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Interference-First Reality Theory: Foundations and Objectivity

—Postulates, Mathematical Structure, and Emergent Objectivity [IFR Theory Series, Part I of VI]

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Abstract

This is Part I of the six-part series presenting the Interference-First Reality (IFR) Theory. We introduce IFR as a variational information-geometric framework in which physical objectivity is not assumed but derived as a stable multi-observer limit of an underlying pre-spatiotemporal interference state $\Psi \in \mathcal{H}_{\chi}$. This part establishes the foundational postulates, the complete mathematical structure, and the formal definition of objectivity as stable multi-observer contraction.

Keywords

Interference-First Reality, Information Geometry, Jensen-Shannon Distance, Fréchet Barycenter, Multi-Observer Stabilization, Emergent Objectivity

1. Introduction

Modern fundamental physics rests on two exceptionally successful, yet conceptually incomplete, descriptions of nature. General relativity identifies gravitation with the dynamical geometry of spacetime, while quantum theory describes physical systems in terms of amplitudes, superposition, interference, and measurement-dependent outcomes. Each framework is internally powerful within its domain, but their conceptual foundations remain difficult to reconcile. In particular, quantum theory presupposes a background structure in which states, measurements, and correlations are defined, whereas general relativity promotes spacetime geometry itself to a dynamical entity. A fully coherent formulation of fundamental physics should therefore explain not only how matter evolves within spacetime, but also how objective spacetime structure, temporal order, and gravitational geometry arise from a deeper level of description.

A common feature of several contemporary approaches is the recognition that spacetime and objectivity may not be primitive. In quantum foundations, decoherence and related redundancy-based accounts show how classical records may become robust through environmental proliferation [1] [2]. In information geometry, distinguishability between states acquires a metric structure [3]. In emergent-gravity programs, gravitational dynamics are often interpreted as macroscopic or thermodynamic consequences of more primitive microscopic degrees of freedom [4]-[7]. These approaches suggest that the classical world may arise through stability, redundancy, coarse-graining, and information-theoretic organization. However, a unified formal principle connecting interference, observer-dependent projections, emergent objectivity, temporal ordering, and gravitational geometry remains lacking.

The purpose of the present paper is to formulate such a principle. We introduce *Interference-First Reality* (IFR) as a variational information-geometric framework in which physical objectivity is not assumed, but derived. The primitive element of the theory is not an object in spacetime, nor a classical field on a pre-existing manifold, but an interference state

$$\Psi \in \mathcal{H}_{\mathcal{X}},$$

defined on an abstract pre-spatiotemporal configuration space $\mathcal{X}$. Operational observers are represented by maps

$$\Pi_a : \mathcal{H}_{\mathcal{X}} \to \mathcal{M}_a,$$

where $\mathcal{M}_a$ denotes the representation space accessible to observer a. These observers need not be conscious agents. They may be detectors, instruments, coarse-graining schemes, observational windows, epochs, catalog partitions, environmental fragments, or any operational subsystem capable of producing a stable projection of the underlying interference structure.

The central hypothesis of IFR is that objective physical structures emerge when multiple observer-dependent projections contract toward a common stable informational center. Agreement is not treated as an epistemic convenience, but as a physical selection principle. Given a common information geometry Γ and a distance function d_Γ, IFR defines the redundant multi-observer dispersion functional

$$\mathcal{D}_{\text{red}}[\Psi,\Gamma] = \sum_{a<b} w_{ab} d_\Gamma^2\left(\Pi_a[\Psi],\Pi_b[\Psi]\right),$$

where $w_{ab} \ge 0$ weights the operational relevance or reliability of the pair of observers (a,b). Low redundant dispersion indicates that distinct observational reconstructions encode the same underlying structure. A stable minimum of this functional defines an objective structure in the IFR sense.

This formulation generalizes and formalizes the core idea developed in our previous work [8]-[10], where objectivity was operationally associated with the convergence of redundant observational reconstructions across gravitational-wave detectors, cosmological maps, physiological epochs, smoothing choices, instrumental modes, and catalog partitions. In those analyses, physical robustness was not identified with any single representation, but with the persistence of a common structure across independent observational cuts. The present paper elevates that empirical and methodological criterion into a general theoretical principle: objectivity is the stable Fréchet-type contraction of observer-dependent projections of an underlying interference state.

A crucial feature of IFR is that the same principle is extended to gravitation. In general relativity, the metric tensor $g_{\mu\nu}$ describes the geometry of spacetime, and gravitational phenomena arise from curvature. In IFR, the corresponding primitive is not initially a spacetime metric, but an information geometry Γ defined on the space of distinguishable observational structures. Gravitation is then interpreted as the observer-stable manifestation of curvature in this emergent informational geometry. More precisely, when stable redundant structures constrain the admissible transitions of the surrounding informational state space, they induce an effective deformation of the geometry available to other structures. In the macroscopic limit, this deformation is represented by an effective spacetime metric

$$g_{\mu\nu}^{\mathrm{eff}},$$

and its curvature reproduces gravitational behavior. Thus, IFR does not add gravity externally to an information-theoretic theory; rather, it identifies gravitational geometry as the large-scale, observer-stable limit of informational curvature generated by persistent objective structures.

The formal dynamics of IFR are specified by a variational principle. The generating functional of the theory is written schematically as

$$\mathcal{Z}_{\mathrm{IFR}} = \int \mathcal{D}\Psi\mathcal{D}\Gamma\mathcal{D}\Pi \exp\left[i\mathcal{S}_{\mathrm{IFR}}\left[\Psi,\Gamma,\Pi\right]\right],$$

where the action contains interference dynamics, informational self-organization, redundant multi-observer contraction, and informational curvature:

$$\mathcal{S}_{\mathrm{IFR}} = \int \mathrm{d}\lambda \left[\mathcal{K}_{\mathrm{int}}\left[\Psi\right] - \mathcal{V}_{\mathrm{int}}\left[\Psi\right] - \alpha\mathcal{D}_{\mathrm{red}}\left[\Psi,\Gamma\right] + \beta\mathcal{R}_{\Gamma}\right].$$

Here $\mathcal{K}_{\mathrm{int}}$ denotes the kinetic or propagating component of the interference state, $\mathcal{V}_{\mathrm{int}}$ denotes an informational potential selecting stable configurations, $\mathcal{D}_{\mathrm{red}}$ enforces multi-observer contraction, and $\mathcal{R}_{\Gamma}$ denotes an intrinsic curvature scalar associated with the information geometry. The constants α and β determine the relative strength of redundant objectivization and informational curvature.

The parameter λ appearing in the action is not assumed to be physical time. This distinction is essential. In IFR, temporal order is not inserted at the fundamental level; it is derived from the ordered succession of stable objective structures. Given a family of minima of redundant dispersion,

$$Q_1^{\star}, Q_2^{\star}, Q_3^{\star}, \cdots,$$

physical time corresponds to the emergent order relation among them, generated by asymmetric memory, irreversible information accumulation, or monotonic stability constraints. Time is therefore treated as a relational ordering of informational stabilization, not as an external background parameter.

The same logic applies to space. IFR does not assume that the fundamental configuration space $\mathcal{X}$ is a spacetime manifold. Spacetime emerges only when the information geometry Γ admits a low-dimensional effective metric representation. If there exists a map

$$\phi : \mathcal{X} \to \mathcal{M}_{\text{eff}}$$

such that the informational distance between configurations is approximated by a metric distance on an effective manifold,

$$d_\Gamma\left(x_i, x_j\right) \approx d_{\text{eff}}\left(\phi\left(x_i\right), \phi\left(x_j\right)\right),$$

then $\mathcal{M}_{\text{eff}}$ is interpreted as emergent space, and the corresponding metric structure defines the effective spacetime geometry. In the high-redundancy semiclassical regime, the IFR action must reduce to an effective gravitational and field-theoretic action of the form

$$\mathcal{S}_{\text{IFR}} \to \int \mathrm{d}^4 x \sqrt{-g_{\text{eff}}}\left[R\left(g_{\text{eff}}\right) + \mathcal{L}_{\text{matter}}^{\text{eff}}\right],$$

up to corrections controlled by residual redundant dispersion and informational curvature terms.

The objective of this paper is therefore not to replace established physics by a speculative metaphor, but to provide a precise mathematical framework in which the emergence of objectivity, time, space, and gravitation can be formulated within a single variational structure. The theory is deliberately constructed so that its core quantities are operationally meaningful: observer maps, information-geometric distances, redundant dispersion, Fréchet centers, stability criteria, and effective metric limits. This makes IFR compatible with empirical estimators already used in previous analyses, while also allowing a more fundamental theoretical interpretation. The remainder of this paper is organized as follows. Section 2 states the eight foundational postulates of IFR. Section 3 develops the corresponding mathematical structure: the pre-spatiotemporal configuration space $\mathcal{X}$, the interference-state space $\mathcal{H}_{\mathcal{X}}$, admissible observer maps Π_a, the common comparison space $\left(\mathcal{M}, \Gamma\right)$, the redundant dispersion functional $\mathcal{D}_{\text{red}}$, and the regularity conditions (Section 3.10) required for the variational principle of Postulate V to be well-posed. Section 4 gives the formal definition of IFR-objectivity as stable multi-observer contraction toward a Fréchet center, establishes existence, uniqueness, and stability results (Propositions 1 - 3), proves the central objectivity theorem (Theorem 1), distinguishes IFR from decoherence, quantum Darwinism, relational approaches, and emergent-gravity programs, and states concrete falsifiability criteria together with the limitations of the present construction. Section 5 summarizes the results of Part I and their role within the series. The dynamical and empirical content of IFR is developed in the remaining parts of the series, which are the subject of separate papers and are not contained in the present Part

I. Part II introduces the IFR action $\mathcal{S}_{\mathrm{IFR}}$, derives the associated variational equations, and develops the gravitational sector, in which effective spacetime curvature arises from informational curvature $\mathcal{R}_{\mathrm{T}}$. The subsequent parts formulate the emergence of temporal order from ordered sequences of stable Fréchet centers, discuss the semiclassical and general-relativistic limits, and connect the framework to the empirical estimators and cross-domain analyses (CMB, HRV, GWOSC, JWST, LSS) reported in our previous work [8]-[10] and in the accompanying reproducibility material. The present Part I is self-contained at the level of foundations: it establishes the postulates, the mathematical structure, and the definition and existence theory of objectivity, on which the later dynamical and empirical developments rely.

2. Foundational Postulates

The purpose of this section is to state the minimal set of assumptions on which Interference-First Reality is built. These postulates are not intended to replace the empirical content of quantum field theory or general relativity at the observational level. Rather, they define a deeper mathematical layer from which objectivity, temporal order, effective spacetime, and gravitational geometry are to be derived as emergent structures.

The guiding principle is that physical reality should not be defined by assuming, from the outset, a background spacetime populated by already-objective entities. Instead, IFR begins from an underlying interference structure and asks under what conditions stable, observer-invariant, geometrically organized phenomena arise.

2.1. Postulate I: Primacy of the Interference State

There exists an abstract configuration space

$$\mathcal{X},$$

whose elements are not assumed to be spacetime events, particle positions, field values on a manifold, or classical states. Rather, $\mathcal{X}$ denotes a pre-spatiotemporal space of possible informational configurations.

The primitive dynamical object is an interference state

$$\Psi \in \mathcal{H}_{\mathcal{X}},$$

where $\mathcal{H}_{\mathcal{X}}$ is a complex Hilbert space associated with $\mathcal{X}$. In a representation where elements of $\mathcal{X}$ can be labeled by x, the state may be written formally as

$$\Psi : \mathcal{X} \to \mathbb{C}, \quad x \mapsto \Psi(x).$$

The quantity $\Psi(x)$ is not interpreted as the amplitude of an event occurring at a spacetime point. It is instead the amplitude associated with a primitive informational configuration. Interference, rather than localization in spacetime, is therefore the primary structural feature of the theory.

$$\boxed{\text{The fundamental state of reality is an interference structure, not an object configuration in spacetime.}}$$

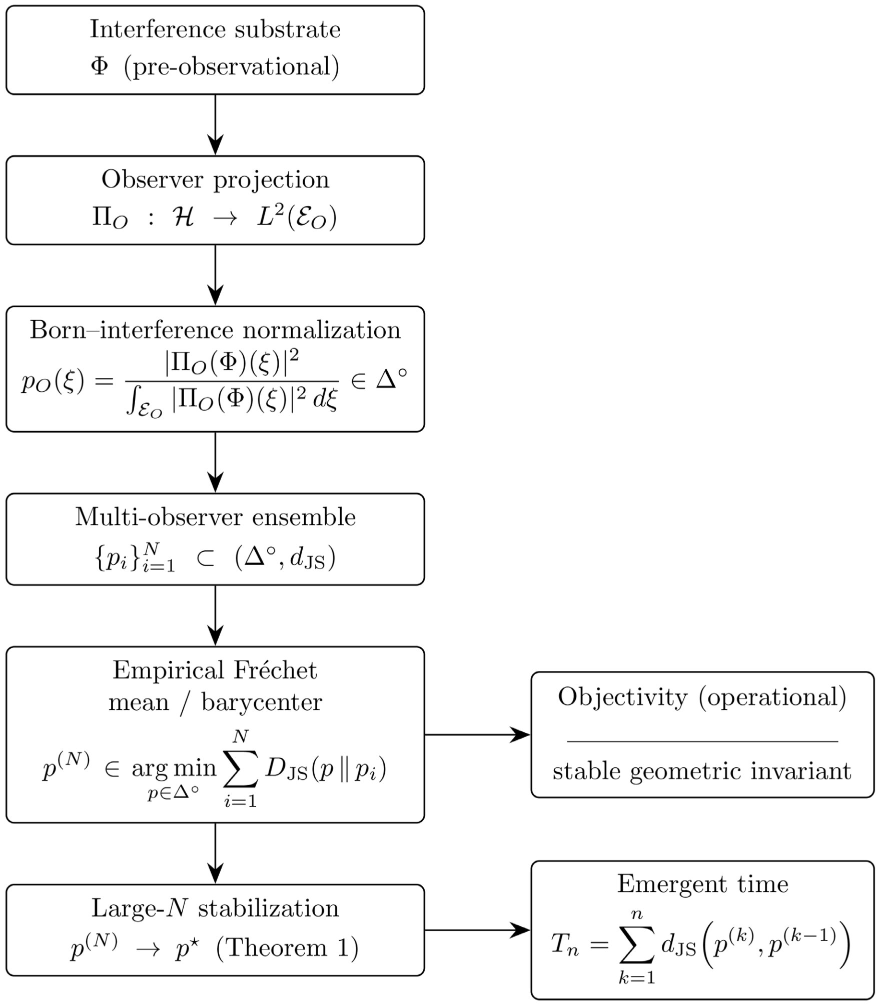

Figure 1. Conceptual pipeline of Interference-First Reality. The pre-observational interference substrate Φ is mapped by an observer projection Π_O into a Born-normalized probability distribution $p_O \in \Delta^\circ$ on the interior of the probability simplex. A multi-observer ensemble $\{p_i\}_{i=1}^N$, compared in Jensen-Shannon geometry $\left(\Delta^\circ, d_{\mathrm{JS}}\right)$, contracts toward an empirical Fréchet barycenter $p^{(N)}$; its large-N stabilization toward a stable center $p^\star$ (Theorem 1) defines operational objectivity as a stable geometric invariant, while the cumulative Jensen-Shannon arc length defines emergent time. The diagram is a conceptual illustration; the corresponding formal objects are defined in Sections 3 - 4.

This postulate distinguishes IFR from approaches in which spacetime, fields, or particles are taken as fundamental. In IFR, spacetime localization, particle-like persistence, and field-theoretic descriptions arise only after stable patterns in Ψ become redundantly accessible to operational observers.

2.2. Postulate II: Operational Observers as Projection Maps

An observer is defined operationally as any physical, instrumental, environmental, or coarse-graining structure capable of extracting a stable representation from the underlying interference state.

Mathematically, an observer O_a is represented by a map

$$\Pi_a : \mathcal{H}_{\mathcal{X}} \to \mathcal{M}_a,$$

where $\mathcal{M}_a$ is the representation space accessible to observer a. The observed representation is

$$m_a = \Pi_a[\Psi] \in \mathcal{M}_a.$$

The index a may label a detector, an environmental fragment, a measurement context, an instrumental configuration, a smoothing scale, a temporal epoch, a catalog partition, or any operational subsystem that produces a reproducible projection of Ψ. No appeal to consciousness or subjective awareness is involved.

The observer map Π_a may include coarse-graining, noise filtering, basis selection, dimensional reduction, statistical estimation, or physical interaction with a subsystem. The essential requirement is that $\Pi_a[\Psi]$ be an operationally accessible representation.

Thus,

Observers are finite projection mechanisms acting on the underlying interference state.

This postulate makes observer dependence explicit without making the theory subjective. Different observers may produce different representations, but IFR will define objectivity through the existence of stable structures common to these representations.

2.3. Postulate III: Information Geometry of Distinguishability

The representation spaces $\mathcal{M}_a$ are not merely sets. They are equipped, locally or globally, with structures that quantify distinguishability between observational representations.

For each observer space $\mathcal{M}_a$, there exists an information-geometric structure

$$\Gamma_a,$$

which induces a distance or divergence function

$$d_{\Gamma_a} : \mathcal{M}_a \times \mathcal{M}_a \to \mathbb{R}_{\geq 0}.$$

When representations from different observers are compared, IFR assumes the existence of a common comparison geometry

$$\Gamma,$$

together with embeddings or alignment maps

$$\iota_a : \mathcal{M}_a \to \mathcal{M},$$

into a common comparison space $\mathcal{M}$. For notational simplicity, we often absorb these embeddings into the definition of Π_a and write

$$\Pi_a[\Psi] \in \mathcal{M}.$$

The distance between two observer projections is then written

$$d_\Gamma\left(\Pi_a[\Psi],\Pi_b[\Psi]\right).$$

The geometry Γ may be Riemannian, metric, statistical, Wasserstein, Fisher-Rao, Bures, Fréchet, or more general, depending on the class of representations under consideration. In the case of a parametric statistical model $p(y\mid\theta)$, a canonical local choice is the Fisher information metric [3]

$$g_{ij}(\theta)=\mathbb{E}_{y\sim p(y|\theta)}\left[\partial_i \log p(y\mid\theta)\partial_j \log p(y\mid\theta)\right].$$

The third postulate is therefore

The geometry relevant to physical emergence is initially a geometry of informational distinguishability.

Spacetime geometry is not assumed at this level. It may emerge only if Γ admits an effective low-dimensional metric representation.

2.4. Postulate IV: Objectivity as Redundant Multi-Observer Contraction

Objectivity is not a primitive property of a state. It is a relational stability property of multiple observer projections.

Given a family of observer maps $\{\Pi_a\}_{a\in A}$ and a common information geometry Γ, define the redundant dispersion functional

$$\mathcal{D}_{\text{red}}[\Psi,\Gamma]=\sum_{a<b} w_{ab} d_\Gamma^2\left(\Pi_a[\Psi],\Pi_b[\Psi]\right),$$

where $w_{ab}\geq 0$ are the weights satisfying

$$\sum_{a<b} w_{ab}=1$$

when normalization is required.

A configuration is said to exhibit redundant contraction when $\mathcal{D}_{\text{red}}$ is small relative to an appropriate null or reference dispersion. A structure is objective when the observer projections admit a stable common center.

More precisely, define the Fréchet functional

$$F_\Psi(Q)=\sum_a w_a d_\Gamma^2\left(Q,\Pi_a[\Psi]\right),\ Q\in\mathcal{M},$$

with $w_a\geq 0$ and $\sum_a w_a=1$. A Fréchet center is any minimizer

$$Q^\star\in\arg\min_{Q\in\mathcal{M}} F_\Psi(Q).$$

The structure $Q^\star$ is objective at resolution $\varepsilon>0$ if

$$F_\Psi\left(Q^\star\right)<\varepsilon$$

and if the minimizer is stable under admissible perturbations of the observer maps,

$$\Pi_a\mapsto\Pi_a+\delta\Pi_a.$$

Thus,

Objectivity is stable convergence of independent observer projections toward a common informational center.

This postulate replaces the assumption of observer-independent objects with a precise criterion for the emergence of observer-invariant structures.

2.5. Postulate V: Variational Selection of Physical Configurations

The physical configurations of IFR are selected by a variational principle. There exists an action functional

$$\mathcal{S}_{\mathrm{IFR}}\left[\Psi,\Gamma,\Pi\right],$$

defined over interference states, information geometries, and admissible observer maps, such that physically realized configurations satisfy

$$\delta\mathcal{S}_{\mathrm{IFR}}=0.$$

In its minimal form, the action is

$$\mathcal{S}_{\mathrm{IFR}}=\int \mathrm{d}\lambda\left[\mathcal{K}_{\mathrm{int}}\left[\Psi\right]-\mathcal{V}_{\mathrm{int}}\left[\Psi\right]-\alpha\mathcal{D}_{\mathrm{red}}\left[\Psi,\Gamma\right]+\beta\mathcal{R}_{\Gamma}\right],$$

where λ is an ordering parameter, $\mathcal{K}_{\mathrm{int}}$ describes interference dynamics, $\mathcal{V}_{\mathrm{int}}$ encodes informational selection or instability, $\mathcal{D}_{\mathrm{red}}$ enforces redundant contraction, and $\mathcal{R}_{\Gamma}$ is an intrinsic curvature scalar associated with the information geometry.

The constants

$$\alpha,\beta>0$$

control, respectively, the strength of objectivizing contraction and the contribution of informational curvature.

For the variational principle $\delta\mathcal{S}_{\mathrm{IFR}}=0$ to be mathematically meaningful, the functionals appearing in $\mathcal{S}_{\mathrm{IFR}}$ must be specified on a precise class of admissible histories and must satisfy minimal regularity conditions; these are stated in full in Section and summarized here. An admissible history is a curve $\lambda\mapsto\left(\Psi(\lambda),\Gamma(\lambda),\Pi(\lambda)\right)$, $\lambda\in I=\left[\lambda_0,\lambda_1\right]\subset\mathbb{R}$, with $\Psi\in H^1\left(I,\mathcal{H}_{\mathcal{X}}\right)$ (*i.e.* both Ψ and its weak derivative $\partial_\lambda\Psi$ are square-integrable in λ with values in $\mathcal{H}_{\mathcal{X}}$, and $\left\|\Psi(\lambda)\right\|_{\mathcal{X}}=1$), $\Gamma(\lambda)\in\mathfrak{G}$ a continuous family of complete geodesic information geometries, and $\Pi(\lambda)\in\mathfrak{P}$ satisfying the admissibility conditions of Section 3.3 uniformly in λ. The kinetic term is taken to be the quadratic velocity functional

$$\mathcal{K}_{\mathrm{int}}\left[\Psi,\partial_\lambda\Psi\right]=\frac{1}{2}\left\|\partial_\lambda\Psi\right\|_{\mathcal{H}_{\mathcal{X}}}^2,$$

which is finite and Fréchet differentiable on $H^1\left(I,\mathcal{H}_{\mathcal{X}}\right)$. The potential $\mathcal{V}_{\mathrm{int}}:\mathcal{H}_{\mathcal{X}}\to\mathbb{R}$ is assumed continuous, bounded below, and Gâteaux differentiable on $\mathcal{H}_{\mathcal{X}}$ (or on the dense domain of an associated self-adjoint operator, when $\mathcal{V}_{\mathrm{int}}$ arises from such an operator). Together with the regularity of $\mathcal{D}_{\mathrm{red}}$ (Section 3.6) and of $\mathcal{R}_{\Gamma}$ (Section 3.9), these conditions ensure that the integrand $\mathcal{L}_{\mathrm{IFR}}(\lambda)=\mathcal{K}_{\mathrm{int}}-\mathcal{V}_{\mathrm{int}}-\alpha\mathcal{D}_{\mathrm{red}}+\beta\mathcal{R}_{\Gamma}$ is integrable on I, so that $\mathcal{S}_{\mathrm{IFR}}$ is finite on admissible histories. Under these conditions, $\delta\mathcal{S}_{\text{IFR}}=0$ is to be understood as the vanishing of the first Fréchet variation of $\mathcal{S}_{\text{IFR}}$ with respect to fixed-endpoint variations $\delta\Psi\in H_0^1\left(I,\mathcal{H}_{\mathcal{X}}\right)$ and variations $\delta\Gamma$, $\delta\Pi$ tangent to $\mathfrak{G}$ and $\mathfrak{P}$, respectively. The explicit Euler-Lagrange form of this problem, and the further structural assumptions needed to render it dynamically predictive, are developed in Part II.

The corresponding formal generating functional is

$$\mathcal{Z}_{\text{IFR}}=\int\mathcal{D}\Psi\mathcal{D}\Gamma\mathcal{D}\Pi\exp\left[i\mathcal{S}_{\text{IFR}}\left[\Psi,\Gamma,\Pi\right]\right].$$

This is not yet a conventional path integral over fields on spacetime. It is a formal sum over interference structures, comparison geometries, and observer projections. A conventional path integral over matter fields and spacetime metrics can arise only after an effective spacetime representation has emerged.

The fifth postulate is therefore

$$\boxed{\begin{array}{l}\text{Physical reality is selected by stationary interference configurations}\\\text{compatible with stable multi-observer contraction.}\end{array}}$$

2.6. Postulate VI: Gravitation as Emergent Informational Curvature

Gravitation is not introduced as a primitive force acting on matter in spacetime. Nor is the spacetime metric assumed to exist at the fundamental level. Instead, IFR postulates that gravitational geometry is the macroscopic, observer-stable manifestation of curvature in the information geometry Γ.

Persistent objective structures constrain the surrounding space of admissible informational transitions. Such constraints deform the geometry of distinguishability and accessibility for other structures. This deformation is encoded by the curvature term

$$\mathcal{R}_{\Gamma}.$$

When the information geometry admits an effective spacetime representation, there exists a map

$$\phi:\mathcal{X}\to\mathcal{M}_{\text{eff}},$$

and an effective metric

$$g_{\mu\nu}^{\text{eff}},$$

such that informational distances and transition constraints are approximated by spacetime metric relations. In that regime, informational curvature induces effective spacetime curvature:

$$\mathcal{R}_{\Gamma}\to R\left(g_{\text{eff}}\right),$$

where $R\left(g_{\text{eff}}\right)$ is the Ricci scalar of the emergent metric.

The gravitational postulate may be written as

$$\boxed{\begin{array}{l}\text{Gravitation is the effective spacetime expression of observer-stable}\\\text{curvature in information geometry.}\end{array}}$$

This postulate ensures that gravity is not an external addition to IFR. It is one of its central emergent sectors.

2.7. Postulate VII: Emergence of Temporal Order

The parameter λ appearing in the variational formulation is not physical time. It is an ordering parameter used to describe families of possible configurations.

Physical time emerges only when the theory produces a sequence of stable objective structures

$$\mathcal{Q}_1^\star, \mathcal{Q}_2^\star, \mathcal{Q}_3^\star, \cdots$$

that admits an intrinsic order relation. IFR defines such an order through asymmetric informational dependence, memory, or monotonic stabilization.

Let $\mathcal{M}_{\text{mem}}\left(\mathcal{Q}_j^\star \mid \mathcal{Q}_i^\star\right)$ denote the amount of recoverable information about $\mathcal{Q}_i^\star$ encoded in $\mathcal{Q}_j^\star$. A temporal ordering relation may be defined by

$$\mathcal{Q}_i^\star \prec \mathcal{Q}_j^\star$$

if

$$\mathcal{M}_{\text{mem}}\left(\mathcal{Q}_j^\star \mid \mathcal{Q}_i^\star\right) > \mathcal{M}_{\text{mem}}\left(\mathcal{Q}_i^\star \mid \mathcal{Q}_j^\star\right).$$

Equivalently, temporal order may be associated with a monotonic sequence of stable minima of redundant dispersion,

$$\tau_{\text{IFR}} = \text{Ord}\left[\arg\min_{\Psi,\Gamma} \mathcal{D}_{\text{red}}\left[\Psi,\Gamma;\lambda\right]\right].$$

The seventh postulate is

$$\boxed{\text{Time is the emergent order of stable informational objectivizations.}}$$

Thus, IFR does not assume time as an external parameter. It derives temporal order from the asymmetric organization of objective structures.

2.8. Postulate VIII: Emergence of Effective Spacetime and Field Theory

Spacetime and ordinary field-theoretic descriptions arise when the information geometry Γ admits a stable, low-dimensional, approximately local representation.

Specifically, if there exists an effective manifold $\mathcal{M}_{\text{eff}}$ and a map

$$\phi : \mathcal{X} \to \mathcal{M}_{\text{eff}},$$

such that

$$d_\Gamma\left(x_i, x_j\right) \approx d_{\text{eff}}\left(\phi\left(x_i\right), \phi\left(x_j\right)\right),$$

then $\mathcal{M}_{\text{eff}}$ is interpreted as emergent space, or spacetime once temporal ordering has also emerged.

In the high-redundancy semiclassical limit, the IFR action must reduce to an effective action of the form

$$\mathcal{S}_{\mathrm{IFR}} \to \int \mathrm{d}^4 x \sqrt{-g_{\mathrm{eff}}} \left[R\left(g_{\mathrm{eff}}\right) + \mathcal{L}_{\mathrm{matter}}^{\mathrm{eff}} \right],$$

possibly with correction terms controlled by residual dispersion, nonlocal informational curvature, or incomplete observer contraction.

The final postulate is therefore

$$\boxed{\begin{array}{l}\text{Spacetime, matter fields, and gravitational dynamics are effective limits}\\ \text{of stable information-geometric objectivity.}\end{array}}$$

2.9. Summary of the Postulates

The postulates may be summarized as follows:

I. Reality is grounded in a pre-spatiotemporal interference state Ψ.

II. Observers are operational projection maps Π_a.

III. Observer representations are compared through information geometry Γ.

IV. Objectivity is stable redundant contraction toward a common center Q^*.

V. Physical configurations are selected by $\delta S_{\mathrm{IFR}} = 0$.

VI. Gravitation is emergent observer-stable informational curvature.

VII. Time is the emergent order of stable objectivizations.

VIII. Spacetime and field theory arise as effective high-redundancy limits.

These postulates define the conceptual and mathematical domain of IFR. The next section develops the corresponding formal structure in detail.

3. Mathematical Structure

This section develops the mathematical framework required by the postulates stated above. The aim is to define the primitive objects of IFR with sufficient precision to support a variational theory, a definition of objectivity, an emergent gravitational sector, and a correspondence limit with ordinary spacetime physics.

We distinguish four levels of structure:

$$\mathcal{X}, \quad \mathcal{H}_{\mathcal{X}}, \quad \{\Pi_a\}_{a \in A}, \quad (\mathcal{M}, \Gamma).$$

Here $\mathcal{X}$ is the pre-spatiotemporal configuration space, $\mathcal{H}_{\mathcal{X}}$ is the associated interference-state space, Π_a are operational observer maps, and $(\mathcal{M}, \Gamma)$ is the common information-geometric comparison space in which observer-dependent projections are compared.

3.1. Pre-Spatiotemporal Configuration Space

Let

$$\mathcal{X}$$

be an abstract measurable space equipped with a sigma-algebra $\Sigma_{\mathcal{X}}$ and a reference measure $\mu_{\mathcal{X}}$. We write this as

$$(\mathcal{X}, \Sigma_{\mathcal{X}}, \mu_{\mathcal{X}}).$$

No manifold structure is assumed at this level. In particular, $\mathcal{X}$ is not required to be differentiable, locally Euclidean, finite-dimensional, metric, or temporally ordered. Its elements

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

represent primitive informational configurations rather than spacetime events.

The absence of an assumed spacetime structure is essential. IFR requires that spatial localization, temporal ordering, and metric geometry be derived from later stability conditions rather than inserted into the ontology at the beginning. Thus, the symbols $x, y \in \mathcal{X}$ should not be interpreted as spacetime points.

The minimal mathematical requirement on $\mathcal{X}$ is that it supports a complex Hilbert space of interference states. In the simplest representation, one may define

$$\mathcal{H}_{\mathcal{X}} = L^2\left(\mathcal{X}, d\mu_{\mathcal{X}}\right),$$

with inner product

$$\langle \Phi, \Psi \rangle_{\mathcal{X}} = \int_{\mathcal{X}} \overline{\Phi(x)}\, \Psi(x)\, \mathrm{d}\mu_{\mathcal{X}}(x).$$

More generally, $\mathcal{H}_{\mathcal{X}}$ may be any separable complex Hilbert space associated with $\mathcal{X}$, including Fock-type constructions, direct integrals, or Hilbert bundles over $\mathcal{X}$. For the foundational development, separability is assumed unless explicitly stated otherwise:

$$\mathcal{H}_{\mathcal{X}} \text{ is separable.}$$

This assumption ensures that standard spectral, variational, and measure-theoretic tools may be applied.

3.2. Interference States

A fundamental IFR state is a normalized vector

$$\Psi \in \mathcal{H}_{\mathcal{X}}, \quad \|\Psi\|_{\mathcal{X}}^2 = 1.$$

In a representation over $\mathcal{X}$, this state is written as

$$\Psi : \mathcal{X} \to \mathbb{C}, \quad x \mapsto \Psi(x),$$

where $\Psi(x)$ is an amplitude associated with a primitive informational configuration.

The phase structure of Ψ is physically relevant. IFR therefore treats the interference pattern encoded in relative phases, overlaps, and superpositions as more fundamental than any classical localization. For two states $\Psi, \Phi \in \mathcal{H}_{\mathcal{X}}$, their interference overlap is

$$\mathcal{I}(\Psi, \Phi) = \langle \Psi, \Phi \rangle_{\mathcal{X}}.$$

The corresponding transition intensity is

$$P(\Psi \to \Phi) = \left|\langle \Phi, \Psi \rangle_{\mathcal{X}}\right|^2.$$

At the primitive level, this expression should not yet be interpreted as a probability of transition between spacetime events. It is a measure of compatibility between interference configurations. Probabilistic and spacetime interpretations become available only after observer projections and stable objectivity conditions have been introduced.

The projective Hilbert space

$$\mathbb{P}(\mathcal{H}_{\mathcal{X}})$$

is the physically relevant state space whenever global phase is unobservable. Thus, states related by

$$\Psi \sim e^{i\theta}\Psi,\ \ \theta \in \mathbb{R},$$

represent the same primitive ray.

When needed, the natural distance between rays is the Fubini-Study distance

$$d_{\mathrm{FS}}\left([\Psi],[\Phi]\right) = \arccos\left(\left|\langle \Psi, \Phi \rangle_{\mathcal{X}}\right|\right).$$

This distance is defined on the primitive interference-state space. It is distinct from the later observer-level distance d_Γ, which compares projected representations.

3.3. Admissible Observer Maps

Let A be an index set labelling operational observers. Each observer $a \in A$ is represented by a map

$$\Pi_a : \mathcal{H}_{\mathcal{X}} \to \mathcal{M}_a,$$

where $\mathcal{M}_a$ is the representation space accessible to observer a.

In general, Π_a need not be linear. It may include nonlinear reconstruction, coarse-graining, statistical estimation, thresholding, dimensional reduction, environmental encoding, or detector response. However, for the variational theory to be well-defined, IFR restricts attention to an admissible class

$$\mathfrak{P} = \{\Pi_a\}_{a \in A}$$

satisfying the following minimal conditions.

Measurability. Each observer map is measurable with respect to the sigma-algebra on $\mathcal{H}_{\mathcal{X}}$ and the measurable structure on $\mathcal{M}_a$:

$$\Pi_a^{-1}(B) \text{ is measurable}$$

for every measurable set $B \subseteq \mathcal{M}_a$.

Finite accessibility. The representation $m_a = \Pi_a[\Psi]$ contains only finite operational information. This condition may be expressed by requiring either finite-dimensional $\mathcal{M}_a$, finite effective rank, finite entropy, or finite statistical resolution. Formally, one may impose

$$\mathcal{C}\left(\Pi_a[\Psi]\right) < \infty,$$

where $\mathcal{C}$ denotes an operational complexity, entropy, or description-length functional.

Stability. Small perturbations of the interference state should not generically produce unbounded changes in the observed representation. Thus, for each admissible observer, there exists a local constant L_a such that

$$d_a\left(\Pi_a[\Psi], \Pi_a[\Phi]\right) \le L_a d_{\mathcal{H}}(\Psi, \Phi)$$

in a neighbourhood of physically relevant states, where d_a is a distance on $\mathcal{M}_a$ and $d_{\mathcal{H}}$ is a Hilbert-space or projective distance.

Operational reproducibility. For repeated application under the same observational conditions, the map Π_a must define a reproducible representation up to a noise model η_a:

$$m_a = \Pi_a[\Psi] + \eta_a, \quad \mathbb{E}[\eta_a] = 0,$$

or, more generally,

$$m_a \sim P_a(\cdot \mid \Psi),$$

where P_a is an observer-specific response distribution.

The deterministic notation

$$m_a = \Pi_a[\Psi]$$

should therefore be understood as either an exact projection in the idealized case or the expectation of an observational response in the stochastic case:

$$\Pi_a[\Psi] = \mathbb{E}_{m \sim P_a(\cdot|\Psi)}[m].$$

These assumptions make the observer concept broad enough to include physical detectors, environmental fragments, data-processing choices, catalog partitions, and coarse-grained reconstructions, while still being mathematically controlled.

3.4. Common Comparison Space

Observer outputs may initially belong to different representation spaces:

$$m_a \in \mathcal{M}_a, \quad m_b \in \mathcal{M}_b.$$

To compare them, IFR assumes the existence of a common comparison space

$$\mathcal{M},$$

together with admissible embedding or alignment maps

$$\iota_a : \mathcal{M}_a \to \mathcal{M}.$$

The common representation of observer a is therefore

$$\tilde{m}_a = \iota_a(\Pi_a[\Psi]) \in \mathcal{M}.$$

For notational economy, we define

$$\tilde{\Pi}_a = \iota_a \circ \Pi_a,$$

and usually write

$$\Pi_a[\Psi] \in \mathcal{M}$$

with the embedding understood.

The comparison space $\mathcal{M}$ is the mathematical arena in which objectivity is evaluated. It is not necessarily spacetime. It may be a statistical manifold, a space of probability distributions, a space of signals, a Wasserstein space, a manifold of density matrices, a metric-measure space, or a more general geodesic metric space.

The key requirement is that $\mathcal{M}$ be equipped with a distance or divergence allowing the comparison of observer projections.

3.5. Information Geometry

Let

$$\Gamma$$

denote the information-geometric structure on $\mathcal{M}$. Depending on the context, Γ may specify a Riemannian metric, an affine connection, a divergence, an optimal-transport geometry, or a more general metric structure.

In the Riemannian case,

$$\Gamma = (\mathcal{M}, g, \nabla),$$

where g is a positive-definite metric tensor and ∇ is a connection [3]. The distance between two points $p,q \in \mathcal{M}$ is the geodesic distance

$$d_\Gamma(p,q) = \inf_\gamma \int_0^1 \sqrt{g_{\gamma(t)}(\dot{\gamma}(t), \dot{\gamma}(t))}\,\mathrm{d}t,$$

where the infimum is taken over all smooth curves $\gamma : [0,1] \to \mathcal{M}$ such that

$$\gamma(0) = p, \quad \gamma(1) = q.$$

In the statistical case, if $\mathcal{M}$ is a parametric family of probability distributions

$$\mathcal{M} = \{ p(y \mid \theta) : \theta \in \Theta \},$$

the canonical local metric is the Fisher information metric

$$g_{ij}(\theta) = \mathbb{E}_{y \sim p(y|\theta)} \left[\partial_i \log p(y \mid \theta) \partial_j \log p(y \mid \theta) \right].$$

If $\mathcal{M}$ is a space of density matrices, a natural choice may be the Bures metric. If $\mathcal{M}$ is a space of probability measures, a natural choice may be a Wasserstein metric. IFR does not require a unique geometry for all applications; rather, it requires that the chosen Γ be operationally justified by the class of observer representations under comparison.

The distance induced by Γ will be denoted

$$d_\Gamma : \mathcal{M} \times \mathcal{M} \to \mathbb{R}_{\geq 0}.$$

For the main theoretical results, we assume that

$$(\mathcal{M}, d_\Gamma)$$

is a complete geodesic metric space. When uniqueness of Fréchet centers is required, additional convexity assumptions will be imposed.

3.6. Redundant Dispersion Functional

Given an interference state Ψ, observer projections

$$m_a = \Pi_a[\Psi] \in \mathcal{M},$$

and pairwise weights $w_{ab} \geq 0$, the redundant dispersion functional is

$$\mathcal{D}_{\text{red}}[\Psi, \Gamma] = \sum_{a<b} w_{ab} d_\Gamma^2(m_a, m_b).$$

Equivalently,

$$\mathcal{D}_{\text{red}}[\Psi,\Gamma]=\sum_{a<b} w_{ab} d_\Gamma^2\left(\Pi_a[\Psi],\Pi_b[\Psi]\right).$$

When the observer set is continuous rather than discrete, with observer measure ν on A, the natural generalization is

$$\mathcal{D}_{\text{red}}[\Psi,\Gamma]=\frac{1}{2}\int_A\int_A w(a,b) d_\Gamma^2\left(\Pi_a[\Psi],\Pi_b[\Psi]\right)\mathrm{d}\nu(a)\mathrm{d}\nu(b),$$

where $w(a,b)\geq 0$ is a symmetric pairwise weight kernel.

Choice and constraints on the weights. The weights w_a (and w_{ab}) are not free parameters fitted independently for each application. IFR fixes them by the following operational rule. For each observer a, let σ_a^2 denote the effective variance (or, more generally, an operational uncertainty functional) of the response distribution $P_a(\cdot|\Psi)$ of Section 3.3. The baseline single-observer weight is the inverse-uncertainty weight

$$w_a=\frac{\sigma_a^{-2}}{\sum_{b\in A}\sigma_b^{-2}},\quad \sum_{a\in A} w_a=1,$$

so that more reliable (lower-variance) observers contribute more strongly to the Fréchet functional. Pairwise weights combine the single-observer weights with an operational independence factor $\rho_{ab}\in[0,1]$, estimated from the empirical correlation of the observer residuals η_a,η_b of Section 3.3:

$$w_{ab}=\frac{(1-\rho_{ab})w_a w_b}{\sum_{c<d}(1-\rho_{cd})w_c w_d},\quad \sum_{a<b} w_{ab}=1.$$

Strongly correlated observers ($\rho_{ab}\to 1$) are downweighted, since they add little independent redundancy; fully independent observers ($\rho_{ab}=0$) recover $w_{ab}\propto w_a w_b$. This rule determines w_a and w_{ab} from operationally measurable quantities (σ_a^2, ρ_{ab}) once the observer family is specified, and removes the underdetermination otherwise present in the objectivity criterion of Postulate IV. The uniform choice $w_a=1/N$, $w_{ab}=\binom{N}{2}^{-1}$ is recovered as the special case of equal reliability and mutual independence, which is the convention adopted in the cross-domain analyses of [8]-[10].

The functional $\mathcal{D}_{\text{red}}$ is the first central scalar quantity of IFR. It measures the degree to which observer-dependent projections fail to agree. A low value indicates that independent observational channels encode mutually compatible representations. A high value indicates disagreement, fragmentation, or absence of a stable common structure.

To make this quantity dimensionless in empirical applications, one may introduce a reference or null dispersion

$$\mathcal{D}_{\text{null}}>0$$

and define the normalized contraction index

$$\Delta_{\mathrm{IFR}} = \frac{\mathcal{D}_{\mathrm{null}} - \mathcal{D}_{\mathrm{red}}}{\mathcal{D}_{\mathrm{null}}}.$$

Positive values indicate contraction relative to the null model:

$$\Delta_{\mathrm{IFR}} > 0.$$

3.7. Fréchet Functional and Objective Centers

Although pairwise dispersion is useful, the definition of objectivity is most naturally expressed through a common center [11] [12].

For a fixed Ψ and Γ, define the Fréchet functional

$$F_{\Psi}(Q) = \sum_{a \in A} w_a d_{\Gamma}^2 \left(Q, \Pi_a[\Psi]\right), \quad Q \in \mathcal{M},$$

where

$$w_a \geq 0, \quad \sum_{a \in A} w_a = 1.$$

A Fréchet center is any minimizer

$$Q^{\star} \in \arg\min_{Q \in \mathcal{M}} F_{\Psi}(Q).$$

If the minimizer is unique, we write

$$Q^{\star} = \mathrm{bar}_{\Gamma}\left(\{\Pi_a[\Psi]\}_{a \in A}, \{w_a\}_{a \in A}\right),$$

where bar_{Γ} denotes the barycenter induced by the geometry Γ.

The distinction between the exact center $Q^{\star}$ and an empirical estimator $\hat{Q}$ is important. The exact center is a mathematical object defined by the variational problem above. An empirical estimator is constructed from finite, noisy, or sampled observations:

$$\hat{Q} = \widehat{\mathrm{bar}}_{\Gamma}\left(\{m_a^{\mathrm{obs}}\}_{a \in A}\right).$$

In general,

$$\hat{Q} \neq Q^{\star}.$$

The estimator $\hat{Q}$ converges to $Q^{\star}$ only under consistency assumptions on the observer noise, sampling procedure, geometry, and optimization method. IFR therefore treats the exact Fréchet center and empirical overlap estimators as conceptually distinct.

This distinction is essential for maintaining mathematical rigor and for avoiding ambiguity between variational objectivity and data-based reconstruction.

3.8. Stability under Observer Perturbations

Objectivity requires not only agreement, but stability. A common center that disappears under arbitrarily small changes of the observers cannot be regarded as physically objective.

Let the observer maps be perturbed as

$$\Pi_a^\epsilon = \Pi_a + \epsilon \delta \Pi_a,$$

where $\delta\Pi_a$ belongs to an admissible perturbation class and ϵ is small.

The perturbed Fréchet functional is

$$F_\Psi^\epsilon(Q) = \sum_a w_a d_\Gamma^2\left(Q, \Pi_a^\epsilon[\Psi]\right),$$

with minimizer

$$Q_\epsilon^\star \in \arg\min_{Q\in\mathcal{M}} F_\Psi^\epsilon(Q).$$

The center $Q^\star$ is stable if

$$\lim_{\epsilon\to 0} d_\Gamma\left(Q_\epsilon^\star, Q^\star\right) = 0.$$

A stronger Lipschitz stability condition is

$$d_\Gamma\left(Q_\epsilon^\star, Q^\star\right) \le C\epsilon + o(\epsilon),$$

for some finite constant C.

This condition ensures that the objective structure is not an artifact of a particular observer choice, coordinate representation, smoothing scale, or reconstruction convention.

3.9. Informational Curvature

The gravitational sector of IFR requires that the information geometry Γ possess a curvature quantity. In the Riemannian case, this is standard. If

$$\Gamma = (\mathcal{M}, g, \nabla)$$

with ∇ the Levi-Civita connection of g, one defines the Riemann curvature tensor

$$R^i{}_{jkl},$$

the Ricci tensor

$$R_{ij} = R^k{}_{ikj},$$

and the scalar curvature

$$\mathcal{R}_\Gamma = g^{ij} R_{ij}.$$

In this case $\mathcal{R}_\Gamma$ is the intrinsic curvature scalar of the observer-comparison geometry.

If $\mathcal{M}$ is not smooth, $\mathcal{R}_\Gamma$ must be replaced by an appropriate generalized curvature quantity. Possible choices include Alexandrov curvature bounds, Ollivier-Ricci curvature, Bakry-Émery curvature, Forman curvature, or curvature derived from optimal-transport convexity. The choice depends on the mathematical category of $\mathcal{M}$.

In the formal theory, $\mathcal{R}_\Gamma$ denotes any curvature scalar satisfying three requirements:

(i) $\mathcal{R}_\Gamma$ is intrinsic to the information geometry;

(ii) $\mathcal{R}_\Gamma$ controls the deformation of distinguishability relations;

(iii) $\mathcal{R}_\Gamma \to R(g_{\text{eff}})$ in the effective spacetime limit.

The third condition is the gravitational correspondence condition of IFR.

3.10. Admissible Histories and the Ordering Parameter

The variational formulation requires histories of the primitive state and geometry. Let

$$\lambda \in I \subseteq \mathbb{R}$$

be an ordering parameter. An IFR history is a map

$$\lambda \mapsto \left(\Psi(\lambda), \Gamma(\lambda), \Pi(\lambda)\right),$$

where

$$\Psi(\lambda) \in \mathcal{H}_{\mathcal{X}}, \quad \Gamma(\lambda) \in \mathfrak{G}, \quad \Pi(\lambda) \in \mathfrak{P}.$$

The set $\mathfrak{G}$ denotes admissible information geometries, and $\mathfrak{P}$ denotes admissible families of observer maps.

The parameter λ is not physical time. It is an ordering parameter used to describe variation, histories, and stationary principles. Physical time emerges only when a sequence of objective centers

$$Q^*(\lambda)$$

admits an intrinsic order relation of the type introduced in Postulate VII (Section 2.7), whose full development is deferred to Part III of the series.

Thus, a history in λ is not yet a temporal evolution. It is a path through the space of interference-geometric configurations.

Regularity conditions for $\mathcal{S}_{\text{IFR}}$. We collect here the hypotheses (R1)-(R4) under which the action $\mathcal{S}_{\text{IFR}}$ of Postulate V is well-posed:

(R1) $\Psi \in H^1(I, \mathcal{H}_{\mathcal{X}})$, with $\|\Psi(\lambda)\|_{\mathcal{X}} = 1$ for all $\lambda \in I$;

(R2) $\mathcal{V}_{\text{int}}$ is continuous, bounded below, and Gâteaux differentiable on $\mathcal{H}_{\mathcal{X}}$;

(R3) $\Gamma(\lambda)$ is a continuous family of complete geodesic metric structures on $\mathcal{M}$, admitting the curvature scalar $\mathcal{R}_\Gamma(\lambda)$ of Section 3.9 as an $L^1(I)$ function of λ;

(R4) the observer family $\Pi(\lambda) \in \mathfrak{P}$ satisfies the measurability, finite-accessibility, stability, and reproducibility conditions of Section 3.3 uniformly for $\lambda \in I$, so that $\mathcal{D}_{\text{red}}\left[\Psi(\lambda), \Gamma(\lambda)\right] \in L^1(I)$.

Under (R1)-(R4) one has $\mathcal{S}_{\text{IFR}}[\Psi, \Gamma, \Pi] < \infty$ for every admissible history, and the first variation $\delta\mathcal{S}_{\text{IFR}}$ is well-defined for variations $\delta\Psi \in H_0^1(I, \mathcal{H}_{\mathcal{X}})$ and $\delta\Gamma$, $\delta\Pi$ tangent to $\mathfrak{G}$, $\mathfrak{P}$. This is the precise sense in which $\delta\mathcal{S}_{\text{IFR}} = 0$ selects physical configurations in Postulate V.

3.11. Minimal IFR State Space

Combining the previous definitions, the complete kinematic state of IFR is an element of

$$\mathfrak{S}_{\mathrm{IFR}} = \mathcal{H}_{\mathcal{X}} \times \mathfrak{G} \times \mathfrak{P}.$$

An element of this space is written

$$s_{\mathrm{IFR}} = (\Psi, \Gamma, \Pi).$$

The physical content of such a state is not given directly by Ψ alone. It is given by the triple:

$$\Psi \text{ determines primitive interference,}$$

$$\Gamma \text{ determines distinguishability and curvature,}$$

$$\Pi \text{ determines operational accessibility.}$$

The observer-accessible content of s_{IFR} is the family

$$\{\Pi_a[\Psi]\}_{a\in A},$$

and the objective content, when it exists, is the corresponding stable Fréchet center

$$Q^{\star}.$$

3.12. Emergent Effective Manifold

An effective spacetime description becomes possible only under additional embedding and locality conditions.

Let $\mathcal{Q} \subset \mathcal{M}$ denote the subset of stable objective centers:

$$\mathcal{Q} = \left\{ Q^{\star} : Q^{\star} = \arg\min_{Q\in\mathcal{M}} F_{\Psi}(Q) \text{ and is stable} \right\}.$$

An effective manifold exists if there is a differentiable manifold $\mathcal{M}_{\mathrm{eff}}$ and an embedding

$$\chi : \mathcal{Q} \to \mathcal{M}_{\mathrm{eff}}$$

such that, for stable centers $Q_i^{\star}, Q_j^{\star} \in \mathcal{Q}$,

$$d_{\Gamma}\left(Q_i^{\star}, Q_j^{\star}\right) = d_{\mathrm{eff}}\left(\chi\left(Q_i^{\star}\right), \chi\left(Q_j^{\star}\right)\right) + \mathcal{O}(\epsilon_{\mathrm{eff}}),$$

where d_{eff} is the metric distance induced by an effective metric tensor $g_{\mu\nu}^{\mathrm{eff}}$ and ϵ_{eff} measures the residual non-geometric distortion.

If

$$\epsilon_{\mathrm{eff}} \ll 1$$

over the domain of interest, the objective structures admit an approximately spacetime description.

In this case,

$$\left(\mathcal{M}_{\mathrm{eff}}, g_{\mu\nu}^{\mathrm{eff}}\right)$$

is not fundamental. It is an emergent representation of stable informational relations.

3.13. Kinematic Correspondence Principle

The mathematical structure introduced above must recover standard physical kinematics in an appropriate limit. IFR therefore imposes the following correspondence condition.

In the high-redundancy, low-dispersion, stable-center limit,

$$\mathcal{D}_{\mathrm{red}} \to 0, \quad F_{\Psi}\left(Q^{\star}\right) \to 0,$$

and under the existence of an effective manifold representation, the observer-independent centers $Q^{\star}$ behave as ordinary physical events, fields, or localized structures on an emergent spacetime:

$$Q^{\star} \to \varphi(x) \ \text{ or } \ Q^{\star} \to \text{event at } x \in \mathcal{M}_{\mathrm{eff}}.$$

The information geometry reduces to an effective spacetime geometry:

$$\Gamma \to g_{\mu\nu}^{\mathrm{eff}},$$

and its curvature scalar reduces to

$$\mathcal{R}_{\Gamma} \to R\left(g_{\mathrm{eff}}\right).$$

Thus, the kinematic limit of IFR reproduces the usual ingredients of relativistic field theory:

events, fields, metric, curvature.

The dynamics of this limit will be specified in the subsequent sections through the IFR action and its variational equations.

4. Emergent Objectivity as Multi-Observer Contraction

In IFR, objectivity is not postulated as a primitive feature of physical reality. It is defined as a stability property of observer-dependent projections of an underlying interference state. This section gives the formal definition of objective structures, distinguishes exact variational objects from empirical estimators, and states the minimal mathematical conditions under which objectivity exists, is unique, and is stable.

The guiding idea is the following: a structure is objective when independent operational observers, acting through distinct projection maps, recover compatible representations that contract toward a common informational center. Objectivity is therefore a property of redundant agreement under controlled perturbations, not a property of any single observational channel.

4.1. Observer Families and Projected Representations

Let

$$\left(\mathcal{X}, \Sigma_{\mathcal{X}}, \mu_{\mathcal{X}}\right)$$

be the pre-spatiotemporal configuration space introduced in Section 3, and let

$$\Psi \in \mathcal{H}_{\mathcal{X}}$$

be a normalized interference state.

Let

$$A = \{1, \cdots, N\}$$

be a finite family of operational observers. Each observer is represented by an admissible projection map

$$\Pi_a : \mathcal{H}_{\mathcal{X}} \to \mathcal{M}_a.$$

After alignment into a common information-geometric comparison space $\mathcal{M}$, the observer-dependent representation is written as

$$m_a(\Psi) = \Pi_a[\Psi] \in \mathcal{M}.$$

The collection

$$\mathcal{O}_\Psi = \{m_a(\Psi)\}_{a=1}^N$$

is called the observational orbit of Ψ with respect to the observer family $\{\Pi_a\}_{a=1}^N$.

The objectivity problem is then the problem of determining whether the orbit $\mathcal{O}_\Psi$ admits a stable common center in the information geometry Γ.

4.2. Redundant Dispersion

Let

$$(\mathcal{M}, d_\Gamma)$$

be a complete metric space induced by the information geometry Γ. Given non-negative pairwise weights

$$w_{ab} \geq 0, \quad w_{ab} = w_{ba}, \quad \sum_{a<b} w_{ab} = 1,$$

define the redundant dispersion functional

$$\mathcal{D}_{\text{red}}[\Psi, \Gamma] = \sum_{a<b} w_{ab} d_\Gamma^2\left(m_a(\Psi), m_b(\Psi)\right).$$

Equivalently,

$$\mathcal{D}_{\text{red}}[\Psi, \Gamma] = \sum_{a<b} w_{ab} d_\Gamma^2\left(\Pi_a[\Psi], \Pi_b[\Psi]\right).$$

This functional measures the failure of observer projections to agree. If

$$\mathcal{D}_{\text{red}}[\Psi, \Gamma] = 0,$$

then all projections coincide pairwise, modulo the identifications induced by d_Γ. If

$$\mathcal{D}_{\text{red}}[\Psi, \Gamma] > 0,$$

then the observer projections are dispersed in the comparison geometry.

A necessary condition for objectivity at resolution $\varepsilon > 0$ is

$$\mathcal{D}_{\text{red}}[\Psi, \Gamma] < \varepsilon.$$

However, pairwise contraction alone is not sufficient. IFR also requires the existence of a stable center.

4.3. Fréchet Functional

Let

$$w_a \geq 0, \quad \sum_{a=1}^{N} w_a = 1,$$

be observer weights. For fixed Ψ and Γ, define the Fréchet functional

$$F_{\Psi,\Gamma}(Q) = \sum_{a=1}^{N} w_a d_{\Gamma}^2 \left(Q, m_a(\Psi)\right), \quad Q \in \mathcal{M}.$$

A Fréchet center is an element

$$Q_{\Psi,\Gamma}^{\star} \in \arg\min_{Q \in \mathcal{M}} F_{\Psi,\Gamma}(Q).$$

When the minimizer is unique, we write

$$Q_{\Psi,\Gamma}^{\star} = \mathrm{bar}_{\Gamma}\left(m_1(\Psi), \cdots, m_N(\Psi); w_1, \cdots, w_N\right).$$

The value

$$F_{\Psi,\Gamma}\left(Q_{\Psi,\Gamma}^{\star}\right)$$

is the centered redundant dispersion. It measures how tightly the observer representations concentrate around their common center.

The pairwise dispersion and centered dispersion are related, but not identical. In Euclidean geometry with suitable weights, they are proportional. In general metric or curved information-geometric spaces, they must be distinguished.

The exact Fréchet center

$$Q_{\Psi,\Gamma}^{\star}$$

is a mathematical object defined by the geometry and the observer projections. It is not the same as a finite-sample estimator obtained from data. This distinction is essential for the theoretical consistency of IFR.

4.4. Definition of IFR Objectivity

We now give the central definition.

Definition 1 (IFR-objective structure). Let $\Psi \in \mathcal{H}_{\mathcal{X}}$ be an interference state, let $\{\Pi_a\}_{a=1}^{N}$ be an admissible observer family, and let $(\mathcal{M}, d_{\Gamma})$ be a complete information-geometric comparison space. A structure

$$Q_{\Psi,\Gamma}^{\star} \in \mathcal{M}$$

is called *IFR-objective at resolution* $\varepsilon > 0$ if the following conditions hold:

1. **Existence of a center:**

$$Q_{\Psi,\Gamma}^{\star} \in \arg\min_{Q \in \mathcal{M}} F_{\Psi,\Gamma}(Q).$$

2. **Redundant concentration:**

$$F_{\Psi,\Gamma}\left(Q_{\Psi,\Gamma}^{\star}\right) < \varepsilon.$$

3. **Observer stability:** for every admissible perturbation

$$\Pi_a^{\delta} = \Pi_a + \delta\Pi_a$$

with perturbation norm

$$\|\delta\Pi\|_{\mathfrak{P}} < \delta,$$

the corresponding perturbed center

$$Q^{\star}_{\Psi,\Gamma,\delta} \in \arg\min_{Q\in\mathcal{M}} \sum_{a=1}^{N} w_a d_{\Gamma}^2\left(Q, \Pi_a^{\delta}[\Psi]\right)$$

satisfies

$$\lim_{\delta\to 0} d_{\Gamma}\left(Q^{\star}_{\Psi,\Gamma,\delta}, Q^{\star}_{\Psi,\Gamma}\right) = 0.$$

4. **Non-triviality relative to a null model:** there exists a reference dispersion

$$\mathcal{D}_{\text{null}} > 0$$

such that

$$\mathcal{D}_{\text{red}}[\Psi,\Gamma] < \mathcal{D}_{\text{null}}.$$

The null condition prevents arbitrary agreement from being interpreted as objectivity when the observer family is degenerate, artificially constrained, or informationally empty.

The associated dimensionless contraction index is

$$\Delta_{\text{IFR}} = \frac{\mathcal{D}_{\text{null}} - \mathcal{D}_{\text{red}}[\Psi,\Gamma]}{\mathcal{D}_{\text{null}}}.$$

Thus,

$$\Delta_{\text{IFR}} > 0$$

is a necessary empirical signature of redundant contraction.

4.5. Strong and Weak Objectivity

The previous definition admits degrees of objectivity. It is useful to distinguish weak, strong, and asymptotic objectivity.

Definition 2 (Weak IFR objectivity). A structure $Q^{\star}_{\Psi,\Gamma}$ is weakly objective at resolution ε if it satisfies existence and redundant concentration:

$$Q^{\star}_{\Psi,\Gamma} \in \arg\min_{Q\in\mathcal{M}} F_{\Psi,\Gamma}(Q), \quad F_{\Psi,\Gamma}\left(Q^{\star}_{\Psi,\Gamma}\right) < \varepsilon.$$

Weak objectivity means that the observer projections agree, but does not guarantee robustness under perturbations.

Definition 3 (Strong IFR objectivity). A structure $Q^{\star}_{\Psi,\Gamma}$ is strongly objective at resolution ε if it is weakly objective and stable under all admissible perturbations of the observer maps, weights, and comparison geometry:

$$\Pi_a \mapsto \Pi_a + \delta\Pi_a, \quad w_a \mapsto w_a + \delta w_a, \quad \Gamma \mapsto \Gamma + \delta\Gamma.$$

In strong objectivity, the center is not an artifact of a particular representation, weighting scheme, or geometric convention.

Definition 4 (Asymptotic IFR objectivity). Let $\{A_N\}_{N\in\mathbb{N}}$ be an increasing sequence of observer families. A structure $Q^{\star}$ is asymptotically objective if

$$\lim_{N\to\infty} F^{(N)}_{\Psi,\Gamma}\left(Q^{\star}_N\right) = 0$$

and

$$Q_N^\star \to Q^\star$$

in d_Γ.

Asymptotic objectivity is the ideal limit in which infinitely many independent observational channels converge to the same informational structure.

4.6. Existence of Objective Centers

The existence of a Fréchet center is not automatic in arbitrary metric spaces. IFR therefore imposes mathematical conditions when exact objectivity is required.

Proposition 1 (Existence of Fréchet centers). *Let* $(\mathcal{M}, d_\Gamma)$ *be a proper complete metric space, meaning that closed bounded subsets are compact. Let*

$$m_1, \cdots, m_N \in \mathcal{M}$$

be observer projections with finite weights $w_a \geq 0$ and $\sum_a w_a = 1$. Then the Fréchet functional

$$F(Q) = \sum_{a=1}^{N} w_a d_\Gamma^2 (Q, m_a)$$

admits at least one minimizer.

Proof. Since $F(Q) \geq 0$, let $\{Q_k\}$ be a minimizing sequence. Choose any observer point m_1. Because

$$F(Q_k)$$

is bounded along the minimizing sequence, and because at least one weight is positive, the distances $d_\Gamma(Q_k, m_a)$ remain bounded for at least one a and therefore, by the triangle inequality, $\{Q_k\}$ lies in a bounded closed subset of $\mathcal{M}$. Properness implies that a convergent subsequence exists:

$$Q_{k_j} \to Q^\star.$$

Continuity of d_Γ^2 implies

$$F(Q^\star) = \inf_{Q \in \mathcal{M}} F(Q).$$

Thus $Q^\star$ is a minimizer.

This proposition establishes that objective centers exist under standard compactness assumptions.

4.7. Uniqueness of Objective Centers

Existence alone is insufficient for a rigorous theory of objectivity. If multiple incompatible centers exist, the observer family does not select a unique objective structure. IFR therefore requires uniqueness for strong objectivity.

Proposition 2 (Uniqueness under strict geodesic convexity). *Let* $(\mathcal{M}, d_\Gamma)$ *be a geodesic metric space. Suppose that for every observer projection* m_a, *the function*

$$Q \mapsto d_\Gamma^2(Q, m_a)$$

is strictly geodesically convex on a convex domain $\mathcal{U} \subseteq \mathcal{M}$. If all observer projections lie in $\mathcal{U}$ and at least two non-identical projections have positive weight, then the Fréchet functional

$$F(Q) = \sum_{a=1}^{N} w_a d_\Gamma^2(Q, m_a)$$

has at most one minimizer in $\mathcal{U}$.

Proof. Assume, for contradiction, that Q_0 and Q_1 are two distinct minimizers in $\mathcal{U}$. Let $\gamma : [0,1] \to \mathcal{U}$ be a geodesic with

$$\gamma(0) = Q_0, \quad \gamma(1) = Q_1.$$

By strict geodesic convexity,

$$d_\Gamma^2(\gamma(t), m_a) < (1-t) d_\Gamma^2(Q_0, m_a) + t d_\Gamma^2(Q_1, m_a)$$

for $t \in (0,1)$ and for at least one term with positive weight. Summing over a gives

$$F(\gamma(t)) < (1-t) F(Q_0) + t F(Q_1).$$

Since Q_0 and Q_1 are both minimizers,

$$F(Q_0) = F(Q_1) = \inf F.$$

Therefore,

$$F(\gamma(t)) < \inf F,$$

which is impossible. Hence the minimizer is unique. □

In smooth Riemannian settings, strict geodesic convexity is guaranteed locally in sufficiently small geodesic balls, and globally under stronger curvature assumptions. Thus IFR objectivity is naturally local when the comparison geometry is curved.

4.8. Stability of Objective Centers

Strong objectivity requires that the Fréchet center depend continuously on the observer projections. The following statement gives a sufficient condition.

Proposition 3 (Stability under perturbations). Let $(\mathcal{M}, d_\Gamma)$ be a geodesic metric space, and suppose the Fréchet functional

$$F(Q) = \sum_{a=1}^{N} w_a d_\Gamma^2(Q, m_a)$$

has a unique minimizer Q^*. Let perturbed observer projections

$$m_a^\delta$$

satisfy

$$\max_a d_\Gamma(m_a^\delta, m_a) \le \delta.$$

Assume that the perturbed functionals

$$F_\delta(Q)=\sum_{a=1}^{N} w_a d_\Gamma^2\left(Q,m_a^\delta\right)$$

are equicoercive and converge uniformly to F on compact sets as $\delta \to 0$. Then any sequence of minimizers

$$Q_\delta^\star \in \arg\min F_\delta$$

satisfies

$$Q_\delta^\star \to Q^\star.$$

Proof. Uniform convergence on compact sets and equicoercivity imply convergence of minimizers for variational problems with unique limiting minimizer. More explicitly, any sequence $Q_\delta^\star$ has a compactly convergent subsequence by equicoercivity. Let its limit be $\tilde{Q}$. Uniform convergence implies

$$F\left(\tilde{Q}\right) \le \liminf_{\delta\to 0} F_\delta\left(Q_\delta^\star\right) \le \limsup_{\delta\to 0} F_\delta\left(Q^\star\right) = F\left(Q^\star\right).$$

Thus $\tilde{Q}$ is a minimizer of F. Since the minimizer is unique,

$$\tilde{Q} = Q^\star.$$

Every convergent subsequence has the same limit; hence

$$Q_\delta^\star \to Q^\star.$$

□

This result formalizes the intuition that an objective structure must persist under small changes of the observational channel.

4.9. Exact Centers and Empirical Estimators

A central distinction in IFR is the distinction between exact theoretical centers and empirical estimators. Let

$$Q_{\Psi,\Gamma}^\star$$

be the exact Fréchet center associated with the ideal observer projections

$$m_a = \Pi_a[\Psi].$$

In empirical applications, one observes noisy finite data

$$m_a^{\mathrm{obs}} = m_a + \eta_a,$$

or more generally,

$$m_a^{\mathrm{obs}} \sim P_a(\cdot \mid \Psi),$$

where P_a is an observer-specific response distribution. An empirical estimator is then defined by

$$\hat{Q} \in \arg\min_{Q\in\mathcal{M}} \hat{F}(Q),$$

where

$$\hat{F}(Q)=\sum_{a=1}^{N} \hat{w}_a d_\Gamma^2\left(Q,m_a^{\mathrm{obs}}\right).$$

In general,

$$\hat{Q} \neq Q^{\star}_{\Psi,\Gamma}.$$

A consistency condition may be stated as

$$\hat{Q} \xrightarrow{P} Q^{\star}_{\Psi,\Gamma}$$

as observational noise decreases, sample size increases, and the estimated geometry satisfies

$$\hat{\Gamma} \to \Gamma.$$

This distinction prevents the theory from confusing an estimator-based overlap with the variational object that defines IFR objectivity. In particular, an empirical geometric overlap is evidence for objectivity only if it can be shown to approximate a stable Fréchet center.

4.10. Null Models and Non-Trivial Contraction

Agreement among observer projections is physically meaningful only relative to an appropriate null hypothesis. Otherwise, trivial projections or shared preprocessing may artificially reduce dispersion.

Let

$$\mathcal{N}$$

denote a null ensemble of observer projections generated under the hypothesis that no common underlying structure is shared. This may be constructed by randomization, permutation, independent phase scrambling, surrogate generation, noise-only simulations, or model-specific independence assumptions.

The null redundant dispersion is

$$\mathcal{D}_{\text{null}} = \mathbb{E}_{\mathcal{N}}\left[\sum_{a<b} w_{ab} d_{\Gamma}^{2}\left(m_a^{\mathcal{N}}, m_b^{\mathcal{N}}\right)\right].$$

The observed contraction index is

$$\Delta_{\text{IFR}} = \frac{\mathcal{D}_{\text{null}} - \mathcal{D}_{\text{red}}}{\mathcal{D}_{\text{null}}}.$$

A statistically significant positive contraction,

$$\Delta_{\text{IFR}} > 0,$$

supports the existence of a shared structure. A value near zero indicates no detectable redundant objectivity. A negative value indicates that the observer projections are more dispersed than expected under the null.

The normalized index is not itself the definition of objectivity. It is an empirical diagnostic of the contraction component of objectivity.

4.11. Objectivity and Observer Independence

IFR does not define objectivity as independence from all observers. Rather, it defines objectivity as invariance across an admissible family of observers. This distinction is important.

A structure may be objective relative to a class

$$\mathfrak{P}_0 \subset \mathfrak{P}$$

of observational maps, while failing to be objective relative to a broader or incompatible class. Thus objectivity is always defined relative to:

$$\left(\mathfrak{P}_0, \Gamma, \varepsilon, \mathcal{N}\right).$$

This relativity does not make objectivity subjective. Instead, it makes explicit the operational domain within which objectivity is claimed.

In the asymptotic limit of increasingly rich, independent, and mutually nondegenerate observer families, objectivity approaches observer invariance:

$$\lim_{N\to\infty} F_{\Psi,\Gamma}^{(N)}\left(Q_N^{\star}\right) = 0.$$

This is the IFR analogue of classical observer-independent reality.

4.12. Relation between Redundancy and Classicality

Classicality is interpreted in IFR as a high-redundancy regime. A structure behaves classically when it is:

(i) redundantly accessible to many observers;

(ii) stable under perturbations of observer maps;

(iii) localized in an emergent effective geometry;

(iv) persistent across an ordered sequence of objective centers.

Thus classicality is not imposed as a fundamental approximation. It is derived from the combined limits

$$\mathcal{D}_{\text{red}} \to 0, \quad F_{\Psi,\Gamma}\left(Q^{\star}\right) \to 0, \quad Q_{\lambda+\delta\lambda}^{\star} \approx Q_{\lambda}^{\star},$$

together with the emergence of an effective metric manifold.

In this regime, the observer-dependent representations become approximately interchangeable:

$$\Pi_a[\Psi] \approx \Pi_b[\Psi] \approx Q^{\star}.$$

The structure $Q^{\star}$ may then be treated as an ordinary physical object, event, or field value in an effective spacetime.

4.13. Objectivity Theorem

We now state the central objectivity theorem of IFR.

Theorem 1 (Emergence of objective structure). Let $\left(\mathcal{M}, d_\Gamma\right)$ be a proper complete geodesic metric space, and let

$$m_a = \Pi_a[\Psi] \in \mathcal{M}, \quad a = 1, \cdots, N,$$

be observer projections of an interference state Ψ. Suppose that:

1. All m_a lie in a geodesically convex domain $\mathcal{U} \subseteq \mathcal{M}$;

2. The squared distance functions

$$Q \mapsto d_{\Gamma}^{2}\left(Q, m_{a}\right)$$

are strictly geodesically convex on $\mathcal{U}$.

3. The Fréchet functional

$$F_{\Psi,\Gamma}\left(Q\right)=\sum_{a=1}^{N} w_{a} d_{\Gamma}^{2}\left(Q, m_{a}\right)$$

is coercive on $\mathcal{U}$.

4. The centered dispersion satisfies

$$\inf_{Q\in\mathcal{U}} F_{\Psi,\Gamma}\left(Q\right)<\varepsilon;$$

5. The observer projections are stable under admissible perturbations.

Then there exists a unique stable center

$$Q_{\Psi,\Gamma}^{\star} \in \mathcal{U}$$

such that

$$Q_{\Psi,\Gamma}^{\star}=\arg\min_{Q\in\mathcal{U}} F_{\Psi,\Gamma}\left(Q\right),$$

and this center is IFR-objective at resolution ε.

Proof. Properness and coercivity imply existence of a minimizer. Strict geodesic convexity implies uniqueness. The dispersion bound gives

$$F_{\Psi,\Gamma}\left(Q_{\Psi,\Gamma}^{\star}\right)<\varepsilon.$$

Stability follows from the assumed perturbative stability of the observer projections and the stability proposition above. Therefore $Q_{\Psi,\Gamma}^{\star}$ satisfies all conditions in the definition of IFR-objectivity.

This theorem is the formal expression of the principle that objective reality emerges when observer-dependent projections contract toward a unique stable informational center.

4.14. Interpretation

The mathematical content of this section can be summarized as follows:

$$\boxed{\begin{array}{c}\text{Objectivity is the existence, uniqueness, and stability of a Fréchet center}\\ \text{of observer projections.}\end{array}}$$

The role of the interference state Ψ is to generate the observer-dependent projections. The role of the observer maps Π_{a} is to define finite operational access. The role of the information geometry Γ is to make comparison and contraction meaningful. The role of the Fréchet center $Q^{\star}$ is to define the objective structure that emerges from the observer family.

This formulation avoids three common ambiguities.

First, objectivity is not reduced to subjective agreement. The observer maps are physical or operational structures, and the center is defined by a variational problem.

Second, objectivity is not identified with a single detector, representation, or reconstruction. It requires redundancy across an admissible family of projections.

Third, objectivity is not confused with empirical overlap. The exact center $Q^{\star}$ and the estimator $\hat{Q}$ are mathematically distinct.

This provides the foundation for the dynamical theory developed in the next section, where the emergence of objective structures is incorporated into the IFR action through the redundant dispersion term.

4.15. Conceptual Novelty Relative to Existing Programs

IFR shares vocabulary with several established programs, and it is therefore important to state precisely where its specific content lies. We distinguish IFR from four families of approaches.

Decoherence and environment-induced superselection. Decoherence explains the suppression of interference for a system coupled to an environment, and selects a preferred (pointer) basis through interaction with that environment. It presupposes a background spacetime, a fixed system/environment split, and an a priori Hilbert-space tensor structure. IFR does not assume any of these: there is no background manifold, no privileged system/environment partition, and observers are general projection maps Π_a rather than environmental couplings. Where decoherence accounts for the *loss* of coherence given a structure, IFR specifies the conditions under which an objective *structure* (a stable Fréchet center) exists at all.

Quantum Darwinism. Quantum Darwinism characterizes classicality through the redundant proliferation of records of a pointer observable into many environmental fragments, quantified by redundancy and mutual information. IFR generalizes the redundancy idea in two ways. First, redundancy is not restricted to environmental fragments but extends to any admissible observer family (detectors, coarse-grainings, epochs, catalog partitions). Second, IFR replaces the existence of multiple records with a sharper criterion: the existence, uniqueness, and stability of a Fréchet center $Q^{\star}$ in a specified information geometry (Definition 1, Theorem 1). Mere multiplicity of records is necessary but not sufficient for IFR-objectivity.

Relational and informational interpretations. Relational quantum mechanics and related views hold that physical quantities are defined only relative to an observer or reference system, and decline to assign observer-independent values. IFR agrees that single-observer projections are relational, but does not stop there: it defines an *intersubjective* invariant, the Fréchet center, and treats objectivity as the stable contraction of relational projections toward that invariant. Objectivity in IFR is thus relational at the level of Π_a but observer-invariant at the level of $Q^{\star}$, with the relativity made explicit through the class $\left(\mathcal{P}_0, \Gamma, \varepsilon, \mathcal{N}\right)$ of Section 4.11.

Emergent-gravity programs. Thermodynamic and entropic-gravity programs derive gravitational dynamics from coarse-grained or holographic degrees of freedom, typically assuming an underlying spacetime or causal/horizon structure. IFR locates gravitation one level deeper, in the curvature $\mathcal{R}_\Gamma$ of an information geometry over observer projections, with the spacetime metric itself emergent (Postulate VI, Section 3.9). The dynamical realization of this identification is the subject of Part II; here we only note that the *carrier* of gravitational information in IFR is the comparison geometry Γ, not a pre-existing manifold.

In summary, the specific content of "interference-first" is that *objectivity*, *time*, *and spacetime are all defined as stability properties of observer projections of a pre-spatiotemporal interference state*, rather than presupposed. This single criterion—stable, unique, perturbation-robust Fréchet contraction relative to an explicit null model—is what distinguishes IFR from a restatement of the programs above.

4.16. Falsifiability Criteria

IFR is intended to be discriminating, not merely interpretive. We list concrete signatures that would support IFR over nearby frameworks, together with the outcomes that would count as failure.

(F1) Positive, null-tested contraction. IFR predicts a statistically significant positive contraction index $\Delta_{\text{IFR}} > 0$ (Section 3.6) for genuinely redundant observer families, exceeding an appropriate null ensemble $\mathcal{N}$ (Section 4.10). *Failure:* $\Delta_{\text{IFR}} \le 0$, or contraction indistinguishable from the null, for families that are independently known to share structure.

(F2) Observer-class invariance of the center. The recovered center $\hat{Q}$ must be stable under enlargement and perturbation of the admissible observer class $\mathcal{P}_0$ (Definition 1, condition 3; Proposition 3). *Failure:* the center drifts beyond the stability bound under admissible changes of smoothing scale, instrumental mode, or catalog partition, indicating a protocol artifact rather than an objective structure.

(F3) Geometry-selection consistency. Because objectivity is defined relative to a comparison geometry Γ, IFR predicts that the *ranking* of structures by contraction is stable across operationally admissible geometries (e.g. Jensen-Shannon versus Bures versus Wasserstein), even when absolute values differ. *Failure:* qualitatively different, geometry-dependent conclusions for the same data under equally justified Γ, with no geometry-independent invariant surviving.

(F4) Convergence with observer number. Asymptotic objectivity (Definition 4) predicts $F^{(N)}_{\Psi,\Gamma}\left(Q^\star_N\right) \to 0$ and $Q^\star_N \to Q^\star$ as the number of independent observers grows. *Failure:* no convergence, or convergence to incompatible centers, as independent channels are added.

(F5) Emergent-metric correspondence (deferred test). In the high-redundancy regime, IFR predicts the existence of an effective metric embedding with small residual distortion $\epsilon_{\text{eff}} \ll 1$ (Section 3.12). *Failure:* persistent, irreducible non-metric distortion of the stable centers, precluding any effective spacetime description. The quantitative form of this criterion is developed in the dynamical parts of the series.

Criteria (F1)-(F4) are testable with the cross-domain estimators already employed in [8]-[10]; (F5) is theoretical at the level of Part I and becomes operational once the IFR action and its emergent-metric limit are specified.

4.17. Limitations of the Present Construction

The objectivity results of this section are conditional, and we state the conditions explicitly. First, IFR-objectivity is defined relative to a chosen comparison geometry Γ; existence and uniqueness (Propositions 1 - 2) rely on completeness, properness, and strict geodesic convexity of $(\mathcal{M}, d_\Gamma)$, which hold locally in geodesic balls but may fail globally in curved geometries. Objectivity is therefore generically a local statement, and the admissible class of geometries has not yet been fully characterized. Second, the criterion depends on the null model $\mathcal{N}$: the contraction index Δ_{IFR} is meaningful only relative to a justified null ensemble, and a poorly chosen null can either mask or manufacture apparent objectivity. Third, objectivity is defined relative to an admissible observer class $\mathcal{P}_0$ (Section 4.11); a structure objective for one class need not be objective for a broader or incompatible class, so all claims are conditional on the operational domain. These conditional features are not defects to be hidden but the precise content of the IFR notion of objectivity: the framework makes its dependence on geometry, null model, and observer class explicit rather than implicit. Narrowing these dependencies—constraining the admissible geometries, deriving canonical null models, and characterizing maximal observer classes—is left to the subsequent parts of the series.

Continuation of the series. Part II develops the IFR variational principle and the emergence of gravitation from informational curvature.

5. Conclusions

This paper has presented Part I of the Interference-First Reality (IFR) series, establishing the conceptual and mathematical foundations on which the later dynamical and empirical developments rest.

We have, first, stated the eight foundational postulates of IFR (Section 2): the primacy of a pre-spatiotemporal interference state $\Psi \in \mathcal{H}_{\mathcal{X}}$; operational observers as projection maps Π_a; the information geometry of distinguishability; objectivity as redundant multi-observer contraction; variational selection of physical configurations; gravitation as emergent informational curvature; the emergence of temporal order; and the emergence of effective spacetime and field theory. These postulates reverse the usual explanatory order, treating spacetime, objectivity, time, and gravitation as derived rather than primitive.

Second, we have developed the corresponding mathematical structure (Section 3): the configuration space $(\mathcal{X}, \Sigma_{\mathcal{X}}, \mu_{\mathcal{X}})$ and its interference-state space $\mathcal{H}_{\mathcal{X}}$; the admissibility conditions on observer maps; the common comparison space $(\mathcal{M}, \Gamma)$ and its information-geometric distance d_Γ; the redundant dispersion functional $\mathcal{D}_{\mathrm{red}}$ with its operationally fixed weights; the Fréchet functional and the distinction between exact centers $Q^\star$ and empirical estimators $\hat{Q}$; informational curvature $\mathcal{R}_\Gamma$; and the regularity conditions (R1)-(R4) under which the IFR action is well-posed.

Third, we have given a precise theory of objectivity (Section 4): the definition of IFR-objectivity at resolution ε relative to an explicit null model, its weak, strong, and asymptotic variants, and the existence, uniqueness, and stability of objective centers (Propositions 1 - 3), culminating in the central objectivity theorem (Theorem 1). We have, in addition, distinguished IFR from decoherence, quantum Darwinism, relational interpretations, and emergent-gravity programs (Section 4.15), stated concrete falsifiability criteria (F1)-(F5) (Section 4.16), and made explicit the conditional character of the objectivity claims (Section 4.17).

The central conclusion of Part I is that objectivity can be given a rigorous, operational, geometry-based definition—the stable, unique, perturbation-robust Fréchet contraction of observer projections of an interference state—without presupposing a background spacetime or observer-independent objects. The dynamical realization of this definition through the IFR action, the emergence of gravitation from informational curvature, the emergence of temporal order, and the connection to the cross-domain empirical estimators are developed in the subsequent parts of the series.

Author Contributions

Conceptualization, M.B.; methodology, M.B.; software, M.B.; validation, M.B.; formal analysis, M.B.; visualization, M.B.; writing—original draft preparation, M.B.; writing—review and editing, M.B.

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Data Availability

All datasets used in this study are publicly available. CMB spectra (TT, TE, EE) are from the Planck 2018 legacy release (Planck Legacy Archive) [13]; for theoretical background on CMB anisotropies see [14] [15]. Scripts associated with the legacy CMB and HRV analyses are archived separately in the Zenodo repository accompanying the previous article. https://doi.org/10.5281/zenodo.17672528. Gravitational-wave strain data (GW150914-v2 and GW170817-v2) are from the Gravitational Wave Open Science Center (GWOSC). ECG/HRV records are from PhysioNet (*Fantasia* and *MIT-BIH Arrhythmia* databases); PSD was estimated using the Welch method [16] and frequency-band definitions follow established

HRV standards [17]. No raw ECG signals are redistributed. JWST spectroscopic data are from the public JADES release [18]. All datasets, Python scripts, and LaTeX materials are openly available on Zenodo at https://doi.org/10.5281/zenodo.17672528. The complete theoretical formulation of the IFR framework, of which this paper constitutes Part I of VI, is available as a preprint on Zenodo: https://doi.org/10.5281/zenodo.20528552.

Generative AI Tools

Generative AI tools (Claude by Anthropic, and GPT-based assistants) were used for manuscript revision, LaTeX formatting, code refactoring, and minor stylistic editing. All analyses, parameter choices, and numerical results were obtained by executing the released Python code on public datasets. **Figure 1** is an original schematic diagram prepared by the author in LaTeX/TikZ; it is a conceptual illustration and was not generated by AI tools. No data, numerical results, or scientific conclusions were generated by AI tools; all scientific analyses, interpretations, and conclusions are the author's own.

Patents

No patents are associated with this work.

Reproducibility and Computational Transparency

Part I is a foundational and mathematical paper: it contains no new empirical results, data tables, or numerical analyses, and its only figure (**Figure 1**) is a conceptual illustration of the framework. There is therefore no data pipeline to reproduce within Part I itself.

For completeness and continuity with the series, we note that the full empirical program of IFR—spanning heart-rate variability (HRV), the cosmic microwave background (CMB), gravitational-wave open data (GWOSC), JWST spectroscopy, large-scale structure (LSS), and their cross-domain synthesis, is documented in the data-oriented publications of the series [8]-[10] and in the accompanying supplementary file *Reproducibility_sequence.txt*, which lists the complete commands, input specifications, execution order, and output descriptions for every figure and table in those works, including both computational pathways used for the CMB analysis (the binned-direct and bootstrap + sweep procedures).

All information-geometric quantities used across the empirical program (the Jensen-Shannon divergence and distance, the geometric and arithmetic barycenters, and the redundant-dispersion functional) are computed by a single audited module, ifr_core, imported by every analysis script. This consolidation guarantees that the information geometry is implemented identically across all domains; property-based and on-data equivalence tests confirm that it leaves all previously reported results numerically unchanged, with a maximum discrepancy below 10^{-13}. To make the workflow directly executable, self-configuring launcher packages for macOS and Windows run the analysis scripts in the prescribed sequence. All datasets, analysis scripts, and LaTeX materials are openly available on Zenodo at https://doi.org/10.5281/zenodo.17672528. The consolidated code module ifr_core, its verification routines, and the ready-to-run launcher packages for macOS and Windows are archived at https://doi.org/10.5281/zenodo.20528552. The empirical instantiation of the formal estimators introduced here is taken up in the later parts of the present series.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Abbreviations

CMB	Cosmic Microwave Background
GWOSC	Gravitational Wave Open Science Center
HRV	Heart Rate Variability
IFR	Interference-First Reality
JS	Jensen–Shannon divergence
JSD	Jensen–Shannon distance
JWST	James Webb Space Telescope
KL	Kullback–Leibler divergence
LSS	Large-Scale Structure
PSD	Power Spectral Density
VLF/LF/HF	Very-Low/Low/High Frequency bands