Technical Notes: Universal Identity Law and the Black Hole Information Paradox

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Summary

This paper derives that Hawking radiation dynamics ($dM/dt \propto -1/M^2$) require information transfer to follow $\sqrt{}$ dampening ($I_{\text{accessible}} = \sqrt{I}$). The derivation uses constraint elimination: seven candidate functional forms are tested against the acceleration requirement, and only $\sqrt{}$ survives.

The resolution of the information paradox follows as a consequence. Linear information transfer—the implicit assumption in AMPS—contradicts Hawking's equations. Correcting this assumption dissolves the firewall paradox.

Selection of $\alpha = 1/2$: Among power laws with $\alpha < 1$, the value 1/2 is selected by three independent constraints: Page curve timing (29.3% released at half-mass), holographic dimensional reduction, and cross-domain empirical validation.

AMPS Resolution: With $\sqrt{}$ dampening, only 29.3% of information has escaped at Page time (not 50%). The entanglement between late radiation and early radiation need not be maximal. The monogamy threshold required for firewall formation is never reached.

1 Key Technical Points

Acceleration Constraint: Hawking radiation gives $dM/dt \propto -1/M^2$. Information transfer functions must be compatible with this. Linear, logarithmic, quadratic, and exponential forms produce constant or decelerating rates. Only power laws with $\alpha < 1$ satisfy the required divergence as $M \to 0$.

Why $|dI_{\mathbf{rad}}/dI|$ Diverges: Both linear and $\sqrt{}$ dampening give $|dI_{\text{rad}}/dt| \to \infty$ as $M \to 0$ (because $|dI/dt|$ already diverges). The additional constraint comes from the Page curve, which requires back-loading: more information remains in the hole at any given mass fraction than linear transfer predicts.

Back-loading requires $I_{\text{hole}} \propto (M/M_0)^\alpha$ with $\alpha < 1$. This gives $|dI_{\text{rad}}/dI| \propto I^{(\alpha-1)} \to \infty$. Linear transfer ($\alpha = 1$) produces uniform information-per-mass, contradicting Page's unitarity requirement.

Why $I = M/M_0$: The paper defines normalized identity $I = M/M_0$, distinct from Bekenstein-Hawking entropy $S \propto M^2$. The relationship is derived from the holographic principle: information capacity is bounded by horizon area, horizon area is determined by mass, therefore information dynamics are constrained by mass dynamics.

2 Clarifications

On mass vs. information: Section 2.3 explicitly distinguishes $I = M/M_0$ (identity) from $S \propto M^2$ (entropy). Section 6.2 derives their relationship:

$$I_{\text{accessible}} = \sqrt{I} = (S_{\text{BH}}/S_0)^{1/4} \tag{1}$$

On the acceleration constraint scope: The constraint applies to $|dI_{\text{rad}}/dI|$ because the Page curve requires back-loading. This is distinct from $|dI_{\text{rad}}/dt|$, which diverges for all models.

On the AMPS argument: The paper's AMPS resolution operates at the aggregate level explicitly. The mode-by-mode implication (reduced per-quantum entanglement burden) follows from the changed information distribution but could be developed more explicitly.

On empirical validation: The cross-domain validation (bearings, neural networks, power grids, turbofans, seismic systems) is supporting evidence. The theoretical derivation in Section 2 stands independently of the empirics.

3 Areas for Future Development

- More explicit derivation of the mode-by-mode AMPS argument
- Expanded mathematical treatment of holographic dimensional reduction
- Detailed documentation of empirical methodology
- Extension to Kerr and Reissner-Nordström geometries

4 Errata

Section 6.2: The paper contains the corrected formula:

$$I_{\text{accessible}} = \sqrt{I} = (S_{\text{BH}}/S_0)^{1/4} \tag{2}$$

An earlier draft incorrectly stated $I_{\text{accessible}} = \sqrt{S_{\text{BH}}/S_0}$.

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