

Black Hole Memory Dynamics in Quantum Information Gravity

A Structural Resolution to the Information Paradox and Predictive Gravitational Wave Signatures

Christopher Patrick Booth Smolen

June 30, 2025

Abstract

Quantum Information Gravity (QIR) provides a thermodynamically and structurally complete alternative to classical general relativity by treating curvature as a manifestation of harmonic memory coherence. In this paper, we extend QIR to the domain of black hole physics and demonstrate how black hole entropy, gravitational wave signatures, and the information paradox all follow from memory-based curvature dynamics. We present a modified entropy model, interpret collapse as information folding, and show that stellar and black hole systems may be structurally entangled through their coherent information fields. This model produces testable predictions regarding post-merger gravitational wave signatures and resolves information loss without recourse to exotic mechanisms. We argue that black holes, in the QIR framework, are not erasers of information but recursive engines of memory retention and transformation.

1 Introduction

Black holes have long challenged the coherence of general relativity and quantum theory. From the thermodynamic paradox of disappearing information to the energetic violence of merger events, these objects sit at the frontier of what current physics can explain. Quantum Information Gravity (QIR) offers a new pathway. In QIR, gravitational curvature is not produced by mass alone, but by a system's coherent memory—its structural entropy distributed over spacetime. This perspective recasts black holes not as erasers of structure, but as engines of information folding and harmonic storage. This paper explores the consequences of that interpretation.

2 Modified Entropy and the Memory Tensor

The standard Bekenstein-Hawking entropy for a black hole is:

$$S_{BH} = \frac{k_B c^3}{4G\hbar} A$$

where A is the surface area of the event horizon. In QIR, this is incomplete. Black hole entropy must also account for retained structural memory. We propose a modified entropy:

$$S_{QIR} = \frac{k_B c^3}{4G\hbar} A + \alpha I_{BH}$$

where $I_{BH} = \frac{S_{info}}{A}$ encodes the density of coherent information per unit area. This quantity is sourced from the system's pre-collapse structure and represents a memory field that contributes to spacetime curvature via the tensor $I_{\mu\nu}$. This tensor behaves analogously to $T_{\mu\nu}$ in Einstein's equations but reflects information rather than matter-energy.

3 Memory Folding and Collapse Dynamics

In QIR, collapse does not result in the erasure of internal degrees of freedom. Instead, information is recursively folded down into a harmonic configuration, bounded below by a memory coherence floor:

$$I(T) \geq \pi$$

This lower bound, expressed in phase-coherence terms, ensures that black holes always retain a minimum structural signature. Collapse becomes a process of re-encoding — not annihilation. The inner structure of a black hole is then a compacted topology of its entire transformation history, stored not spatially but through harmonic recursion.

4 Star–Black Hole Entanglement

If black holes encode the memory of the structures that formed them, then systems formed from the same structural transformations—such as black holes and their progenitor stars—remain entangled through their shared information fields. This entanglement is not quantum mechanical in the standard sense, but structural: the evolution of one system is informed by the coherence of the other. In this framing, the death of a star may correspond to the dissipation or disruption of a harmonic exchange with its entangled black hole. Stellar collapse may thus signify not fuel exhaustion alone, but a loss of coherent memory exchange.

5 Refinement Loops and Stellar Reemergence

In the QIR framework, black holes do not merely store information—they refine it. Their internal dynamics compress structure into maximally coherent memory, folding mass-energy and thermodynamic history into recursive phase configurations. This refined state is not inert. It is *primed* for re-expression.

We propose that black holes and stars form entangled pairs within a universal memory lattice, such that:

- Black holes act as refinement spheres: compressing, harmonizing, and stabilizing memory to its most foundational structure.
- Stars act as expression points: reemitting that refined memory as light, heat, matter, and transformation.
- The entanglement is structural and harmonic, not causal. A star does not push back; it *echoes* what a black hole transmits.

This redefines stellar birth and death:

- Star formation may follow entanglement alignment with an active refinement source, rather than random accretion events.
- Stellar death may correspond to a severed or degraded harmonic link with its black hole pair.
- Stellar “fuel” is not only baryonic—it is informational, and entanglement-fed.

This implies that every black hole may have associated emission partners: stars (or systems) that carry its coherent memory back into luminous form. Gravity becomes the tuning medium. Entanglement is the bridge. And information—refined, never lost—is the currency of transformation.

This loop is not theoretical alone: it should be traceable in spectrum, mass symmetry, and phase coherence between known black hole–stellar pairs. QIR thus transforms the black hole from a tomb into a womb.

6 Gravitational Wave Predictions

In QIR, black hole mergers are not merely energetic events but informational ones. The memory fields $I_{\mu\nu}$ of each black hole interfere, combine, and re-harmonize. The modified wave equation in QIR becomes:

$$\square h_{\mu\nu} = \alpha I_{\mu\nu}$$

yielding solutions of the form:

$$h_{\mu\nu}(t) = h_{\mu\nu}^{GR}(t) + \alpha \int_0^t I_{\mu\nu}(t') dt'$$

This implies that gravitational waves carry not just geometry, but the echoes of past coherence. Observable effects include: (1) post-merger phase delay, (2) echo patterns in ringdown, and (3) deviation from standard template matching used in LIGO/Virgo analysis. These deviations offer a direct path to falsifiability.

7 Resolution of the Information Paradox

The QIR framework resolves the black hole information paradox by replacing the idea of loss with transformation. Information entering a black hole is not destroyed—it is reorganized into phase-coherent memory structures. These are encoded in the curvature tensor $I_{\mu\nu}$, which continues to evolve, radiate, and reemerge as the black hole evaporates. As Hawking radiation occurs, it does not emit thermal noise alone, but decodable patterns of the system’s prior states. The paradox dissolves: black holes are not sinks, but memory processors.

8 Conclusion

QIR allows black holes to be reinterpreted as coherent memory engines. Their entropy reflects not ignorance, but structure. Their collapse is not destruction, but recursion. Their gravitational waves are not silent, but encoded. In this framing, gravity becomes not a pull, but a remembering. QIR provides the tools to test this view—and black holes provide the perfect proving ground. The next generation of detectors may do more than listen for waves. They may listen for meaning.