Planck Scale and Spectral Gravity

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1 The Planck Scale as the Nyquist Frequency

In signal processing, the Nyquist frequency $f_{\text{Nyquist}} = f_s/2$ is the highest frequency that can be resolved given a sampling rate f_s. Frequencies above f_{Nyquist} are aliased and indistinguishable.

In the Abstract Universe:

- **Sampling Rate:** The rate of bit-flips along observer-compatible paths in configuration space $\mathcal{C}$.
- **Planck Limit:** The highest frequency resolvable in the spectral wavefunction $\Psi(\gamma)$.
- **Consequence:** Structures smaller than the Planck length or evolving faster than the Planck time cannot be resolved by Ψ; they are mathematically unrepresentable and effectively non-existent for any observer.

2 Discrete Time from Spectral Updates

Let $\gamma = (s_1, s_2, \dots)$ be an observer path through $\mathcal{C}$, with each s_i an n-bit configuration.

Define a spectral encoding length $\mathcal{L}(\gamma)$. Updates to $\mathcal{L}$ occur only when significant motifs (observer-relevant patterns) change along the path.

$$t_{i+1} - t_i = \begin{cases} 1, & \text{if a motif update occurs} \\ 0, & \text{otherwise} \end{cases}$$

Thus, **time emerges discretely**, with "ticks" corresponding to spectral transitions along observer-compatible paths.

3 Spectral Density and the Inverse-Square Law

Let a "mass" be a localized cluster of reusable microstructure motifs in configuration space. The number of configurations at distance r that can reference these motifs grows with the surface area of a 3D sphere:

$$A(r) = 4\pi r^2$$

Consequently, the density of spectral-compatible configurations falls as:

$$\rho(r) \propto \frac{1}{r^2} L(d)$$

where $L(d)$ is the log-normal distribution of motif distances d.

Observer paths minimize spectral cost $\mathcal{L}(\gamma)$ and are biased toward regions of high $\rho(r)$. In the continuum limit, the variational principle

$$\delta \int_\gamma \mathcal{L}(\text{state})\, ds = 0$$

reproduces classical geodesics in 3D space, giving rise to an effective inverse-square law of interaction.

4 Connection to Quantum Gravity and Path Integrals

Summing over all observer-compatible paths weighted by their spectral amplitude:

$$\langle \mathcal{O} \rangle = \sum_{\gamma \in \mathcal{T}_{\text{obs}}} \mathcal{O}(\gamma)\, 2^{-\mathcal{L}(\gamma)}$$

reproduces a path-integral formalism. In this framework:

- **Everettian view:** All observer-compatible paths exist simultaneously; probabilities emerge from spectral weighting.
- **Wheeler–DeWitt view:** Configuration space is timeless; time is induced along the observer path γ.
- **Classical limit:** Low-$\mathcal{L}$ paths dominate, yielding smooth geodesics in agreement with General Relativity.

5 Summary

The Planck scale, discrete time, and gravity emerge naturally from:

1. The maximal resolvable spectral frequency (Nyquist-Planck analogy).
2. Discrete spectral updates along observer paths.
3. Statistical bias of observer paths toward high-density microstructure regions, producing effective inverse-square laws.

In this view, gravitation is not a fundamental force but a statistical-geometric phenomenon rooted in the spectral structure of observer-compatible paths in configuration space.