Kernel Law in Black Holes

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Subject: Reclassification of Black Hole Information Loss as Kernel Amplification.
Framework: History-Augmented Configuration Space $\mathcal{X}$ with External Observer Observable Algebra $\mathcal{O}_{\text{ext}}$.

Abstract

We apply the Kernel Law framework to black hole physics to reclassify the Black Hole Information Paradox as an observer-access artifact rather than a fundamental conflict in physical law. Classical no-hair theorems already demonstrate extreme kernel dominance by collapsing vast sets of distinct collapse histories into identical external observables. We show that Hawking evaporation amplifies this kernel structure by transferring information from geometric degrees of freedom into exponentially inaccessible radiation correlations. The apparent loss of information arises from the mismatch between observer kernels, not from non-unitary evolution.

1. The Classical Kernel — No-Hair Theorem

Classically, a black hole is an archetypal kernel-dominated system.

- **History Space ($\mathcal{X}$):** The set of all admissible collapsing matter configurations forming the black hole, including arbitrarily detailed information about shape, composition, internal dynamics, and higher multipole structure.
- **External Observable Algebra ($\mathcal{O}_{\text{ext}}$):** The algebra of measurements accessible to an observer at infinity, consisting of asymptotic metric observables and conserved charges.
- **Kernel Structure ($\mathcal{K}_{\text{BH}}$):** The No-Hair Theorem establishes that all higher multipole information either radiates away or becomes inaccessible behind the event horizon. The final external state depends only on three parameters:

$$(M, Q, J).$$

Kernel Mapping

$$\mathcal{X} \xrightarrow{\pi_{\mathcal{O}_{\rm ext}}} \{M, Q, J\}.$$

Distinct collapse histories with identical (M, Q, J) are kernel-equivalent for the external observer.

2. The Quantum Kernel — Hawking Radiation

Semi-classical gravity extends kernel dominance into the quantum regime.

- **Process:** Black hole evaporation produces Hawking radiation at temperature

$$T_H \propto \frac{1}{M}.$$

- **Observable State:** The radiation accessible to $\mathcal{O}_{\rm ext}$ is described by a thermal density matrix

$$\rho_{\rm thermal},$$

  dependent only on macroscopic parameters.

Kernel Amplification

As evaporation proceeds, the only externally observable handle on the history—the mass M—decreases.

- **Early Stage:** The kernel contains the full collapse history, constrained only by total energy.
- **Late Stage:** The observable state approaches a maximum-entropy thermal bath.

Entropy S measures the logarithmic volume of the kernel:

$$S \sim \log(\#\text{ microstates mapping to the same observable state}).$$

As evaporation proceeds,

$$S \to S_{\max} \quad \Rightarrow \quad \dim(\mathcal{K}_{\rm BH}) \to \text{maximal}.$$

3. Deconstructing the Information Paradox

The Apparent Conflict

Unitary quantum mechanics requires

$$|\Psi_{\rm in}\rangle \xrightarrow{U} |\Psi_{\rm out}\rangle.$$

A thermal mixed state for the radiation appears to violate this requirement.

Kernel Resolution

The paradox arises from conflating two levels:

- **History Evolution ($\mathcal{X}$):** Global evolution is unitary, with information encoded in non-local correlations.
- **Observable Projection ($\mathcal{X}/\mathcal{K}_{\mathrm{BH}}$):** Restriction to $\mathcal{O}_{\mathrm{ext}}$ produces an effectively mixed state.

Distinguishing purity from thermality requires exponentially complex observables, scaling as $\sim e^{S_{\mathrm{BH}}}$, which are not elements of $\mathcal{O}_{\mathrm{ext}}$. The distinction lies entirely in the kernel.

4. The Page Curve as Kernel Access

The Page curve tracks radiation entropy over time.

- **Rising Phase:** Kernel dominance grows; radiation appears thermal.
- **Late Phase:** Entropy decrease is visible only to observers with super-access to global correlations.

For a standard observer, entropy saturates at the thermal maximum:

$$\mathcal{K}_{\mathrm{Alice}} \neq \mathcal{K}_{\mathrm{God}}.$$

Final Verdict — Paradox Dissolved

The Black Hole Information Paradox is a kernel-access artifact. Black holes act as extreme kernel amplifiers, mapping distinct micro-histories onto observationally identical macrostates. Information is preserved in $\mathcal{X}$ but rendered inaccessible to $\mathcal{O}_{\mathrm{ext}}$. This is a direct and powerful realization of the Kernel Law.