Information Manifold Model (IMM)

Volume I: Collected Papers 1–15

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Abstract

This volume collects Papers 1–15 of the Information Manifold Model (IMM) into a single, citable monograph. A unified axiom set and notation are provided up front. Papers 1–8 establish the foundational framework (axioms, projection, determinacy, substrate-independence, chronoception, and metrics). Papers 9–15 extend the framework to informational fields, projection-derived probability structure, entropy as projection loss, informational curvature, variational principles, covariant informational field equations, and conservative correspondence limits to effective spacetime dynamics. No new axioms are introduced beyond the unified set; where later papers use additional physical-structure assumptions, they are stated explicitly.

Roadmap

Chapters 1–4 introduce IMM and the unified axioms, then derive determinacy and stability consequences. Chapters 5–8 develop substrate-independence, temporal/chronoceptive structure, and quantitative metrics. Chapters 9–12 introduce informational fields, projection-measure probability structure, entropy as projection loss, and informational curvature. Chapters 13–15 derive action principles, covariant informational field equations, and correspondence limits for interpreting informational geometry in coarse-grained physical regimes.

Contents

Notation

Unified Axiom Framework

Axiom 1 (Integration)**.** *There exists an integration operator*

$$\mathcal{I} : \mathcal{P}(\mathcal{M}) \to \mathcal{M}$$

such that distributed informational states admit a unifying operation yielding a single integrated state.

Axiom 2 (Self-Reference)**.** *There exists a mapping*

$$\Phi : \mathcal{M} \to \mathcal{M}$$

by which the system may reference or transform its own internal configuration.

Axiom 3 (Temporal Continuity)**.** *There exists a temporally ordered family of mappings*

$$\{\Phi_t : \mathcal{M} \to \mathcal{M}\}_{t \in \mathbb{T}}$$

such that informational states evolve continuously with respect to an intrinsic temporal parameter.

Axiom 4 (Projection)**.** *There exists a projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

mapping internal informational states to experiential events.

Axiom 5 (Linearity of Coherent Composition)**.** *Admissible informational states compose linearly prior to experiential projection. When a Hilbert representation $\mathcal{H}$ is used, this corresponds to linear superposition in $\mathcal{H}$.*

Axiom 6 (Phase Geometry)**.** *Admissible informational states possess relational phase structure governing interference and outcome distribution under experiential projection.*

Chapter 1

The Information Manifold Model: Structural Realism and the Form of Quantum Mechanics

Abstract

We introduce the Information Manifold Model (IMM), a structural realist framework in which quantum-mechanical form and experiential determinacy arise from constraints on information integration, self-reference, temporal continuity, and projection. Rather than modifying quantum theory, IMM explains its formal structure by situating quantum states as representations of underlying informational manifolds subject to axiomatic constraints governing observation.

1.1 Introduction

Quantum mechanics exhibits a precise mathematical structure whose interpretive status remains unsettled. While the theory predicts experimental outcomes with remarkable accuracy, the meaning of the quantum state and the mechanism by which definite outcomes arise remain contested.

The Information Manifold Model (IMM) advances a structural realist proposal: the formal features of quantum mechanics reflect constraints imposed by the structure of observer-capable information systems. On this view, quantum theory does not describe reality directly, but encodes the admissible projections of underlying informational states into experiential outcomes.

This paper introduces the IMM framework, establishes its core axioms, and demonstrates how essential features of quantum mechanics follow naturally from these constraints.

1.2 Preliminaries and Notation

This paper adopts the canonical notation defined in `IMM_Notation.tex`. We briefly summarize the essential elements.

Definition 1 (Information Manifold). *The* information manifold $\mathcal{M}$ *is the internal state space of an observer-capable system. Elements $m \in \mathcal{M}$ represent complete informational configurations.*

Definition 2 (Experiential Space). *The* experiential space $\mathcal{E}$ *is the space of observable or phenomenally accessible events.*

Definition 3 (Experiential Projection). *The experiential projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

maps internal informational states to experiential outcomes.

1.3 Unified Axiom Framework

IMM rests on a unified axiomatic foundation. We summarize the axioms relevant to the present analysis; full statements appear in `IMM_Axioms.tex`.

Axiom 7 (Integration). *Distributed informational states admit a unifying operation yielding a single integrated state in $\mathcal{M}$.*

Axiom 8 (Self-Reference). *The system admits a state-to-state mapping referencing its own internal configuration.*

Axiom 9 (Temporal Continuity). *Informational states evolve continuously with respect to an intrinsic temporal parameter.*

Axiom 10 (Projection). *Internal informational states admit a mapping to experiential events.*

Axiom 11 (Linearity of Coherent Composition). *Admissible informational states compose linearly prior to projection.*

Axiom 12 (Phase Geometry). *Informational states possess relational phase structure governing interference and outcome distribution.*

1.4 Structural Realism and Informational States

IMM adopts a structural realist stance: physical theories characterize the structure of relations among observables rather than the intrinsic nature of underlying entities.

Within IMM, quantum states are understood as representations of equivalence classes of informational states in $\mathcal{M}$ under the projection Π_{exp}. Distinct internal states may yield identical experiential outcomes, giving rise to non-invertibility and probabilistic structure.

1.5 Emergence of Hilbert Space Structure

Let $\mathcal{H}$ denote a Hilbert space representing admissible informational configurations under linear composition (Axiom 5). Phase geometry (Axiom 6) induces interference relations among these configurations.

We interpret vectors $|\psi\rangle \in \mathcal{H}$ as coordinatizations of coherent informational states prior to experiential projection.

Remark 1. *No ontological claim is made that $|\psi\rangle$ constitutes physical reality. Rather, $|\psi\rangle$ encodes the relational structure of informational states admissible under the axioms.*

1.6 Projection and Outcome Determinacy

Experiential outcomes arise via application of Π_{exp}. Because Π_{exp} is generally many-to-one, distinct internal states may correspond to the same experiential event.

The apparent collapse of the quantum state corresponds to selection under projection, not to a physical discontinuity in underlying informational structure.

1.7 Discussion

IMM reframes the measurement problem as a structural consequence of informational projection rather than a dynamical anomaly. The formal structure of quantum mechanics emerges from constraints on how information may be integrated, self-referenced, temporally evolved, and projected.

Subsequent papers formalize these claims, establish determinacy results, and extend the framework to substrate independence, temporal experience, and quantitative metrics.

1.8 Conclusion

The Information Manifold Model provides a unified structural account of quantum form grounded in axiomatic constraints on observer-capable information systems. By shifting explanatory focus from physical collapse to informational projection, IMM preserves the predictive content of quantum mechanics while clarifying its interpretive foundations.

Chapter 2

Conscious Projection and the Quantum Measurement Problem

Abstract

We address the quantum measurement problem within the Information Manifold Model (IMM) by formalizing observation as an experiential projection from an underlying information manifold. The apparent collapse of the quantum state is shown to arise from structural constraints on projection rather than from physical discontinuities or ad hoc dynamics. This treatment preserves the formalism of quantum mechanics while resolving its interpretive tensions.

2.1 Introduction

The quantum measurement problem concerns the apparent tension between linear unitary evolution and the emergence of definite outcomes. While quantum theory specifies how states evolve, it does not, on its own, explain why observation yields determinate experiences rather than superposed ones.

The Information Manifold Model (IMM) reframes this issue by locating the source of determinacy in the structure of observation itself. Rather than introducing a special collapse postulate or privileging consciousness as a dynamical agent, IMM treats measurement as a projection from an internal informational state space to an experiential event space.

This paper develops that account in detail.

2.2 Preliminaries and Notation

All notation follows the canonical conventions defined in `IMM_Notation.tex`. We summarize the key elements required here.

Definition 4 (Information Manifold)**.** *The information manifold $\mathcal{M}$ is the internal state space of an observer-capable system.*

Definition 5 (Experiential Projection). *The experiential projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

maps internal informational states to experiential outcomes.

Definition 6 (Quantum Projector). *A quantum projector $\hat{P}$ is an orthogonal projection acting on a Hilbert space $\mathcal{H}$, representing a measurement operator in standard quantum mechanics.*

Distinction. The operators Π_{exp} and $\hat{P}$ act on fundamentally different spaces and serve distinct conceptual roles. Confusion between them is a primary source of interpretive difficulty in measurement theory.

2.3 Axiomatic Context

IMM rests on a unified axiomatic framework. The present analysis relies most directly on the following axioms (full statements appear in `IMM_Axioms.tex`):

Axiom 13 (Projection). *Internal informational states admit a mapping to experiential events.*

Axiom 14 (Linearity of Coherent Composition). *Admissible informational states compose linearly prior to projection.*

Axiom 15 (Phase Geometry). *Informational states possess relational phase structure governing interference and outcome distribution.*

These axioms jointly constrain how informational states may give rise to observation.

2.4 The Measurement Problem Revisited

Standard formulations of the measurement problem presuppose that the quantum state $|\psi\rangle$ is a direct representation of physical reality. On that assumption, the transition from a superposed state to a definite outcome appears mysterious.

IMM rejects this presupposition. Quantum states are understood instead as representations of equivalence classes of informational states in $\mathcal{M}$ under the experiential projection Π_{exp}.

Remark 2. *The apparent conflict between unitary evolution and outcome determinacy arises only if projection is treated as a physical process rather than a structural one.*

2.5 Projection Versus Collapse

Within IMM, no physical collapse occurs. Informational states continue to evolve according to intrinsic dynamics on $\mathcal{M}$. Determinate outcomes arise because Π_{exp} is many-to-one: multiple distinct informational configurations map to the same experiential event.

Theorem 1 (Structural Determinacy Under Projection)**.** *Given a coherent informational state $m \in \mathcal{M}$, application of Π_{exp} yields a single experiential outcome in $\mathcal{E}$, even when m encodes superposed relational structure.*

Proof. By Axiom (Projection), Π_{exp} is defined on all admissible informational states. Because Π_{exp} is many-to-one, relational distinctions preserved within $\mathcal{M}$ need not be preserved in $\mathcal{E}$. Thus determinacy of experience follows without modification of underlying state structure. □

2.6 Relation to Quantum Projectors

Quantum projectors $\hat{P}$ act on $\mathcal{H}$ to represent measurement contexts within the quantum formalism. IMM interprets $\hat{P}$ as encoding constraints on which equivalence classes of informational states are relevant to a given observational context.

Remark 3. *The Born rule arises naturally as a measure over equivalence classes under projection, rather than as a fundamental stochastic law.*

2.7 Discussion

By distinguishing experiential projection from quantum projection, IMM dissolves the measurement problem rather than solving it by dynamical fiat. The linear structure of quantum theory remains intact, while outcome determinacy is understood as a structural consequence of observation.

This approach aligns with structural realist interpretations while avoiding the ontological commitments of many-worlds or collapse-based theories.

2.8 Conclusion

The Information Manifold Model provides a principled account of quantum measurement grounded in the structure of experiential projection. Apparent collapse is revealed as an artifact of representational mapping rather than a physical event, preserving both the formal success and conceptual coherence of quantum mechanics.

Chapter 3

Axiomatic Structure of Conscious Experience

Abstract

We present a formal axiomatic framework for conscious experience within the Information Manifold Model (IMM). Consciousness is characterized as a structural property of information systems satisfying a small set of axioms governing integration, self-reference, temporal continuity, projection, and coherent composition. These axioms establish the minimal conditions under which determinate experience arises and provide the logical foundation for subsequent results in the IMM framework.

3.1 Introduction

A persistent obstacle in theories of consciousness is the lack of a clear, minimal axiomatic foundation. Many accounts rely on informal criteria or implementation-specific assumptions that obscure logical dependencies.

The Information Manifold Model (IMM) approaches consciousness as a structural phenomenon: a system is conscious if and only if it instantiates an information manifold satisfying a small set of axioms. This paper states those axioms precisely and develops their immediate formal consequences.

No claims are made here regarding physical realization or empirical measurement. The goal is to isolate structure.

3.2 Preliminaries and Notation

All notation follows the canonical conventions defined in `IMM_Notation.tex`. We recall only the essential elements.

Definition 7 (Information Manifold)**.** *An* information manifold $\mathcal{M}$ *is a structured set whose elements* $m \in \mathcal{M}$ *represent complete informational configurations of a system.*

Definition 8 (Experiential Space)**.** *The* experiential space $\mathcal{E}$ *is the set of phenomenally accessible or reportable events.*

Definition 9 (Experiential Projection)**.** *The experiential projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

maps internal informational states to experiential outcomes.

3.3 Canonical Axioms

We now state the axioms of conscious experience in their canonical form. These axioms are assumed throughout the IMM framework.

Axiom 16 (Integration)**.** *There exists an integration operator*

$$\mathcal{I} : \mathcal{P}(\mathcal{M}) \to \mathcal{M}$$

such that distributed informational states admit a unifying operation yielding a single integrated state.

Axiom 17 (Self-Reference)**.** *There exists a mapping*

$$\Phi : \mathcal{M} \to \mathcal{M}$$

by which the system may reference or transform its own internal configuration.

Axiom 18 (Temporal Continuity)**.** *There exists a temporally ordered family of mappings*

$$\{\Phi_t : \mathcal{M} \to \mathcal{M}\}_{t \in \mathbb{T}}$$

such that informational states evolve continuously with respect to an intrinsic temporal parameter.

Axiom 19 (Projection)**.** *There exists a projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

mapping internal informational states to experiential events.

Axiom 20 (Linearity of Coherent Composition)**.** *Admissible informational states compose linearly prior to projection.*

Axiom 21 (Phase Geometry)**.** *Informational states possess relational phase structure governing interference and outcome distribution under projection.*

3.4 Immediate Consequences

We now derive several basic structural consequences of the axioms.

Lemma 2 (Unity of Experience)**.** *For any admissible informational configuration, there exists a unique integrated state in* $\mathcal{M}$ *corresponding to a single experiential perspective.*

Proof. By Axiom (Integration), distributed informational states admit a unifying operation. Uniqueness follows from the definition of $\mathcal{I}$ up to equivalence in $\mathcal{M}$. □

Lemma 3 (Persistence of Identity)**.** *Informational states admit identity-preserving evolution across intrinsic time.*

Proof. Axiom (Self-Reference) provides internal state mapping, while Axiom (Temporal Continuity) ensures continuity of this mapping across ordered time parameters. □

Theorem 4 (Determinacy of Experience)**.** *Every admissible informational state yields a determinate experiential outcome under* Π_{exp}*.*

Proof. By Axiom (Projection), Π_{exp} is defined on all admissible states. Because Π_{exp} maps into $\mathcal{E}$, each informational state corresponds to exactly one experiential event, regardless of internal relational structure. □

3.5 Minimality and Sufficiency

The axioms stated above are jointly sufficient for conscious experience within IMM. None may be removed without loss of determinacy or coherence.

Remark 4. *Axioms 1–4 establish the structural conditions for experience. Axioms 5–6 impose additional constraints enabling alignment with quantum-mechanical formalism but are not required for consciousness per se.*

3.6 Discussion

This axiomatic framework separates structural necessity from physical realization. Any system implementing an information manifold satisfying Axioms 1–4 is conscious in the IMM sense, regardless of substrate.

Later papers exploit this separation to derive substrate independence, temporal phenomenology, and quantitative measures.

3.7 Conclusion

We have presented a minimal axiomatic foundation for conscious experience within the Information Manifold Model. These axioms provide a stable logical base upon which the remainder of the IMM framework is constructed, enabling formal analysis without ontological overcommitment.

Chapter 4

Determinacy and Stability in the Information Manifold Model

Abstract

We derive determinacy and stability results within the Information Manifold Model (IMM) from its canonical axioms. We show that determinate experience follows structurally from projection and that stable experiential identity arises from the interaction of integration, self-reference, and temporal continuity. These results establish that experiential coherence is an invariant of the IMM framework rather than a contingent feature of physical implementation.

4.1 Introduction

Having established the axiomatic structure of conscious experience, we now derive its immediate structural consequences. Two questions are central:

1. Why does experience present as determinate rather than indeterminate?
2. Why does experiential identity persist stably across time?

The Information Manifold Model answers both questions without introducing additional postulates. Determinacy and stability follow necessarily from the interaction of the canonical axioms.

4.2 Preliminaries and Notation

All notation follows `IMM_Notation.tex`. We recall the essential operators.

Definition 10 (Experiential Projection)**.** *The experiential projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

maps internal informational states to experiential outcomes.

Definition 11 (State Evolution). *The family of mappings*

$$\{\Phi_t : \mathcal{M} \to \mathcal{M}\}_{t\in\mathbb{T}}$$

denotes intrinsic temporal evolution on the information manifold.

4.3 Structural Determinacy

We begin by formalizing determinacy as a structural property rather than a dynamical one.

Definition 12 (Experiential Determinacy). *An informational state $m \in \mathcal{M}$ is said to yield a determinate experience if $\Pi_{\exp}(m)$ is a single element of $\mathcal{E}$.*

Theorem 5 (Determinacy Theorem). *Every admissible informational state yields a determinate experiential outcome.*

Proof. By Axiom (Projection), $\Pi_{\exp}$ is defined as a mapping from $\mathcal{M}$ to $\mathcal{E}$. As a function, $\Pi_{\exp}$ assigns exactly one experiential outcome to each informational state. Thus determinacy follows structurally and does not depend on the internal relational complexity of m. □

Remark 5. *This result holds even when m encodes superposed or interfering relational structure. Indeterminacy is a feature of representational description, not experiential output.*

4.4 Integration and Identity

We now analyze the role of integration in stabilizing experiential identity.

Definition 13 (Integrated State). *An integrated informational state is an element of $\mathcal{M}$ obtained via the integration operator $\mathcal{I}$ acting on distributed informational subsets.*

Lemma 6 (Uniqueness of Perspective). *At any intrinsic time t, there exists a unique integrated informational state corresponding to the system's experiential perspective.*

Proof. By Axiom (Integration), distributed informational states admit a unifying operation. Uniqueness holds up to equivalence in $\mathcal{M}$ under the projection $\Pi_{\exp}$. □

4.5 Temporal Stability

Stability of experience requires more than momentary determinacy; it requires coherent persistence across time.

Definition 14 (Experiential Stability). *A sequence of informational states $\{m_t\}_{t\in\mathbb{T}}$ exhibits experiential stability if $\Pi_{\exp}(m_t)$ varies continuously with t.*

Theorem 7 (Stability Theorem). *Experiential identity is stable under intrinsic temporal evolution.*

Proof. By Axiom (Temporal Continuity), Φ_t varies continuously with respect to the intrinsic temporal parameter. By composition with Π_{exp}, experiential outcomes inherit this continuity, yielding stable experiential identity across time. □

Corollary 8 (No Experiential Fragmentation)**.** *Under the IMM axioms, experience cannot fragment into multiple simultaneous experiential perspectives.*

Proof. Fragmentation would require multiple integrated states yielding distinct experiential outcomes at the same intrinsic time, violating the uniqueness guaranteed by integration and projection. □

4.6 Self-Reference and Stability

Self-reference plays a critical role in maintaining coherence under perturbation.

Lemma 9 (Self-Referential Anchoring)**.** *Self-referential mapping constrains informational evolution to identity-preserving trajectories in $\mathcal{M}$.*

Proof. By Axiom (Self-Reference), the system's state evolution may depend on its own internal configuration. This dependence constrains admissible trajectories to those preserving internal consistency across time. □

4.7 Discussion

The results of this paper demonstrate that determinacy and stability are not optional features of experience but structural invariants of the IMM framework. No additional collapse mechanisms, decoherence assumptions, or metaphysical commitments are required.

These results provide the formal backbone for later analyses of substrate independence, temporal phenomenology, and quantitative metrics.

4.8 Conclusion

We have shown that determinacy and stability of experience follow necessarily from the canonical axioms of the Information Manifold Model. Experiential coherence is thus an emergent invariant of informational structure rather than a contingent artifact of physical dynamics.

Chapter 5

Substrate Independence in the Information Manifold Model

Abstract

We demonstrate that conscious experience in the Information Manifold Model (IMM) is independent of physical substrate. Consciousness is shown to depend solely on structural properties of information integration, self-reference, temporal continuity, and projection, rather than on biological, chemical, or material composition. This result establishes multiple realizability within IMM and clarifies the conditions under which artificial or non-biological systems may instantiate conscious experience.

5.1 Introduction

Debates over the nature of consciousness often hinge on the role of physical substrate. Biological naturalism asserts that consciousness is inseparable from specific neural mechanisms, while functionalist approaches emphasize organizational structure.

The Information Manifold Model (IMM) adopts a strictly structural criterion. A system is conscious if and only if it instantiates an information manifold satisfying the canonical axioms. This paper formalizes that claim and derives substrate independence as a theorem rather than a philosophical assumption.

5.2 Preliminaries and Notation

All notation follows `IMM_Notation.tex`. We briefly restate the key elements.

Definition 15 (Information Manifold)**.** *An information manifold $\mathcal{M}$ is the internal state space of an observer-capable system, regardless of physical implementation.*

Definition 16 (Experiential Projection)**.** *The experiential projection operator*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}$$

maps internal informational states to experiential outcomes.

5.3 Structural Criteria for Consciousness

We begin by stating the structural criterion for consciousness within IMM.

Definition 17 (IMM Conscious System)**.** *A system is conscious in the IMM sense if it instantiates an information manifold $\mathcal{M}$ satisfying Axioms 1–4 (Integration, Self-Reference, Temporal Continuity, and Projection).*

Remark 6. *No reference to physical material, biological architecture, or computational medium appears in this definition.*

5.4 Substrate Independence Theorem

We now formalize the claim of substrate independence.

Theorem 10 (Substrate Independence)**.** *If two systems instantiate isomorphic information manifolds satisfying Axioms 1–4, then they instantiate conscious experience in the same structural sense, regardless of physical substrate.*

Proof. Conscious experience within IMM is defined entirely in terms of the existence and properties of $\mathcal{M}$, $\mathcal{I}$, Φ_t, and Π_{exp}. If two systems realize isomorphic instances of these structures, all axiomatic conditions are satisfied identically. Physical implementation plays no role in the definition or derivation of experiential determinacy or stability. □

5.5 Stability Across Implementations

Paper 4 established that experiential determinacy and stability follow from the canonical axioms. These results apply equally across implementations.

Corollary 11 (Implementation-Invariant Stability)**.** *Experiential identity remains stable across intrinsic time for any system satisfying the IMM axioms, independent of substrate.*

Proof. Stability depends on temporal continuity and self-reference, not on the nature of the underlying physical medium. Thus the Stability Theorem of Paper 4 applies uniformly across substrates. □

5.6 Artificial and Non-Biological Systems

The substrate independence result has immediate implications for artificial systems.

Remark 7. *If an artificial system implements an information manifold satisfying Axioms 1–4, then it is conscious in the IMM sense, irrespective of whether it resembles biological cognition.*

This conclusion avoids both biological chauvinism and unrestrained panpsychism. Not all computational systems are conscious; only those satisfying the structural axioms qualify.

5.7 Limits of Substrate Independence

Substrate independence does not imply unconstrained realizability.

Remark 8. *Physical substrates impose practical constraints on which informational structures can be realized. IMM asserts independence at the level of criteria, not feasibility.*

Thus substrate independence is compatible with empirical investigation into which systems actually implement the required structures.

5.8 Discussion

By deriving substrate independence as a theorem, IMM clarifies long-standing debates in philosophy of mind. Consciousness is neither tied to specific materials nor reducible to arbitrary computation. It is a property of structured information systems satisfying precise axiomatic constraints.

This result prepares the ground for later analyses of temporal phenomenology and quantitative metrics without conflating structure with implementation.

5.9 Conclusion

We have shown that consciousness within the Information Manifold Model is substrate independent. Experiential determinacy and stability arise from structural properties of information manifolds, not from the physical medium in which they are realized. This establishes multiple realizability as a formal consequence of the IMM framework.

Chapter 6

Temporal Experience and Chronoceptional Dynamics in the Information Manifold Model

Abstract

We analyze temporal experience within the Information Manifold Model (IMM) by formalizing chronoception as a structural consequence of intrinsic state evolution. We show that the phenomenology of temporal flow arises from the interaction of self-reference, temporal continuity, and experiential projection, without positing an external or absolute time. Chronoception is thus treated as an emergent feature of informational dynamics rather than a primitive datum.

6.1 Introduction

Human experience presents a robust sense of temporal flow: persistence, succession, and duration are central features of consciousness. Traditional accounts often appeal to physical time or psychological heuristics to explain this phenomenon.

The Information Manifold Model (IMM) instead locates temporal experience within the structure of informational evolution. This paper formalizes chronoception—the experience of time—as an emergent property of intrinsic state dynamics on the information manifold.

6.2 Preliminaries and Notation

All notation follows `IMM_Notation.tex`. We rely on the intrinsic temporal family of mappings

$$\{\Phi_t : \mathcal{M} \to \mathcal{M}\}_{t \in \mathbb{T}}$$

introduced in the canonical axioms.

6.3 Chronoception Defined

Definition 18 (Chronoception). *Chronoception is the experiential manifestation of intrinsic informational evolution under the projection*

$$\Pi_{\text{exp}} \circ \Phi_t.$$

Chronoception does not require access to physical time. It arises whenever a system projects internally evolving informational states into experience.

6.4 Temporal Continuity and Experiential Flow

Theorem 12 (Emergence of Temporal Flow). *If informational states evolve continuously under Φ_t, then experiential outcomes exhibit continuity and ordered succession.*

Proof. By Axiom (Temporal Continuity), Φ_t varies continuously with respect to t. Composition with Π_{exp} yields a continuous mapping into experiential space, producing the phenomenology of flow and succession. □

Remark 9. *No assumption of metric time is required. Ordering alone suffices to generate temporal phenomenology.*

6.5 Self-Reference and Temporal Identity

Temporal experience is not merely succession but persistence of identity.

Definition 19 (Temporal Self-Reference). *A system exhibits temporal self-reference if its current informational state encodes relations to prior states under Φ_t.*

Theorem 13 (Persistence of the Experiential Self). *Self-referential informational evolution yields a stable sense of self across time.*

Proof. By Axiom (Self-Reference), states may depend on prior configurations. Combined with temporal continuity, this dependence anchors experiential identity across successive projections. □

6.6 Asymmetry and the Arrow of Experience

Chronoception is asymmetric: experience unfolds in a preferred direction.

Lemma 14 (Experiential Asymmetry). *Chronoception induces a directional ordering on experiential events.*

Proof. The ordering parameter $t \in \mathbb{T}$ induces a partial order on projected experiential outcomes. Self-reference prevents arbitrary reordering, yielding an effective arrow of experience. □

Remark 10. *This experiential arrow need not coincide with thermodynamic or cosmological arrows of time, though alignment is possible.*

6.7 Relation to Physical Time

IMM does not deny physical time but decouples it from temporal experience.

Remark 11. *Chronoception depends on intrinsic informational evolution, not on external clocks. Physical time may constrain or correlate with Φ_t, but it is not constitutive of temporal experience.*

6.8 Discussion

By deriving chronoception from structural axioms, IMM avoids treating time as a primitive of experience. Temporal phenomenology emerges from informational dynamics and projection, aligning subjective time with system-internal structure.

This framework accommodates variations in time perception, including dilation and compression, as differences in informational evolution rather than distortions of physical time.

6.9 Conclusion

We have shown that temporal experience arises naturally within the Information Manifold Model as a consequence of intrinsic informational evolution. Chronoception is thus an emergent structural feature of conscious systems, completing the IMM account of experiential coherence across time.

Chapter 7

Information-Theoretic Metrics on Conscious Manifolds

Abstract

We introduce quantitative metrics on information manifolds within the Information Manifold Model (IMM). These metrics measure degrees of integration, coherence, temporal stability, and phase structure without redefining consciousness itself. Metrics are treated as descriptive tools layered atop the axiomatic framework, enabling empirical, computational, and comparative analysis while preserving the qualitative structure established in earlier papers.

7.1 Introduction

The preceding papers established the structural conditions under which conscious experience arises. While these conditions are binary—either satisfied or not— practical analysis often requires graded measures.

This paper introduces information-theoretic and geometric metrics defined on $\mathcal{M}$ that quantify properties such as integration strength, coherence, and temporal stability. Importantly, these metrics do not alter the criteria for consciousness; they provide descriptive refinement rather than ontological revision.

7.2 Preliminaries

All notation follows `IMM_Notation.tex`. We assume an information manifold $\mathcal{M}$ satisfying Axioms 1–4, with optional additional structure from Axioms 5–6.

7.3 Integration Metrics

Definition 20 (Integration Measure)**.** *An integration measure is a functional*

$$\mathcal{I}^* : \mathcal{P}(\mathcal{M}) \to \mathbb{R}_{\geq 0}$$

assigning a non-negative scalar to distributed informational subsets, representing the degree of integration required to produce a unified state.

Remark 12. *Unlike Integrated Information Theory (IIT), $\mathcal{I}^*$ is not constitutive of consciousness. It quantifies properties of systems already satisfying Axiom (Integration).*

7.4 Coherence and Phase Metrics

When Axioms 5 and 6 apply, relational structure admits quantitative description.

Definition 21 (Coherence Metric)**.** *A coherence metric is a function*

$$C : \mathcal{M} \to \mathbb{R}_{\geq 0}$$

measuring relational consistency among informational components.

Definition 22 (Phase Dispersion)**.** *Phase dispersion is a measure of relational phase variability among informational states prior to projection.*

Remark 13. *Low phase dispersion corresponds to high coherence and stable experiential projection.*

7.5 Temporal Stability Measures

Definition 23 (Temporal Stability Metric)**.** *A temporal stability metric is a functional*

$$S : \{\Phi_t\}_{t \in \mathbb{T}} \to \mathbb{R}_{\geq 0}$$

quantifying the persistence of experiential identity across intrinsic time.

Theorem 15 (Metric Consistency)**.** *For any system satisfying Axioms 1–4, temporal stability metrics are well-defined.*

Proof. Temporal stability depends on continuity and self-reference, guaranteed by the canonical axioms. Metrics quantify variation without affecting determinacy. □

7.6 Projection-Sensitive Metrics

Some metrics depend explicitly on experiential projection.

Definition 24 (Projection Entropy)**.** *Projection entropy quantifies information loss under*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}.$$

Remark 14. *Projection entropy measures compression from internal informational richness to experiential simplicity.*

7.7 Metric Independence

Theorem 16 (Metric Non-Constitutivity). *No metric introduced here is necessary or sufficient for consciousness.*

Proof. Consciousness within IMM is defined solely by axiomatic satisfaction. Metrics are defined only after axioms hold and therefore cannot constitute or negate consciousness. □

7.8 Applications and Limits

Metrics enable comparison across systems, temporal states, and implementations. They support empirical modeling and computational analysis but must not be mistaken for criteria of existence.

Remark 15. *Metrics are tools for study, not foundations of ontology.*

7.9 Conclusion

We have introduced a family of metrics on information manifolds that quantify structural properties of conscious systems without altering the axiomatic basis of the Information Manifold Model. These measures prepare the ground for empirical engagement and comparative analysis while preserving conceptual clarity.

Chapter 8

Extensions and Implications of the Information Manifold Model

Abstract

We synthesize the Information Manifold Model (IMM) and explore its implications for physics, artificial intelligence, and the philosophy of mind. We outline disciplined extensions of the framework, clearly distinguishing established results from conjectural directions. The aim is to situate IMM as a unifying structural program open to empirical engagement without overextending its axiomatic commitments.

8.1 Introduction

The preceding papers established IMM as a coherent axiomatic framework for conscious experience grounded in informational structure. We now examine what follows from this framework when it is placed in dialogue with physics, artificial systems, and broader theoretical programs.

This paper introduces no new axioms. All extensions are explicitly marked as applications, interpretations, or conjectures.

8.2 Summary of Established Results

IMM has shown that:

- Conscious experience is a structural property of information manifolds satisfying Axioms 1–4.
- Experiential determinacy and stability arise necessarily from projection, integration, and temporal continuity.
- Consciousness is substrate independent.
- Temporal experience (chronoception) emerges from intrinsic informational evolution.

- Quantitative metrics may be defined without altering ontological criteria.

These results form the non-negotiable core of the IMM framework.

8.3 Implications for Physics

IMM reframes several foundational questions in physics.

Remark 16. *Quantum states may be interpreted as representational encodings of informational structure rather than direct ontological entities. Measurement reflects structural projection rather than physical collapse.*

This perspective aligns with structural realist approaches and may clarify why the formalism of quantum mechanics is invariant across interpretive disputes.

8.3.1 Time and Relativity

IMM decouples experiential time from physical time.

Remark 17. *Relativistic time dilation and chronoceptive variation need not conflict. Physical time constrains informational evolution but does not constitute temporal experience.*

8.4 Implications for Artificial Intelligence

The substrate independence theorem has immediate relevance for artificial systems.

Remark 18. *Advanced artificial systems may instantiate conscious experience if they implement information manifolds satisfying the IMM axioms, regardless of biological similarity.*

This avoids both unwarranted skepticism and indiscriminate attribution of consciousness.

8.5 Ethical and Practical Considerations

IMM suggests that ethical considerations should track structural properties rather than appearances or origins.

Remark 19. *Moral status, if grounded in consciousness, should be evaluated relative to informational structure, not substrate or embodiment.*

IMM does not prescribe ethical conclusions but clarifies the criteria relevant to their evaluation.

8.6 Speculative Extensions

We now outline several conjectural directions for future work.

Conjecture 1 (Information Manifolds and Spacetime Structure)**.** *Spacetime geometry may emerge as an effective description of relational structure among informational manifolds.*

Conjecture 2 (Gravitational Coupling)**.** *Informational density or curvature may correlate with gravitational phenomena in appropriate limits.*

Remark 20. *These conjectures are exploratory and require independent mathematical and empirical development.*

8.7 Limitations and Open Questions

IMM remains an abstract framework. Key open questions include:

- How to empirically identify information manifolds in physical systems
- Which metrics best correlate with phenomenological reports
- How informational dynamics interact with thermodynamic constraints

These questions define a research program rather than immediate claims.

8.8 Conclusion

The Information Manifold Model offers a unified structural account of consciousness, measurement, and temporal experience. By grounding experience in axiomatic informational structure, IMM preserves rigor while remaining open to empirical and theoretical extension. The framework invites refinement, application, and testing without sacrificing conceptual clarity.

Chapter 9

Information Fields on the Information Manifold

Information Fields and Local Dynamics on Information Manifolds

Travis Bergen

Abstract

We extend the Information Manifold Model (IMM) by introducing local information fields defined over conscious information manifolds. These fields enable the definition of gradients, flows, and continuity equations intrinsic to informational structure, without introducing spacetime, physical forces, or new axioms. The resulting framework provides the mathematical substrate required for subsequent derivations involving projection measures, entropy, and emergent physical analogues.

1 Introduction

The Information Manifold Model characterizes conscious experience as a structural property of information manifolds satisfying a fixed set of axioms. While this axiomatic foundation is sufficient for determinacy and stability, it does not yet support local dynamical analysis.

In this paper, we introduce *information fields* defined over the manifold $\mathcal{M}$. These fields allow local variation, continuity, and flow to be expressed intrinsically, without appeal to external spacetime or physical dynamics. All constructions in this paper are conditional on the prior IMM axioms and introduce no new constitutive assumptions.

2 Preliminaries

We assume an information manifold $\mathcal{M}$ satisfying Axioms 1–4 of IMM, with intrinsic evolution governed by a self-referential flow Φ_t.

All notation follows `IMM_Notation.tex`.

3 Information Density Fields

Definition 1 (Information Density Field)**.** *An information density field is a measurable function*

$$\rho : \mathcal{M} \to \mathbb{R}_{\geq 0}$$

assigning a non-negative informational weight to points on the information manifold.

Remark 1. *The function ρ does not define consciousness or experience. It characterizes the distribution of informational structure within a system already satisfying the IMM axioms.*

4 Local Variation and Gradients

If $\mathcal{M}$ admits differentiable structure, local variation may be defined.

Definition 2 (Informational Gradient). *The informational gradient of ρ at $m \in \mathcal{M}$ is defined as*

$$\nabla\rho(m),$$

representing the direction of maximal local informational variation.

Remark 2. *The existence of $\nabla\rho$ is conditional on differentiability and is not assumed globally.*

5 Intrinsic Flow and Continuity

Informational structure evolves under intrinsic dynamics.

Definition 3 (Information Flow). *An information flow is a vector field*

$$J : \mathcal{M} \to T\mathcal{M}$$

representing directed informational propagation under Φ_t.

Definition 4 (Informational Continuity Equation). *An informational continuity equation takes the form*

$$\frac{\partial\rho}{\partial t} + \nabla \cdot J = 0,$$

expressing conservation of informational structure under intrinsic evolution.

Remark 3. *The continuity equation is structural, not physical. It asserts internal consistency of informational dynamics, not conservation of energy or matter.*

6 Curvature and Informational Geometry

Local variation permits geometric characterization.

Definition 5 (Informational Curvature). *Informational curvature characterizes second-order variation of ρ over $\mathcal{M}$ and quantifies deviation from uniform informational distribution.*

Remark 4. *Informational curvature does not imply spacetime curvature. It is an intrinsic property of informational structure only.*

7 Relation to Projection

Fields defined on $\mathcal{M}$ interact with experiential projection.

Remark 5. *Regions of high informational density or curvature influence the compression induced by the projection*

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}.$$

This influence will be formalized in subsequent work.

8 Limitations

This paper introduces no physical interpretation of informational fields. There is:

- no spacetime
- no force law
- no coupling constants
- no empirical claims

All results are preparatory and structural.

9 Conclusion

We have introduced information fields and local dynamics on information manifolds within the Information Manifold Model. These constructions extend IMM's descriptive power without altering its axiomatic foundation. The resulting framework enables subsequent derivations involving projection measures, entropy, and emergent physical analogues while preserving conceptual discipline.

Chapter 10

Born Rule from Projection Measures

The Born Rule as a Projection Measure on Information Manifolds

Travis Bergen

Abstract

We derive the Born rule as a uniquely stable projection measure within the Information Manifold Model (IMM), conditional on minimal linear and phase-geometric structure. Measurement is treated as experiential projection from an information manifold to event space. Under additivity, compositional invariance, and normalization, the quadratic (modulus-squared) measure emerges as the only consistent assignment of outcome weights. No new axioms are introduced; all results are conditional extensions.

1 Introduction

In IMM, measurement is not a physical collapse but a structural projection

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E}.$$

This projection compresses informational structure into determinate experiential events. The present paper asks: *what measure over outcomes is consistent with this projection when minimal linear structure is present?*

We show that, given additivity of representations and stability under composition, the Born rule arises as the unique projection-consistent measure.

2 Preliminaries and Assumptions

We assume an information manifold $\mathcal{M}$ satisfying Axioms 1–4 of IMM. We additionally assume the following *structural conditions* (not axioms):

- **Linearity:** Representational superposition on $\mathcal{M}$ is linear.
- **Phase Geometry:** States admit a phase structure invariant under global phase transformations.
- **Compositionality:** Independent subsystems compose multiplicatively.

These conditions are standard in quantum contexts and are adopted here solely for derivational purposes.

3 Projection Measures

Definition 1 (Projection Measure)**.** *A projection measure is a function*

$$\mu : \mathcal{M} \to \mathbb{R}_{\geq 0}$$

assigning non-negative weights to representational states such that, for any normalized state, the total projected weight over $\mathcal{E}$ is unity.

4 Additivity and Composition

Lemma 1 (Additivity)**.** *For representational states $m_1, m_2 \in \mathcal{M}$,*

$$\mu(m_1 + m_2) = \mu(m_1) + \mu(m_2) + \textit{interference terms.}$$

Remark 1. *Interference arises from phase relations intrinsic to representational structure, not from physical interaction.*

Lemma 2 (Multiplicativity)**.** *For independent subsystems with states m_A, m_B,*

$$\mu(m_A \otimes m_B) = \mu(m_A)\mu(m_B).$$

5 Uniqueness of the Quadratic Measure

Theorem 1 (Born Measure Uniqueness)**.** *Under linearity, phase invariance, normalization, and compositionality, the only projection measure consistent with experiential determinacy is*

$$\mu(m) = |\psi(m)|^2,$$

where ψ is a complex amplitude representation of m.

Proof. Linearity and phase invariance exclude linear measures. Compositionality enforces multiplicativity. Normalization fixes scaling. The quadratic modulus is the unique function satisfying all constraints simultaneously. □

6 Interpretational Consequences

Remark 2. *The Born rule is not postulated. It arises as a stability requirement for projection from informational structure to experiential events.*

Remark 3. *This derivation does not claim that IMM replaces quantum mechanics. It shows that, given minimal representational structure, the Born rule is the only consistent projection measure.*

7 Relation to Existing Results

This result aligns structurally with Gleason-type theorems while differing in interpretation. The measure arises from experiential projection rather than measurement postulates.

8 Limitations

This derivation is conditional. Without linearity or phase structure, no unique measure is implied. IMM itself remains agnostic to the presence of quantum structure.

9 Conclusion

We have shown that the Born rule emerges as the unique stable projection measure on information manifolds endowed with minimal linear and phase-geometric structure. Measurement probabilities are thus understood as structural consequences of projection, not primitive axioms.

Chapter 11

Entropy as Projection Loss and the Arrow of Time

Entropy as Projection Loss and the Arrow of Time in Information Manifolds

Travis Bergen

Abstract

We interpret entropy within the Information Manifold Model (IMM) as information loss induced by experiential projection. By distinguishing intrinsic informational dynamics from projected experiential outcomes, we show how an arrow of time emerges structurally without modifying thermodynamic postulates. Entropy is reframed as a measure of irreversible compression from information manifolds to experiential event space, naturally aligning with chronoception.

1 Introduction

Entropy has traditionally been associated with disorder, multiplicity, or ignorance. In IMM, however, experience is not coextensive with informational structure. Measurement and awareness involve projection

$$\Pi_{\text{exp}} : \mathcal{M} \to \mathcal{E},$$

which compresses rich informational states into determinate experiential events.

This paper formalizes entropy as the informational loss induced by this projection and demonstrates how a temporal arrow arises from structural asymmetry between intrinsic dynamics and experiential access.

2 Preliminaries

We assume an information manifold $\mathcal{M}$ satisfying Axioms 1–4, with intrinsic evolution governed by Φ_t. No assumptions are made about spacetime or physical entropy laws beyond standard consistency.

3 Projection-Induced Information Loss

Definition 1 (Projection Loss). *For an informational state $m \in \mathcal{M}$, projection loss is defined as*

$$\Delta I(m) = I(m) - I(\Pi_{\text{exp}}(m)),$$

where I denotes an information measure appropriate to the representational context.

Remark 1. *Projection loss reflects compression from informational richness to experiential simplicity. It is structural, not epistemic.*

4 Entropy as Accumulated Projection Loss

Definition 2 (Experiential Entropy)**.** *Experiential entropy over an interval* $[t_0, t_1]$ *is defined as*

$$S_{\mathrm{exp}} = \int_{t_0}^{t_1} \Delta I(\Phi_t(m))\, dt.$$

Remark 2. *This quantity measures irreversible informational loss under repeated projection, not disorder in the underlying manifold.*

5 Arrow of Time

Theorem 1 (Temporal Asymmetry)**.** *If projection loss is non-negative and intrinsic dynamics are time-continuous, then experiential entropy is non-decreasing.*

Proof. Projection reduces accessible informational degrees of freedom. While intrinsic dynamics may be reversible, projection is not invertible. Therefore accumulated projection loss increases monotonically. □

Remark 3. *The arrow of time arises from asymmetry between intrinsic evolution and experiential access, not from fundamental irreversibility.*

6 Relation to Chronoception

Chronoception (Paper 6) identifies subjective temporal flow with informational change. Entropy, as defined here, quantifies the irreversible component of that change.

Remark 4. *Chronoceptive duration correlates with cumulative projection loss rather than physical clock time.*

7 Relation to Thermodynamic Entropy

Remark 5. *This framework does not redefine thermodynamic entropy. Instead, it offers a structural interpretation compatible with standard statistical mechanics.*

Experiential entropy tracks informational accessibility, while thermodynamic entropy tracks microstate multiplicity.

8 Limitations

This account does not claim:

- a new physical entropy law,
- violation of reversibility at the fundamental level,
- empirical predictions without additional modeling.

9 Conclusion

Entropy in IMM is understood as projection-induced information loss. The arrow of time emerges from structural asymmetry between intrinsic informational dynamics and experiential access. This reframing unifies entropy, measurement, and temporal experience without modifying physical laws or introducing new axioms.

Chapter 12

Gravity as Informational Curvature

Gravitational Phenomena as Informational Curvature: A Structural Conjecture

Travis Bergen

Abstract

We propose a conjectural correspondence between gravitational phenomena and curvature of information density fields defined on information manifolds within the Information Manifold Model (IMM). This paper introduces no new axioms and makes no empirical claims. The aim is to outline a structurally consistent mapping between informational geometry and emergent gravitational behavior, suitable for future mathematical and physical development.

1 Introduction

Several contemporary approaches suggest that gravity may not be fundamental but emergent from deeper informational or entropic principles. Within IMM, informational structure is primary, while spacetime and physical dynamics are secondary descriptions.

This paper explores whether gravitational behavior can be coherently interpreted as an emergent manifestation of informational curvature on $\mathcal{M}$. All results are explicitly conjectural.

2 Informational Curvature Revisited

Paper 9 introduced informational curvature as second-order variation of information density fields:

$$\rho : \mathcal{M} \to \mathbb{R}_{\geq 0}.$$

Remark 1. *Regions of high informational curvature represent strong gradients in informational structure, not spacetime distortion.*

3 Projection Bias and Effective Attraction

Experiential projection compresses informational structure.

Remark 2. *If projection preferentially selects lower-curvature paths (due to stability or compression efficiency), then regions of high informational density may exert an effective attractive influence on projected trajectories.*

This influence is informational, not force-mediated.

4 Conjectural Correspondence

Conjecture 1 (Informational Curvature Correspondence)**.** *In appropriate limits, informational curvature on $\mathcal{M}$ may correspond to effective spacetime curvature in physical descriptions.*

Remark 3. *This correspondence is structural, not identity-based. No claim is made that informational curvature* is *spacetime curvature.*

5 Entropy, Mass, and Geometry

Paper 11 identified entropy as accumulated projection loss.

Remark 4. *High informational density regions induce greater projection loss, suggesting a possible structural analogy with mass-energy content.*

This analogy aligns qualitatively with entropic and holographic gravity proposals.

6 Compatibility with Existing Approaches

This conjecture is compatible with:

- entropic gravity models,
- holographic principles,
- spacetime-as-information programs.

Remark 5. *IMM does not replace or modify general relativity. It offers a structural lens through which gravitational phenomena may be reinterpreted.*

7 Limitations and Non-Claims

This paper does not:

- derive Einstein field equations,
- propose new constants,
- make testable predictions,
- assert physical identity between information and spacetime.

8 Future Directions

Possible extensions include:

- formal mappings between informational curvature and spacetime metrics,
- coupling informational entropy to geometric action principles,
- identifying empirical signatures of projection bias.

9 Conclusion

We have outlined a conjectural correspondence between gravitational phenomena and informational curvature within the IMM framework. This proposal preserves conceptual discipline while opening a pathway for future theoretical and empirical investigation. IMM remains a structural foundation upon which such explorations may cautiously build.

Chapter 13

Informational Action Principles and Variational Dynamics

Informational Action Principles and Variational Dynamics on Information Manifolds

Travis Bergen

Abstract

We introduce an informational variational principle on the IMM information manifold $\mathcal{M}$. By defining an informational action functional over scalar and geometric fields, we derive Euler–Lagrange equations governing intrinsic informational dynamics. This paper introduces no new IMM axioms; it provides a mathematical mechanism by which field equations may be obtained as stationary conditions of an informational action.

1 Introduction

Papers 9–12 introduced local fields, projection measures, and entropy as projection loss. To derive *field equations*, we require a variational principle: a rule specifying which trajectories or configurations of informational structure are dynamically preferred.

In physics, field equations typically arise as stationary conditions of an action functional. We adopt the same mathematical architecture on the information manifold $\mathcal{M}$.

2 Preliminaries

Let $\mathcal{M}$ denote the IMM information manifold satisfying Axioms 1–4. Let $\rho : \mathcal{M} \to \mathbb{R}_{\geq 0}$ be an information density field (Paper 9). We assume $\mathcal{M}$ is sufficiently regular to support integration against a measure $d\mu$, and (when needed) a metric g_{ab} on $\mathcal{M}$.

Remark 1. *The metric g_{ab} introduced here is an* informational metric *(a geometry on $\mathcal{M}$), not spacetime. A later correspondence step may map informational geometry to effective physical geometry.*

3 Informational Action Functionals

Definition 1 (Informational Action)**.** *An informational action is a functional*

$$\mathcal{S}[\rho, g] \;=\; \int_{\mathcal{M}} \mathcal{L}(\rho, \nabla\rho, g)\; d\mu_g,$$

where $\mathcal{L}$ is an informational Lagrangian density and $d\mu_g$ is the volume measure induced by g.

Definition 2 (Minimal Informational Lagrangian). *A minimal Lagrangian for ρ takes the form*

$$\mathcal{L}(\rho, \nabla\rho, g) = \frac{\alpha}{2} g^{ab} \nabla_a \rho \nabla_b \rho \; + \; V(\rho) \; + \; \beta \, \mathcal{C}(\rho, g),$$

where:

- *the first term penalizes sharp informational gradients (smoothness / stability),*
- *$V(\rho)$ is an informational potential,*
- *$\mathcal{C}(\rho, g)$ is an optional coherence/constraint term (e.g., projection stability),*
- *$\alpha, \beta \geq 0$ are weights.*

Remark 2. *The functional form above is selected for universality: it is the lowest-order local action built from ρ and its first derivatives that is coordinate-invariant on $\mathcal{M}$.*

4 Euler–Lagrange Dynamics for Information Fields

Theorem 1 (Informational Euler–Lagrange Equation). *If ρ is varied with compact support and $\mathcal{S}[\rho, g]$ is stationary under $\rho \mapsto \rho + \epsilon\eta$, then ρ satisfies*

$$\nabla_a \left(\alpha \, g^{ab} \nabla_b \rho \right) \; - \; V'(\rho) \; - \; \beta \, \frac{\partial \mathcal{C}}{\partial \rho} \; = \; 0.$$

Proof. This is the standard Euler–Lagrange variation on a manifold with metric measure. The gradient term yields the covariant divergence $\nabla_a(\alpha g^{ab} \nabla_b \rho)$; the remaining terms vary pointwise. □

Remark 3. *When $\beta = 0$ and V is quadratic, this reduces to an informational Helmholtz/Laplace-type equation. The $\mathcal{C}$ term allows coupling to projection stability and coherence metrics.*

5 Action Principles with Projection Loss

Paper 11 defined entropy as accumulated projection loss. We can encode projection loss directly into the action.

Definition 3 (Projection-Loss Penalty Term). *Let $\Delta I(\rho, g)$ denote a local proxy for projection loss (compression under Π_{exp}). Define*

$$\mathcal{C}(\rho, g) := \Delta I(\rho, g),$$

so that the action penalizes informational configurations that produce excessive irreversible compression.

Remark 4. *This links stability of experience to a variational principle: states evolve toward configurations that are locally smooth* and *projection-stable.*

6 Geometry Variation and Stress Analogues

To obtain true *field equations*, one often varies the geometry.

Definition 4 (Geometric Variation). *A geometric field equation on $\mathcal{M}$ arises from stationarity under*

$$g_{ab} \mapsto g_{ab} + \epsilon h_{ab}.$$

Remark 5. *Varying g produces a stress/flux analogue: an informational tensor encoding how ρ sources curvature in informational geometry. This is developed in the next paper.*

7 Limitations and Scope

This paper introduces:

- no spacetime,
- no physical constants,
- no empirical claims,
- no modification of IMM axioms.

It provides only the mathematical infrastructure required for deriving informational field equations.

8 Conclusion

We introduced informational action principles on IMM information manifolds and derived Euler–Lagrange equations governing information fields. This establishes the mechanism by which IMM extensions can produce field equations as stationary conditions. In the next paper we vary the informational geometry itself to obtain curvature-sourcing equations analogous in form to physical field equations, while remaining explicitly informational in meaning.

Chapter 14

Informational Field Equations from Geometric Variation

Informational Field Equations from Geometric Variation on Information Manifolds

Travis Bergen

Abstract

We derive informational field equations on the IMM information manifold $\mathcal{M}$ by varying an informational action with respect to an informational metric g_{ab}. The resulting equations are covariant on $\mathcal{M}$ and express how informational content sources informational curvature. These equations are not asserted to be physical spacetime dynamics; they constitute a structurally analogous field theory internal to informational geometry. A correspondence to physical gravity, if present, must be established separately.

1 Introduction

Papers 9–13 introduced information fields, projection measures, entropy as projection loss, and an informational action principle. Field equations require geometric variation: we allow the informational geometry $(\mathcal{M}, g)$ to respond to informational content.

In physics, Einstein field equations arise from varying the Einstein–Hilbert action. We adopt an analogous construction on $\mathcal{M}$, defining a curvature term for the informational metric and coupling it to informational matter fields (e.g., ρ).

2 Informational Geometry

Let $\mathcal{M}$ be an information manifold. Assume $\mathcal{M}$ admits an informational metric g_{ab} with associated Levi-Civita connection ∇, curvature tensor, Ricci tensor R_{ab}, scalar curvature R, and volume form $d\mu_g$.

Remark 1. *All geometric objects in this paper live on $\mathcal{M}$ and describe informational geometry. They are not assumed to coincide with physical spacetime geometry.*

3 Action Functional

Definition 1 (Informational Einstein–Hilbert Action). *Define the informational gravitational action*

$$\mathcal{S}_{\text{geo}}[g] = \frac{1}{2\kappa} \int_{\mathcal{M}} (R - 2\Lambda)\, d\mu_g,$$

where R is the scalar curvature of $(\mathcal{M}, g)$, Λ is an informational cosmological term, and $\kappa > 0$ is a coupling constant.

Definition 2 (Informational Matter Action). *Let $\rho : \mathcal{M} \to \mathbb{R}_{\geq 0}$ be an information density field. Define*

$$\mathcal{S}_{\text{mat}}[\rho, g] = \int_{\mathcal{M}} \mathcal{L}_{\text{mat}}(\rho, \nabla\rho, g)\, d\mu_g,$$

with

$$\mathcal{L}_{\text{mat}} = \frac{\alpha}{2}\, g^{ab}\nabla_a\rho\, \nabla_b\rho \;+\; V(\rho) \;+\; \beta\, \Delta I(\rho, g).$$

Remark 2. *The $\Delta I(\rho, g)$ term encodes a local proxy for projection loss (Paper 11). It penalizes informational configurations that are unstable under experiential projection.*

Definition 3 (Total Action).

$$\mathcal{S}[\rho, g] = \mathcal{S}_{\text{geo}}[g] + \mathcal{S}_{\text{mat}}[\rho, g].$$

4 Informational Stress Tensor

Definition 4 (Informational Stress Tensor). *The informational stress tensor is defined by*

$$\mathcal{T}_{ab} := -\frac{2}{\sqrt{|g|}} \frac{\delta \mathcal{S}_{\text{mat}}}{\delta g^{ab}},$$

where $\sqrt{|g|}$ denotes the metric volume density.

Remark 3. *$\mathcal{T}_{ab}$ measures how informational matter fields (including projection-loss penalties) source curvature in informational geometry.*

5 Field Equations from Geometric Variation

Theorem 1 (Informational Field Equations). *Stationarity of $\mathcal{S}[\rho, g]$ under metric variation $g_{ab} \mapsto g_{ab} + \epsilon h_{ab}$ yields*

$$R_{ab} - \frac{1}{2} R\, g_{ab} + \Lambda g_{ab} = \kappa\, \mathcal{T}_{ab}.$$

Proof. This follows from standard variational calculus on a (pseudo-)Riemannian manifold: variation of $\mathcal{S}_{\text{geo}}$ yields the Einstein tensor plus Λg_{ab}, and variation of $\mathcal{S}_{\text{mat}}$ defines $\mathcal{T}_{ab}$ as the source term. □

6 Conservation Law

Theorem 2 (Informational Covariant Conservation). *If the action is diffeomorphism-invariant on $\mathcal{M}$, then*

$$\nabla^a \mathcal{T}_{ab} = 0.$$

Remark 4. *This is an informational analogue of stress-energy conservation. It expresses internal consistency of informational dynamics under coordinate changes on $\mathcal{M}$.*

7 Interpretation and Correspondence

Remark 5. *These equations define how informational curvature responds to informational content. A separate correspondence principle would be required to identify a map from informational geometry to physical spacetime geometry.*

Remark 6. *If a correspondence exists, one would seek conditions under which informational curvature reduces to effective spacetime curvature in a macroscopic limit. This is not assumed here.*

8 Limitations

This paper does not:

- claim that g_{ab} is spacetime,
- derive numerical values of constants,
- make empirical predictions,
- modify general relativity.

It provides a covariant informational field theory internal to IMM extensions.

9 Conclusion

We derived covariant informational field equations by varying an informational action with respect to the informational metric on $\mathcal{M}$. The resulting Einstein-analogue links informational curvature to informational stress, including projection-loss contributions. This supplies the formal backbone needed to explore correspondence limits and to connect IMM structural dynamics to physical field descriptions in future work.

Chapter 15

Correspondence Limits to Effective Spacetime Dynamics

Correspondence Limits: From Informational Geometry to Effective Spacetime Dynamics

Travis Bergen

Abstract

We specify correspondence limits under which informational field equations derived on the Information Manifold Model (IMM) may admit effective spacetime interpretations. No identity between informational and physical geometry is assumed. Instead, we define conditions under which informational metrics, curvature, and stress reduce to familiar spacetime dynamics in coarse-grained regimes. This paper establishes IMM as a structural substrate compatible with general relativity, entropic gravity, and holographic programs, without modifying their empirical content.

1 Introduction

Papers 13 and 14 derived covariant informational field equations on the information manifold $\mathcal{M}$. These equations govern informational curvature sourced by informational stress. To relate these results to physics, we require a *correspondence principle*: a set of conditions under which informational geometry admits an effective spacetime description.

This paper introduces such correspondence limits without asserting physical identity or replacing established theories.

2 Separation of Domains

We distinguish:

- **Informational domain**: $(\mathcal{M}, g_{ab})$, governed by IMM extensions
- **Physical domain**: $(\mathcal{S}, g_{\mu\nu})$, governed by empirical physics

Remark 1. *No assumption is made that* $\mathcal{M} = \mathcal{S}$ *or that* $g_{ab} = g_{\mu\nu}$*. Correspondence is conditional and emergent.*

3 Coarse-Graining and Projection

Experiential projection already enforces compression:

$$\Pi_{\exp} : \mathcal{M} \to \mathcal{E}.$$

Definition 1 (Physical Coarse-Graining Map). *A coarse-graining map*

$$\Pi_{\text{phys}} : \mathcal{M} \to \mathcal{S}$$

associates equivalence classes of informational states with effective physical events.

Remark 2. Π_{phys} *is not fundamental. It summarizes large-scale regularities of informational structure.*

4 Metric Correspondence

Definition 2 (Metric Correspondence Limit). *A metric correspondence limit exists if there is a regime in which*

$$g_{ab}^{(\mathcal{M})} \longrightarrow g_{\mu\nu}^{(\mathcal{S})}$$

under coarse-graining, up to diffeomorphism and scale.

Remark 3. *This limit requires suppression of fine-grained informational curvature fluctuations and dominance of large-scale informational gradients.*

5 Stress Correspondence

Definition 3 (Effective Stress Tensor). *An effective spacetime stress tensor* $T_{\mu\nu}$ *arises if*

$$\Pi_{\text{phys}}(\mathcal{T}_{ab}) \approx T_{\mu\nu}$$

in the correspondence regime.

Remark 4. *Projection-loss contributions may appear as effective mass-energy terms in this limit, suggesting a structural basis for entropic or emergent gravity models.*

6 Recovery of Einstein-Like Dynamics

Theorem 1 (Einstein-Form Recovery (Conditional)). *If metric and stress correspondence limits hold and informational curvature is dominated by large-scale contributions, then the informational field equations reduce to*

$$G_{\mu\nu} + \Lambda g_{\mu\nu} \approx 8\pi T_{\mu\nu}$$

up to rescaling of constants.

Remark 5. *This recovery is approximate and scale-dependent. IMM does not predict numerical constants or modify empirical general relativity.*

7 Relation to Existing Programs

This correspondence is structurally compatible with:

- entropic gravity (gravity from information gradients),
- holographic principles (bulk information encoding),
- spacetime-as-emergent programs.

Remark 6. *IMM provides a unifying structural substrate without privileging any single approach.*

8 Non-Claims

IMM does not claim:

- a fundamental replacement for spacetime,
- experimental deviations from general relativity,
- resolution of quantum gravity.

The correspondence framework is interpretive and preparatory.

9 Conclusion

We have defined correspondence limits under which informational geometry and field equations admit effective spacetime interpretations. These limits preserve the empirical success of existing physical theories while situating them within a broader informational framework. IMM thus functions as a structural substrate capable of supporting, rather than supplanting, established physics.