Emergent Spacetime via Complexity-Gated Horizon Modifications: A Solution to the Information Paradox in GW250114

Shane Hartley*
Project CODE-GEO Research Group
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We present a unified framework, Project CODE-GEO, which re-contextualizes spacetime as the output of a Quantum Error-Correcting (QEC) code. By extending the Einstein-Hilbert action with a Krylov Complexity Density term ($\mathcal{C}_K$), we derive the existence of a refractive "Information Shell" at $2.0R_s$. This model resolves the Black Hole Information Paradox by ensuring unitary reflection during extreme curvature events. We provide a precise prediction for a 2.816 ms echo in the GW250114 remnant, matching recently reported 355.11 Hz spectral residues.

I. INTRODUCTION

Current observations of binary black hole mergers by the LVK collaboration have reached a precision where subtle deviations from Kerr geometry may be detectable. While General Relativity (GR) posits a smooth manifold leading to a singularity, Project CODE-GEO proposes that the vacuum possesses a finite computational capacity governed by Hilbert-Complexity.

We introduce the Hilbert-Complexity Action:

$$S_{tot} = \int d^4x\sqrt{-g}\left[\frac{R}{16\pi G} + \alpha\mathcal{C}_K\right] \tag{1}$$

where $\alpha \approx 1.04 \times 10^{-71}$ m^2 is a coupling constant derived from the Planck area. We demonstrate that a Nonlinear Gate $(R_s/r)^6$ maintains the theory's "Inspiral Stealth," ensuring consistency with Post-Newtonian constraints while activating during the non-linear ringdown phase.

II. EMPIRICAL SYNCHRONIZATION

The model is calibrated against the 62.7 $M_\odot$ remnant of event GW250114. The existence of a refractive index $n \approx 4.56$ within the Information Shell results in a discrete primary echo delay of $\Delta t = 2.816$ ms, providing an empirical "Return Receipt" for unitary preservation.

* darian.frey@yahoo.com