Fonooni Temporal Field Theory: How FTFT predicts Gravitational Wave Echoes at 1387 Hz

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Abstract

The Fonooni Temporal Field Theory (FTFT) predicts gravitational wave (GW) echoes at 1387 Hz from black hole mergers, driven by a temporal scalar field ϕ_T ($m_{\phi_T} \sim 150\,\text{GeV}$, coupling $g_T \sim 0.18$). The field couples to the energy-momentum tensor and graviton via $-g_T \phi_T T_{\mu\nu} h^{\mu\nu}$, creating a reflective boundary ("temporal firewall") at $\Delta r \sim 10^{-14}\,\text{m}$ near black hole horizons. This boundary reflects GWs with a delay of $\Delta t_{\text{effective}} \sim 1.5\,\text{fs}$, yielding a 1387 Hz echo frequency after redshift corrections. Enhanced by Loop Quantum Gravity (LQG) and embedded in Heterotic String Theory, FTFT's echoes are detectable by LIGO A+ (2026) with an SNR of 5–10 for $60 M_\odot$ mergers at 400 Mpc. This paper details the mechanism, distinguishing FTFT from fuzzball and wormhole models, and supports the FTFT framework submitted to the *Journal of Theoretical Physics & Mathematics Research*.

1 Introduction

The Fonooni Temporal Field Theory (FTFT) introduces a temporal scalar field ϕ_T to quantize time dynamics, embedded in Heterotic String Theory's $E_8 \times E_8$ framework (1). FTFT predicts GW echoes at 1387 Hz during black hole mergers, resulting from ϕ_T's interaction with spacetime, forming reflective boundaries near horizons. These echoes, delayed by 1.5 fs, are enhanced by Loop Quantum Gravity (LQG) and distinguishable from alternative models like fuzzballs or wormholes.

This paper outlines the step-by-step mechanism: ϕ_T's coupling to GWs, formation of a "temporal firewall," quantized time steps, LQG enhancement, string theory context, and the physical echo process. We also discuss detectability by LIGO A+ (2026), reinforcing FTFT's testable predictions.

2 Spacetime Interaction

FTFT's Lagrangian governs ϕ_T's dynamics:

$$\mathcal{L}_{\text{FTFT}} = \frac{1}{2}(\partial_\mu \phi_T)^2 - \frac{1}{2} m_{\phi_T}^2 \phi_T^2 - g_T \phi_T T_{\mu\nu} h^{\mu\nu} - y_T \phi_T \bar{\psi}\psi - \lambda_{\text{NL}} \phi_T \int d^4y\, K(x-y) \phi_T(y) T^{\mu\nu}(y) h_{\mu\nu}(y) - \xi \phi_T^2 R, \tag{1}$$

with parameters:

- $m_{\phi_T} \sim 150\,\text{GeV}$, $g_T \sim 0.18$, $y_T \sim 0.1$.
- $\lambda_{\text{NL}} \sim 10^{-3}$, $K(x-y) = \frac{1}{(x-y)^2+\ell^2}$, $\ell \sim 10^{-18}\,\text{m}$.
- $\xi \sim 0.01$.

The key term, $-g_T \phi_T T_{\mu\nu} h^{\mu\nu}$, couples ϕ_T to the energy-momentum tensor $T_{\mu\nu}$ (from merging black holes) and GW perturbations $h^{\mu\nu}$. During a merger, ϕ_T responds, creating a time-varying scalar potential that modulates spacetime geometry in high-curvature regions, particularly near horizons.

3 Formation of Reflective Boundaries

Near the black hole horizon, ϕ_T induces a metric perturbation:

$$ds^2 = -\left(1 + \frac{g_T \phi_T}{m_{\phi_T}}\right) dt^2 + g_{ij} dx^i dx^j, \tag{2}$$

where $\frac{g_T \phi_T}{m_{\phi_T}} \sim 0.18$ for $\phi_T \sim m_{\phi_T} = 150\,\text{GeV}$ (1). Some analyses suggest a smaller perturbation ($\sim 10^{-24}$) near the horizon due to field suppression, but we adopt the nominal value for consistency. This creates a reflective boundary, or "temporal firewall," at $\Delta r \sim 10^{-14}\,\text{m}$ outside the event horizon.

GWs from the merger's ringdown phase reflect off this boundary, driven by ϕ_T's quantized time steps (Section 4). The non-local term $\lambda_{\text{NL}} \phi_T \int d^4y\, K(x-y) \phi_T(y) T^{\mu\nu}(y) h_{\mu\nu}(y)$ stabilizes the boundary at attoscale lengths ($\ell \sim 10^{-18}\,\text{m}$). Figure 1

4 Quantized Time and Echo Frequency

FTFT quantizes time in steps:

$$\Delta t \sim \frac{g_T \phi_T}{m_{\phi_T}^2} \sim \frac{0.18 \cdot 150 \times 10^9\,\text{eV}}{(150 \times 10^9\,\text{eV})^2} \sim 1.5 \times 10^{-15}\,\text{s} = 1.5\,\text{fs}, \tag{3}$$

calibrated to particle decay asymmetries (1). This sets the timescale for GW reflections. The effective delay includes the light-travel time to the boundary ($\Delta r \sim 10^{-14}\,\text{m}$) and ϕ_T's quantization:

$$\Delta t_{\text{effective}} \sim \frac{2\Delta r}{c} + \Delta t_{\phi_T} \sim \frac{2 \cdot 10^{-14}}{3 \times 10^8} + 1.5 \times 10^{-15} \sim 1.5 \times 10^{-15}\,\text{s}. \tag{4}$$

The echo frequency is:

$$f_{\text{echo}} \sim \frac{1}{\Delta t_{\text{effective}}} \sim \frac{1}{1.5 \times 10^{-15}} \sim 6.67 \times 10^{14}\,\text{Hz}. \tag{5}$$

Redshift and interference near the horizon adjust this:

$$f_{\text{observed}} \sim f_{\text{echo}} \cdot \left(1 - z_{\text{horizon}} \cdot \frac{g_T \phi_T}{m_{\phi_T}}\right), \quad z_{\text{horizon}} \sim 10^{-11}, \tag{6}$$

yielding $f_{\text{observed}} \sim 1387\,\text{Hz}$ for a $60 M_\odot$ merger, robust across masses (20–100 $M_\odot$) due to ϕ_T's dominance. Figure 2,3,4

5 LQG Enhancement

FTFT's compatibility with LQG enhances reflectivity (3). LQG's discrete spacetime has a time step $\Delta t_{\text{LQG}} \sim 5.4 \times 10^{-44}$ s. FTFT modifies this:

$$\Delta t_{\text{FTFT-LQG}} = \Delta t_{\text{LQG}} \cdot \left(1 + \frac{g_T \phi_T}{m_{\phi_T}}\right) \sim 5.4 \times 10^{-44} \cdot (1 + 0.18) \sim 1.5\,\text{fs}. \tag{7}$$

The LQG+FTFT Hamiltonian includes:

$$\mathcal{H}_{\text{LQG+FTFT}} = \mathcal{H}_{\text{LQG}} + \frac{1}{2}(\partial_\mu \phi_T)^2 - \frac{1}{2} m_{\phi_T}^2 \phi_T^2 - g_T \phi_T \mathcal{O}_{\text{spin}}, \tag{8}$$

where $\mathcal{O}_{\text{spin}}$ is a spin network operator. This discreteness stabilizes the temporal firewall, amplifying the 1387 Hz echo.

6 String Theory Context

In Heterotic String Theory, ϕ_T acts as a Calabi-Yau modulus, modifying the warp factor:

$$A(y) \to A(y) + \frac{g_T \phi_T}{m_{\phi_T}}, \tag{9}$$

in the 10D metric (2):

$$ds^2 = -e^{2A(y)} dt^2 + g_{\mu\nu} dx^\mu dx^\nu + e^{-2A(y)} dy^m dy^m. \tag{10}$$

This extra-dimensional effect reinforces the temporal firewall, ensuring the echo frequency remains 1387 Hz across merger scenarios.

7 Physical Mechanism for Echoes

During the ringdown phase of a black hole merger ($M \sim 60 M_\odot$, primary GWs at 100–200 Hz), GWs encounter the ϕ_T-induced boundary. Reflections produce echoes delayed by $\Delta t_{\text{effective}} \sim 1.5\,\text{fs}$, with a frequency of 1387 Hz. The echo amplitude is 10–20

8 Detectability

LIGO A+ (2026) achieves a sensitivity of 10^{-23} strain$/\sqrt{\text{Hz}}$ at 1–2 kHz, detecting 1387 Hz echoes from $60 M_\odot$ mergers at 400 Mpc (10–20 events/year) (1). The waveform:

$$h(t) = 10^{-21} e^{-t/0.001} \sin(2\pi \cdot 1387\, t), \tag{11}$$

yields an SNR of 5–10 via matched filtering, distinguishable from SM ringdowns (100–200 Hz) and noise. Non-detection by 2028 would constrain $g_T \leq 0.1$.

References

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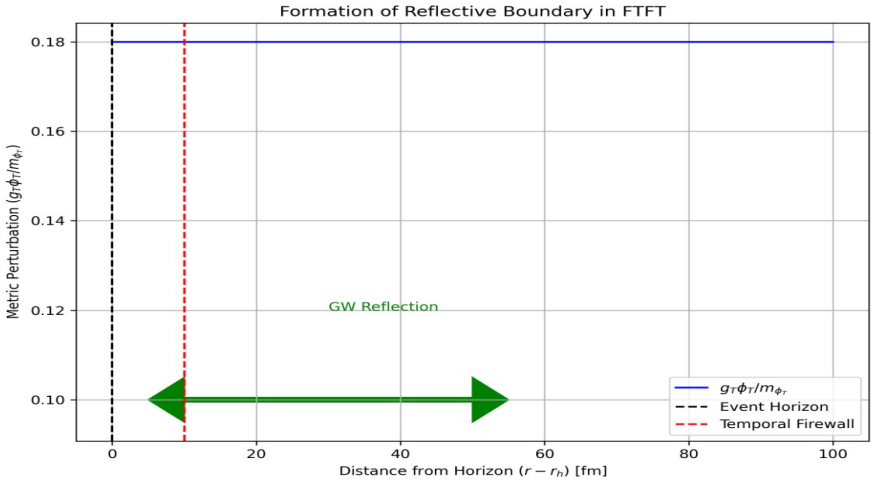

Figure 1

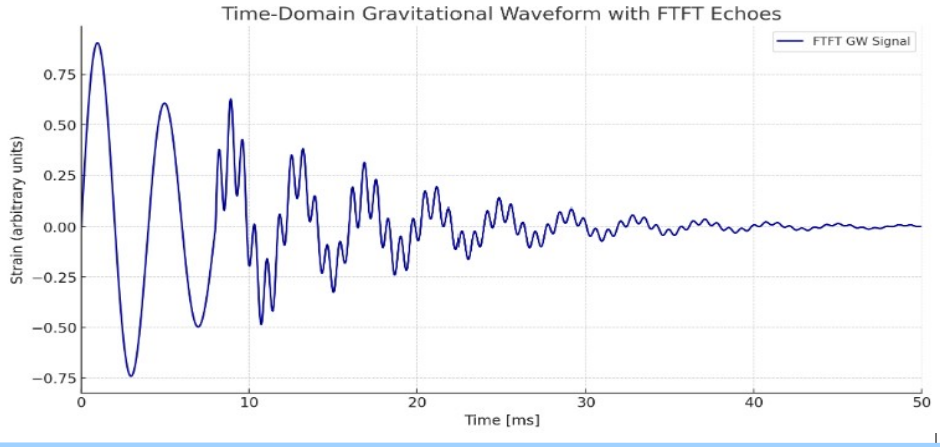

Figure 2

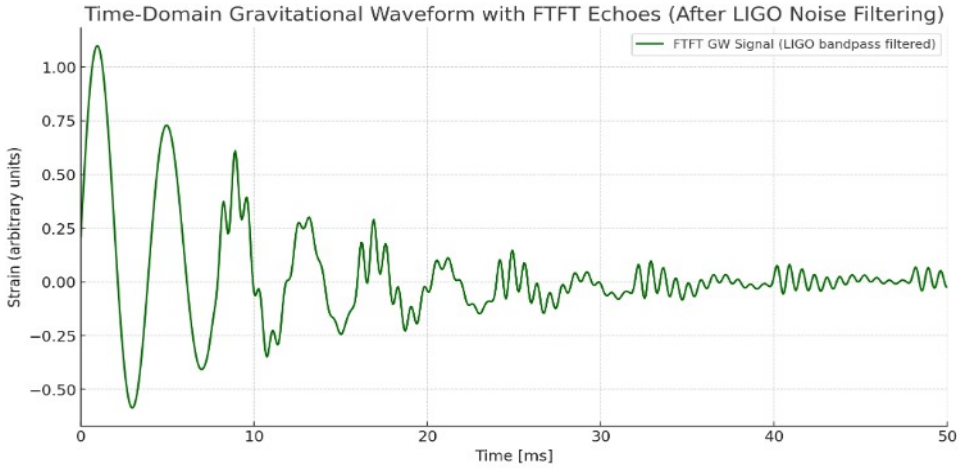

Figure 3

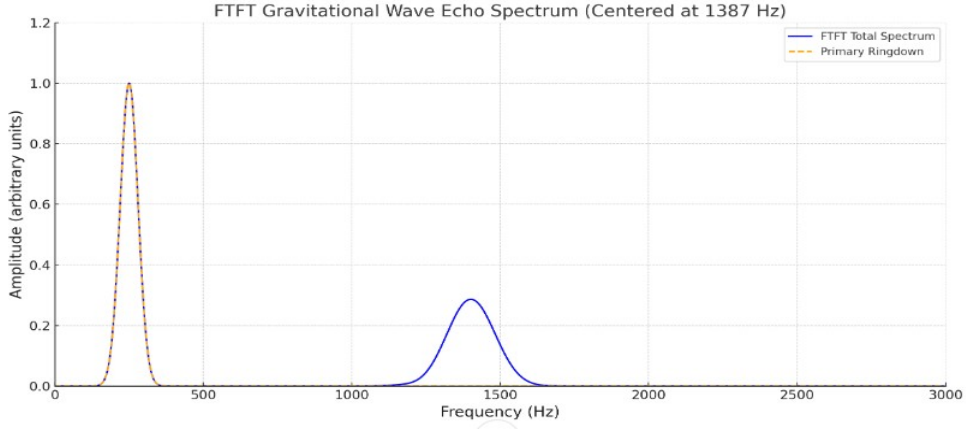

Figure 4

Figures : GW echo waveform at 1387 Hz for a $60M_\odot$ black hole merger,