1. [1]
2. [2]
3. [3]
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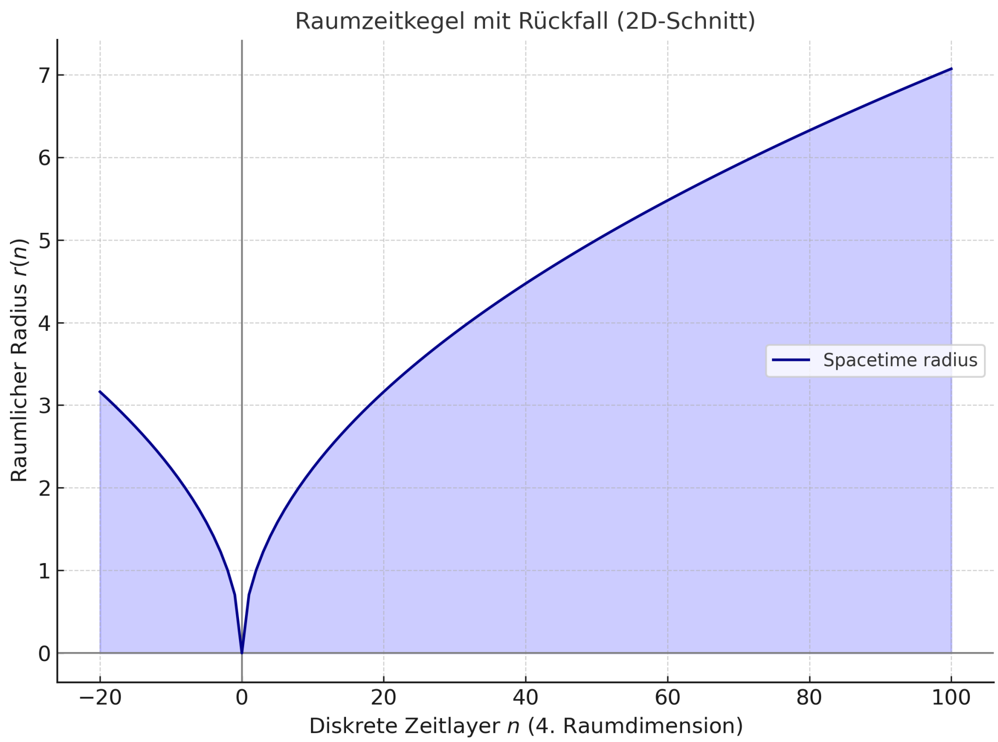

Figure 11: SVM Figure 6

Figure 12: Spacetime cone visualization showing forward expansion and backward collapse through Planck time layers.

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- The origin of the arrow of time,
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- The nature of dark matter and dark energy,
- The inability to naturally implement cyclic or entropy-resetting cosmologies.

The Spaciotemporal Vortex Model (SVM) introduces a restructured interpretation of time as a layered, discretized spatial dimension. Energy transitions between these temporal layers define temporal progression. Gravitational interactions are reinterpreted as impedance to such transitions. This framework offers a thermodynamically coupled, cyclic cosmology that is ontologically novel, mathematically formalized, and empirically tractable.

Operator Definition

Let $f(\Delta E_n(x)) := \alpha\, \nabla^2 \Delta E_n(x)$ with α a dimensionless scaling factor.

The temporal layer transition becomes:

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Table 2: Comparison of key features across several cyclic and quantum cosmological models.

SVM distinguishes itself by integrating time as a spatial layer dimension and offering a fully thermodynamic-coupled formalism including entropy, temperature, and free energy evolution. It supports empirical modeling via geometric curvature and quantum entropy fluctuations.

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The Spaciotemporal Vortex Model (SVM) provides a physically motivated and mathematically consistent alternative to conventional cosmological models by redefining time as a layered spatial dimension. This ontological shift allows energy and entropy to evolve along discrete temporal transitions, which are interpreted as physical processes rather than abstract parameters.

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Future refinements of the model will involve:

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- Deriving gravitational field equations based on thermodynamic conjugates.
- Incorporating black hole boundary layers as entropy flux gates.

SVM proposes a coherent language that bridges thermodynamic irreversibility, quantum uncertainty, and geometric structure. Continued development will focus on rendering this framework testable, implementable, and compatible with fundamental physical constraints.

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A.1 Discrete Action Derivation

We start from the discrete action:

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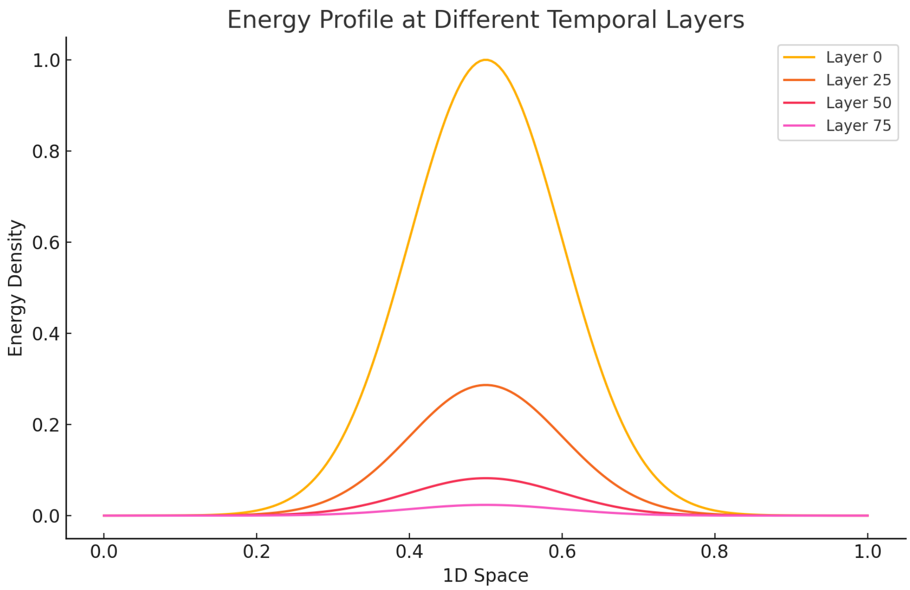
B Visualization of Layer Dynamics



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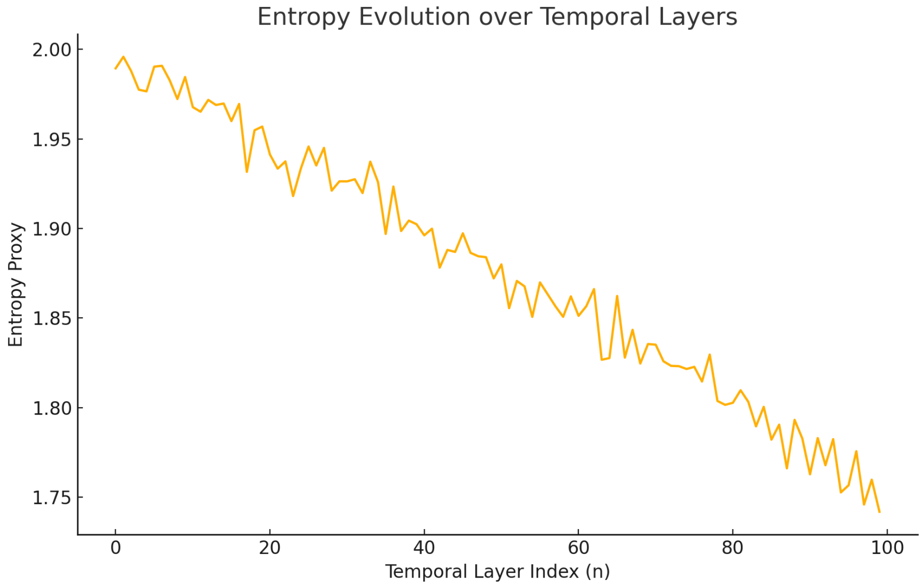

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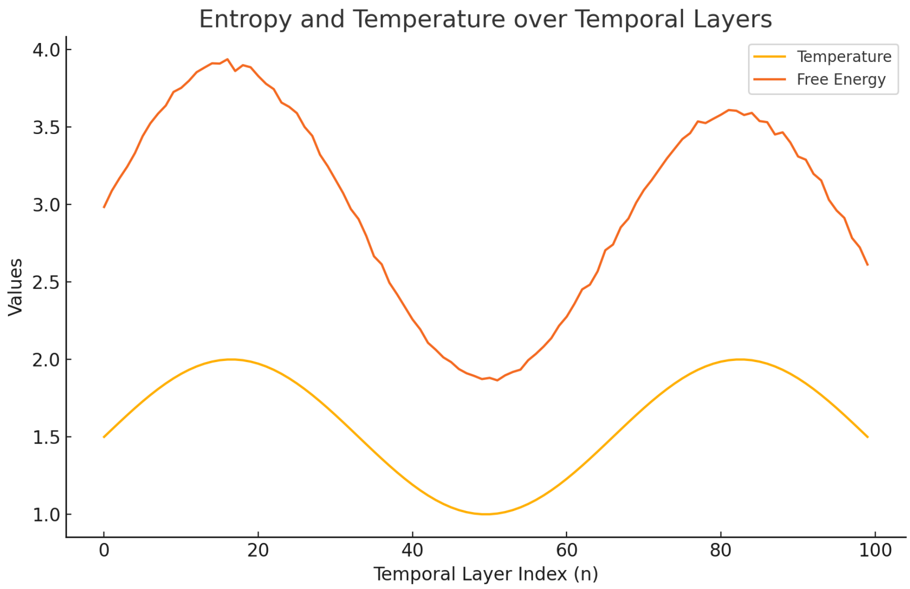

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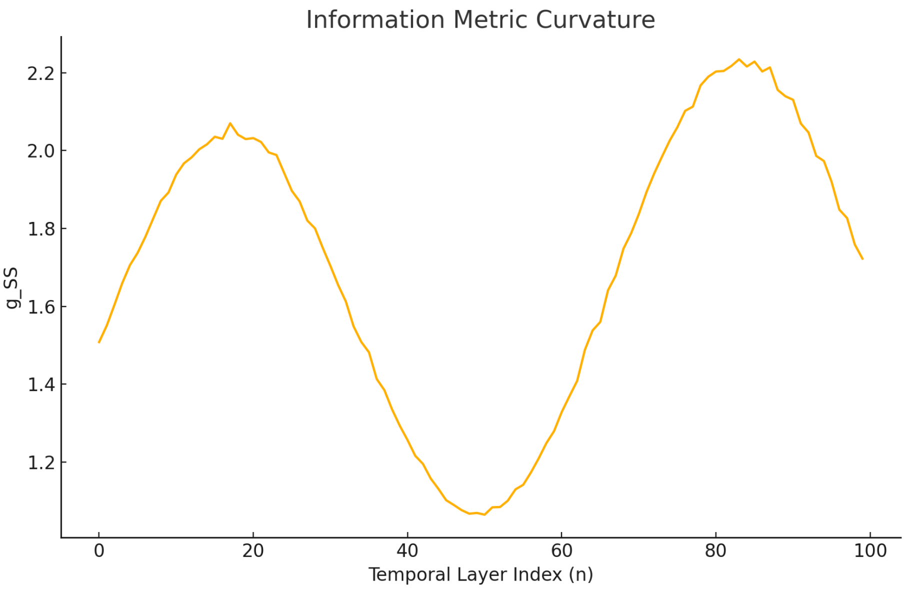

Figure 16: Information metric curvature g_{SS} derived from synthetic entropy and temperature series.