Theory of Everything

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Constraint-Driven Information Dynamics as a Unifying Principle for the Fundamental Interactions

Abstract

We present a unifying framework in which the four fundamental interactions emerge as constraint-enforcement mechanisms on an underlying information manifold. Gravity is reinterpreted as a global constraint on admissible state space over time, electromagnetism as phase dynamics between conjugate informational states of matter and antimatter, the weak interaction as a generator of time-asymmetric entropy flow, and the strong interaction as a local information confinement mechanism. The Big Bang is described as an initial condition of maximal constraint leading to a dominant entropy gradient. We propose a single variational principle based on constrained free-energy minimization from which classical gravity and gauge dynamics arise. This framework avoids direct quantization of gravity, reframes gauge symmetries as representational redundancies, and naturally extends to decentralized inference systems and collective intelligence.

1 Introduction

Despite remarkable success of General Relativity and Quantum Field Theory, their incompatibility suggests a deeper structural misclassification of gravity. Existing unification attempts focus on embedding gravity into quantum frameworks, often introducing mathematical complexity without conceptual necessity.

We argue instead that gravity is not a force but a global constraint on evolution. When physics is reformulated as constrained information dynamics, the four interactions arise naturally as distinct enforcement modes of a single principle.

2 Information Manifold and Constraint Structure

Let $\mathcal{I}$ denote an information manifold representing all admissible system states. Physical evolution corresponds to trajectories on $\mathcal{I}$ subject to constraints.

We define a global constraint functional:

$$\mathcal{C}[\rho] = \int_{\mathcal{I}} \rho(x,t)\, \Phi(x,t)\, dx, \tag{1}$$

where $\rho(x,t)$ is the probability density over states and Φ encodes admissibility constraints.

2.1 Gravity as Global Constraint

Gravity constrains the causal accessibility of states. This induces a metric structure over $\mathcal{I}$ equivalent to spacetime curvature. Importantly, gravity does not generate transitions but restricts them.

Entropy follows directly:

$$S(t) = -\int \rho \ln \rho \, dx, \tag{2}$$

and increases whenever constraints relax over time.

2.2 The Big Bang as Entropy Gradient

The Big Bang is reinterpreted as an initial condition of maximal global constraint. Subsequent relaxation produces the largest entropy gradient, defining the arrow of time. No singular explosive dynamics are required.

3 Unified Action Functional

We propose a single variational principle:

$$\mathcal{S} = \int dt \left[\underbrace{\mathcal{C}_g}_{\text{Gravity}} + \underbrace{\mathcal{C}_\phi}_{\text{Electromagnetism}} + \underbrace{\mathcal{C}_\tau}_{\text{Weak}} + \underbrace{\mathcal{C}_\ell}_{\text{Strong}} - \lambda \mathcal{F} \right], \tag{3}$$

where $\mathcal{F}$ is a free-energy functional:

$$\mathcal{F} = \mathbb{E}[\ln \rho] - \mathbb{E}[\ln p(o|x)]. \tag{4}$$

Minimizing $\mathcal{F}$ under constraints yields physical laws.

4 Electromagnetism as Phase Dynamics

Matter and antimatter are treated as conjugate informational states:

$$\psi \leftrightarrow \psi^*. \tag{5}$$

Electromagnetism governs phase evolution:

$$\psi(x) \to e^{i\theta(x)} \psi(x), \tag{6}$$

which arises naturally as a connection over the constrained manifold. Gauge invariance emerges as representational redundancy.

5 Weak Interaction: Directional Entropy Injection

Weak interactions break conjugate symmetry and induce irreversible transitions:

$$\frac{dS}{dt} > 0. \tag{7}$$

This links CPT violation and the arrow of time directly to entropy flow, rather than symmetry breaking by fiat.

6 Strong Interaction: Local Information Confinement

The strong interaction enforces locality by penalizing factorization of internal degrees of freedom. Informationally, it maximizes mutual information between subcomponents, preventing free propagation.

7 Emergent Einstein and Maxwell Equations

Extremizing the constraint functional yields:

- Einstein-like equations from variation of $\mathcal{C}_g$
- Maxwell-like equations from phase conservation of $\mathcal{C}_\phi$

Gravity resists quantization because it constrains probability flow rather than mediating it.

8 Comparison with Existing Frameworks

General Relativity	Geometry without inference
QFT	Dynamics without global constraint
String Theory	Geometry without epistemic grounding
LQG	Quantization of space, not causality
This Work	Constraint-driven inference physics

9 Connection to Bayesian Inference and Free Energy

Physical evolution is equivalent to Bayesian updating:

$$\rho_{t+1}(x) \propto \rho_t(x) p(o_t|x). \tag{8}$$

Forces emerge as Lagrange multipliers enforcing consistency between beliefs and observations.

10 Extension to Decentralized Intelligence

In distributed systems:

- Gravity $\rightarrow$ global consensus constraint
- EM $\rightarrow$ phase synchronization
- Weak $\rightarrow$ irreversible updates
- Strong $\rightarrow$ local coupling

This directly maps to decentralized AGI, swarm intelligence, and consensus protocols.

11 Implications

This framework:

- Explains force hierarchy
- Explains time asymmetry
- Avoids gravity quantization
- Unifies physics and inference
- Bridges cosmology and intelligence

12 Conclusion

Reality is best described as a constrained information manifold undergoing free-energy minimization. Forces are not fundamental entities but enforcement mechanisms of admissibility, locality, and temporal consistency. This provides a minimal and coherent Theory of Everything.

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