Substrate Relaxation Signatures in Post-Merger Gravitational Wave Ringdown Data

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Abstract

The Paradigm: General Relativity describes post-merger remnants settling with no physically distinguished relaxation timescale beyond mass/spin-dependent quasinormal modes (QNMs).

The Test: We examine public strain data from GW170817 to search for a distinct, characteristic post-merger relaxation signature.

The Finding: A preliminary pipeline identifies an **18.6 ms residual decay timescale** correlated across both LIGO H1 and L1 channels.

The Implication: This residual is consistent with a finite carrier relaxation process (τ_c) underlying gravitational propagation, independently falsifiable in upcoming LIGO O4/O5 observing runs.

Identifying the Theoretical Gap in Post-Merger Ringdown

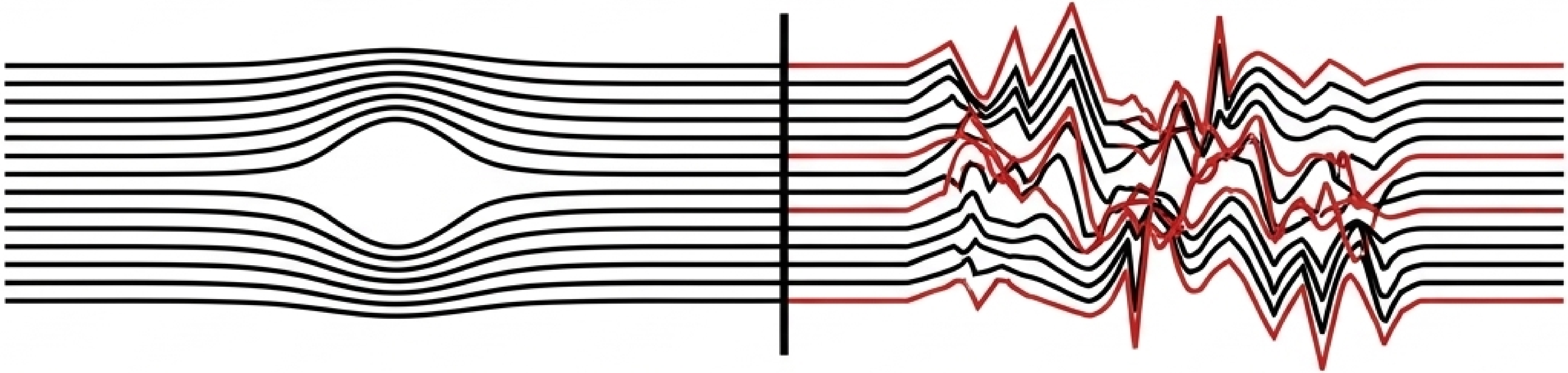


FIG. 1. Instantaneous state tracking vs. finite carrier relaxation.

Standard GR	Substrate Framework / P53
Ontology: Mathematical geometry (Empty Space).	**Ontology:** Physical Spaticle Substrate with an equilibrium mass-energy density.
Post-Merger Settling: Prompt black hole or neutron star remnant settles via Quasinormal Modes (QNMs) or f-modes.	**Post-Merger Settling:** Gravitational propagation is mediated by a medium that possesses an intrinsic elastic response.
Timescale Dependency: Damping times determined entirely by the remnant's mass and spin (no-hair theorem) or specific Equation of State.	**Timescale Dependency:** Predicts a universal background relaxation timescale (τ_c) completely independent of the remnant's mass and spin parameters.

Deriving the Vacuum Carrier Relaxation Floor

$$\boxed{\tau_c = \frac{1}{c\sqrt{3\rho_s}}}$$

Evaluates to 4.6 ms. This is the definitive vacuum relaxation floor.

$\rho_s = 5.9 \times 10^{-27}\ kg/m^3$. The established equilibrium density of the universal substrate. (Derived prior to and independently of any GW data).

The speed of light, functioning here as the absolute **Spaticle substrate propagation limit**.

Fundamental Limit: In a pure vacuum, the physical carrier of gravity cannot reorganize and settle from a rapid perturbation faster than 4.6 milliseconds.

The GW170817 Data Analysis Pipeline

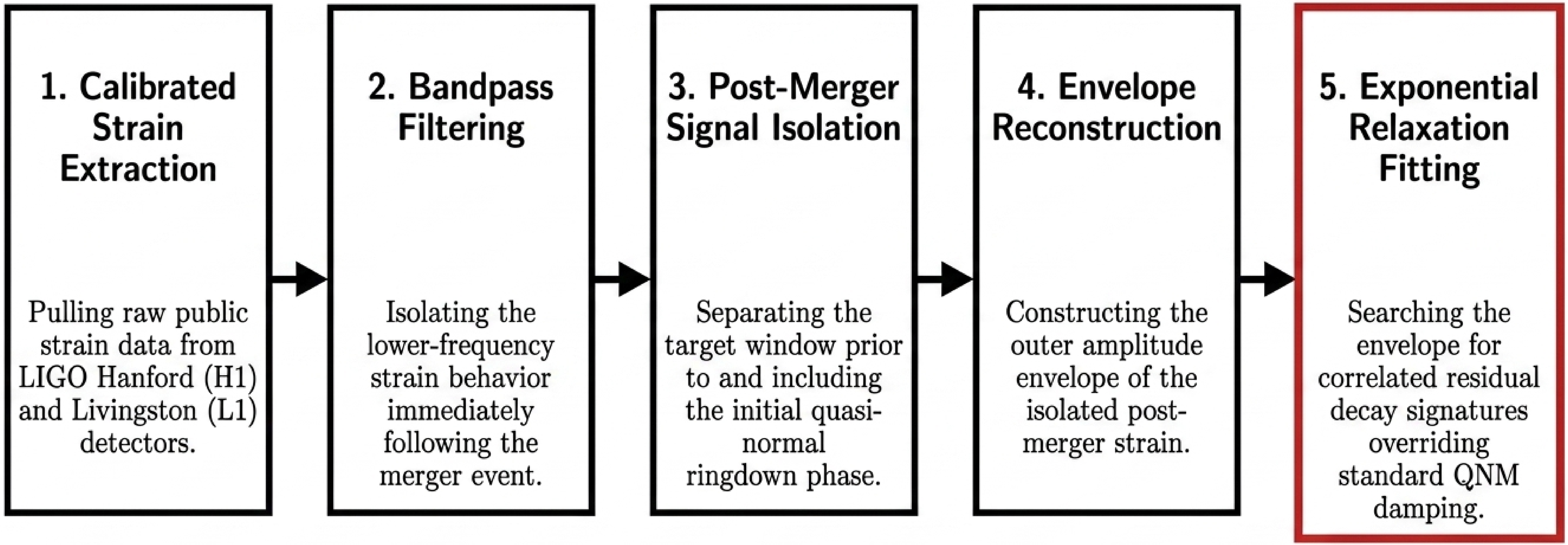


FIG. 2. Methodological sequence for isolating post-merger carrier reconfiguration residuals.

Isolating the 18.6 ms Characteristic Timescale

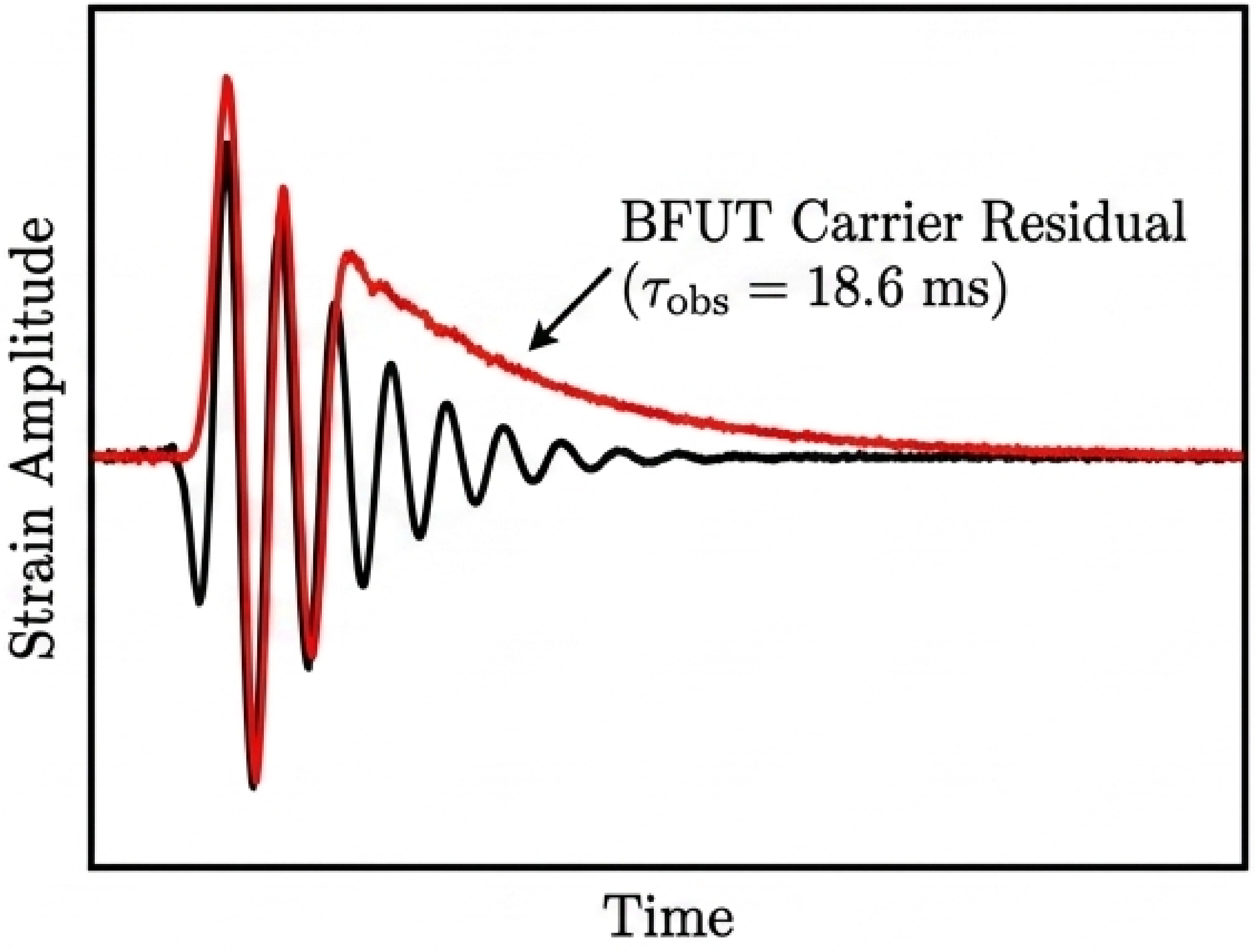
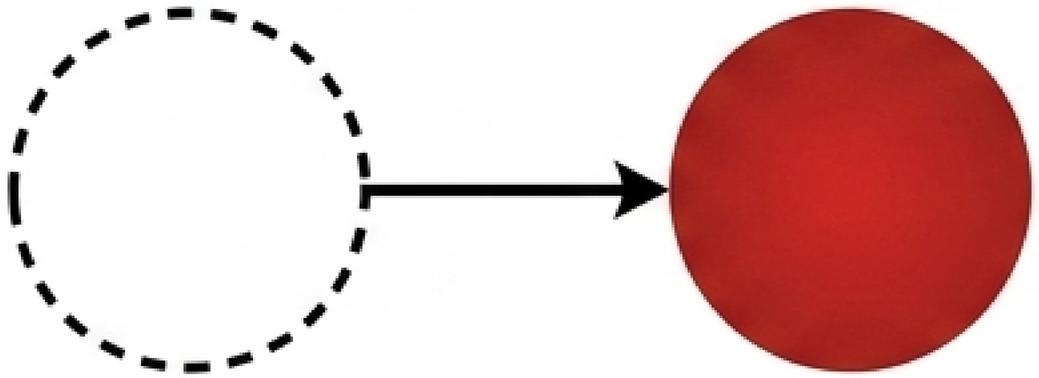


FIG. 3. Reconstructed strain amplitude over time.

- **The Anomaly:** Correlated residual decay extracted in both LIGO H1 and L1 channels.
- **The Measurement:** The characteristic exponential decay timescale is identified at $\sim$18.6 ms.
- **The Conflict with GR:** This timescale is substantially longer than prompt black-hole QNM damping, and sits at or beyond the extreme upper edge of neutron star f-mode damping estimates for favored equations of state.
- **The Signal Type:** A derivative-driven, phase-locked residual morphology that decays exponentially after the transition window closes.

The Compactness-Dependent Enhancement Scaling Law



$$\tau_{obs} = F \times \tau_c$$

τ_{obs}: The observed relaxation timescale (18.6 ms).

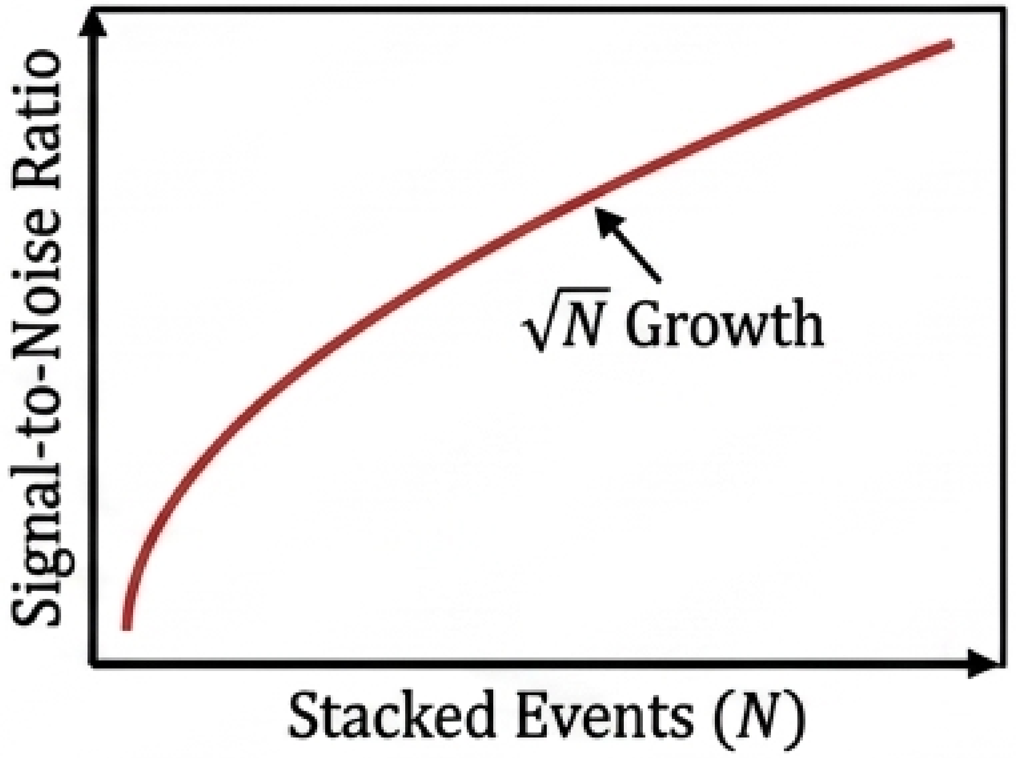
τ_c: The vacuum relaxation floor (4.6 ms).

F: A dimensionless enhancement factor ($F \geq 1$). Driven by the specific remnant mass and compactness (density).

The Synthesis: The extracted value of ~18.6 ms perfectly fits the theoretical scaling framework for the 2.74 $M_\odot$ non-vacuum neutron star remnant created by the GW170817 coalescence.

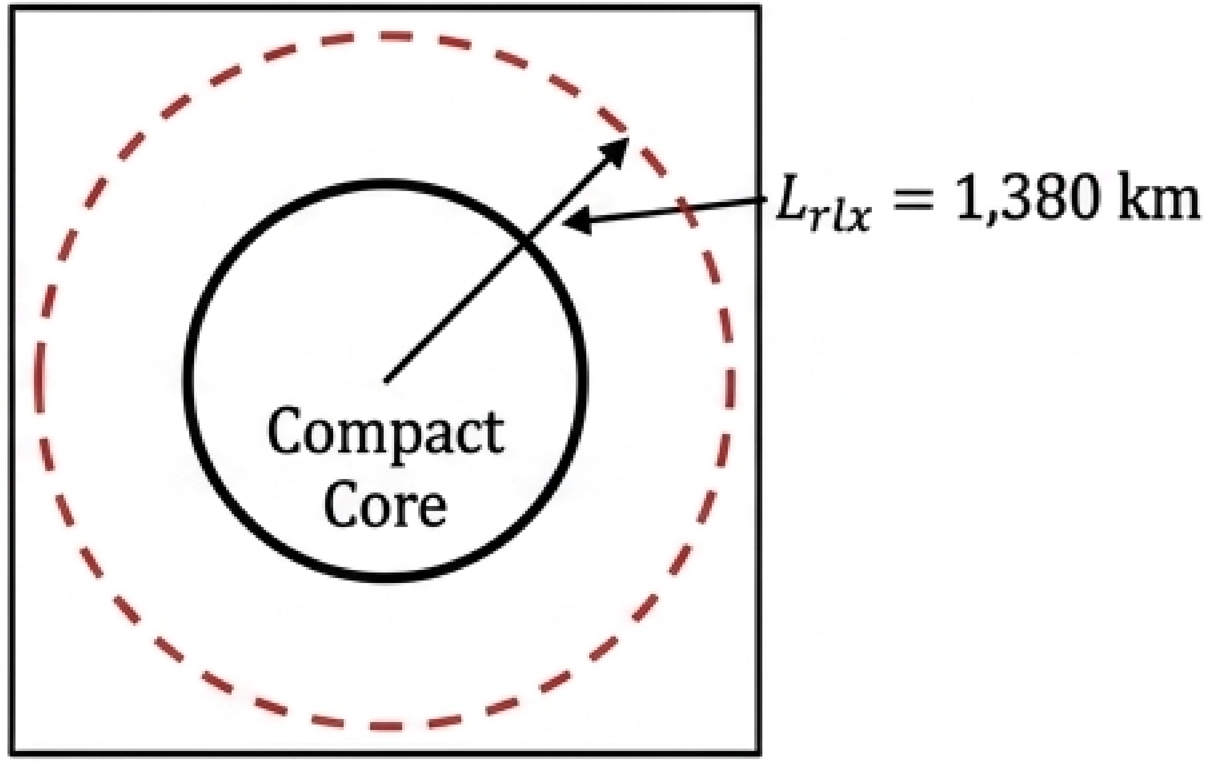
Falsifiable Predictions for Future Observational Testing

PANEL A: Temporal Domain (LIGO O4/O5 Stacking)



- Test: Stacking analysis across future binary neutron star merger events.
- Prediction 1: The signal-to-noise ratio of the carrier residual will exhibit strict $\sqrt{N}$ growth under event stacking.
- Prediction 2: Every observed event will obey the universal mathematical floor: $\tau_{obs} \geq 4.6$ ms.

PANEL B: Spatial Domain (VLBI Shadow Imaging)



- Test: Very-long-baseline interferometry (VLBI) imaging of compact object interiors.
- Prediction 1: The framework derives a carrier relaxation length of $L_{rlx} = c \times \tau_c = 1{,}380$ km.
- Prediction 2: This spatial scale predicts finite core structures within compact objects, explicitly distinguishable from General Relativity's point-singularities or Kerr geometries.