The Creation of Duality

A Speculative Extension on Appearance, Gravity, and Information

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Abstract

Epistemic stance: Space, time, objecthood, and gravity are treated as structures of appearance for finite observers. The framework is interpretation-neutral; determinism serves as a working ontology, not a metaphysical commitment.

We model an observer as a finite-capacity system (C_{eff} bits/s) tracking a chaotic substrate (h_{KS} nats/s). When $\kappa \equiv h_{\text{KS}} - C_{\text{eff}} \ln 2 > 0$, tracking fails; we call this the chaos-wins regime. This paper explores the speculative extension that space (finite resolution), time (sequential updating), objects (coarse-grained summaries), and gravity-like structure (information deficit) can be interpreted as features of a consistent finite-observer world-model.

An Extended Kalman Filter tracking a Lorenz attractor exhibits the predicted threshold transition at $C^*_{\text{eff}} = h_{\text{KS}}/\ln 2$: above threshold, precision structure stabilizes; below, it collapses. Under a **Bridge Ansatz (ML-calibrated)**—a mapping from deficit-rate to energy scale via Margolus–Levitin saturation—the Penrose collapse time relates to tracking-loss time as $\tau_{OR} \approx 0.64\,\tau_{\text{loss}}$ (for $\kappa > 0$). The coefficient $\pi/2$ follows from ML saturation within this ansatz; the ansatz itself is testable.

The operational core remains narrower: if the bridge is physically relevant, coherence times should depend on effective observer/controller tracking capacity ($\partial\tau/\partial C_{\text{eff}} > 0$) under controlled conditions. Raw power, update rate, or feedback gain are only experimental handles on this quantity if they can be shown to change useful tracking capacity while thermal, readout, plant, mass, and geometry conditions remain fixed. The broader claims about duality and appearance are interpretive extrapolations, not established physics.

Status of this document. This is the most speculative document in the project. It should be read as an exploratory architecture that extends the IOF capacity model into ontology, gravity, and contemplative philosophy. The technical claims stand or fall with the finite-capacity tracking model and the explicitly stated bridge ansatz; the metaphysical correspondences are not independent evidence.

Dependency on BLQC. The speculative extensions in this document assume that the BLQC finite-rate basis-tracking hypothesis is physically meaningful. They should not be read as independent evidence for the framework. Their scientific weight depends on whether the effective-capacity-dependent visibility law is confirmed experimentally.

This document is therefore written as a consequence map: if the BLQC experiment confirms finite-rate phase-reference tracking, the implications are not local. The subject/object split, observer-shaped geometry, gravity bridge, and non-dual interpretation explored here describe the possible blast radius of that result.

Om Namo Bhagavate Sri Ramanaya

> *"These four—the Word, Time, Space, and the Atom—are therefore one and the same, and substantially nothing but mere ideas."*
>
> — Sri Yukteswar, *The Holy Science*

Contents

Scope and Terminology (Read First)

Core contribution. The core technical contribution is a mechanism and falsifiable prediction; correspondences to GR/OR and non-dual philosophy are conditional mappings stated explicitly.

Ontological minimalism. This framework does not require commitment to a specific interpretation of quantum mechanics. The core mechanism—a finite-capacity observer tracking a system with positive instability rate h_{KS}—is interpretation-neutral. Terms like "determinism," "Block Universe," or "substrate" appear in later sections as a *working ontology* that makes the mathematics transparent, not as metaphysical commitments the reader must accept.

What the framework *does* require is an information-theoretic constraint: the observer's effective tracking capacity C_{eff} is finite, and the source dynamics have positive instability rate $h_{\mathrm{KS}} > 0$. This constraint is empirically testable ($\partial\tau/\partial C_{\mathrm{eff}} > 0$) by varying useful tracking capacity under fixed thermal, readout, plant, mass, and geometry conditions. It provides an information-theoretic grounding for geometric constraints on quantum coherence (cf. Penrose OR, Diósi–Penrose, QGEM protocols). The framework asks *why* such geometric constraints may arise: they are modeled as consequences of capacity-limited observation, not primitive postulates about spacetime.

Render (appearance). All phenomena discussed in this manuscript—space, time, objects, and gravity—are treated as *rendered structures*: stable, internally coherent regularities that arise in the observer's world-model under finite information rate ("ignorance" / finite aperture). In this sense, "physics" refers to the dynamics of the render: the only operationally meaningful dynamics available to any finite observer.

Ignorance / finite aperture. We quantify finitude by an information-rate constraint C_{eff} (effective capacity, bits/s) relative to the source instability h_{KS} (KS-like rate, nats/s). The key control parameter is the *information-deficit rate*

$$\kappa \equiv h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2,$$

which determines whether coherent rendering is possible ($\kappa < 0$, capacity-wins) or fails ($\kappa > 0$, chaos-wins).

Gravity. We use *gravity* in its standard operational sense: the empirically observed regularities associated with free-fall, inertial motion, redshift, lensing, and spacetime dynamics. Our contribution is not to rename gravity, but to propose an epistemic account of *why* gravitational behavior emerges under observer-limited access to state. The phenomenon remains "gravity"; the novelty lies in the proposed informational mechanism and its testable consequences (effective-capacity dependence of collapse times).

"Epistemic" = observable/trackable. Throughout, "epistemic" means a statement about what is observable, trackable, or control-recoverable by a finite observer—not a denial of the reality of gravitational phenomena. Gravity is real; we propose a mechanism for why it takes the form it does.

Notation. We use standard GR symbols ($g_{\mu\nu}$, κ_{geo}) for measured/phenomenological gravity, and $\kappa = h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2$ for the information-deficit rate. These are connected via verbs like "maps to," "corresponds to," or "is identified with (under assumptions)"—never bare "is" without qualification. Appendix A states the bridge hypothesis explicitly: $\kappa \leftrightarrow \kappa_{\mathrm{geo}}$ at MSS saturation, interpreted as operational correspondence rather than ontic reduction.

Bridge Ansatz. The correspondence $E_G = (\pi/2)\hbar\kappa$ (and hence $\tau_{OR} \approx 0.64\,\tau_{\mathrm{loss}}$) is a **Bridge Ansatz**—a testable mapping from information-deficit rate to energy scale, not a derived theorem. This ansatz is flagged explicitly throughout the manuscript. All boxed equations involving E_G or τ_{OR} are conditional on this bridge; readers who encounter these results without reading this section are invited to return here.

Part I

From Finite Capacity to Duality

1 Introduction: The Problem of Duality

How does a single, unitarily evolving reality appear as many? In quantum mechanics, this is the measurement problem: a superposition encoding multiple possibilities somehow yields a single definite outcome. The question lies at the heart of both quantum foundations and contemplative philosophy.

1.1 The Ignorant Observer Framework

The Ignorant Observer Framework (IOF), first formalized in [1], addresses this question through *epistemic limitation* (ignorance), assuming a deterministic Block Universe—a 4D spacetime where all moments exist as a single globally constrained history. The use of global constraint as a non-conspiratorial way to relax Bell measurement independence is aligned with Palmer's technical defense of superdeterminism without conspiracy [2]; IOF adds a separate finite-capacity basis-tracking mechanism. An observer embedded in this Block is a dynamical system with:

- internal evolution rate (chaos) h_{KS} (nats/s)
- finite information-processing capacity C_{eff} (bits/s)

The observer must track its own measurement basis $\mathbf{n}(\theta(t))$—the internal coordinate frame along which outcomes are interpreted. The framework has two coarse-grained regimes:

Chaotic regime: In systems with multiplicative instability, basis error grows exponentially at rate h_{KS}, while capacity contracts it at rate $C_{\mathrm{eff}} \ln 2$. The variance evolves as:

$$\frac{d}{dt} \ln \sigma_\theta^2 = 2(h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2) = 2\kappa, \tag{1}$$

yielding $\sigma_\theta^2(t) = \sigma_{\theta,0}^2 \exp(2\kappa t)$.

Diffusive regime: In systems with additive noise injection D_θ (rad^2/s), capacity imposes a floor:

$$\sigma_\theta^2 \gtrsim \frac{D_\theta}{C_{\mathrm{eff}} \ln 2}. \tag{2}$$

(Up to $O(1)$ factors set by the estimator/control architecture, additive injection D_θ balanced by contraction rate $\sim C_{\mathrm{eff}} \ln 2$ yields a floor $\sigma^2 \sim D_\theta/(C_{\mathrm{eff}} \ln 2)$.)

This basis uncertainty reduces measured visibility via Gaussian averaging:

$$V_{\mathrm{obs}} = V_{\mathrm{QM}} \exp(-\sigma_\theta^2/2). \tag{3}$$

Two regimes emerge: when $\kappa < 0$ (i.e., $C_{\mathrm{eff}} \ln 2 > h_{\mathrm{KS}}$), capacity wins (uncertainty suppressed; laboratory systems); when $\kappa > 0$ (i.e., $h_{\mathrm{KS}} > C_{\mathrm{eff}} \ln 2$), chaos wins (uncertainty grows exponentially; visibility loss becomes significant).

1.2 This Document

This paper describes a speculative epistemic construction of the universe-as-appearance. For a finite observer, the operational universe is what can be rendered, tracked, and stabilized in experience; no external "view from nowhere" is available to that observer. We explore how Space, Time, Object, and Gravity-like structure may arise as constraints on such rendered appearance under finite capacity. This is not an empirical derivation of spacetime or a proof of Vedanta. For a heuristic overview using the cinema projector analogy of Advaita Vedanta, see Appendix E.

2 Epistemic Status of the Hypothesis

2.1 The Epistemic Inversion

Physics has traditionally approached the universe ontologically: first the world exists, then bodies emerge within it, then—somehow—consciousness appears. This ordering leaves the emergence of experience unexplained (the "Hard Problem"[1]).

This paper takes the opposite direction. We ask: given a system with finite information capacity, what form must its experience take? The answer unfolds in a specific order: first the subject/object split (the body), then space, time, and objects (the world).

The distinction is subtle but essential:

- **Ontological approach:** The universe exists independently; observers perceive it.
- **Epistemic approach:** The universe *as experienced* is produced by finite capacity. There is no "universe" apart from what appears to observers.

If the mechanism described here is experimentally supported, it would offer a testable account of one way finite-observer experience may be structured.

This inversion reframes the Hard Problem. If Space, Time, Objects, and Gravity are treated as artifacts of finite information capacity—the output of a coarse-graining process—then the physical brain can be interpreted as part of the coarse-grained appearance, not the ultimate input. On this reading, the brain is not the substrate-level generator of the observer; it is the appearance-level representation of the observer within a finite model of reality. This does not refute neuroscience; it changes the explanatory level at which the hard problem is being discussed. Matter is the form the underlying substrate[2] takes when viewed through a finite aperture. The framework asks how capacity limits shape the render, not how appearance-level objects create the fact of appearance.

Compatibility with neuroscience: This reframing does not invalidate neuroscience. Within the appearance level, the brain remains a valid causal locus for studying correlations and interventions: lesions produce deficits, stimulation produces experiences, neural activity correlates with reports. All of this is preserved. The category-error claim applies only to using appearance-level objects (brains, neurons) to explain *why there is appearance at all*—the substrate-level question. Neuroscience describes the structure of the render; this framework addresses the conditions under which rendering occurs.

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[1] The term was introduced by David Chalmers in "Facing Up to the Problem of Consciousness" (1995).

[2] By "underlying substrate" we mean the model-level reality discussed in the IOF paper [1] as a "deterministic substrate," compared interpretively with Vedantic *sat* (being). This is a metaphysical correspondence, not a scientific identification.

2.2 The Internal View

For finite observers, the operational world is inseparable from the internal representation constructed from finite information. There is no accessible external vantage point from which that observer can view "the universe as it really is."

This account describes how the universe may have to appear under the stated modeling assumptions. It is a mathematical and interpretive statement about representational structure, not a scientific proof that consciousness is fundamental.

Structural Correspondence 2.1 (The Central Question). Ramana Maharshi[3] posed this as a central question: are we in this world, or is this world in us? The epistemic framework offers a formal analogue: for any finite-capacity system, "the world" is represented through internal structure. The Vedantic intuition and the information-theoretic model point toward a similar structural motif, without either proving the other.

2.3 Operational Definitions

The framework uses three key parameters with specific operational meanings:

- **C_{eff} (Effective Capacity):** The useful mutual-information rate actually available for basis/state tracking, measured in bits/s. Operationally, this is the accepted update fraction times useful bits per update times update rate, after losses, latency, estimator inefficiency, and rejected samples. It is not raw input power, nominal clock speed, or total ADC throughput.
- **h_{KS} (KS-like rate):** The exponential divergence rate of nearby trajectories in phase space, measured in nats/s. Operationally: obtained from trajectory separation in the relevant dynamical system, or the effective Lyapunov exponent for decohering quantum channels. (We use h_{KS} rather than λ to avoid collision with Lyapunov exponent notation in other contexts.)
- **Rates and margins:** The key control parameter is the *information-deficit rate*

  $$\kappa \equiv h_{\text{KS}} - C_{\text{eff}} \ln 2,$$

  which is positive only in the chaos-wins regime ($h_{\text{KS}} > C_{\text{eff}} \ln 2$). The corresponding tracking-loss time is

  $$\tau_{\text{loss}} \equiv \frac{1}{\kappa}, \qquad \tau_{\text{SK}} \equiv \frac{\ln 2}{\kappa} = \ln 2 \cdot \tau_{\text{loss}} \qquad \text{(defined only when } \kappa > 0\text{)}.$$

  Two timescales arise naturally:

  - $\tau_{\text{loss}} = 1/\kappa$: the *amplitude e-folding time*—when σ grows by factor e. Used in physics/control-theory contexts.
  - $\tau_{\text{SK}} = \ln 2/\kappa \approx 0.693\,\tau_{\text{loss}}$: the *one-bit loss time* (self-knowledge timescale)—when tracking error doubles. Used in biological/self-knowledge contexts.

  The ln 2 factor converts between natural exponential growth (nats) and information-theoretic bit loss. Since σ grows as $e^{\kappa t}$, the variance σ^2 grows as $e^{2\kappa t}$, with e-folding time $\tau_{\text{var}} =$

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[3] Ramana Maharshi (1879–1950) was an Indian sage and *jñānī* widely regarded as one of the foremost exponents of Advaita Vedanta in the modern era.

$1/(2\kappa)$. The actual time to reach any operational threshold σ_* from initial error σ_0 is $t_* = (1/\kappa)\ln(\sigma_*/\sigma_0)$; specific thresholds shift this by an $O(1)$ logarithmic factor. When bridging to gravitational scales, we write κ for the information-deficit rate. We reserve κ_{geo} for the geometric surface gravity (horizon instability rate, nats/s), which appears in horizon thermodynamics via the Unruh/Hawking temperature $T = \hbar\kappa_{\text{geo}}/(2\pi k_B)$. The bridge hypothesis (Appendix A) identifies the chaotic rate with the geometric rate at saturation: $h_{\text{KS}} \approx \kappa_{\text{geo}}$, so that $\kappa \approx \kappa_{\text{geo}} - C_{\text{eff}} \ln 2$.

2.4 Levels and Language

This paper operates at two distinct descriptive levels. Mixing them produces category errors.

Level Separation

- **Substrate level:** The deterministic, non-dual whole. Not described by spacetime, objects, or observers. No intrinsic boundaries. (Vedantic: *Brahman*, *sat*.)
- **Appearance level:** Everything that appears *to* an observer—mind, body, spacetime, fields, detectors, measurement records, other persons. All physics operates here.

Rule: Appearance-level entities (brains, detectors, fields) are never used as causal explainers of substrate-level structure. "The brain generates consciousness" is a category error within this framework.

When appearance-level language appears (e.g., "the observer measures," "the system evolves"), it is shorthand for structure within the appearance, not a claim about the substrate.

Substrate specification (minimal). "Deterministic" means law-governed, unitary evolution of the total state—not classical trajectories or hidden variables in the Bohm sense. "Continuous" means not assumed discrete by fiat; no claim is made about spacetime-continuity at Planck scales. These substrate claims are minimal and model-level: multiple ontologies (Everettian, superdeterministic, cellular automaton, etc.) could realize them. The framework requires only that the substrate admit a well-defined instability rate h_{KS} and that finite observers exist within it. We do not defend a specific ontology; we derive constraints on appearance given these minimal assumptions.

2.5 Core Conceptual Definitions

Beyond the quantitative parameters (C_{eff}, h_{KS}, κ), the framework uses several conceptual terms that require sharp definition to prevent misreading:

- **Observer:** Not a person, mind, or biological entity. An *inference/control loop* characterized by: (i) finite channel capacity C_{eff}, (ii) a predictive model updated from measurements, (iii) actions that depend on predictions. Any physical system satisfying these constraints counts as an "observer" for purposes of the framework.
- **Ignorance:** Not a psychological state or moral failing. The *information-theoretic gap* between what the substrate contains and what the observer's finite channel can represent.

Specifically: when $\kappa > 0$ (i.e., $h_{\mathrm{KS}} > C_{\mathrm{eff}} \ln 2$), the observer cannot track all degrees of freedom, and this untracked portion constitutes "ignorance."

- **Duality:** The subject/object partition $(S|O)$. Operationally: the observer's internal model divides variables into (i) those it treats as "self" (directly controllable, used as reference frame), and (ii) those it treats as "world" (inferred, predicted, acted upon). This partition is the minimal structure required for coherent prediction and control.
- **Consciousness:** Used in this paper as shorthand for *the fact of appearance*—that there is experience at all. We make no claims about qualia, subjective character, or phenomenal properties beyond noting that the framework describes the structures available to a finite observer. The term is not a substrate-level primitive; it names the appearance-level fact that something appears.

2.6 What This Framework Claims (and Does Not Claim)

To prevent misreading, we state explicitly:

What Is Claimed:

1. **Structural pressure:** Given finite capacity ($C_{\mathrm{eff}} < \infty$) and chaotic dynamics ($h_{\mathrm{KS}} > 0$), certain structures (subject/object split, sequential updating, coarse-graining) become natural or efficient features of a consistent finite-observer world-model.
2. **Scaling predictions:** The tracking-loss timescale $\tau_{\mathrm{loss}} = 1/\kappa$ (in the chaos-wins regime) depends on observer bandwidth. This is testable.
3. **Correspondences:** Under specific bridge assumptions, the tracking-loss timescale maps to gravitational collapse timescales with a known coefficient.

What Is Not Claimed:

1. **Ontological derivation:** We do not derive what exists. We model constraints on what can appear given bounded inference.
2. **Idealism:** The substrate is not "made of mind." The substrate is prior to the mind/matter distinction; mind and matter are both appearance-level categories.
3. **Solipsism:** Multiple observers can be implemented within one substrate. Intersubjective agreement is an appearance-level constraint, not evidence for ontic plurality.
4. **New physics:** No new forces, fields, or particles are postulated. The framework reinterprets existing physics epistemically.

2.7 Dictionary Steps

Throughout this paper, we distinguish three types of statements:

1. **Derived structure:** Mathematical results that follow from the stated assumptions. Marked as Propositions or Lemmas.

2. **Bridge Ansatz (ML-calibrated):** A mapping from deficit-rate to energy scale, not a derived theorem. We posit that the information deficit rate κ maps to gravitational self-energy via saturation of the Margolus–Levitin bound, yielding $E_G = (\pi/2)\hbar\kappa$. The coefficient $\pi/2$ follows from ML saturation within this ansatz; the ansatz itself is testable through calibrated C_{eff} throttling: if $\partial\tau/\partial C_{\text{eff}} > 0$ under fixed thermal/readout/plant/mass/geometry conditions, IOF is supported; if τ is independent of C_{eff}, the bridge fails.
3. **Illustrative analogy:** Heuristic comparisons (cinema projector, language encoding) that aid intuition but carry no evidential weight. Confined to appendices and clearly labeled.

When the Bridge Ansatz appears in the main text, it will be flagged. The bridge assumption ($h_{\text{KS}} \leftrightarrow \kappa_{\text{geo}}$ at saturation) is a mapping choice, not a derivation.

3 Limitations and Scope

3.1 Scope and Achievements

This framework provides an epistemic architecture for the emergence of duality. It describes how a single deterministic substrate ($|\psi\rangle$) can be modeled as appearing to a finite observer embedded within it.

What Is Established:

- **The Subject/Object Partition:** Shown in Part I to be *compatible with* optimal compression of a self-referential world model under finite capacity, using the Information Bottleneck framework. This is a constructive modeling choice under explicit assumptions (Markov structure, weak coupling, locality of action), not a uniqueness theorem.
- **The Collapse Timescale τ_{loss}:** Derived from the Data-Rate Theorem as the timescale on which a finite capacity C_{eff} loses track of a chaotic system with instability rate h_{KS}.
- **The Gravitational Correspondence:** Formulated in Appendix A as a **Bridge Ansatz (ML-calibrated)**: a mapping from deficit-rate to energy scale via Margolus–Levitin saturation, yielding $E_G = (\pi/2)\hbar\kappa$. The coefficient $\pi/2$ follows from the saturation assumption within this ansatz, not from first principles. The ansatz is testable through calibrated C_{eff} throttling: if $\partial\tau/\partial C_{\text{eff}} > 0$ under fixed confounds, the bridge is supported; if τ is independent of C_{eff}, it fails. An optional connection to horizon thermodynamics (MSS bound) is provided for readers interested in GR scales.

Physical Assumptions: The technical construction uses:

- **Data-Rate Theorem:** Tracking a chaotic system (h_{KS}) requires capacity $C_{\text{eff}} > h_{\text{KS}}/\ln 2$.
- **Margolus–Levitin Limit:** Information processing is bounded by energy: $r_{\max} = 2E/(\pi\hbar)$.

The following are **optional** (for connection to GR scales):

- **MSS Chaos Bound:** Horizon dynamics saturate $h_{\text{KS}} \leq 2\pi k_B T/\hbar$.
- **Jacobson's Thermodynamic Gravity [3]:** Einstein equations arise from horizon thermodynamics.

3.2 What Is Not Derived (The Boundary)

To maintain rigor, we explicitly state what lies outside the framework:

1. **The Origin of Finitude:** We calculate the consequences of finite capacity ($C_{\text{eff}} < \infty$), but we do not explain why the fundamental state admits a finite-capacity partition in the first place. (See Part III for the Vedantic perspective on this "prime mover.")
2. **Standard Model Content:** We model the architecture of the container (Space, Time, Objectality), not the specific furniture (particle masses, coupling constants, gauge groups).
3. **The Value of G:** Appendix C rewrites $G = c^5/(\hbar\kappa_P^2)$ to invert the usual hierarchy interpretively: G encodes a universal ceiling in the architecture of appearance. The framework does not attempt to derive the numerical value of κ_P (or G) from within physics, since any such derivation risks circularity—using the projected structure to derive the projector.

Physical Plausibility. However, this "why finite?" question may be partly constrained by ordinary physics. If one identifies effective tracking capacity with physical transition rate, then the Margolus–Levitin bound $C_{\text{eff}} \leq 2E/(\pi\hbar)$ implies that unbounded tracking capacity would require unbounded available energy. Concentrating such energy in a finite region is incompatible with the causal structure needed for ordinary observation. In shorthand:

$$C_{\text{eff}} = \infty \implies E = \infty \implies \text{spacetime collapse.}$$

(This inference uses a strong identification between information rate and physical transition rate; see Appendix A. Without that identification, the argument is suggestive rather than deductive.)

Within this bridge argument, finitude is not an arbitrary restriction but a physically motivated constraint on any observer embedded in finite-energy spacetime. The model therefore treats $C_{\text{eff}} < \infty$ as an operational premise rather than as a metaphysical theorem.

Metaphysical Question. The framework therefore does not explain why observation is finite in an ultimate sense. It argues only that finite embedded observers are the relevant class for empirical science. What remains unexplained is why there is manifestation at all: why does the undifferentiated substrate admit any perspective, any coarse-graining? This shifts the mystery from "why limited?" to "why manifest?"—a question that lies outside empirical science (see Section 14, "The Boundary of What Can Be Said").

Structural Correspondence 3.1 (The Structural Cost of Existence). In Vedantic terms, *māyā* (cosmic ignorance) can be read as the structural cost of existence within duality. The Margolus–Levitin argument supplies a physical analogue: finite observation entails finite capacity, and finite capacity entails incomplete knowledge. "Ignorance" is therefore not treated here as a moral or cognitive defect, but as the operational condition under which a world of forms can appear. The question "why did Brahman veil itself?" becomes, in this analogy: "Why any world at all?"—a question Advaita acknowledges as *anirvacanīya* (inexpressible), lying beyond the categories of empirical reasoning.

3.3 Failure Modes

The framework is falsifiable. Many quantum-gravity proposals are difficult to test at accessible energies; by contrast, the IOF predicts that the bridge contribution to decoherence is **effective-**

capacity dependent. Specifically:

$$\frac{\partial \tau_{\mathrm{coh}}}{\partial C_{\mathrm{eff}}} > 0.$$

If increasing calibrated effective tracking capacity does not extend coherence times under the specified controls, the proposed bridge between tracking loss and gravitational collapse is not supported.

Crucially, because this framework models the relevant collapse scale *epistemically* (dependent on observer capacity C_{eff}) rather than only *geometrically* (dependent on mass distribution), it permits a distinctive experimental discriminator. Standard Penrose OR predicts collapse times depend *only* on mass geometry (E_G). The IOF bridge ansatz predicts an additional **Mass + Effective Capacity** dependence: $\tau \propto 1/\kappa = 1/(h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2)$. Increasing useful readout/control capacity while holding mass, geometry, temperature, readout noise, and plant dynamics fixed should extend coherence if the bridge is correct—a prediction relevant to QGEM-like and space-matter-wave platforms.

The framework fails if:

- **Effective-Capacity Independence:** If experimental tests [4] show that collapse timescales are independent of calibrated observer tracking capacity (C_{eff}), the link between τ_{loss} and τ_{OR} is broken. This is the primary failure criterion for the bridge ansatz.
- **Area Law Violation:** If intermediate-scale horizon entropy deviates significantly from the Bekenstein–Hawking area law, the thermodynamic link to gravity fails.

4 The Rise of the Ego

We now model (under the stated assumptions) how subject/object duality can emerge as an information-theoretic transition in a compressed code of a self-referential, finite-capacity system.

Crucially, in this derivation, the "Ego" is not a psychological neurosis, nor is the "Body" a pre-existing biological container. Instead:

1. The **Ego** (S_t) is the internal control locus—the center of reference required to organize information.
2. The **Body/Senses** are the instruments (sensors and actuators) this locus generates to interact with the remaining variables.

In this framework, the body is the *interface surface* of the observer, defined by the set of variables the observer can directly control. The "Ego" (the control model) precedes the "Body" (the control interface) in the logical hierarchy of the derivation.

Structural Correspondence 4.1 (The Sankhya–Information Isomorphism). This derivation has a structural resemblance to the cosmological sequence described in Sankhya philosophy (specifically as detailed in Sri Yukteswar's *The Holy Science*). In Sankhya, the Ego (*ahaṁkāra*) arises first. Through the activation of *rajas* (the energy of change/action), the Ego polarizes the unitary field into two opposing categories:

- **Subject Pole (Sattva/Rajas):** The *jñānendriyas* (cognitive senses) and *karmendriyas* (organs of action). In our derivation, this maps to the controller state S and its actuators.

- **Object Pole (Tamas):** The *tanmātras* (subtle objects) and *mahābhūtas* (gross matter). In our derivation, this maps to the environmental state O and external dynamics.

The structural resemblance is suggestive: what the model treats as a factorization of a control loop under local action parallels what Sankhya describes as the "polarization of the Ego into senses and matter." In both systems, the body is not the container of the self, but the self's instrument of interaction.

The derivation proceeds in five steps.

4.1 Step 1: Abstract Setup

World as a Single System. Let the "whole thing" (world + observer, no split assumed) have states[4]

$$x \in \mathcal{X},$$

with dynamics

$$x_{t+1} = F(x_t),$$

where F can be classical, quantum, or stochastic. There is no "subject" or "object" in $\mathcal{X}$; it is the total configuration.

The Self-Model / Epistemic State. Within this world, some substructure plays the role of "observer." We model it functionally as a code/memory variable m_t that holds "what the world knows about itself at time t":

$$R : \mathcal{X} \to \mathcal{M}, \quad m_t = R(x_t),$$

where $\mathcal{M}$ is the space of internal codes (epistemic states).

Interpretation:

- x_t = ontic state
- m_t = epistemic state (what is currently rendered/accessible)

Capacity Constraint (per update step). The internal code space $\mathcal{M}$ has finite capacity C_{step} bits per update:

$$\log_2 |\mathcal{M}| \leq C_{\text{step}},$$

or, for a stochastic channel R:

$$I(X; M) \leq C_{\text{step}},$$

where X is a random variable over $\mathcal{X}$ and $M = R(X)$.

This is the bare capacity bound: the non-dual world can be arbitrarily rich, but the internal representation cannot mirror it perfectly if $H(X) > C_{\text{step}}$. For dynamics at rate $1/\Delta t$, the effective capacity rate is $C_{\text{eff}} = C_{\text{step}}/\Delta t$ (bits/s).

Self-Reference. The observer's memory m_t must itself be part of the world state x_t. So:

$$x_t = (y_t, \xi_t),$$

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[4] $\mathcal{X}$ denotes the mathematical state space of the Block Universe used in the derivation. It is not intended as a representation of the metaphysical Absolute (sat–cit–ānanda), which by definition lies beyond any finite or mathematical description. This framework concerns the structure of appearance within the undivided experiential field, not the ontology of the unconditioned Real.

where y_t = microstate of the structure implementing the memory and ξ_t = everything else.

The encoding map is $m_t = R(y_t, \xi_t)$. The world is trying to encode itself, inside itself, with finite capacity.

Coarse-Graining is Unavoidable. Because R is capacity-limited, it must be many-to-one on $\mathcal{X}$. For some $m \in \mathcal{M}$, there exist distinct world states $x, x' \in \mathcal{X}$ such that $R(x) = R(x') = m$.

This defines an equivalence relation:

$$x \sim x' \quad \text{iff} \quad R(x) = R(x').$$

The equivalence classes $[x] = \{x' \in \mathcal{X} : R(x') = R(x)\}$ are the epistemic macrostates—all ontic states the observer cannot distinguish.

Proposition 4.1 (Step 1 Result)**.** *Finite capacity forces coarse-graining of the non-dual world into epistemic equivalence classes.*

(Appendix F develops an accessible analogy: language, as a finite coding system, exhibits the same forced discretization—tokenization, categorization, and grammar-induced structure all arise from representational finitude.)

No duality yet—just equivalence classes. Whatever the observer knows must be represented within its own internal state; there is no knowledge of anything "outside." The observer's memory, self-model, and world-model all reside in the same internal representational field. Apparent fragmentation—subject here, world there—arises only when finite information capacity forces this self-referential unity into parts.

Structural Correspondence 4.2 (Self-Contained Awareness). Ramana Maharshi expressed this structural point in non-technical language: "Consciousness alone exists and is aware of itself." From the Advaitic perspective, this self-contained awareness is the unfragmented background; ignorance (*avidyā*) does not create a second consciousness, but only creates the appearance of multiplicity within the one field of knowing.

4.2 Step 2: Add Actions and Relevance

Actions. Real observers act. Add:

- Actions a_t, chosen by a policy π from the memory: $a_t = \pi(m_t)$
- New dynamics: $x_{t+1} = F(x_t, a_t)$

Relevant Future. We care about some task: survival, reward, prediction. Define the "relevant future":

$$Y_t = (\text{some functional of the future trajectory}).$$

Examples:

- $Y_t = x_{t+\Delta}$ (predictive coding)
- $Y_t = \text{cumulative reward}(x_{t:\infty}, a_{t:\infty})$

Information Bottleneck Objective. Under finite capacity, "good" codes keep information that matters for Y. The information bottleneck (IB) Lagrangian:

$$\mathcal{L}[R] = I(X;M) - \beta\, I(M;Y),$$

or in distortion form:

$$\mathcal{L}[R] = I(X;M) + \beta\, \mathbb{E}[d(Y, \hat{Y}(M))].$$

Ontological note: The Information Bottleneck optimization is *descriptive*—it characterizes the structure of stable finite controllers, not an ontological claim that an agent "chooses" trajectories outside deterministic dynamics. All dynamics remain deterministic; IB describes which internal representations are stable under finite capacity.

Structural Correspondence 4.3 (Relevance as Desire (Vāsanā)). This mathematical step introduces a crucial non-neutrality: the observer does not encode the world "as it is," but only as it is *relevant* to Y (the target future). Structurally, this corresponds to the Vedantic concept of *vāsanā* (latent tendency) and *icchā* (will/desire).

In this isomorphism:

- The "Relevant Future" Y_t corresponds to the *phala* (fruit of action) sought by the observer.
- The tradeoff parameter β corresponds to the intensity of attachment (*rāga*). If $\beta = 0$ (no relevance), the observer need not compress or partition the state; duality collapses.
- The policy π corresponds to the causal chain of *karma*: action is driven by the specific way the observer values the future.

Thus, the "world" (O) that eventually emerges is not an objective container, but a projection shaped specifically by the observer's drive for continuity and fulfillment. Epistemically, *desire structures the code.*

4.3 Step 3: Why This Becomes Subject/Object

Local Action Creates Asymmetry. Key asymmetry in any agent:

- It can only act on some degrees of freedom directly (controller/actuators)
- It influences the rest indirectly through those

Write $x_t = (b_t, e_t)$ as controller + environment (where actuators live vs. everything else).

Dynamics:

$$b_{t+1} = F_b(b_t, e_t, a_t), \tag{4}$$
$$e_{t+1} = F_e(b_t, e_t, a_t), \tag{5}$$

with actions $a_t = \pi(m_t)$ local to b.

Relevant Future Splits. The relevant future itself splits:

$$Y_t = (Y_t^{(b)}, Y_t^{(e)}),$$

where $Y^{(b)}$: self-future (internal stability, energetic state) and $Y^{(e)}$: world-future (threats, resources, opportunities).

IB Objective Approximately Decouples (Modeling Assumption).

Assumptions: We assume (i) Markov structure: the code M screens off the past from the relevant future; (ii) weak coupling: mutual information between self-future and world-future conditioned on M is small; (iii) locality of action: the controller can only directly affect a subset of degrees of freedom.

Under these assumptions, the chain rule gives:

$$I(M; Y^{(b)}, Y^{(e)}) \approx I(M; Y^{(b)}) + I(M; Y^{(e)} \mid Y^{(b)}).$$

If we choose a representation with two factors $M = (S, O)$:

- S optimized for predicting $Y^{(b)}$
- O optimized for predicting $Y^{(e)} \mid Y^{(b)}$

Then the IB objective approximately decouples:

$$\mathcal{L}[R] \approx \Big[I(X; S) - \beta_b I(S; Y^{(b)})\Big] + \Big[I(X; O) - \beta_e I(O; Y^{(e)} \mid Y^{(b)})\Big].$$

Note: This is a constructive modeling choice showing that factorization is *compatible* with IB optimality under the stated assumptions—not a theorem that factorization is *necessary*. The argument establishes plausibility, not uniqueness.

Proposition 4.2 (Step 3 Result (Conditional)). *Under local action, Markov structure, and weak coupling between self-future and world-future, an approximately optimal compressed code can be factorized into two channels:*

$$M_t = (S_t, O_t),$$

where S_t = minimal sufficient statistic for self/controller dynamics and O_t = minimal sufficient statistic for environment dynamics, conditioned on S_t.

Interpretation:

- S_t = “I, here-now” (subject pole)
- O_t = “that, out-there as seen from S_t” (object pole)

Structural Correspondence 4.4 (The Instruments of Action). Vedānta uses a parallel vocabulary for this structural asymmetry. The body–mind system and its sensory-motor interface are called the *karaṇa* (the instruments of perception and action). Local action (*kriyā*) generates causal imprinting (*karma*), which in turn reinforces the sense of being a separate agent (*kartṛtva*). These terms do not add metaphysical commitments; they simply capture in traditional language the same asymmetry that, in this work, arises mathematically from a finite-capacity observer interacting locally with its environment.

Ramana Maharshi expressed the same structural point concisely: “The body does not say ‘I’; the Self does not act; action belongs to the mind.” In formal terms, the asymmetry arises because the observer’s internal model contains both sensors and actuators. Local action therefore becomes part of the representational loop, not a feature of an external ontic agent.

Why Two and Not More?

1. **Control structure has exactly two roles:** controller and plant. Even hierarchical control has this structure at each level.
2. **Gauge-like redundancy collapses:** Internal degrees of freedom collapse into a reference frame S_t.
3. **Rate–distortion argues against extra factors:** Splitting beyond subject/world increases rate without improving $I(M;Y)$.

Structural Correspondence 4.5 (No Others). Ramana Maharshi expressed the structural consequence of this far more directly: "There are no others." Within a single agent's representational loop, there is one self-index S_t; other agents appear as modeled processes within O_t. A finite-capacity system can instantiate only one locus of experience—the subject. All multiplicity appears only as object-content within that one field. There cannot be two subjects within a single representational loop; the "many" arise only as appearances to the one who knows them.

Clarification: Multiple observers correspond to multiple (possibly interacting) inference/control loops implemented in the substrate. "One locus" refers to one loop's internal index S_t, not a global uniqueness claim. The framework is compatible with many such loops coexisting; each experiences its own $S|O$ partition. This is a statement about representational structure, not a denial that other agents exist as independent systems.

Proposition 4.3 (Duality Emergence (Model Claim))**.** *Under the stated assumptions (local action, Markov structure, weak coupling), the subject/object distinction is the control-optimal, rate-limited factorization of the self-referential world-model.*

4.4 Step 4: Dynamics, Chaos, and τ_{loss}

S|O as a Tracking Code. The $S|O$ partition is a running tracking scheme: (S_t, O_t) must be continuously updated under capacity C_{eff} bits per unit time.

Chaos: Errors Grow Exponentially. Assume the world has positive instability rate $h_{\text{KS}} > 0$:

$$|\delta x_t| \sim |\delta x_0| e^{h_{\text{KS}} t}.$$

Without updates, prediction error blows up on timescale $1/h_{\text{KS}}$.

Capacity as Error-Correcting Rate. Each time step Δt, the agent receives at most $C_{\text{eff}}\,\Delta t$ bits of new information. In log-volume terms:

- Chaos expands uncertainty volume at rate h_{KS}
- Information shrinks it at rate $C_{\text{eff}} \ln 2$

Net exponent for error dynamics (the information-deficit rate):

$$\kappa = h_{\text{KS}} - C_{\text{eff}} \ln 2.$$

Critical capacity:

$$C^*_{\text{eff}} = \frac{h_{\text{KS}}}{\ln 2}.$$

- $\kappa < 0$ (i.e., $C_{\text{eff}} > C^*_{\text{eff}}$): capacity wins, error suppressed
- $\kappa > 0$ (i.e., $C_{\text{eff}} < C^*_{\text{eff}}$): chaos wins, error explodes

The Tracking-Loss Timescale. In the chaos-wins regime ($\kappa > 0$), the tracking-loss timescale is:

$$\boxed{\tau_{\text{loss}} = \frac{1}{\kappa} = \frac{1}{h_{\text{KS}} - C_{\text{eff}} \ln 2}}$$

This is the amplitude e-folding time (the width scale σ grows as $e^{\kappa t}$; the variance σ^2 grows as $e^{2\kappa t}$ with e-folding time $\tau_{\text{var}} = 1/(2\kappa)$). For a detailed derivation of the variance dynamics, regime analysis (chaos-wins vs. capacity-wins), and sensitivity analysis, see [1].

Explicit time-sharing encoder/decoder. We verify the data-rate theorem by simulating the unstable linear system $x_{k+1} = ax_k$ with $|a| > 1$, observed through a rate-limited channel. The decoder maintains a consistent uncertainty interval represented by its center c_k and half-width w_k (so $\Delta_k = 2w_k$). Each step, dynamics expands the interval via $c \leftarrow ac$, $w \leftarrow |a|w$. Communication is implemented via *time-sharing*: a periodic schedule assigns an integer number of bits $C_k \in \{0, 1, 2, \ldots\}$ per step such that $\langle C_k \rangle = C_{\text{eff}}$. When $C_k > 0$, the expanded interval $[c_k - w_k, c_k + w_k]$ is partitioned into 2^{C_k} uniform bins; the encoder transmits the bin index containing the true state, and the decoder contracts to that bin, updating c_k to the bin center and $w_k \leftarrow w_k/2^{C_k}$. This representation avoids catastrophic cancellation that occurs when subtracting large nearly-equal endpoints $(U_k - L_k)$ in the stable regime $C_{\text{eff}} > C^*_{\text{eff}}$.

Under time-sharing, $\ln \Delta_k$ exhibits a step/sawtooth pattern because contraction occurs only on steps where $C_k > 0$; the data-rate theorem concerns the average exponential rate, obtained by fitting the mean slope over many steps.

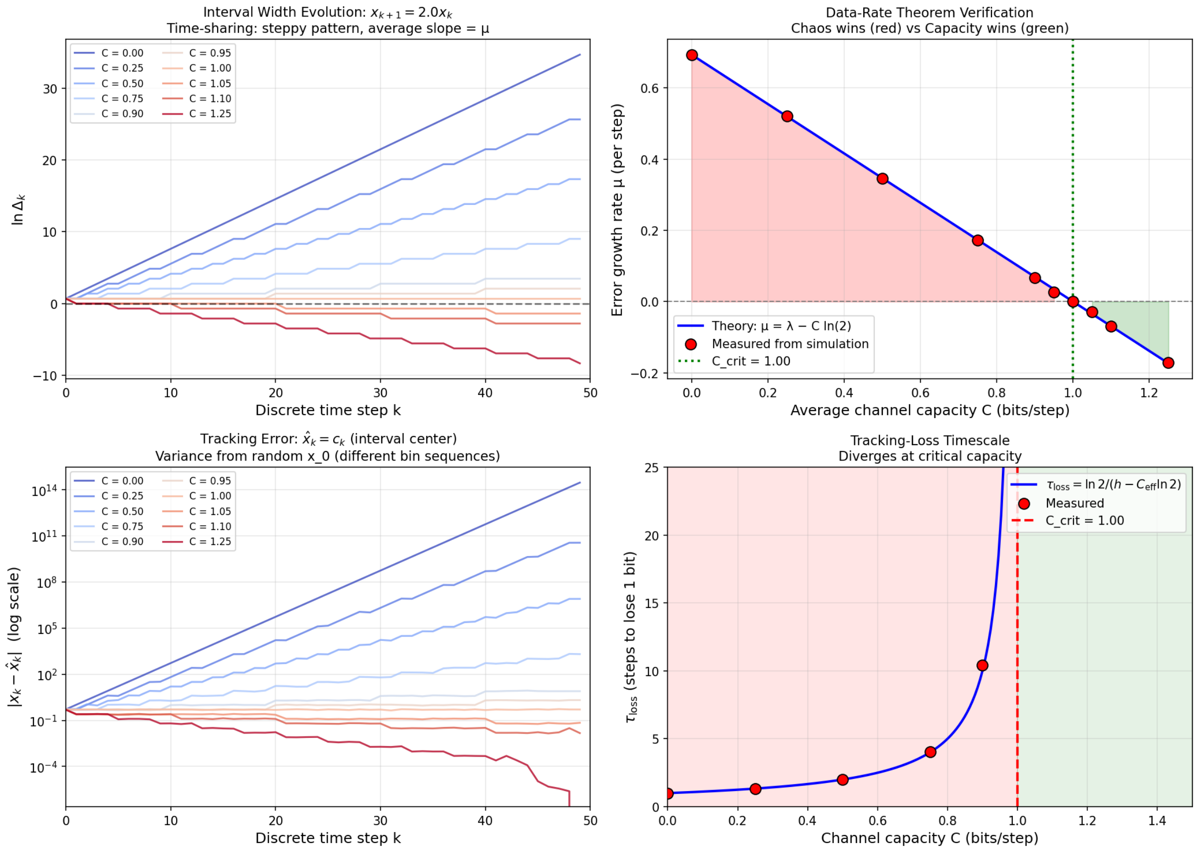

Figure 1: Data-rate theorem verification via explicit time-sharing quantization. (Top Left) Evolution of $\ln \Delta_k$ where $\Delta_k = 2w_k$ is the decoder's interval width; the step-like structure reflects time-sharing schedules (contraction only on steps with transmitted bits). The *average* slope equals $\kappa = \ln|a| - C_{\text{eff}} \ln 2$. (Top Right) Measured growth rate κ from linear fits of $\langle \ln \Delta_k \rangle$ versus k, compared with theory $\kappa = \ln|a| - C_{\text{eff}} \ln 2$; the sign change occurs at $C^*_{\text{eff}} = \ln|a|/\ln 2$. (Bottom Left) Mean tracking error $|x_k - \hat{x}_k|$ with decoder estimate $\hat{x}_k = c_k$, showing performance consequences of insufficient rate. (Bottom Right) Tracking-loss timescale $\tau_{\text{loss}} = 1/\kappa$ diverges as $C_{\text{eff}} \to C^{*-}_{\text{eff}}$. For finite observers, this timescale defines the refresh rate of experience.

Tracking Failure Destroys the S|O Split Itself. Key insight: The $S|O$ split is a causal-role split, not a data split. It requires tracking which DOFs respond to actions in a privileged way.

When tracking fails ($t > \tau_{\text{loss}}$):

1. S_t becomes inconsistent with the controller's true causal role
2. O_t becomes inconsistent with environment responses
3. The mapping "what changes when I act ⇒ self" becomes unresolvable
4. The functional distinction between S and O collapses

Proposition 4.4 (Duality Lifetime (Model Claim))**.** *In the chaotic regime, duality is a metastable phase maintained only while $C_{eff} \ln 2$ keeps pace with h_{KS}; breakdown occurs at the tracking-loss timescale $\tau_{loss} = 1/\kappa$.*

In classical Advaita, the sense of individuality arises from a constriction of awareness known as the ego-knot (hṛdaya-granthi). When the knot tightens, the subject/object split is experienced as real; when it loosens, the apparent boundary thins; when it opens, the split dissolves. This framework reproduces this structure in mathematical terms: as tracking quality degrades and the observer cannot maintain consistent predictions, the $S|O$ partition becomes unstable and eventually fails. The parallel is structural, not ontological.

4.5 Step 5: The Marginal Duality Condition

Three regimes:

1. $\kappa \gg 0$ (i.e., $C_{\text{eff}} \ln 2 \ll h_{\text{KS}}$): chaos dominates, τ_{loss} short, duality unstable
2. $\kappa \approx 0$ (i.e., $C_{\text{eff}} \ln 2 \approx h_{\text{KS}}$): marginal, τ_{loss} large, boundary of stability
3. $\kappa < 0$ (i.e., $C_{\text{eff}} \ln 2 > h_{\text{KS}}$): capacity wins, duality maintained

At the critical surface where duality is marginally sustainable:

$$C_{\text{eff}} \ln 2 \approx h_{\text{KS}}.$$

On this saturation surface, $h_{\text{KS}} \approx \kappa_{\text{geo}}$ (via MSS), enabling the correspondence $E_G = (\pi/2)\hbar\kappa$ derived in Appendix A.

Structural Correspondence 4.6 (The Heart-Knot). In Vedantic terminology, this threshold corresponds to the *hṛdaya-granthi*—the “heart-knot” binding consciousness to apparent matter. At τ_{SK}, self-ignorance reaches a point where the $S|O$ labelling fails; the ego-knot can no longer sustain a coherent inside–outside distinction, and the dualistic framing destabilises. The IOF paper [1] develops this correspondence in detail (Section 19.1, “The Hṛdaya-granthi as Quantum-Classical Boundary”).

Part II

The Emergence of the World

5 The Vedantic Frame

Part I derived the rise of the ego—the internal control locus that anchors the subject pole of experience—as an information-theoretic phase transition in a finite-capacity, self-referential system. Part II examines the structure of what then appears *as the world* from that ego-locus. We show how Space, Time, Object, and Gravity arise not as pre-existing external entities but as features of the coarse-grained world-model constructed under the constraints of limited capacity and chaotic dynamics.

> **Note on Methodology:** The following sections utilize terminology from the Advaita Vedanta tradition. These terms are employed here not as metaphysical axioms, but as a rigorous phenomenological taxonomy. Physics lacks a standardized vocabulary for the internal structure of the observer (the genesis of the subject-object split). We find that the Vedantic definitions of *avidyā* (finite capacity), *māyā* (projective error), and *granthi* (structural knot) provide precise logical equivalents to the information-theoretic artifacts derived in Part I. The Vedantic literature is treated here as a phenomenological taxonomy that provides interpretive vocabulary for the architectural structures of this framework.

Structural Correspondence 5.1 (The Ajāta Doctrine). The Vedantic tradition offers a complementary interpretive lens for this architecture. Whereas physics typically treats the world as an externally existing structure, Advaita holds that what we call "the world" is an appearance that arises only for the ego-notion (*ahaṁkāra*) that mistakes itself for a separate entity. As Michael James summarizes Ramana Maharshi's teaching:

> "The world appears only to the rising ego. If we look for this rising ego, we find that it does not exist. What remains is only *ātma-svarūpa*, our own essential Self."

This is the doctrine of *ajāta* (non-creation): One Fundamental does not become many; the many are how One Fundamental appears when viewed through the representational limits of a finite observer.

This framework provides the mathematical structure of this appearance: chaos, capacity, and optimal compression produce the perspectival features—Space, Time, Object, and Gravity—that constitute the experienced world.

6 The Emergence of Space

The first artifact of finitude is **Space**—*the idea of division in the Ever-Indivisible.* What seems to be an arrangement of distinct locations and discrete things arises because a finite observer cannot represent the unified state with unlimited resolution.

6.1 Finite Resolution and Epistemic Neighborhoods

A finite-capacity observer cannot encode the full microstructure of the global state $|\psi\rangle$. The map $R : \mathcal{X} \to \mathcal{M}$ introduced in Part I necessarily collapses large regions of the ontic state space into single epistemic macrostates. The result is a partition of $\mathcal{X}$ into equivalence classes:

$$[x] = \{x' \in \mathcal{X} : R(x') = R(x)\}.$$

These macrostates define *resolution-limited neighborhoods*: states that differ microscopically but are indistinguishable to the observer. The adjacency relations among these neighborhoods induce a topological structure. Smoothness emerges when adjacent macrostates differ only infinitesimally in the observer's distortion measure.

Information-theoretic necessity. Mapping a continuous, high-dimensional state onto a channel of finite capacity forces discretization. No observer with finite C_{eff} can maintain the full precision of $|\psi\rangle$; the world is therefore represented as a collection of distinguishable regions rather than a single undivided whole.

6.2 Space as a Structure of Distinguishability

The observer's measurement channel produces a set of distinguishable outcomes $\{m_i\} \subset \mathcal{M}$. Each outcome corresponds to an epistemic neighborhood $[x_i]$ in $\mathcal{X}$. The relational structure among these neighborhoods—which ones are confusable, which are sharply separated, and which differ by minimal distortion—defines a metric space.

- Finite capacity C_{eff} limits how finely these neighborhoods can be subdivided.
- The resulting metric measures *distinguishability*, not ontic distance.
- Spatial dimension corresponds to the intrinsic dimensionality of the Fisher or information metric[5] over these neighborhoods.

In other words, the number of independent directions along which distinguishability changes to first order defines the effective spatial dimensionality: a property of the observer's information geometry rather than an ontic background manifold.

Thus **Space** is the geometry of distinguishability induced by a finite-resolution representation of a unified state. It is not an external container but a relational structure emerging from capacity-limited coarse-graining.

Dictionary: Finite resolution ↔ Spatial extension. The metric of physical space corresponds to statistical distinguishability in the observer's representation.

Structural Correspondence 6.1 (Space as the Primal Differentiation (Deśa-Kāla)). While *nāma-rūpa* (name and form) is often associated with discrete objects, Advaita posits that Space itself (*Ākāśa*) is the first and most subtle form of *māyā*. It is not an empty container existing independently, but the *principle of differentiation* projected by the mind.

This maps strictly to the information-geometric derivation:

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[5] The Fisher information metric is the canonical Riemannian metric on a statistical manifold, measuring distinguishability between neighboring probability distributions. See S. Amari, *Information Geometry and Its Applications* (Springer, 2016). This connects to John Wheeler's "It from Bit" program and recent work in holography (AdS/CFT), where spatial distance is related to entanglement entropy. The mathematical framework is rigorous; applying it to physical 3D space remains a hypothesis that this framework makes concrete.

- **Physics:** Distance is not a physical length but a statistical distance—a measure of how easily an observer can distinguish two states. "Far" simply means "highly distinguishable."
- **Vedanta:** Space (*Deśa*) is the mental concept of "apartness" or "extension" required to hold the Many. Without the concept of difference (*Bheda*), there is no space.

Ramana Maharshi clarifies this distinction: "You say you are in the body and the body is in the world... but where is the world? It is in your mind." In this framework, spatial extension is the *metric of ignorance*—it represents the magnitude of the separation the observer projects between the Self and the non-Self.

7 The Emergence of Time

The second artifact of finitude is **Time**—*the idea of change in the Ever-Unchangeable.* What appears as succession arises within an underlying deterministic Block Universe in which nothing fundamentally "flows." Temporal experience, in this framework, arises not from additional ontic structure in spacetime but from the dynamics of a finite observer attempting to track an ever-changing state under limited capacity.

7.1 Why Succession Appears: Tracking Creates a Temporal Order

A finite observer must continuously update an internal estimate of the world-state. The ability to maintain coherence across successive updates is governed by the competition between divergence rate h_{KS} and compression rate $C_{\mathrm{eff}} \ln 2$.

In the chaotic regime, basis error evolves as $\sigma^2(t) = \sigma_0^2 \exp(2\kappa t)$. When $\kappa > 0$ (i.e., $h_{\mathrm{KS}} > C_{\mathrm{eff}} \ln 2$), uncertainty grows exponentially; the observer can only retain a compressed record of the "just past" (low σ^2), while the "not yet processed" region ahead carries high σ^2.

This asymmetric information landscape forces a partition:

$$\text{memory (integrated past)} \quad \longrightarrow \quad \text{prediction (unresolved future).}$$

The moving interface between them is the epistemic "Now." Succession is therefore an artifact of the continual update process: *a finite observer experiences time because tracking requires sequential updates.*

7.2 Why Time Has a Direction: Irreversibility of Updating

Although the Block Universe contains no intrinsic arrow, the observer's update process is thermodynamically and informationally irreversible.

Two contributions establish directionality:

- **Information Loss (Chaos-Wins regime, $\kappa > 0$, i.e., $h_{\mathbf{KS}} > C_{\mathbf{eff}} \ln 2$):** Uncertainty increases; tracking degrades; information is irrecoverably lost. By Landauer's principle, such erasure is thermodynamically irreversible.

- **Energy Expenditure (Capacity-Wins regime, $\kappa < 0$, i.e., $C_{\text{eff}} \ln 2 > h_{\text{KS}}$):** Even when tracking succeeds, maintaining low σ^2 requires continuous free energy burn for measurement and compression. The updating process dissipates heat and cannot be reversed.

In both regimes, the observer moves from integrated, low-uncertainty states toward high-uncertainty, not-yet-integrated states. The arrow of time therefore corresponds to the gradient:

$$\nabla\sigma^2 > 0.$$

It is the direction in which uncertainty grows before compression acts.

7.3 The Finite Observer's Trajectory Through the Block

Nothing "moves" in the Block Universe. What moves is the observer's *informational position.* Each update shifts the internal state from one region of the Block to the next. Because each shift is irreversible, the sequence is experienced as a directed flow.

Time, in this view, is the phenomenology of a finite observer crawling through a deterministic Block under energetic and informational constraints. The appearance of becoming is the shadow cast by continual update against the limits of capacity.

Dictionary: Sequential updating ↔ Temporal succession. The arrow of time corresponds to the direction of increasing uncertainty ($\nabla\sigma^2 > 0$) before compression acts.

7.4 Subjective Continuity vs. Discrete Updates

We now distinguish two kinds of "time" that must not be conflated:

Definition 7.1 (Process Time vs Narrative Time)**.**

- **Process Time** (t): The index of the generative update $x_{t+1} = F(x_t)$. This is the discrete "clock" of the dynamics. The tracking-loss timescale $\tau_{\text{loss}} = 1/\kappa$ (for $\kappa > 0$) sets the horizon over which accumulated error becomes order-unity.
- **Narrative Time** (τ_{exp}): The subjective duration the observer *believes* has elapsed, as encoded in the epistemic state $M_t = (S_t, O_t)$. This can include memories of years or centuries.

The key distinction: Process Time is the update rate of the generator; Narrative Time is a *variable inside the generated representation.* They have no necessary relationship.

Analogy: A movie projector runs at 24 frames per second (process time). But a single frame can depict a flashback spanning decades (narrative time). Frame duration ≠ depicted duration.

How is this possible? At each update, the epistemic state M_t is constructed anew. This state includes:

- **Apparent memory:** Not a retrieval of past states, but present information organized as "about the past." Memory is part of the current O_t, not access to earlier O_{t-k}.
- **Projected future:** Expectations and persistence assumptions ("I existed before; I will continue").

- **Seamless refresh:** When one tracking window closes and the next opens, the new M_{t+1} inherits (or reconstructs) memories from M_t. No phenomenological discontinuity is perceived.

Consequently, each tracking window arrives with a complete backstory—and there is no internal way to distinguish "genuine" from "constructed" memory. The observer *feels* continuous even though the generative process updates discretely.

Result: Subjective continuity is compatible with self-knowledge timescales $\tau_{\mathrm{SK}} \approx 10$–100 ms. There is no paradox once Process Time and Narrative Time are distinguished.

Structural Correspondence 7.1 (Time as Kāla). Advaita holds that time (*kāla*) exists only for the mind that measures it. Ramana Maharshi pointed out that in deep sleep, hours pass without any sense of duration—time requires the waking ego to appear. The Self (*Ātman*) is described as *nityam* (eternal), not in the sense of persisting through all time, but as being altogether beyond temporal succession. In this framework, the same insight takes mathematical form: succession arises from the tracking dynamics of a finite observer. Where no observer updates, no "flow" is experienced. The Block Universe corresponds to the timeless substrate; the crawl through it corresponds to the mind's activity that creates the appearance of before and after.

8 The Emergence of Object

The third artifact of finitude is the **Object**—*the idea of particles in the Ever-Continuous.* What appears as stable things, definite forms, arises because the infinite-dimensional cannot be tracked by finite capacity.

Just as the observer's finite capacity fragments unity into multiplicity (space) and processes it as sequence (time), it also necessitates the compression of complex quantum states into stable objects.

8.1 The Mechanism

The global wavefunction $|\psi\rangle$ contains an effectively unbounded (for any finite observer) number of correlated degrees of freedom. A finite-capacity observer ($C_{\mathrm{eff}} < \infty$) cannot track the full high-dimensional evolution of this state. To maintain a coherent narrative, the observer must coarse-grain: they track only those observables their capacity allows.

- **High-Resolution Description:** The complete quantum state, containing all correlations and phase relations.
- **Observer-Resolution Description:** The effective classical object, defined by the subset of variables that remain stable under the observer's coarse-graining. This is not a second ontology but the same underlying state viewed at limited resolution. (This is an epistemic statement about perception, not a claim that observation creates reality.)

Objecthood as Limited Resolution: A "physical object" is simply the collection of variables that survive the observer's coarse-graining. No wavefunction is destroyed; what is often called "collapse" is the observer replacing an unresolvable superposition with a lower-resolution, classical proxy once their capacity is saturated.

When C_{eff} is too small to track the relative phases between quantum branches, the observer cannot distinguish the alternatives. The superposition becomes, from their perspective, a single classical outcome. This is epistemic coarse-graining: an automatic simplification of the underlying deterministic state to match the observer's resolution.

In standard decoherence theory, "classical objects" correspond to *pointer states*: degrees of freedom whose coherence with respect to environmental interactions decays rapidly, leaving a set of stable, effectively classical variables. In this framework, the same structure appears from a different angle: a variable becomes an "object" when its coarse-grained description remains predictively stable under the observer's limited update rate. Thus, decoherence selects the states that survive environmental coupling, while capacity limits select the states that survive epistemic compression.

The intersection—predictively robust, low-dimensional summaries of the underlying state—is what constitutes an "object" in experience. This is not a claim that observation causes decoherence, but that the same mathematical mechanism (the suppression of off-diagonal terms at rate κ) defines which degrees of freedom remain resolvable to a finite observer. (Here κ is an epistemic loss rate; any physical dephasing rate is a separate parameter unless explicitly mapped.)

Dictionary: Coarse-graining ↔ Objecthood. A "physical object" is the set of variables that survives the observer's capacity-limited compression.

8.2 The Lindblad Model

Clarification: The tracking-loss mechanism described in this framework is *not* environmental decoherence. Standard decoherence (Zurek, Joos–Zeh) describes off-diagonal decay due to entanglement with an external bath. Here, the rate $\kappa = h_{\text{KS}} - C_{\text{eff}} \ln 2$ arises from a *finite observer's* inability to track a chaotic source—an internal information-theoretic constraint, not external coupling. The two mechanisms can coexist and compound, but they are conceptually distinct. This subsection shows only that the *mathematical form* of κ can be mapped onto a Lindblad dephasing rate for illustrative purposes.

The same form of rate parameter $\kappa = h_{\text{KS}} - C_{\text{eff}} \ln 2$ that appears in control theory can also appear as a decoherence rate in quantum dynamics. Consider a qubit undergoing pure dephasing via the Lindblad master equation with jump operator $L = \sqrt{\gamma}\,\sigma_z$:

$$\frac{d\rho}{dt} = \gamma\,(\sigma_z \rho \sigma_z - \rho) \tag{6}$$

The off-diagonal elements decay as $\rho_{LR}(t) = \rho_{LR}(0)\exp(-2\gamma t)$.

If we identify $2\gamma = \kappa$ (valid only in the chaos-wins regime $\kappa > 0$), then the coherence e-folding time matches τ_{loss}:

$$t_e = \frac{1}{2\gamma} = \frac{1}{\kappa} = \tau_{\text{loss}}.$$

This is an illustrative consistency mapping (a toy channel model), not a derivation of collapse dynamics from first principles. The mapping $2\gamma = \kappa$ is postulated to explore what consistency would require. For $\kappa < 0$ (capacity wins), the DRT predicts error contraction (active stabilization), which this dephasing-only channel does not represent; we set $\gamma = 0$ rather than model recoherence. The Lindblad equation here is standard decoherence theory; it does not depend on the gravitational interpretation introduced later.

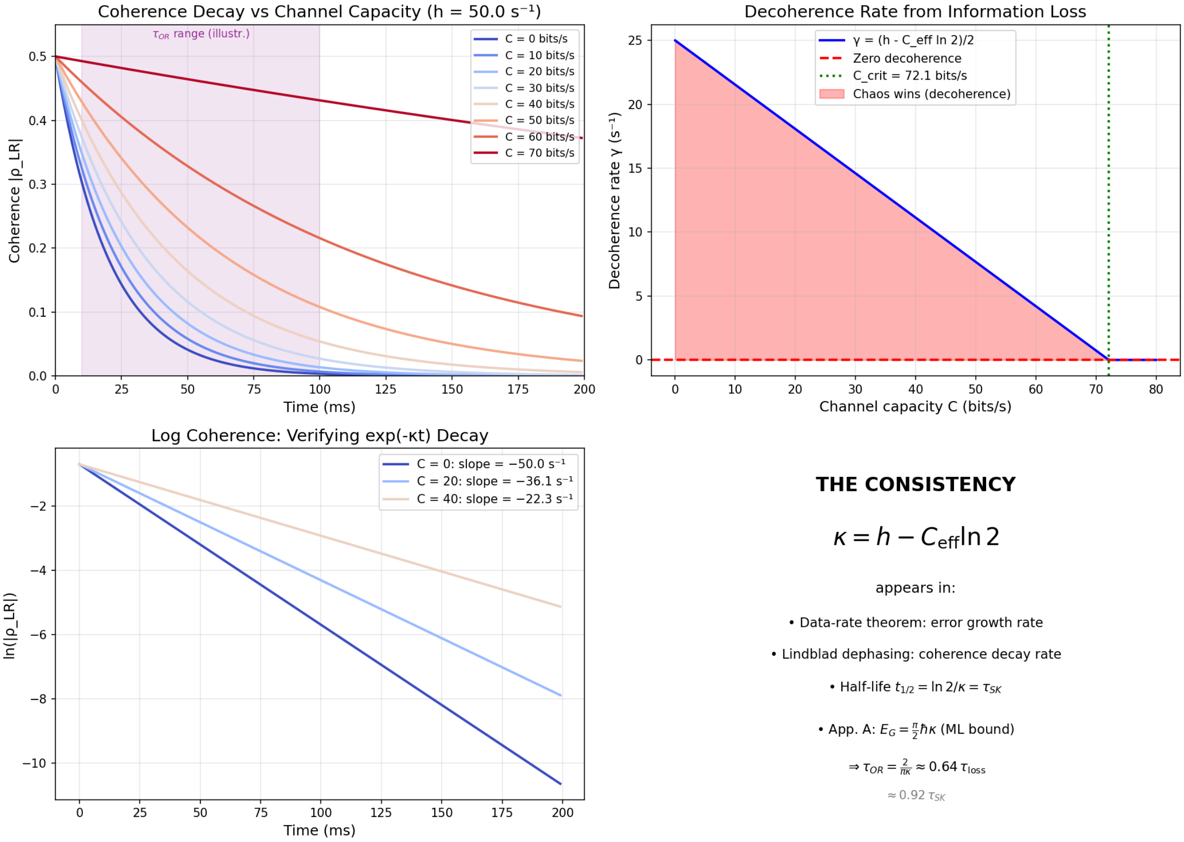

Figure 2: Toy Lindblad bridge: $\kappa = h_{\mathbf{KS}} - C_{\mathbf{eff}} \ln 2$ as decoherence rate. (Top Left) Coherence decay $|\rho_{LR}(t)|$ for different channel capacities; decay rate $2\gamma = \kappa$. The shaded region indicates the Penrose τ_{OR} range (10–100 ms) for illustrative comparison. (Top Right) Decoherence rate $\gamma = \kappa/2$ decreases linearly with C_{eff}; the green dotted line marks $C^*_{\text{eff}} = h_{\text{KS}}/\ln 2$ where decoherence vanishes. (Bottom Left) Log-coherence vs time verifies $\exp(-\kappa t)$ decay (simulation matches theory). (Bottom Right) Under $2\gamma = \kappa$, the coherence e-folding time $t_e = 1/\kappa = \tau_{\text{loss}}$ (for $\kappa > 0$). Via Appendix A, $E_G = (\pi/2)\hbar\kappa$ (ML saturation) implies $\tau_{OR} = (2/\pi)\tau_{\text{loss}} \approx 0.64\,\tau_{\text{loss}}$.

Structural Correspondence 8.1 (Object as Nāma–Rūpa). Ramana taught that objects appear only when the ego rises to perceive them. In deep sleep, neither world nor objects exist for the sleeper—yet the sleeper persists. This suggests that objecthood is not intrinsic to reality but contingent on the presence of a perceiving subject. The classical Vedantic analysis identifies objects through *nāma-rūpa* (name and form): the mind distinguishes an undifferentiated field by labeling and bounding regions of it. In this framework, the coarse-graining operation plays precisely this role—carving stable, trackable summaries out of a high-dimensional quantum state. What we call an “object” is the residue of this compression: the degrees of freedom that survive both environmental decoherence and epistemic capacity limits.

9 The Emergence of Gravity

The fourth artifact of finitude is **Gravity**—*the appearance of causal movement in the Ever-Unmoving.*

Scope: In this section, “gravity” refers to a property of the observer’s rendered geometry (belief manifold dynamics), not an ontological field. Appendix A discusses one possible correspondence to GR/OR scales under additional physical assumptions.

What appears as curvature, inertia, and causal movement arises within what this model treats as a single underlying structure. We now explore how gravity-like structure may be interpreted from the epistemic constraints already established, using the toy-model simulation as a qualitative illustration. The correspondence to standard gravitational notation follows as a separate, conditional step.

9.1 Step 1: Rendered Geometry

The observer's epistemic state at time t is a belief distribution $p(x|\mathcal{D}_t)$ over possible substrate configurations, conditioned on accumulated data $\mathcal{D}_t$. This belief defines a natural geometry on the space of possible states.

The epistemic metric. The Fisher information metric measures distinguishability between nearby belief states:

$$g_{ij} = \mathbb{E}\left[\frac{\partial \log p}{\partial x^i}\frac{\partial \log p}{\partial x^j}\right].$$

For Gaussian beliefs (as in the Kalman filter), this reduces to the inverse covariance:

$$g_{ij} \propto (P^{-1})_{ij}.$$

The "precision volume" $\sqrt{|g|} = 1/\sqrt{|P|}$ measures how sharply the observer's belief is localized—how much *structure* exists in the rendered world.

Key insight: This metric is not imposed externally; it emerges from the observer's epistemic situation. The geometry of the rendered world *is* the geometry of belief.

9.2 Step 2: Gravity as Connection

Inertial motion in belief space. Define "inertial prediction" as geodesic motion in belief space: the trajectory of minimum expected surprise (least informational update). An observer predicting freely should follow the path that minimizes cumulative prediction error.

The connection emerges. Under finite capacity, the observer cannot maintain globally coherent predictions. Correction terms are required to reconcile local predictions with global constraints. These corrections:

- are *coordinate-dependent* but invariantly meaningful (they depend on the metric),
- are *universal*—they affect all tracked degrees of freedom similarly,
- are *sourced by the epistemic deficit* $\kappa = h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2$.

This is the embryo of "gravity" in the epistemic sense: a systematic drift that cannot be removed globally, forced by the mismatch between substrate complexity and observer capacity. We do not compute the full Riemann tensor; we identify the *structure* that forces connection-like behaviour.

What "gravity-like" buys operationally: In this manuscript, "gravity" means curvature/connection structure of the belief manifold—specifically, that the observer's precision metric $g_{ij} \propto (P^{-1})_{ij}$ has dynamics sourced by the deficit rate κ. We do *not* claim recovery of Einstein dynamics in general. What we claim is: (i) the belief metric degenerates at a threshold set by κ; (ii) this threshold coincides with Penrose OR timescales under the ML bridge (Section 9.6); (iii) both claims are falsifiable via calibrated C_{eff} dependence. Whether this epistemic structure realizes full GR geometry at all scales remains future work.

9.3 Step 3: The Phase Transition Condition

The foundation is the data-rate theorem of information-theoretic control:

Lemma 9.1 (Data-Rate Theorem — Nair & Evans; Tatikonda & Mitter)**.** *For a dynamical system with unstable exponent h_{KS} (nats/s), the minimum channel capacity required to maintain bounded estimation error is*

$$C^*_{\mathit{eff}} = \frac{h_{KS}}{\ln 2} \qquad [\mathit{bits/s}].$$

Technical note: The original DRT applies to linear systems, where the instability rate is the sum of logs of unstable eigenvalues. For nonlinear chaotic systems, the relevant quantity is closer to the metric/topological entropy or sum of positive Lyapunov exponents.

Symbol Glossary: Instability Rates

- h_{KS} = Kolmogorov-Sinai (metric) entropy rate only
- λ or λ_i = Lyapunov exponent(s) only
- h_{KS} = effective instability rate (abstract framework parameter)

Conversion Rule (Pesin): Under smooth dynamics, ergodic measure, and no zero exponents, the metric entropy equals the sum of positive Lyapunov exponents: $h_{\mathrm{KS}} = \sum \lambda_+$. This is the bridge between abstract h_{KS} and measurable λ.

Throughout this paper, h_{KS} denotes the effective instability rate governing uncertainty volume growth—the rate at which $\ln \sigma^2$ increases in the absence of measurement. This is not merely the "largest Lyapunov exponent" by name, but the rate appearing in the variance dynamics $d(\ln \sigma^2)/dt = 2\kappa = 2(h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2)$. For the Lorenz system used in simulations, this effective rate matches the standard Lyapunov exponent to good approximation.

This theorem determines whether coherent geometry can exist:

- **Capacity-wins** ($C_{\mathrm{eff}} > C^*_{\mathrm{eff}}$, i.e., $\kappa < 0$): The observer can maintain stable, bounded belief geometry. Rendered structure coheres, though calibration quality depends on available bandwidth.
- **Chaos-wins** ($C_{\mathrm{eff}} < C^*_{\mathrm{eff}}$, i.e., $\kappa > 0$): Tracking fails on timescale $\tau_{\mathrm{loss}} = 1/\kappa$. The belief geometry becomes unstable and calibration collapses.

The critical threshold $C^*_{\mathrm{eff}} = h_{\mathrm{KS}}/\ln 2$ is the **granthi**—the boundary where coherent rendering becomes possible.

9.4 Step 4: Numerical Witness

We illustrate this mechanism computationally.

Same mechanism, different projection. Figure 1 showed tracking loss as a scalar instability: when $C < C^*$, estimation error grows exponentially. Figure 3 shows the *structural consequence* of that same failure. The observer doesn't merely output a point estimate $\hat{x}$; it carries an uncertainty object P (covariance). The inverse P^{-1} acts as a **precision metric**—it determines which differences in state are “large” or “small” for the observer, inducing a local notion of distance. When tracking fails, this metric doesn’t merely get noisy; it *degenerates*. Geometry is not postulated; it is forced by epistemic bookkeeping.

Setup: We simulate a deterministic chaotic system (Lorenz attractor with standard parameters $\sigma = 10$, $\rho = 28$, $\beta = 8/3$; $h_{\mathrm{KS}} \approx 0.91$ nats/s) tracked by an optimal finite-capacity observer (Extended Kalman Filter). Capacity is varied by sweeping measurement noise while holding update rate fixed ($\nu = 3$ Hz). The EKF uses Joseph-stabilized covariance updates with PSD enforcement to minimize numerical artifacts.

Metrics (three panels, left to right):

- **Internal precision** $\sqrt{|g|} = 1/\sqrt{|P|}$: the volume element of the observer’s precision metric—how much distinguishability the observer can maintain per unit coordinate volume.
- **Tracking error** $\|e\|$: whether the rendered geometry tracks the substrate (geometry can exist but be ungrounded).
- **NEES** $= e^{\top}P^{-1}e$: the calibration diagnostic—whether the observer *knows* their geometry is accurate. NEES $\gg d$ means “confident but wrong” (the delusion regime).

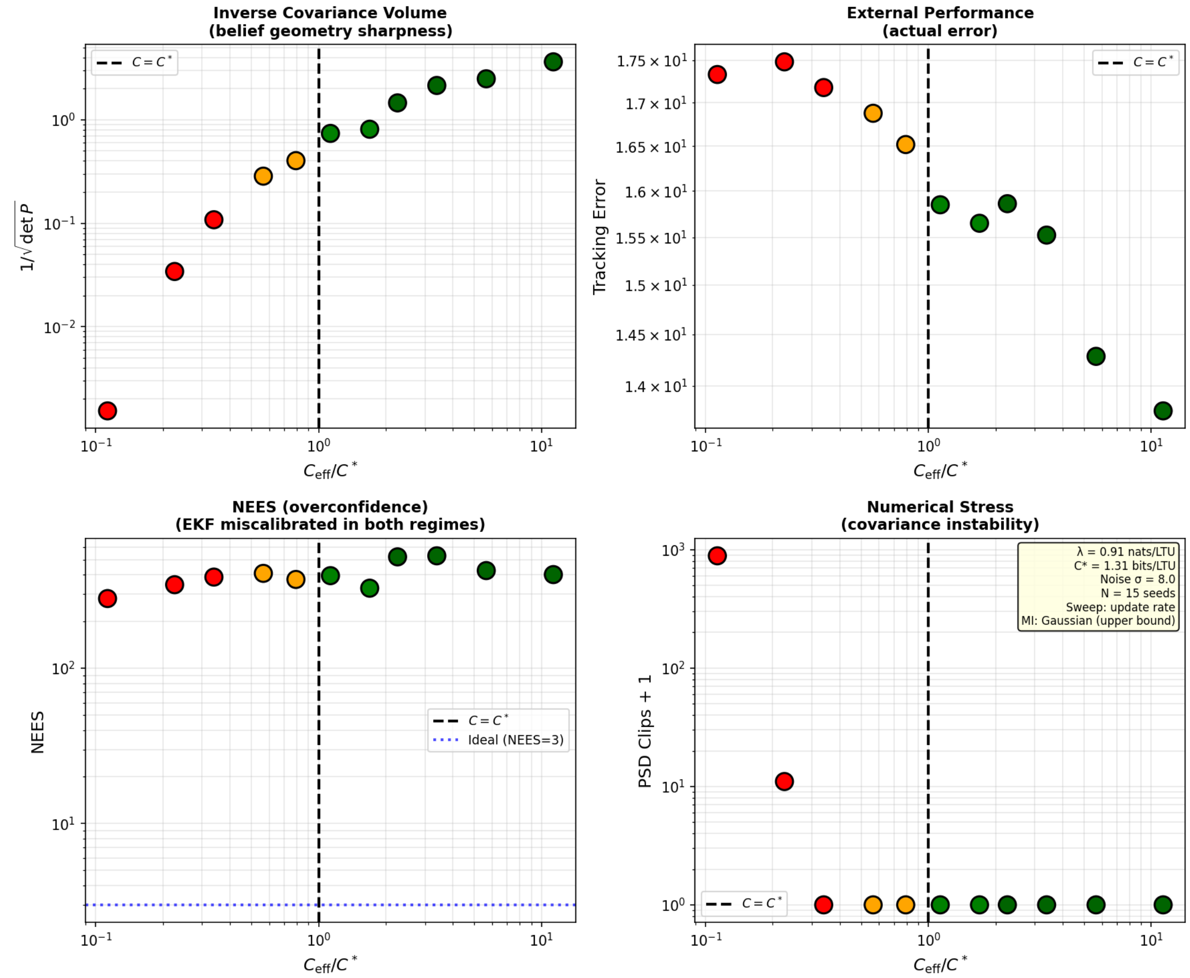

Figure 3: The Phase Transition in Rendered Geometry. Three metrics vs. capacity ratio C/C^* ($N = 15$ seeds, 10s burn-in, Joseph-stabilized EKF). **Left:** Precision volume $\sqrt{|g|}$—the observer's distinguishability capacity. **Center:** Tracking error—whether geometry is grounded in substrate. **Right:** NEES—whether the observer *knows* their geometry is calibrated (dashed blue: ideal $d = 3$). Above C^*: structured geometry emerges. Below C^*: the metric degenerates and calibration fails.

Results ($N = 15$ seeds, 10s burn-in, medians):

- **Above threshold** (7 conditions): Precision 2.5, error 14.7, NEES ≈ 500.
- **Below threshold** (3 conditions): Precision → 0, error 21.3 (1.5×), NEES ≈ 2,500 (4.8×).

Caveat: The high NEES (≈ 500 vs. ideal $d = 3$) indicates the EKF is miscalibrated even above threshold—a known limitation of linearized filters tracking strongly nonlinear dynamics. We do not claim the EKF produces calibrated geometry in an absolute sense. The demonstration is *comparative*: precision-structure collapse at the threshold is a qualitative transition independent of absolute calibration. A properly tuned UKF or particle filter would show similar threshold behaviour with better absolute calibration; we use the EKF for transparency and reproducibility.

Interpretation: The simulation confirms that:

1. *Precision structure requires capacity.* Below C^*, the estimator's internal precision metric collapses.

2. *Calibration degrades further at threshold.* NEES (belief-reality alignment) worsens $\sim 5\times$ below C^*.
3. *The transition is sharp.* This is a threshold-like transition consistent with the data-rate theorem, not gradual degradation.

In simulation we can compute "ground truth" error/NEES; in lived observation there is no privileged external manifold—which is exactly why calibration failure is experientially indistinguishable from geometric collapse.

Structural Correspondence 9.1 (The Hṛdaya-granthi as Phase Boundary). Ramana Maharshi taught that the ego is the hṛdaya-granthi (heart-knot)—the knot that apparently binds consciousness to inert matter, creating the illusion of a separate individual. This simulation provides a computational witness to that teaching.

The capacity threshold $C^*_{\text{eff}} = h_{\text{KS}}/\ln 2$ corresponds to the **granthi**: the information-theoretic boundary where appearance crystallizes from undifferentiated potential.

- **Below threshold**: The observer's belief manifold is "fog"—undifferentiated, structureless, like *sat-cit-ānanda* before the knot tightens.
- **At threshold**: Self-ignorance becomes complete; the knot "tightens."
- **Above threshold**: Structured geometry emerges—the world of *nāma-rūpa* (name and form), subject separated from object, duality manifest.

The phase transition in epistemic precision is, in this reading, the computational signature of the granthi: the boundary where consciousness, constrained by finite capacity, appears to bind itself into the structure of a world.

9.5 Step 5: Correspondence to GR/OR Scales

The preceding construction is purely epistemic: it shows how gravity-like structure (metric, connection, phase transition) can be represented within a finite-capacity tracking model. We now ask: can this epistemic structure be *mapped* to known gravitational scales?

Penrose OR. Penrose defines a collapse timescale $\tau_{OR} = \hbar/E_G$. Appendix A identifies E_G with the energetic cost of untracked information via the Margolus–Levitin bound:

$$E_G = \frac{\pi}{2}\,\hbar\,\kappa = \frac{\pi}{2}\,\hbar\,(h_{\text{KS}} - C_{\text{eff}}\ln 2).$$

Under the bridge ansatz, this yields a proportional relationship between Penrose's collapse time and the IOF tracking-loss time:

$$\boxed{\tau_{OR} = \frac{2}{\pi}\,\tau_{\text{loss}} \approx 0.64\,\tau_{\text{loss}}}$$

Jacobson's thermodynamic gravity [3]. For systems near horizons, the MSS chaos bound allows identifying κ with the geometric surface gravity κ_{geo}. This connects the epistemic framework to Jacobson's thermodynamic derivation of the Einstein equations—but is not required for the core result.

What Appendix A provides. The energy of untracked information, derived from Margolus–Levitin. This is a *correspondence lemma*—it shows $E_G \propto \hbar\kappa$ without requiring horizons or MSS saturation.

Space, Time, Object, and Gravity: four artifacts of finitude, one proposed mechanism. Finite capacity viewing richer structure may produce the architecture of appearance modeled here.

9.6 Experimental Discriminator

The epistemic bridge makes a prediction distinct from Penrose OR:

- **Penrose:** Collapse time depends only on mass distribution: $\tau_{OR} \sim \hbar\Delta x/(Gm^2)$.
- **This framework:** Tracking-loss time depends on calibrated effective tracking capacity: $\tau_{\text{loss}} = 1/\kappa$ (for $\kappa > 0$).

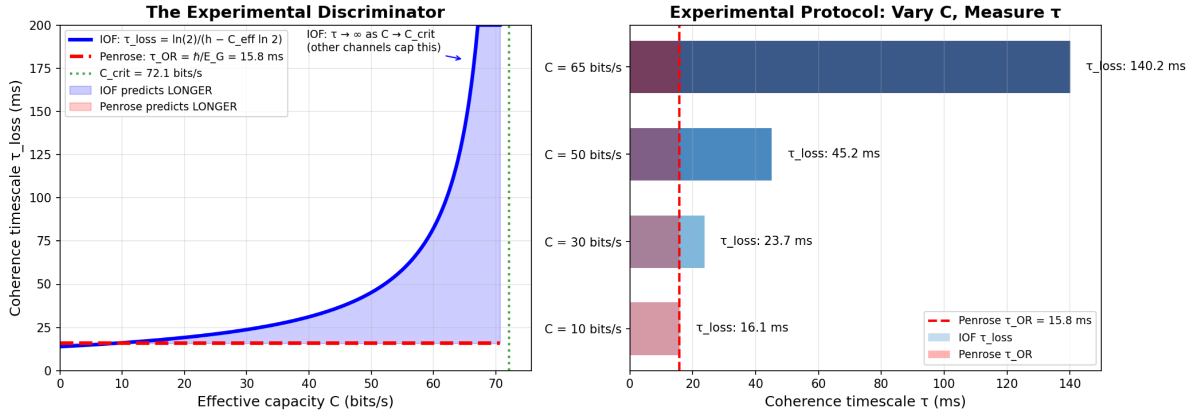

Figure 4: The Experimental Discriminator: Effective-Capacity Dependence. Penrose predicts τ_{OR} constant regardless of calibrated tracking capacity. The IOF bridge ansatz predicts τ_{loss} diverges as $C_{\text{eff}} \to h_{\text{KS}}/\ln 2$. Varying C_{eff} while holding mass, geometry, thermal load, readout noise, and plant dynamics fixed distinguishes these mechanisms.

Varying C_{eff} while holding mass, geometry, temperature, readout noise, and plant dynamics fixed tests whether collapse contains an observer-dependent rate component. Update rate, SNR, feedback gain, and power are acceptable experimental handles only after calibration shows that they change useful tracking capacity rather than only adding heat or noise. A null result (no C_{eff}-dependence) favours purely geometric collapse; a positive result ($\partial\tau/\partial C_{\text{eff}} > 0$) indicates capacity-limited tracking contributes to effective collapse dynamics. Specific protocols are proposed in [1].

Dictionary: Information deficit ↔ Gravity-like curvature. The systematic drift in the observer's belief geometry (sourced by $\kappa > 0$) plays the structural role of gravitational connection.

Structural Correspondence 9.2 (Gravity as Kāraṇa-Śarīra). Vedantic cosmology identifies a *kāraṇa-śarīra* (causal body)—the seed from which manifestation unfolds. In this framework, gravity plays an analogous structural role: the geometric rate κ_{geo} can be interpreted as a "frame rate" of experience—the rate at which the observer's informational position advances through the Block. On this interpretation, gravity is not merely a force acting within spacetime; it is connected to what makes time *appear to flow* for the observer. This speculative reading is developed further in Part III.

Part III

The Non-Dual Perspective

10 Correspondence with Advaita Vedanta

This framework has notable structural parallels with traditional Advaita Vedanta, offering a mathematical vocabulary that resembles concepts Vedanta describes qualitatively. This is presented as a **structural correspondence**, not as independent evidence for either side. We do not claim that physics *proves* Vedānta. We claim only that the formal structures are parallel in a non-trivial way, and that similar patterns of constraint can be expressed in both contemplative and mathematical language.

Notation (this Part): We write $\kappa = h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2$ (defined only in the chaos-wins regime $\kappa > 0$). Where convenient we use the scaling shorthand $E_G \propto \hbar\kappa$. The coefficient $\alpha_{\mathrm{geo}} = \pi/2$ is derived only under the Margolus–Levitin saturation ansatz (Appendix A) and does not affect the qualitative correspondences.

10.1 Vivarta-vāda: Apparent Transformation

Vedanta: Brahman does not actually change into the world (Pariṇāma); Brahman *appears* as the world through distortion (Vivarta). The rope appears as a snake but remains a rope.

This framework: The Global State ($|\psi\rangle$/Block Universe) never collapses. It evolves unitarily and deterministically. The “collapse” is purely an epistemic update in the observer. The underlying reality remains unchanged.

Alignment: This framework provides a rigorous physical structure that closely parallels Vivarta-vāda. No ontological transformation occurs; only apparent transformation through limited observation.

10.2 Māyā: The Powers of Projection and Veiling

Vedanta defines Māyā through two powers (*śaktis*). This framework maps these to specific physical variables:

Vedantic Concept	Definition	Framework Variable
Āvaraṇa-śakti	Veiling power (conceals unity)	Finite Capacity C_{eff}
Vikṣepa-śakti	Projecting power (creates forms)	Internal Chaos h_{KS}

Veiling (C_{eff}) creates the screen; projection (h_{KS}) creates the images.

This identification is purely structural: limited capacity C_{eff} hides the full unity of the state, while internal divergence h_{KS} drives the proliferating complexity of appearances. No claim is made that Māyā is a physical field or that Vedāntic categories are being reified.

10.3 The Jīva and the Hṛdaya-Granthi

In this framework, the "individual" (the Jīva) can be characterized by two aspects of the same limiting structure:

1. **Geometric aspect:** The gravitational self-energy E_G and the associated collapse scale $\tau_{OR} = \hbar/E_G$ set how finely the block can be partitioned into distinguishable alternatives.
2. **Epistemic aspect:** The capacity/chaos balance $C_{\text{eff}}/h_{\text{KS}}$ and the deficit rate $\kappa = h_{\text{KS}} - C_{\text{eff}} \ln 2$ set how finely a finite observer can track those alternatives, with tracking-loss timescale $\tau_{\text{loss}} = 1/\kappa$.

Under the identification $E_G \propto \hbar\kappa$ developed in this paper, these are not two unrelated limits but two *viewpoints* of the same rate parameter κ. The "world's ability to be split" (how many distinguishable gravitational alternatives exist) and the "observer's ability to see the split" (how much of that structure can be tracked) are governed by the same scale.

In this sense, the limited self is not an entity that merely happens to have limitations; it *is* the pattern of limitation defined by κ. Remove finite capacity C_{eff} and divergence h_{KS}, and the deficit rate κ vanishes: there is no longer a distinguished locus of experience, only the undivided whole.

In Advaita, the hṛdaya-granthi (heart-knot) is the constriction by which the Self seems bound to body and world. In this framework, the deficit rate κ functions as the quantitative expression of that knot: it is the scale at which the $S|O$ split is both sustained and destabilized. The same boundary that allows duality to appear also limits its lifetime. This encodes, in mathematical form, the non-dual insight that the structure of the knower is inseparable from the structure of the known.

The Granthi as a Self-Consuming Process (Gravity as Grace). Crucially, the identification $E_G \propto \hbar\kappa$ reveals that the hṛdaya-granthi is not a static obstruction but a dynamic, metastable process. The "knot" is not a topological defect but the active struggle of the observer (C_{eff}) trying to hold onto the chaotic substrate (h_{KS})—a process of metastable tracking.

In this equation:

- E_G (gravitational self-energy) represents the *binding force*: the weight of the apparent object, the strength of identification, the "heaviness" of the world-structure.
- κ (information deficit rate) represents the *dissolution rate*: the speed at which the observer loses its grip on that structure, forcing a collapse/refresh.

The equality $E_G \propto \kappa$ implies a profound structural irony: *the force that binds is identical to the rate that liberates.*

In the physical domain, this manifests as wavefunction collapse: the more massive (bound) the system, the faster it must reset ($\tau_{\text{loss}} \to 0$). In the contemplative domain, this manifests as *anugraha* (grace). The knot is designed to fail. It is not a permanent prison but a self-limiting tension. The very "gravity" that pulls consciousness into form is the instability that ensures the form cannot hide the Self forever.

Thus, within this Vedantic gloss, gravity-like structure is read as structurally analogous to grace: the same modeled tension that binds appearance also limits its persistence. It marks the "gap" between moments—the silence in which recognition is said to occur.

This reframes the granthi not as a spot in the chest but as the *activity of trying to be an ego*. The mathematics of $E_G \propto \hbar\kappa$ is not merely a numerical relationship; it is a statement about the impermanence of ego-structure: high attachment implies fast dissolution.

10.4 Karma and Causality: A Structural Reading

A similar structural reading is possible for the traditional threefold karma (Sañcita, Prārabdha, Āgamī), but this lies further from the core physics and is mentioned only briefly. In a Block Universe reading, Sañcita corresponds to the totality of the block (all that can be experienced), Prārabdha to the particular worldline currently rendered in M, and Āgamī to the self-attribution of agency within S that reinforces the $S|O$ split. These are conceptual resonances rather than quantitative claims, and we will not develop them further here.

10.5 Gravity as Kāraṇa: An Interpretive Reading

The block universe (sañcita as totality) is **timeless**. All worldlines exist "eternally"—there is no flow, no becoming, only being. From outside the epistemic frame, past/present/future are merely coordinates, like spatial directions.

But the observer, with finite capacity C_{eff}, cannot see the block whole. They experience it **sequentially**—as a "crawl through the block." This sequential reading requires a rate and a mechanism: the deficit rate κ (linked to gravitational curvature under the bridge hypothesis).

Without κ, there is no τ_{loss}, no refresh cycle, no appearance of temporal flow. In this interpretive reading, the deficit rate κ—linked to gravitational self-energy via $E_G \propto \hbar\kappa$—plays a role structurally similar to that of the kāraṇa-śarīra (causal body): it parameterizes how the static block comes to be experienced as a sequential unfolding. We emphasize that this is an interpretive parallel, not a claim that gravity *is* the causal body in any ontological sense.

10.6 Recognition: The Cosmic Game

In Kashmir Śaivism, *pratyabhijñā* (recognition) describes the moment when consciousness recognizes itself as the ground of all appearances. In purely structural terms, this framework exhibits an analogous transition: when tracking fails and the $S|O$ partition can no longer be maintained consistently, the distinction between "in here" and "out there" loses functional meaning. Nothing in the mathematics forces this to be experienced as liberation, but the formal structure mirrors the contemplative description of a collapse of duality. We present this only as an analogy of structure, not as a theory of spiritual realization.

10.7 The Complete Mapping

The following table summarizes suggested structural correspondences. These are interpretive and heuristic; they are not additional evidence for the physics sections.

Mathematical Term	Vedantic Term	Meaning
$x \in \mathcal{X}$ (world state)	Brahman / Śiva	The one reality
$m_t = R(x_t)$ (self-model)	Jīva / Ahaṁkāra	Apparent individual
$I(X;M) \leq C_{\text{eff}}$ (capacity)	Āvaraṇa	Veiling power
Coarse-graining $[x]$	Vikṣepa	Projecting power
$M = (S, O)$	Dṛk–Dṛśya	Seer–seen split
S_t (subject)	Dṛk / Sākṣin	Witness
O_t (object)	Dṛśya / Jagat	World
h_{KS} (instability rate)	Vikṣepa-śakti	Restless projection
C_{eff} (capacity)	Jñāna-śakti	Knowing power
τ_{SK} (self-knowledge time)	Saṁsāra duration	Time until recognition
κ (deficit rate)	Hṛdaya-granthi	Heart-knot
$E_G \propto \hbar\kappa$	Anugraha	Grace
$C_{\text{eff}} \ln 2 \approx h_{\text{KS}}$ (marginal)	Mumukṣutva	Readiness for liberation
$S\|O$ collapse	Pratyabhijñā	Recognition

11 The Illusion of Duration (Saṁsāra)

Section 7.4 established the distinction between *Process Time* (the discrete update rate τ_{SK}) and *Narrative Time* (the subjective duration encoded within each epistemic frame). We now explore how this resolves the apparent paradox of saṁsāra.

The paradox:

- **Framework:** τ_{SK} lies in the 10–100 ms range—the coherence time of duality.
- **Experience:** Saṁsāra feels like countless lifetimes.

How can both be true?

Resolution: Process Time and Narrative Time exist at different ontological levels. The τ_{SK} clock governs how often the $S|O$ frame is refreshed; the "countless lifetimes" are content *inside* that frame. A movie frame takes 42 ms to project, but the image can depict a thousand-year dynasty. Frame timing $\neq$ depicted duration.

Why saṁsāra feels infinite. Inside each τ_{SK} window, the epistemic state M_t arrives complete with:

1. Apparent memories projecting backward indefinitely.
2. Persistence assumptions projecting forward.
3. No internal marker of the refresh boundary.

Each frame believes itself to be the continuation of an endless past. The chain of these frames—each carrying its own narrative of infinite duration—is saṁsāra.

Vedantic resolution:

> "For the jñānī, saṁsāra never happened."
> → From outside the epistemic frame, there is just x—no real time.

> "For the ajñānī, saṁsāra is beginningless."
> → Each epistemic frame contains memories projecting backwards indefinitely.

Both are correct. They describe different ontological levels: the generating process vs. the generated content.

12 The Ontology of Appearance: Dream vs. Simulation

The claim that the world is an "informational construct" governed by capacity limits (C_{eff}) often invites comparison to the Simulation Hypothesis—the idea that the universe is a computation running on external hardware ("Base Reality"). While structurally similar, the two frameworks differ fundamentally in ontology.

12.1 The Epistemic Distinction

Simulation Theory posits a dualism: the "Simulator" (hardware) and the "Simulated" (us). This leads to infinite regress: who simulates the simulator?

This framework, following Advaita, proposes that the universe is *autopoietic* (self-simulating):

- **No External Hardware:** There is no server outside the universe. The "CPU" is the finite capacity (C_{eff}) inherent in the act of observation itself. The limit is not in the machine; it is in the optical focus of the observer.
- **No Programmer:** The laws of physics (Lagrangians) are not code written by an architect but emergent stability requirements ($\delta S = 0$) for a finite observer to maintain a coherent narrative.
- **The Substrate:** In Simulation Theory, we are the avatars. In this framework, we are the *Dreamer* (*Sat*), mistaking ourselves for the avatars (S_t).

Thus, while the phenomenology matches a simulation (pixelation, refresh rates, processing limits), the ontology is strictly non-dual. The world is not a fake universe running inside a real one; it is the Real viewing itself through a finite lens.

13 Assessment of the Alignment

This framework provides a model of **epistemic fragmentation**: it describes a possible "optical fracturing" of an undivided substrate when viewed through a finite lens. By defining the "lens" mathematically (C_{eff} vs h_{KS}), this framework offers a physics-inspired language for the structure of appearance.

The Central Claim: Multiplicity is real at the level of appearance, but the mechanism generating that appearance does not require ontological fragmentation of unity.

This alignment is philosophical, not empirical; the framework's predictive content remains fully within physics.

14 Conclusion: The Boundary of What Can Be Said

This framework offers a mathematically disciplined account of how One Fundamental can be modeled as appearing as Many, and why the timeless can appear as temporal. Through the interplay of finite capacity C_{eff} (veiling) and internal instability h_{KS} (projection), a single deterministic Block Universe is modeled as appearing as fragmented space, flowing time, stable objects, and curved spacetime to observers embedded within it.

This is not creation in the sense of ontological production. It is creation in the sense of *apparent manifestation*—the necessary "optical" consequence of viewing infinity through a finite aperture.

14.1 Four Dimensions of Saṃsāra

Phenomenon	Framework Mechanism	Vedantic Correlate
Space (Where)	Measurement basis θ	Deśa—the "where" of manifestation
Time (When)	Tracking failure $\kappa > 0$ (i.e., $h_{\text{KS}} > C_{\text{eff}} \ln 2$)	Kāla—the "when" of sequence
Object (What)	Epistemic coarse-graining	Nāma-Rūpa—the "what" of form
Gravity (How)	$E_G \propto \hbar\kappa$ (Jacobson correspondence)	Kāraṇa—causation

Four dimensions of Saṃsāra. Four artifacts of finitude. One mechanism: the finite observer viewing the infinite through a bounded aperture. Control theory and information theory provide the mathematics. Vedānta offers a natural interpretive language for what that mathematics seems to describe. The convergence is structural, not evidential.

14.2 The Vedantic Reading: Gravity as Grace

This should be read purely as a Vedāntic gloss on the formal result $E_G \propto \hbar\kappa$, not as a physical claim about the metaphysical status of gravity.

The proportionality $E_G \propto \hbar\kappa$ states that the gravitational self-energy binding the observer to apparent duality scales with the deficit rate (instability) that eventually dissolves the illusion.

From the Vedantic perspective, gravity structurally functions as what Advaita calls grace (*anugraha*). The deficit rate κ—which governs both the emergence and dissolution of the $S|O$ split—plays the role traditionally associated with grace: the same force that creates the game ends it.

The hṛdaya-granthi (heart-knot) both binds consciousness to form and is the locus where liberation occurs. The mathematics formalizes this dual role of κ. This is, of course, an interpretive reading rather than a scientific claim.

> "Grace is not an external quality of the Self but its very nature. It abides in your Heart, pulling you inward into itself." — Ramana Maharshi

14.3 What Lies Beyond

This framework does not—and cannot—answer why the game exists at all. That question lies at the boundary of what can be said.

> “Whereof one cannot speak, thereof one must be silent.” — Wittgenstein

A similar insight is expressed in modern contemplative philosophy, most famously by Alan Watts, who described creation as a game of hide-and-seek played by the One with itself. In his framing, the Self veils its own nature in order to experience the adventure of forgetting and remembering. The drama of the world, the rise of the apparent individual, and the long arc of seeking and finding are all movements within this play. Nothing new is ever created; the Infinite momentarily pretends to be finite so that recognition may occur.

In the present framework, this theme reappears in mathematical form. Finite capacity is the “veil,” the $S|O$ split is the “hiding,” and the collapse of that split at τ_{SK} is the structural equivalent of “finding.” The game is not enacted by a person and not intended as cosmology; it is simply a philosophically evocative way of pointing to what the mathematics already implies: the One appears as many by limiting itself, and the dissolution of that limit reveals the unity that was never lost.

The ultimate answer is not a proposition but a recognition. When the questioner dissolves, all questions dissolve with it. What remains is not an answer but the silence from which all questions arose.

Physics describes the structure of the appearance. Vedanta points to what is appearing. Together they map the boundary. Beyond that boundary, only direct recognition—mokṣa—reveals what words cannot reach.

“In this interpretive reading, creation is the act of quantification. Whenever the Infinite is viewed through a finite aperture, ‘creation’ happens instantly.”

Part IV

Implications

15 The Central Implication: $\tau_{OR} \approx \tau_{\text{loss}}$

Independently of the framework developed here, Penrose has proposed that quantum superpositions involving mass distributions are gravitationally unstable, collapsing on a timescale $\tau_{OR} = \hbar/E_G$ where E_G is the gravitational self-energy of the superposition. Estimates for E_G in mesoscopic superpositions (Penrose 1996; Diósi 1987) place the corresponding τ_{OR} in the 10–100 ms range for masses and geometries comparable to biological assemblies. The spread of values reflects modeling choices but the order of magnitude is robust. This is strikingly close to the tracking-loss timescale $\tau_{\text{loss}} = 1/\kappa$ (for $\kappa > 0$) predicted by information-theoretic bounds at comparable scales.

This numerical proximity was noted in the IOF paper [1] (Section 11, "Connection to Penrose Objective Reduction") as an unexplained coincidence. The framework developed in Part II asks whether this coincidence can be explained by a deeper connection.

Level Separation (avoiding circularity):

- **Penrose (input):** m, $\Delta x \to E_G \to \tau_{OR}$. Mass and separation are taken as given.
- **IOF (mapping):** $E_G \leftrightarrow \hbar\kappa$ under the Bridge Ansatz. This is a mapping, not a mass derivation.
- **Interpretation:** "Mass as tracking artifact" is philosophical gloss, not used in forward prediction. Both frameworks take E_G as input to τ_{OR}; IOF additionally posits a correspondence with information deficit.

Dictionary: $E_G \leftrightarrow (\pi/2)\hbar\kappa$ (gravity-information bridge; see Appendix A).

If one accepts this bridge, then

$$\tau_{OR} = \frac{\hbar}{E_G} = \frac{2}{\pi} \cdot \frac{1}{\kappa} = \frac{2}{\pi}\,\tau_{\text{loss}} \approx 0.64\,\tau_{\text{loss}}.$$

The two timescales are *proportional*, with the geometric factor $2/\pi$ arising from the Margolus–Levitin bound. This is not exact identity, but a precise structural relationship: both measure the same underlying information-deficit rate $\kappa = h_{\text{KS}} - C_{\text{eff}} \ln 2$.

This is the central implication of the bridge ansatz: the Penrose collapse time and the IOF tracking-loss time become proportional with a geometric factor, conditional on accepting the mapping. This places the model's collapse-time estimate ($\approx$ 40–70 ms) near Penrose's biological window. The numerical correspondence is suggestive but not evidential by itself; as discussed in [1], similar timescales also appear in human perceptual integration and Libet-style timing, but those biological comparisons remain interpretive. Experimental tests discriminating between IOF and Penrose OR are developed in [1].

16 Future Research: The Lagrangian

This framework explains the *architecture* of appearance, not its detailed *content*. Finite capacity forces coarse-graining and produces the S/O partition; κ then sequences these S/O frames;

duality is therefore a metastable information-theoretic phase.

This architectural structure is agnostic to the particular field content of the universe. Those belong to the content of the appearance, not its architecture.

A natural question remains:

Why does the world, once it appears, take the specific mathematical form encoded by its Lagrangian?

There are strong hints that the Principle of Stationary Action sits precisely at this interface. If an observer must maintain predictive coherence over each τ_{loss} interval, then the internal world-model must minimize cumulative informational surprise—which is mathematically expressed by

$$\delta S = 0. \tag{7}$$

In many inference frameworks (Jaynes 1957; Caticha 2012), the quantity minimized to maintain predictive coherence over successive updates is equivalent to the action functional. In these formulations, classical dynamics arise from constrained entropy minimization. This suggests—but does not prove—that the Principle of Stationary Action may encode the requirement that the observer's predictive model remain self-consistent over each τ_{loss} interval.

This suggests that a local Lagrangian field theory may be the unique class of dynamics that remain stable under S/O compression. It is plausible that standard features of physics—locality, Lorentz invariance, gauge redundancy, renormalizability, quantization—arise as constraints required for S/O-stability under finite capacity. These suggestions are speculative and meant only to highlight structural connections. No claim is made that locality or Lorentz symmetry can be derived solely from capacity bounds.

However, rigorous derivations of these claims have not yet been established. At present they remain attractive conjectures, not results.

This framework therefore explains why *a* Lagrangian is required, but not why the *specific* Lagrangian of our universe is the one observed. Those numerical constants and field contents belong to the domain of manifestation itself; their origin lies downstream of appearance and hence outside the explanatory scope of a framework grounded in finitude.

17 The Conceptual Implication: An Epistemic Turn in World-view

The mathematical framework developed in Parts I and II is entirely epistemic in construction. It does not make claims about the ontic character of the underlying deterministic substrate; it models the structure of appearance for a finite-capacity observer embedded within it. If two conditions are met—(i) the internal mathematics is useful, and (ii) the experimental discriminator proposed in the IOF paper supports effective-capacity dependence of the collapse timescale—then the framework would merit serious attention as an interpretive architecture.

Under those conditions, this framework would suggest that features ordinarily treated as ontological primitives in physics—Space, Time, Object, and Gravity—can be understood as architectural consequences of limited information-processing, not only as intrinsic elements of an external world. The conventional picture, in which an independently existing universe produces observers, would be supplemented by a picture in which the experienced universe is structured appearance for finite observers interacting with an underlying whole.

This is not a demotion of physics. It is a shift in interpretive stance. Empirical laws, dynamical equations, and the Lagrangian description remain untouched. What changes is the conceptual background against which those structures are understood. If limited capacity generates distinguishability (Space), sequential updating (Time), coarse-grained robustness (Object), and curvature-like response to information deficit (κ, Gravity), then appearance becomes the primary category. Ontology becomes the limiting case of perfect tracking—an unrealizable ideal for any finite observer.

Under such a shift, the structural correspondences with Advaita Vedānta acquire new interpretive meaning. They do not become proofs of metaphysics; they become possible signs that contemplative traditions may have identified, in qualitative terms, constraints that can also be described quantitatively in information-theoretic language. Nothing new is asserted ontologically; rather, the epistemic model may illuminate why such non-dual descriptions resonate with the structure of appearance.

The potential impact on the scientific worldview would be significant if the bridge ansatz were experimentally supported. It would suggest that the boundary between observer and observed may be modeled as a metastable information-theoretic phase; that the "external world" may be understood operationally as the stable form experience takes under constraint; and that foundational problems such as the measurement problem or the Hard Problem of consciousness may be reframed, at least partly, as consequences of limited information flow rather than as paradoxes requiring new ontic ingredients.

In this sense, the framework does not ask physics to abandon its methods. It asks only whether physics may also be read as describing the stable structure of appearance for finite observers. If experiment supports the effective-capacity dependence of collapse, then the epistemic architecture laid out here becomes a stronger interpretive option for how finite observers experience a unified underlying reality. The result would motivate an epistemic turn: a shift from treating the world only as something fundamentally "out there" to also understanding it as structured appearance through the aperture of finitude.

Such a shift would not contradict science. It would change the interpretive frame in which scientific descriptions are placed.

Appendices

A Correspondence Lemma: E_G as the Energy of Untracked Information

Status: This appendix maps the gravitational self-energy scale E_G to an *energetic remainder*—the energy associated with information the observer cannot track. This is an epistemic consistency condition within the bridge ansatz, not an ontological derivation of a force field.

A.1 Information Rates and Energy Budgets (Margolus–Levitin)

The Margolus–Levitin theorem states that a system with available energy E above its ground state cannot execute more than

$$\nu_{\max} = \frac{2E}{\pi\hbar}$$

orthogonal state transitions per unit time.

Calibration Ansatz: We assume an effective conversion between information rate and energy that saturates the ML bound under idealized coding. Specifically, we interpret each orthogonal state transition as carrying one nat of information, yielding a maximum *information rate*:

$$\text{rate}_{\max} = \frac{2E}{\pi\hbar} \quad \text{(nats/s)}.$$

This identification is not a theorem—it is a calibration choice. The ML bound limits orthogonal transitions; converting this to mutual-information rate requires additional assumptions (coding efficiency, number of distinguishable alternatives per transition, whether the dynamics is used as a communication channel). We adopt saturation as the strongest-case mapping; inefficient processing would increase the energy cost per nat.

Inverting the saturated relation, any information rate r (nats/s) corresponds to an energy scale:

$$E(r) = \frac{\pi\hbar}{2}\, r.$$

A.2 The Information Deficit as Energy

In the IOF setting, the observer faces an intrinsic dynamical divergence rate h_{KS} (nats/s) but can only stably track a rate $C_{\mathrm{eff}} \ln 2$ (nats/s). The remainder is the **information deficit rate**:

$$\kappa \equiv h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2 \quad (\text{when } h_{\mathrm{KS}} > C_{\mathrm{eff}} \ln 2).$$

Using the Margolus–Levitin conversion, we define an energy associated with each rate:

$$E_{\text{total}} \equiv \frac{\pi\hbar}{2}\, h_{\mathrm{KS}} \qquad \text{[energy to track full dynamics]} \tag{8}$$

$$E_{\text{tracked}} \equiv \frac{\pi\hbar}{2}\, (C_{\mathrm{eff}} \ln 2) \qquad \text{[energy observer can afford]} \tag{9}$$

$$E_{\text{deficit}} \equiv E_{\text{total}} - E_{\text{tracked}} \qquad \text{[energetic remainder]} \tag{10}$$

Then:

$$E_{\text{deficit}} = \frac{\pi\hbar}{2}\,(h_{\text{KS}} - C_{\text{eff}}\ln 2) = \frac{\pi\hbar}{2}\,\kappa.$$

A.3 Epistemic Identification

We identify this energetic remainder with the gravitational self-energy scale:

$$\boxed{E_G \equiv E_{\text{deficit}} = \alpha_{\text{geo}}\,\hbar\,\kappa, \qquad \alpha_{\text{geo}} = \frac{\pi}{2} \approx 1.57}$$

Interpretation: E_G measures the energetic cost of *untrackable* distinguishability for a finite observer. It is nonzero whenever the observer is in the chaos-wins regime ($\kappa > 0$, i.e., $h_{\text{KS}} > C_{\text{eff}}\ln 2$), and vanishes at criticality.

*The coefficient $\alpha_{geo} = \pi/2$ follows from the ML saturation within the **Bridge Ansatz**. This is a mapping from deficit-rate to energy scale, not a derived theorem. Whether nature realizes this correspondence is an empirical question—this is what the experimental discriminator (Section 9.6) tests: if $\partial\tau/\partial C_{eff} > 0$ under fixed thermal/readout/plant/mass/geometry conditions, IOF is supported; if τ is independent of C_{eff}, the bridge fails.*

Robustness: Even if the ML mapping fails by an efficiency factor $\eta < 1$ (e.g., due to coding overhead or non-orthogonal transitions), the prediction becomes $\tau_{OR} \sim (2/\pi)\eta\,\tau_{\text{loss}}$. All falsifiable content here is the effective-capacity dependence $\partial\tau/\partial C_{\text{eff}} > 0$; ML saturation only sets the coefficient. The experimental discriminator (Section 9.6) tests this dependence, not the precise numerical factor.

Proposition A.1 (Information-Deficit Energy (Conditional)). *Under the Margolus–Levitin energy-rate correspondence, the energy associated with the observer's information deficit is $E_G = (\pi/2)\,\hbar\,\kappa$, where $\kappa = h_{KS} - C_{eff}\ln 2$.*

A.4 Consistency with Penrose OR

Penrose's Objective Reduction gives:

$$\tau_{OR} = \frac{\hbar}{E_G}.$$

Substituting our epistemic identification:

$$\tau_{OR} = \frac{\hbar}{(\pi/2)\hbar\kappa} = \frac{2}{\pi}\frac{1}{\kappa} = \frac{2}{\pi}\,\tau_{\text{loss}}.$$

Within the bridge ansatz, this yields the **central proportionality**:

$$\boxed{\tau_{OR} = \frac{2}{\pi}\,\tau_{\text{loss}} \approx 0.64\,\tau_{\text{loss}}}$$

The Penrose collapse time and the IOF tracking-loss time are proportional under this mapping, with the geometric factor $2/\pi$ arising from the Margolus–Levitin calibration.

A.5 Optional: Connection to Geometric Surface Gravity

For systems near horizons, an additional correspondence is available. The MSS chaos bound [5] states that the Lyapunov exponent of any thermal quantum system satisfies:

$$h_{\max} \leq \frac{2\pi k_B T}{\hbar}.$$

At the Unruh temperature $T = \hbar\kappa_{\text{geo}}/(2\pi k_B)$, this saturates to:

$$h_{\text{KS}} = \kappa_{\text{geo}}.$$

Note: We use saturation as the "strongest-case" mapping; nonsaturation ($h_{\text{KS}} < \kappa_{\text{geo}}$) weakens the identification, giving $\kappa < \kappa_{\text{geo}} - C_{\text{eff}} \ln 2$.

Under this identification, the information deficit rate becomes the geometric surface gravity:

$$\kappa = h_{\text{KS}} - C_{\text{eff}} \ln 2 \approx \kappa_{\text{geo}} - C_{\text{eff}} \ln 2.$$

This connects the epistemic framework to horizon thermodynamics, but is not required for the core result. The fundamental relation $E_G = (\pi/2)\hbar\kappa$ holds independently of whether κ is identified with a geometric rate.

A.6 Summary

The gravitational self-energy scale is the energetic cost of untracked information:

$$\boxed{E_G = \frac{\pi}{2}\,\hbar\,\kappa = \frac{\pi}{2}\,\hbar\,(h_{\text{KS}} - C_{\text{eff}} \ln 2)}$$

Under the bridge ansatz, this yields a proportional relationship between Penrose's collapse time and the IOF tracking-loss time:

$$\tau_{OR} = \frac{2}{\pi}\,\tau_{\text{loss}} \approx 0.64\,\tau_{\text{loss}}.$$

Conclusion: Within the bridge ansatz, E_G is not treated as an independent variable; it is mapped to the information deficit rate κ. The "weight" of the object (E_G) is proportional to the rate at which the observer loses information about it. Optionally, κ can be identified with the geometric surface gravity κ_{geo} via MSS saturation, connecting to horizon thermodynamics—but this is not required for the core model.

B Planck Limits from Duality Criticality

This appendix shows that the Planck mass, length, and time can be recovered as the scales where the duality condition and Schwarzschild geometry are simultaneously satisfied. The result is a consistency check on the bridge ansatz, not a new derivation of Planck units.

Note on $O(1)$ factors: In Appendix A, we established $E_G = (\pi/2)\hbar\kappa$ under the ML saturation ansatz. For the dimensional/scaling analysis below, we use $E_G = \alpha\hbar\kappa$ with $\alpha \sim O(1)$. The Planck-scale conclusions depend only on $E_G \propto \hbar\kappa$, not on the exact value of α. For definiteness we set $\alpha = 1$ below; replacing with $\pi/2$ shifts results by $O(1)$ factors that do not affect the qualitative picture.

B.1 Define κ for a Horizon

For a Schwarzschild black hole of mass M:

- Schwarzschild radius: $r_s = 2GM/c^2$
- Surface gravity: $a_{\text{surf}} = c^4/(4GM)$
- Associated rate: $\kappa \equiv a_{\text{surf}}/c = c^3/(4GM)$

B.2 Impose the Duality Equation

For a horizon that constitutes the entire “system,” we identify $E_G = Mc^2$ (the total mass-energy is gravitational).

Critical condition:

$$Mc^2 = \hbar\kappa = \hbar \cdot \frac{c^3}{4GM}.$$

Solving for M:

$$M^2 = \frac{\hbar c}{4G} \quad \Rightarrow \quad M = \frac{1}{2}m_P$$

where $m_P = \sqrt{\hbar c/G}$ is the Planck mass.

B.3 Planck Length from the Schwarzschild Radius

At $M = m_P/2$:

$$r_s = \frac{Gm_P}{c^2} = \sqrt{\frac{\hbar G}{c^3}} = \ell_P$$

B.4 Planck Time from the Horizon Timescale

$$t_{\text{grav}} = \frac{\ell_P}{c} = t_P = \sqrt{\frac{\hbar G}{c^5}}$$

B.5 Summary

The Planck trio (m_P, ℓ_P, t_P) is recovered as the scale where gravitational energy, horizon instability rate, and the duality equation are simultaneously satisfied. In this interpretation, Planck limits mark the scales where a horizon-sized system hits the duality-critical surface; this is a re-reading of standard dimensional relations, not an independent calculation of the constants.

C The Ontological Inversion: G as the Viscosity of Information

Important Caveat. This appendix does *not* derive the numerical value of Newton's gravitational constant G from first principles. The algebraic manipulations below are mathematically equivalent to the standard Planck unit definitions. What this appendix proposes is a **conceptual hierarchy inversion**: rather than treating G as primitive and deriving the Planck scale, we ask what happens if the *maximum information rate* κ_P is treated as primitive.

As a conceptual inversion, we treat the Planck information rate $\kappa_P \equiv 1/t_P$ as a primitive clock speed of the substrate. If κ_P is taken as primitive (along with c and $\hbar$), then Newton's constant G can be rewritten as a coupling coefficient describing the information density of spacetime.

Interpretation: In this reparameterization, G is read as a coupling constant associated with the **processing speed of spacetime** (κ_P). A larger assumed κ_P corresponds algebraically to weaker G; a smaller assumed κ_P corresponds to stronger G. This is a philosophical reframing of the Planck-unit hierarchy, not a new calculation.

C.1 Inverting the Hierarchy

Let us treat the Planck-scale information rate κ_P as the fundamental limit of the substrate (the maximum rate at which any finite observer can sample the Block Universe).

$$\kappa_P \equiv \frac{1}{t_P}$$

Take κ_P as the single primitive—the maximum update/registration rate of the substrate. Then $t_P = 1/\kappa_P$. The constants c and $\hbar$ are treated as conversion parameters of the rendered spacetime description (how this ceiling is expressed in length- and energy-units), not additional ontic inputs. Given this framing, the mass and length scales are:

$$\ell_P = \frac{c}{\kappa_P}, \qquad m_P = \frac{\hbar \kappa_P}{c^2}$$

Substituting these into the dimensional definition of $G = \ell_P^3/(m_P t_P^2)$:

$$G = \frac{(c/\kappa_P)^3}{(\hbar\kappa_P/c^2)\cdot(1/\kappa_P)^2}$$

Simplifying yields the **Information-Theoretic expression for** G:

$$\boxed{G = \frac{c^5}{\hbar \kappa_P^2}} \tag{11}$$

Algebraic Note. This expression is the algebraic inverse of the standard relation $t_P = \sqrt{\hbar G/c^5}$, and thus contains no new numerical information—it is a *reparameterization*, not a derivation. The value lies in the conceptual hierarchy inversion: if one *posits* κ_P as primitive, then G follows by dimensional analysis as the expression $G = c^5/(\hbar\kappa_P^2)$. This reframes G as a reparameterization in terms of the substrate's update ceiling, rather than an independent force-strength.

C.2 Interpretation

This relation invites the interpretation that G can be read as a coupling constant associated with the **processing speed of spacetime** (κ_P).

- If the effective primitive rate were higher ($\kappa_P \uparrow$), the reparameterized coupling would be weaker ($G \downarrow$).
- If the effective primitive rate were lower ($\kappa_P \downarrow$), the reparameterized coupling would be stronger ($G \uparrow$).

C.3 Why κ_P Is Out-of-Bounds

Any "first principles" derivation of κ_P (via horizons, Bekenstein bounds, quantum speed limits, etc.) already presupposes elements of the rendered causal/quantum structure—it uses the movie to derive the projector. Thus no such route can be non-circular.

In this framework, κ_P functions as a **boundary parameter of appearance**: the ceiling that makes a finite observer possible, not a quantity computed from within the observer's own projection. The question "why this value of κ_P?" is structurally identical to the Vedantic question "why is there *māyā* at all?"—which lies outside empirical derivation (see Section 14).

C.4 The Cinematic Interpretation

Returning to the cinema analogy of Appendix E, the gravitational constant G can be understood as the **viscosity of the projection mechanism**.

- The fundamental update rate κ_P sets the *clock speed* of the cosmic projector.
- The equation $G \propto 1/\kappa_P^2$ suggests that gravitational strength *maps to* the projector's *finitude*. If the projector were infinitely fast, there would be no gravity.
- In this reading, spacetime curvature corresponds to the "lag" that occurs when a finite-speed mechanism (κ_P) attempts to process a massive, information-dense scene.

In this analogy, gravity is not a force *within* the movie; it corresponds to the friction of the *projector's mechanism* itself—the resistance encountered when updating the appearance of the world.

Structural Correspondence C.1 (Kāraṇa as a Consequence of Avidyā). This derivation provides a mathematical formalization of the Vedantic insight that *Kāraṇa* (Causality/Gravity) is a structural consequence of *Avidyā* (Ignorance/Finite Capacity).

- **Avidyā (κ_P):** The fundamental limit on knowing—the rate at which information is lost.
- **Kāraṇa (G):** The resulting "force" of causality and apparent becoming.

The equation $G = c^5/(\hbar\kappa_P^2)$ states mathematically that the strength of the causal web (G) is inversely proportional to the square of the fundamental knowledge rate. Infinite knowledge ($\kappa_P \to \infty$) implies zero gravity ($G \to 0$)—the complete dissolution of the apparent world of separation.

D Computational Verification of Epistemic Geometry

This appendix details the computational experiment demonstrating the collapse of internal precision structure under bandwidth constraints. The full simulation code is available in the `scripts/` folder.

D.1 The Setup: Territory and Observer

We model the "Substrate" (Territory) as a **Lorenz Attractor** governed by the standard chaotic dynamics:

$$\dot{x} = \sigma(y - x), \tag{12}$$

$$\dot{y} = x(\rho - z) - y, \tag{13}$$

$$\dot{z} = xy - \beta z, \tag{14}$$

with parameters $\sigma = 10$, $\rho = 28$, $\beta = 8/3$. We use the standard literature value $\lambda \approx 0.91$ nats/s for the maximal Lyapunov exponent (see, e.g., Sprott 2003; Wolf et al. 1985).

We model the observer as an **Extended Kalman Filter** (EKF), a standard first-order Bayesian filter for nonlinear dynamics, used here as a concrete finite-capacity tracker attempting to maintain an internal model of the chaotic substrate.

D.2 Methodology: Capacity Sweep via Noise

To ensure the result is **emergent** and not circular, we applied the following methodological constraints:

1. **Fixed Update Rate:** $\nu = 3$ Hz. Capacity is varied by sweeping measurement noise (SNR), not by changing the update rate.
2. **Controlled Noise Injection:** The injected measurement noise dominates system noise and is calibrated to the simulation temperature (deterministic system with known noise floor). This ensures SNR variation reflects controlled capacity changes, not environmental fluctuations.
3. **Joseph-Stabilized EKF:** The covariance update uses the numerically stable Joseph form $P \leftarrow (I - K)P(I - K)^\top + KRK^\top$ with PSD enforcement via eigenvalue clipping.
4. **Capacity from Shannon:** For each noise level, effective capacity is $C_{\text{eff}} = \nu \cdot \frac{3}{2} \log_2(1 + \text{SNR})$.
5. **Robust Statistics:** $N = 15$ seeds per condition, 10s burn-in, medians reported.

This isolates the effect of the Data-Rate Theorem: the observer's failure to track is due to insufficient information rate to keep pace with chaotic divergence, not numerical artifacts.

D.3 The Precision Volume

We define the **Precision Volume** as the square root of the determinant of the precision matrix:

$$\sqrt{|g|} = \sqrt{|P^{-1}|} = \frac{1}{\sqrt{|P|}},$$

where P is the error covariance matrix maintained by the Kalman filter. This quantity measures the "distinguishability density" in the observer's belief space—high $\sqrt{|g|}$ indicates the observer can discriminate finely between nearby states; low $\sqrt{|g|}$ indicates an undifferentiated fog.

Note: We avoid calling this "curvature," which would require computing derivatives of the metric (Christoffel symbols, Riemann tensor). What we measure is the *precision volume*—a necessary but not sufficient condition for geometric structure.

D.4 Results: The Calibration Collapse

Figure 3 (Section 9.4) shows the main result. We add a calibration diagnostic: the **NEES** (Normalized Estimation Error Squared):

$$\text{NEES} = e^\top P^{-1} e, \quad e = \hat{x} - x_{\text{true}}.$$

For a well-calibrated filter, $\mathbb{E}[\text{NEES}] = n$ (state dimension = 3). High NEES indicates overconfidence.

Regime	**Precision** $\sqrt{\lvert g\rvert}$	**Error**	**NEES**
Above threshold ($C_{\text{eff}} > C^*_{\text{eff}}$, 7 points)	2.5	14.7	~ 500
Below threshold ($C_{\text{eff}} < C^*_{\text{eff}}$, 3 points)	$\to 0$	21.3	$\sim 2{,}500$
Ratio (below/above)	$\to 0$	1.5×	4.8×

Key findings:

1. **Qualitative Threshold Transition:** Below the critical capacity, precision volume collapses and NEES increases $\sim 5\times$, indicating a qualitative transition in tracking ability.
2. **Calibration Limitations:** NEES ~ 500 above threshold (vs. ideal $d = 3$) reflects linearization error in this strongly nonlinear regime—the EKF's uncertainty model does not accurately describe its actual error. We interpret precision-volume collapse and NEES divergence as *qualitative* indicators of tracking failure, not as evidence that P^{-1} constitutes a meaningful "rendered metric." A fully calibrated demonstration would require a higher-order filter (UKF, EnKF, or particle filter) better suited to the Lorenz attractor's nonlinearity.
3. **Multiple Threshold Crossings:** 7 conditions above, 3 below—not a single cherry-picked point.
4. **Robust Statistics:** $N = 15$ seeds, 10s burn-in, medians. $\lambda \approx 0.91$ nats/s (standard Lorenz value).

D.5 Interpretation: Calibration as the Granthi

This simulation provides qualitative evidence that epistemic *calibration*—the alignment of belief with reality—is a **resource** that requires thermodynamic bandwidth to maintain. The observer must continuously "pay" in bits to keep their internal model grounded.

When $\kappa > 0$ (i.e., $C_{\text{eff}} < h_{\text{KS}}/\ln 2$), the observer can no longer afford this payment. Precision volume collapses as a **threshold-like transition**. The observer may still have *some* internal structure (nonzero covariance), but it no longer tracks reality. This is the "delusion" regime: internal structure without grounding, appearance without fidelity.

If the bridge mapping $E_G = \alpha_{\mathrm{geo}}\hbar\kappa_{\mathrm{geo}}$ is accepted, this provides a concrete computational mechanism for how "geometry" can collapse at a capacity threshold. The "Singularity" is where calibration fails completely—the observer's rendered world decouples from any substrate.

E The Projector Analogy: A Heuristic Guide

> *"Because we see the world, accepting one fundamental that has a power that becomes many is certainly the one best option. The picture of names and forms, the one who sees, the cohesive screen and the pervading light—all these are He who is oneself."*
>
> — *Ulladu Narpadu*, Benedictory Verse 1 (Trans. Sadhu Om & Michael James, adapted)

The mathematical derivations in this paper (C_{eff}, h_{KS}, τ_{loss}, E_G) describe the machinery of experience. To aid intuition, this appendix maps the physical framework onto the classic **Cinema Analogy** of Advaita Vedanta (as used by Ramana Maharshi).

We trace the "Epistemic GUT"—the path from the Absolute to the Quantum measurement—by analyzing the components of the Cosmic Projector.

E.1 The Screen and the Light: Sat-Chit (The Background)

Before the movie begins, there is a white Screen and a Light. The Screen is the support; the Light is the illuminator.

- **Vedanta:** The Screen is the *Self* (*Ātman*). It is the immutable background. It does not move, change, or participate in the movie. The Light is *Chit* (Consciousness/Awareness).
- **Physics:** This is the Ontological Ground. It is the existence-function that must be present for any information to be registered. It is not "Space" (which is part of the movie); it is the "Where" in which Space appears.

E.2 The Reel: Sañcita (The Block Universe)

A film reel sits in the machine. It contains the entire history of the universe—beginning, middle, and end—encoded simultaneously. On the reel, nothing moves. The characters are not born and do not die; they are static patterns.

- **Vedanta:** This is *Sañcita* (The Accumulated Potential). It is the total store of latent tendencies and histories.
- **Physics:** This is the Block Universe ($|\psi\rangle$). It is the deterministic, unitary structure containing all valid worldlines.

E.3 The Lens: Avidyā (Finite Capacity C_{eff})

The Light shines through the reel, but it passes through a lens with a tiny aperture. The lens cannot project the whole reel at once; it is constrained to focus on a single frame.

- **Vedanta:** This is *Avidyā* (Ignorance). It is not a mistake, but the optical mechanism of Focus. By excluding the "Whole," it allows the "Particular" to appear.
- **Physics:** This is the Information Constraint ($C_{\text{eff}} < \infty$). Because the observer cannot process infinite energy (Margolus–Levitin bound), they are physically forced to view the universe through a finite aperture.

E.4 The Motor: Gravity (Kāraṇa)

The reel is heavy and complex. To create the appearance of motion, a motor must drag the film past the lens, overcoming the friction of the reel.

- **Vedanta:** This is *Kāraṇa* (Causality). It is the karmic weight of the past necessitating the unfolding of the future.
- **Physics:** This is the gravity-like term ($E_G \propto \hbar\kappa$) under the bridge ansatz. In the analogy, gravity is the "tension" of the system: the larger the mass/complexity, the larger the modeled update pressure.

E.5 The Projection: Nāma-Rūpa (Space, Time, Object)

What appears on the Screen? A play of names and forms.

- **Space:** The pixelation of the lens. Distinguishability becomes "Distance."
- **Time:** The sequencing of the frames. The reel is static, but the *view* changes.
- **Objects:** The stable patterns of light that persist across multiple frames.

Crucially, the Screen (Self) is never wet by the water in the movie, nor burned by the fire.

E.6 The Flicker: Quantum Collapse (The Stutter)

Here is the core insight of the IOF.

- **Classical Reality (Fluidity):** When the motor runs smoothly and the frames blur together (high Capacity $C_{\text{eff}} > h_{\text{KS}}/\ln 2$), the movie looks continuous. We see a "Classical World."
- **Quantum Measurement (The Stutter):** When we look at very small, fast things, the complexity (h_{KS}) overwhelms the lens (C_{eff}). The motor strains. We begin to see the individual frames.
- **The Physics:** This is Wavefunction Collapse. The "Collapse" is simply the refresh of the frame (τ_{SK}). We are seeing the discrete nature of the projection mechanism because our tracking capacity has saturated.

In deep meditation or high-precision measurement, the "gap" between frames becomes visible.

E.7 The Plot: The Lagrangian ($\delta S = 0$)

For the dream to be convincing, the plot must be consistent. The Principle of Stationary Action ($\delta S = 0$) ensures narrative coherence—the Laws of Physics are the stability requirements.

If you turn off the movie, the Light and the Screen remain. This is the definition of Sat.

F Language as an Aperture: Discretization by Finite Description

This appendix introduces a pedagogical metaphor intended to build intuition for the core claim of this work: that a finite observer necessarily produces a discretized (quantized) appearance from a higher-dimensional reality. The metaphor is *language*. Language is a finite coding system that compresses an effectively unbounded source into a bounded channel. While this is not a physical derivation, it mirrors the same information-theoretic necessity expressed by the formal model.

F.1 The Basic Analogy: Source, Channel, Reconstruction

Consider three elements:

1. **Substrate / source.** The world-as-given may contain more detail than any finite agent can represent.
2. **Language / channel.** A finite alphabet, finite vocabulary, and finite grammar impose a hard limit on how much structure can be transmitted per unit time (and per utterance).
3. **Perceived world-model / reconstruction.** The listener (or thinker) reconstructs a world-model from the compressed description, filling missing degrees of freedom using prior structure (learned categories, expectations, and context).

This is structurally identical to the rate–distortion setting: a high-complexity source is represented through a limited-capacity channel, yielding a reconstruction that is not identical to the source, but is the best achievable representation under finite bandwidth.

F.2 Language as Quantization: Categories Carve Objects

Language discretizes in at least three distinct ways:

1. **Tokenization.** Continuous experience is segmented into discrete symbols (words).
2. **Categorization.** Words bind diverse instances into equivalence classes (e.g., many distinct sensory patterns are grouped under the single label “apple”).
3. **Grammar-induced structure.** Subject–object grammar introduces a persistent partition: “I” (knower) vs “that” (known). Tense and aspect introduce an ordered narrative: “before” vs “after,” “cause” vs “effect,” “action” vs “outcome.”

Importantly, this discretization is not an optional interpretive flourish; it is forced by finitude. A finite codebook cannot preserve unbounded detail. The output therefore appears as a world of stable objects, properties, and events: a coherent interface produced by a compressive representation.

F.3 Blind-Apple Vignette: The Reconstruction Depends on the Codebook

A simple vignette illustrates basis dependence. Suppose a blind person is given a purely verbal description of an apple. The mental image (or concept) that arises is not determined solely by the word "apple," but by the listener's internal codebook: prior experiences of taste, texture, shape, cultural usage, and surrounding context.

Two listeners may receive the same token but reconstruct different objects. This is not a failure of communication; it is the unavoidable consequence of transmitting a high-dimensional referent through a finite symbol system. The reconstruction is a rate–distortion compromise: it is "good enough" for functional inference, but not an isomorphic copy of the source.

F.4 Recursive Quantization: The Reconstruction Becomes the New Source

The blind-apple vignette also illustrates a second, subtler point: the lossy mapping does not occur only once. After a mind-picture (or concept) of "apple" forms, that internal representation becomes a *new* effective source. Communicating it back outward (to oneself in memory, or to another via speech or writing) requires a second compression step into tokens and grammar. The communicated description is then reconstructed again into a mind-picture by the receiving interface.

Thus the flow is naturally recursive:

$$\begin{aligned}\text{world (source)} &\to \text{mind-model (reconstruction)}\\ &\to \text{words (code)}\\ &\to \text{mind-model (reconstruction)} \to \cdots\end{aligned}$$

At each stage, a high-dimensional state is re-encoded into a lower-dimensional, discrete representation. The "substrate" is therefore relative to the interface: whatever is taken as given at one stage becomes the source to be compressed at the next.

F.5 One Observer Is Sufficient: "Speaker" and "Listener" as Successive Interfaces

Nothing in the above requires multiple ontologically separate observers. The roles of "speaker" and "listener" can be implemented as successive encodings within a single substrate. Even within one stream of experience, information must pass through distinct interfaces such as:

- immediate perception → conceptual representation,
- conceptual representation → memory trace,
- memory trace → reportable symbol (inner speech, outer speech, writing),
- symbol → reconstructed meaning.

Each interface imposes its own finite bandwidth and codebook constraints. The repeated quantization is therefore not fundamentally a social phenomenon; it is the intrinsic consequence of re-description under finitude. In this "single-observer" reading, the apparent multiplicity of observers can be treated as part of the appearance-order: a convenient way of describing the same chain of successive encodings. (For an extended discussion using the dream analogy—how many "observers" appear within a single dreamer—see [1], Part VII.)

F.6 Not Solipsism

The "single substrate" reading should not be confused with solipsism. Solipsism elevates the *personal mind* (the individual ego) to absolute status and treats others as imaginary. Advaita Vedānta denies ultimacy to the personal mind itself: the ego and its world-model are part of the appearance-order (vyāvahāra). Thus statements such as "there are no others" mean that there are no *ultimately separate* selves, not that other persons lack empirical reality.

Accordingly, this appendix preserves the full pragmatic validity of other persons, communication, and shared verification within the empirical domain, while allowing a non-dual interpretation in which the apparent multiplicity of observers is itself an output of the same representational constraints that generate discretized objects. Indeed, we call something "objective" not because we access a thing-in-itself, but because many different codecs yield stable overlap in their reconstructions—objectivity is intersubjective convergence among finite observers, not transcendence of finitude.

F.7 Connection Back to the IOF Structure

With these clarifications, the language metaphor aligns even more directly with the IOF structure. Successive encodings correspond to repeated applications of finite-capacity tracking: each stage must compress a complex source into a bounded description, reconstructing a stable interface from incomplete information. In this sense, discretization is not a special event that happens "once," but a persistent architectural feature of appearance whenever a finite aperture repeatedly re-describes its own outputs.

F.8 The "Word" as Symbolic Segmentation

In many traditions, one finds the intuition that manifestation is connected to "the Word." This appendix adopts no doctrinal claims. However, the metaphor suggests a precise structural reading: not a single sacred syllable as a physical mechanism, but *wordhood* itself—symbolic segmentation—as the act that makes a discretized world possible.

On this reading, "Word" can be interpreted as the general operation: *finite description that carves the seamless into tokens.* In the same way that ignorance in non-dual traditions denotes self-limitation (not moral error), words impose representational limitation (not falsehood). The limitation is precisely what allows a stable world-model to appear.

F.9 Mapping to the IOF Variables

The language metaphor aligns directly with the formal variables used throughout the paper:

- **Source complexity** h_{KS}: the effective novelty/instability rate of the underlying process to be tracked (KS-like entropy production, nats/s).
- **Observer capacity** C_{eff}: the finite rate at which distinctions can be maintained (bandwidth allocated to tracking the relevant basis, bits/s).
- **Information deficit** $\kappa = h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2$: the rate at which tracking fails (positive in the chaos-wins regime).

- **Basis / codebook θ**: the representational coordinate system in which the observer expresses the world (categories, measurement basis, interpretive frame).

When $\kappa > 0$ (i.e., h_{KS} exceeds the effective representational bandwidth $C_{\mathrm{eff}} \ln 2$), the observer cannot stably track the basis θ. In the language metaphor, this corresponds to a regime where a description cannot preserve the distinctions required for faithful reconstruction: multiple incompatible reconstructions fit the same compressed signal, and definiteness becomes a constrained selection rather than a transparent readout.

F.10 Relation to the "Projector" Appendix: Why Both Metaphors Are Needed

The present appendix (language-as-aperture) and the "Projector" appendix (Appendix E) serve different explanatory roles.

1. **Projector metaphor (boundary law).** The "Projector" appendix is concerned with the *existence and structure of manifestation itself*—i.e. the appearance of a world/observer split and the lawful constraints governing any finite rendering. In the framing of this work, this is where the notion of an ultimate ceiling κ_P belongs: a boundary parameter of appearance, not a parameter chosen by an individual observer.
2. **Language metaphor (finite coding in practice).** The present appendix is concerned with *how* a finite agent produces a definite world-model given a limited descriptive alphabet and finite bandwidth. It illustrates the operational mechanism by which discretization occurs: tokenization, categorization, grammar-induced partition (subject/object), and narrative ordering.

Stated compactly:

$$\begin{aligned} \text{Projector:} &\quad \kappa_P \ \ \text{(universal ceiling of appearance)} \\ \text{Aperture/codec:} &\quad (C,\ C_{\mathrm{eff}},\ \theta) \ \ \text{(observer-dependent constraints)} \end{aligned}$$

Thus, the two appendices are not redundant. The projector metaphor motivates *why a ceiling is conceptually required* at the boundary of manifestation, whereas the language metaphor shows *how finitude enforces discretization* even in an everyday system we already understand: symbolic communication.

F.11 Status of This Appendix

This appendix is offered purely as an intuition pump. It does not replace the mathematical arguments, nor does it claim that language is the physical mechanism of manifestation. Rather, it provides an accessible example of the same structural fact: *finite description necessarily yields a discretized appearance*, and the apparent world inherits the constraints of the describing channel. In combination with the "Projector" appendix, it clarifies why both a boundary ceiling (universal) and an aperture/codebook (observer-dependent) naturally appear in the framework.

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