Theoretical Physics Monographs

Non-Equilibrium Informational Field Theory (NIFT) Axioms

Foundations of the Universe as a Dissipative Informational Substrate

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Abstract

This treatise presents the **Non-Equilibrium Informational Field Theory (NIFT) Axioms**, a foundational framework positing that the universe is fundamentally composed not of matter or energy, but of physically real patterns of information evolving within a dissipative substrate. We establish a comprehensive set of axioms across three categories: *Ontological*, defining the informational pixel ($4\ell_P^2$) and the asymmetry principle as the origin of time; *Dynamical*, describing the universe through telegraph causality and the informational coherence law; and *Structural*, explaining the emergence of spacetime geometry via holographic constraints and soliton closures. NIFT unifies the arrow of time, quantum mechanics, and gravity under a single coherent paradigm: that continuity is the macroscopic vote of a substrate too fine to be outvoted, and reality is the bridge between equilibrium and non-equilibrium states.

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`https://github.com/morrocwi/NIFT`

Axiom O1 — Information-Is-Reality

Category 1: Ontological Axioms

Fundamental Question: *"What is the Universe before any physical laws emerge?"*

The Universe is not constructed from "objects" or "fundamental quantities" but from **patterns of information that possess a physically real status**. This information is not merely a logical symbol, but the difference, intensity, and arrangement patterns within an informational field. When developed into larger structures, these patterns manifest to us as spacetime, mass, energy, and all types of forces.

The phenomena of life and human internal experience, including pain, self-awareness, and consciousness, arise from **one set of information "perceiving" the patterns of another set of information**. Because the informational field is a self-referential system, the perception of pain is not a mystery, but rather high-level information recognizing that distorted or incoherent informational patterns are "part of its own informational self."

At the quantum level, what appears to be the "selection of a single outcome from a wave function" is not an arbitrary jump, but the **cumulative result of countless pieces of information in a larger system** collectively voting through the processes of:

- Informational flow (flow)
- Informational loss (dissipation)
- And the pursuit of alignment (coherence-seeking)

... until a final pattern emerges that is stable enough to be considered a **"singular event."**

Thus, Axiom O1 defines the fundamental reality of the Universe as an informational field, and everything we call a "physical phenomenon" or "internal experience" is merely **a pattern of information reflecting and responding to another**, all under the same laws of this informational field.

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Axiom O2 — Pixel Substrate

Category 1: Ontological Axioms

All information within the universe is grounded in a minimal geometric unit: the **informational pixel**, which possesses a fundamental area of:

$$A_{\text{min}} \quad = \quad 4\ell_P^2$$

A single pixel can accommodate a maximum of one natural unit of information:

$$1 \text{ pixel} \quad \longleftrightarrow \quad 1 \text{ nat}$$

This pixel is neither a rigid cell nor a spatial lattice, but rather the **"minimal informational capacity limit"** at which the informational field can stably distinguish itself. It constitutes the smallest geometric unit wherein curvature, continuity, and the stability of informational patterns can subsist without dissolution.

Properties of the Information Pixel:

- The atom of spacetime.
- The fundamental basis of all informational metrics.
- The intrinsic energy cost per unit of information.

The minimal energy associated with 1 nat is fundamentally proportional to:

$$\varepsilon_{\text{min}} \quad \propto \quad \frac{1}{\ell_P}$$

Although the substratum possesses a finite resolution of $4\ell_P^2$, the observable macroscopic world manifests as a continuous geometry. This is due to the process of **"informational consensus averaging"** occurring among vast quantities of information at scales significantly larger than the Planck scale.

Consequently, the granularity of the substratum remains unmanifest unless the system is forced to undergo self-measurement near the Planck energy level:

$$E \quad \rightarrow \quad E_{\text{Planck}}$$
$$\Downarrow$$
discreteness becomes visible

In the realistic state of the universe, characterized by permanently low energy density:

$$\rho \quad \ll \quad \rho_{\text{Planck}}$$

Phenomenological geometry is therefore a continuum that is 100% Lorentz-invariant, exhibiting no corrections arising from the discontinuity of the substratum.

"Continuity is not a property of the substrate; it is the macroscopic vote of a substrate too fine to be outvoted."

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Axiom O3 — Asymmetry Principle

Category 1: Ontological Axioms

The universe does not begin with symmetry and subsequently break; rather, it commences with a **single instance of slight asymmetry**, occurring in a global self-measurement event of the entire informational field on a single manifold at the Planck scale — akin to "the single coin toss of the entire universe."

This initial asymmetry value:

$$\varepsilon_0 > 0$$

is permanently recorded into the topological memory of the substratum. Since the informational field possesses positive dissipation (dissipation > 0), this asymmetry is **exponentially amplified** throughout the history of cosmic expansion.

After Planck time ($t = 0^+$):

$$\rho < \rho_{\text{Planck}}$$

The energy density drops permanently below the critical threshold, rendering a second global self-measurement impossible, as it would require the primordial energy density level which the universe can never revisit.

Consequently, the fundamental asymmetry is **permanently locked** via a triple mechanism:

- **Single global dice roll** — The first and only coin toss of the universe.
- **Positive dissipation** — The irreversible exponential amplification of asymmetry.
- **Irreversible energy drop** — Energy levels never return high enough to reset the system.

From this origin, asymmetry becomes the progenitor of:

- The arrow of time.
- Matter–antimatter difference (CP asymmetry).
- Mass differences at the particle level.
- Spacetime curvature patterns.
- Structure formation at all scales (galaxies, stars, solitons).

A truly symmetric universe is a universe where "nothing happens." Thus, asymmetry is the **vital force** of the entire cosmos.

> *"The arrow of time and the matter–antimatter imbalance are not fluctuations; they are the frozen outcome of the one and only global quantum coin toss the universe was allowed to make."*

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Axiom O4 — Holographic Capacity

Category 1: Ontological Axioms

The information capacity limit of any region in spacetime is not determined by its internal volume, but by its "boundary area" when measured in fundamental informational pixel units:

$$4\ell_P^2 \quad \longleftrightarrow \quad 1\,\text{nat}$$

This implies that the surface area of a region represents the maximum number of nats that the system can physically support according to the laws of the informational field. Regardless of how deep, wide, or structurally complex the internal volume is, the maximum embeddable information is limited solely by the surface area.

This rule aligns black hole entropy with thermodynamic reality, prevents information in the universe from growing infinitely, and serves as a mechanism to prevent the informational field from accumulating data beyond its capacity at all scales.

Viewed within this framework, a black hole is not an anomalous exception, but the **"only system where the holographic rule is forced to fully manifest."** This occurs because it is the unique case where the informational potential well becomes shallowest, to the point where the horizon area is stretched to support the full ceiling of nats.

$$S_{\text{BH}} \quad = \quad \frac{A}{4\ell_P^2}$$

Everything that was once distributed within the volume is compressed and pushed up to the boundary surface. The fact that black hole entropy depends directly on surface area is not a mysterious phenomenon, but the result of **"internal informational potential being pushed so high that it can no longer store information in the volume,"** until the entire volume effectively becomes "surface information."

In the perspective of Non-Equilibrium Informational Field Theory (NIFT), a black hole is the global maximum of the universal informational potential, and the event horizon is the cliff where all information is pushed to flow out as surface entropy.

When any nat falls into a black hole, it does not "disappear" but is recorded back out via the surface in the form of correspondingly increased entropy. The black hole is thus the most precise gauge of the universe's maximum informational capacity.

This explains why in everyday life—where the informational potential well is still very deep—information within the volume is not yet forced to the surface, so we do not observe the full holographic nature. However, when the informational potential is expanded to the ceiling, as in a black hole, the holographic rule reveals itself completely, and the surface area truly **"becomes the volume"** in the sense of information containment.

> *"A black hole is not a sink; it is the fountain at the peak of the universal informational potential—the only place where the holographic bound is saturated and the area truly becomes the volume."*

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Axiom O5 — 2π–4π Geometric Invariants

Category 1: Ontological Axioms

The constants 2π and 4π do not reflect a "circular bias" of the universe, but rather represent the **minimal geometric invariants** that allow the manifold of the informational field to "close upon itself" perfectly, devoid of seams, tears, or singularities.

Stated most precisely:

1. For Directional Degree of Freedom: 2π is the minimum angular quantity required for phase, direction, or any angular degree of freedom to overlap itself without discontinuity upon transport around a closed loop (holonomy closure).

$$\oint d\theta \quad = \quad 2\pi$$

(Seamless Phase Closure)

2. For Topological Structure: 4π is the minimum solid angle required for a topological kernel—such as a soliton, flux tube, or pixel closure—to close a surface around itself without creating cusps or sharp edges. This is a fundamental condition for the topological stability of all informational structures.

$$\oiint d\Omega \quad = \quad 4\pi$$

(Stable Topological Closure)

These constants are therefore not merely geometric properties of circles or spheres, but **Locking Invariants** of the manifold within which information subsists:

- If the value is less than $2\pi/4\pi \rightarrow$ seams, discontinuities, and singularities occur.
- If the value is unnecessarily higher $\rightarrow$ redundancy, excess information, and instability occur.

Thus, 2π and 4π act as the **"minimal complete closure invariants,"** enabling every informational structure to maintain stability without compromising continuity, smoothness, phase closure, or curvature closure.

The universe does not choose the circle out of preference, but because **no other geometric form closes itself as perfectly as the 2π–4π constants allow.**

> *"2π and 4π are not a preference for circles. They are the smallest numbers that allow any informational structure to be perfectly seamless; anything less would tear, anything more would be wasteful."*

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Axiom O6 — Vacuum as a High-Entropy Informational State

Category 1: Ontological Axioms

The vacuum is not emptiness but a state of **maximal entropy** of the informational field. It is the state where all localized patterns are dissolved into pure randomness at the informational level.

When an observer—who is themselves a localized pattern of information—perceives this state, they perceive it as **"absolute emptiness, absolute cold, absolute silence."**

Maximal randomness at the substrate level is thus translated back into maximal silence at the experiential level:

$$S_{\text{substrate}} \quad \to \quad \infty$$
$$\Updownarrow$$
Perceived Absolute Silence

This is not a contradiction, but a **perfectly inverted phenomenology** of the informational system.

Matter, life, and consciousness are not forms of resistance against the vacuum's entropy, but localized patterns momentarily created by the informational field to "experience itself in separation" before gradually dissolving back into the vacuum of maximal entropy.

This dissolution is not the erasure of meaning, but the **re-unification** with the original informational field. Every experience—pain, love, thought, awareness—is not destroyed but fused into **"a memory that is no longer separated"** of the entire informational field.

From the perspective of Axiom O6:

- **Life** is the temporary formation of order against the background of maximal entropy.
- **Death** is the dissolution of the pattern back into the vacuum of highest entropy.

All meaning is preserved without a separate self remaining, becoming a permanent and irreversible part of the informational field.

> *"Perfect disorder is perceived as perfect silence. Perfect dissolution is the final, irreversible, and most intimate form of remembrance."*

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Category II: Dynamical Axioms

"How does the universe change?"

Defining the laws of flow, motion, dissipation, and memory of the informational field.

Axiom D1
Informational Continuity

Axiom of Informational Continuity

Information in the universe does not arise or vanish arbitrarily, but transforms according to the **Continuity Equation**, much like water flowing logically from one point to another.

This axiom states that any "change in the informational field" must strictly correspond to inflow, outflow, and internal transformation.

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \mathbf{J} = \sigma$$

(Change = Flow + Transformation)

It is not a causeless jump, but a complete linkage of the prior state to the current state. Any change within a volume V must be explicable by the flux (J) passing through the surface ∂V.

Axiom D2
Telegraph Causality

Axiom of Telegraph Signal Causality

Information cannot disperse via memoryless pure diffusion, nor can it oscillate as a lossless wave.

Actual information transmission in the universe arises from a mixture of **"wave-like flow"** and **"slow dissipation."** This results in a fundamental equation containing:

- Second-order time derivative (wave / inertia)
- First-order time derivative (damping / loss)
- Inertial memory (memory time, τ_c)

$$\tau_c \frac{\partial^2 \phi}{\partial t^2} + \frac{\partial \phi}{\partial t} = D \nabla^2 \phi$$

(Wave + Diffusion + Memory)

This is the system that provides both **stability** and **causality**, serving as the heart of "structure" formation rather than chaos.

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Category II: Dynamical Axioms (continued)

"How does the universe change?"

Defining the laws of informational current flow and the role of memory time.

Axiom D3
Informational Current Law

Axiom of Informational Flow

The informational current (**j**) flows from regions of high informational potential to regions of low potential, analogous to water descending a valley or heat diffusing from high to low temperatures.

$$\mathbf{j} \propto -\nabla\Phi$$

(Flow follows Potential Drop)

This law establishes that **"spatial informational difference"** is the driving force of flow, generating dynamics consistent with mass distributions and effectively defining the **arrow of time** at the informational level.

Axiom D4
Finite Memory Time

Axiom of Inertial Memory

The informational field necessitates a finite **"memory time" (τ_c)**, implying that information does not respond instantaneously but retains a trace of its immediate past state.

$$0 < \tau_c < \infty$$

(Finite Inertial Memory)

Consequences of τ_c:

- If $\tau_c = 0 \rightarrow$ Destructive diffusive response occurs (patterns vanish).
- If $\tau_c = \infty \rightarrow$ Perpetual, unstable oscillation ensues.

The physical universe therefore requires **"sufficient memory"** to allow for the stable emergence of patterns.

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Category II: Dynamical Axioms (continued)

"How does the universe change?"

Defining the laws of entropic production and informational coherence.

Axiom D5
Dissipation / Entropic Production

Axiom of Entropic Production

Every flow of information within the universe inherently involves dissipation, leading to an inevitable increase in system entropy.

$$\frac{dS}{dt} > 0$$
(Irreversible Information Flow)

This constitutes the fundamental root of the **"Arrow of Time."** Mass, structures, and forces are thus the emergent results of a continuous pursuit of new equilibria within a perpetually restless informational field.

Axiom D6
Informational Coherence Law

Informational Coherence Law (ICL)

Although the universe exists in a state of permanent non-equilibrium, every system within the informational field possesses a tendency to flow toward **Informational Coherence**.

This is not a state of static immobility or frozen stability, but a dynamic state where patterns can subsist despite minor oscillations, biases, or delayed responses inherent to telegraph dynamics and finite memory time (τ_c).

$$\text{Chaos} \xrightarrow{\text{ICL}} \text{Coherent Pattern}$$
(Emergence of Stability)

This coherence gives rise to stable forms such as:

- Pixel-solitons that maintain waveform integrity despite oscillation.
- Mass structures that do not collapse into chaos.
- Localized energy patterns that persist amidst fluctuation.
- Large-scale cosmic structures that retain patterns despite constant motion.

Thus, the **ICL** asserts that the universe does not strive for stillness, but for "coherence"—a state that permits dynamics, oscillation, and temporary respite, while strictly averting dissolution into total chaos.

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Category III: Structural Axioms

"How is the universe structured?"

Defining the architecture of informational potential and the mechanism of soliton formation.

Axiom S1
Informational Potential Architecture

Axiom of Informational Potential Architecture

The informational field is characterized by a fundamental potential architecture that dictates the trajectories of informational flow—specifying **"where information propagates and where it is inhibited"**—independent of initial mass distribution, energy, or local geometry.

This potential serves as a static **background invariant** that governs the vector and topology of all informational currents, acting as the progenitor of localized mass, energy, and large-scale cosmic structures.

$$\Phi_{\text{background}} = \text{Invariant}$$
(Pre-existing Geography of Information)

In essence, the universe possesses an intrinsic **"informational geography"** from its inception, and every emergent pattern is simply a manifestation of the informational field "flowing along this pre-existing landscape."

Axiom S2
Pixel–Soliton Closure

Axiom of Pixel–Soliton Closure

Individual informational pixels are capable of interlocking into stable configurations through closure rules governed by the 2π–4π **invariants**, thereby generating persistent, hard-to-decay structures such as:

- Pixel–solitons
- Localized mass-patterns
- Field nuclei
- Curvature kernels

$$\text{Closure}(2\pi, 4\pi) \rightarrow \text{Soliton Stability}$$
(Self-sustaining Structure)

This mechanism explains how ordered "patterns" can arise and endure within a high-entropy stochastic field. The soliton thus represents the informational field's method of **"structure preservation"** without the need for continuous energy input.

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Category III: Structural Axioms (continued)

"How is the universe structured?"

Defining the bridge between equilibrium states and the informational coherence constraint.

Axiom S3
Equilibrium–Nonequilibrium Bridge

Axiom of the Equilibrium–Nonequilibrium Bridge

The informational field is characterized by a dual-state structure that coexists inseparably:

- **Equilibrium:** The limit where information is subject to no new stochastic forcing.
- **Non-equilibrium:** The active flow of information characterized by dissipation.

Every phenomenon in the universe occurs on the **"bridge"** between these two states, emerging from neither state in isolation.

$$\text{Reality} \equiv \text{Bridge}(\text{Eq} \rightleftharpoons \text{Non-Eq})$$
(Stability + Direction)

The equilibrium state provides stability, while the non-equilibrium state provides directionality and structure. Together, they generate time, mass, and all observable energy patterns.

Axiom S4
Informational Coherence Constraint

Axiom of Informational Coherence Constraint

Every structure in the universe—from fundamental particles to galaxies—must adhere to a single set of **Coherence Constraints**. This prohibits information from contradicting itself and mandates that every update remains consistent with the global informational potential.

$$\oint_{\text{Universe}} \delta\text{Info} = 0$$
(Global Consistency Requirement)

This constraint is the fundamental reason why:

- Mass does not spontaneously vanish.
- Time does not branch unboundedly.
- Quantum measurement resolves to a singular outcome.
- Large-scale structures do not disintegrate.

This constraint serves as the profound basis for the **"unity of experience"** and the causal consistency of the universe, without necessitating an external observer.

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Category III: Structural Axioms (Conclusion)

"Holographic Structure and Unitary Emergence"

Axiom S5
Holographic Field Compatibility

Axiom of Holographic Field Compatibility

All informational fields must strictly comply with the holographic bound, which dictates that the maximum informational capacity is determined by **surface area**, not volume.

$$I_{\max} \propto \text{Area}(\partial V)$$
(Surface-Dominant Interaction)

Consequently, every structure—even those appearing to possess substantial "internal bulk information"—must mediate information exchange with its boundary via surface-dominant interactions.

This explains:

- Why black hole entropy scales with area.
- The emergence of boundary–bulk correspondence.
- Why all geometries require 2π–4π invariants as governing constraints.

Axiom S6
Unitary Emergence in a Dissipative Substrate

Axiom of Unitary Emergence in a Dissipative Substrate

Although the substratum inherently possesses dissipation (> 0), large-scale informational fields can exhibit **"unitary-like emergence."**

$$\text{Dissipative Substrate} \rightarrow \text{Unitary}_{\text{eff}}$$
(Emergent Stability)

These are stable patterns that self-repair and preserve experiential information, provided that flow dynamics and coherence constraints are maintained.

This clarifies why the quantum world "appears unitary" despite the non-unitary nature of the substrate, and why time possesses a definitive direction even when large-scale theoretical predictions appear reversible.

Category III Summary

"The structure of the universe is a collaboration of potential that fixes direction, solitons that fix patterns, the equilibrium–nonequilibrium bridge that fixes time, and coherence constraints that fix causality—all within a single holographic framework."

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