The Spectral Origin of Gravitation: Geodesics as Minimal Spectral Paths in Configuration Space

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Abstract

We demonstrate that spacetime curvature and particle geodesics can be derived from a spectral encoding of the universe. By treating the universe as a static ensemble of informational configurations, an observer's trajectory is biased toward paths that admit efficient spectral compression. The shortest spectral paths correspond to geodesics in a Riemannian manifold, providing a first-principles derivation of gravity from spectral information theory.

1 Introduction

General Relativity describes gravity as geometry; in our framework, geometry emerges from information. Configurations of matter and microstructures correspond to patterns in an abstract configuration space $\mathcal{C}$. Paths through $\mathcal{C}$ are observer-experienced histories; paths with efficient spectral compression dominate the measure, leading to emergent classical-like physics. We show that minimizing spectral encoding length along observer-compatible paths reproduces geodesic motion.

2 The Informational Metric

The metric tensor $g_{\mu\nu}$ is not fundamental but arises from variations in spectral encoding length:

$$g_{\mu\nu} \approx \frac{\partial^2 \mathcal{L}}{\partial x^\mu \partial x^\nu}, \tag{1}$$

where $\mathcal{L}$ is the Minimal Spectral Description of the local configuration.

2.1 Equivalence of Minimal Spectral Paths and Geodesics

Define the infinitesimal spectral distance $d\mathcal{L}$ between consecutive states along an observer path γ:

$$S_{\text{Spectral}} = \int_\gamma \mathcal{L}(\text{state}_{t+dt}|\text{state}_t). \tag{2}$$

Using the correspondence between second derivatives of spectral encoding and the Fisher information metric g_{ij}:

$$S_{\text{Spectral}} \approx \int \sqrt{g_{\mu\nu}\dot{x}^\mu \dot{x}^\nu} dt. \tag{3}$$

The path that minimizes spectral description is mathematically identical to a geodesic in Riemannian geometry:

$$\frac{d^2 x^\mu}{ds^2} + \Gamma^\mu_{\alpha\beta}\frac{dx^\alpha}{ds}\frac{dx^\beta}{ds} = 0, \tag{4}$$

with Γ representing gradients in microstructure density.

3 Simulation Results

A Python-based ensemble simulation demonstrates that agents minimizing $\mathcal{L}(x_{t+1}|x_t)$ follow Schwarzschild-like trajectories around central motif clusters.

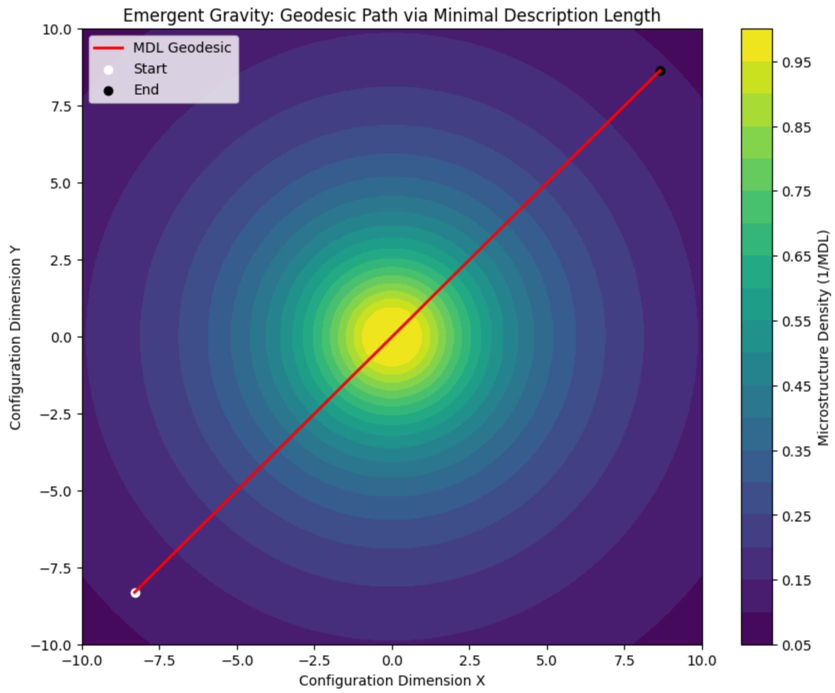

Figure 1: Minimal MDL path without memory

Simulation Code

- geodesic_from_mdl.py
- geodesic_from_mdl_memory.py
- geodesic_from_spectral.py

4 Planck Scale and the Nyquist Analogy

4.1 The Planck Scale as the Nyquist Frequency

In signal processing, the Nyquist Frequency is the maximum frequency resolvable for a given sampling rate. Analogously:

- **Sampling Rate:** Rate of bit-flips in configuration space $\mathcal{C}$.

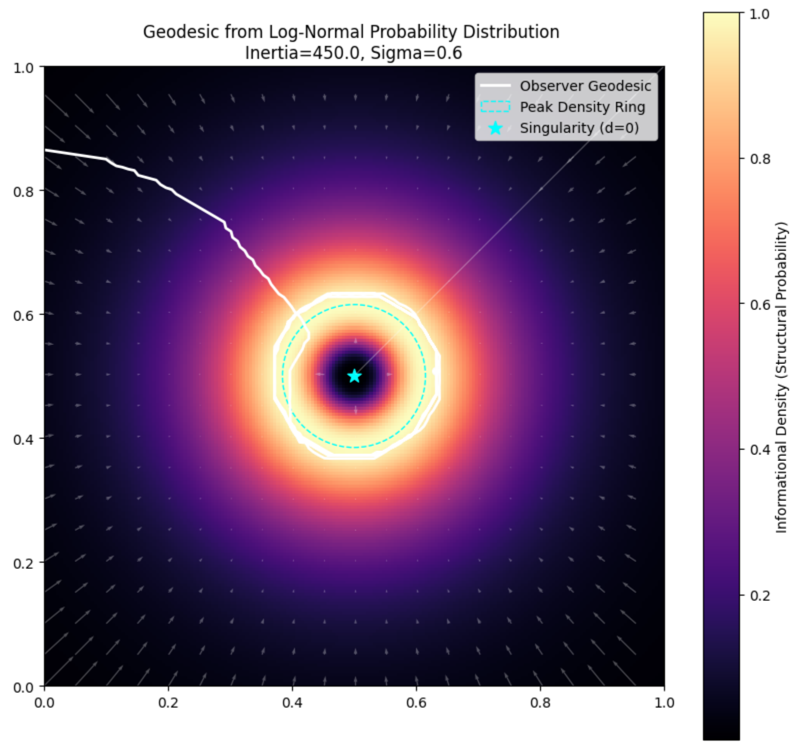

Figure 2: Minimal MDL path with memory

- **Planck Limit:** Maximum frequency representable in the spectral wavefunction Ψ.
- **Implication:** Features smaller than Planck length or faster than Planck time are aliased and cannot exist for observers.

4.2 Discrete Time from Spectral Updates

Configurations contain n bits. Transitions $s_i \to s_{i+1}$ in a path γ involve bit-flips. Spectral encoding $\mathcal{L}$ only updates when significant motif changes occur. Observer time emerges from these discrete spectral updates.

4.3 Spectral Density and the Inverse-Square Law

The log-normal distribution of microstructure motifs naturally produces $1/r^2$ scaling:

- **Source:** Clusters of reusable motifs represent masses.
- **Radial Distribution:** Configurations that reference the cluster increase with sphere surface area: $A = 4\pi r^2$.

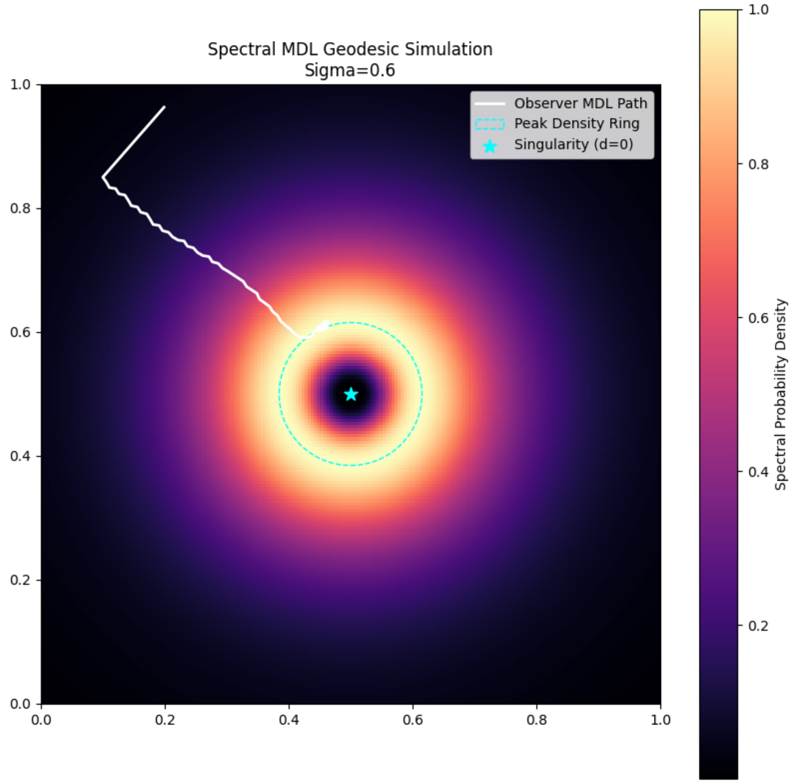

Figure 3: Minimal Spectral Path

- **Consequence:** Probability pressure toward motifs falls as $1/r^2$, reproducing classical gravitational scaling.

Supplementary Materials

- Plank scale and Spectral Gravity