Fonooni Temporal Field Theory (FTFT): A Minimal Phenomenologically-Safe Framework and Updated Predictions (Nov 2025)

Manoochehr Fonooni
Independent Researcher
manoochehrfonooni@gmail.com

November 2025

Abstract

We present a full, self-contained formulation of Fonooni Temporal Field Theory (FTFT), a minimal, portal-free effective theory in which time is promoted to a dynamical scalar degree of freedom ϕ_T. The model is UV-completable in heterotic string constructions and designed to be phenomenologically safe in the infrared. We display the final minimal Lagrangian used in all phenomenological studies, derive the equations of motion and the modified Einstein equations including a controlled nonlocal kernel, and collect observational and experimental constraints. We update the temporal scalar mass to $m_{\phi_T} = 152$ GeV to reflect emerging collider hints, and we show compatibility with GW170817, electroweak precision tests, and fifth-force bounds. We summarize predictions for colliders (narrow diphoton resonance), gravitational-wave observables (near-horizon echoes), and quantum experiments (attosecond entanglement delays), and provide appendices with detailed derivations and numerical recipes.

Contents

1 Introduction

Reconciling the quantum description of microscopic systems with the dynamical spacetime of general relativity remains a central open problem. Fonooni Temporal Field Theory (FTFT) approaches this by promoting time to a dynamical scalar field $\phi_T(x)$ that couples to matter and curvature, thereby introducing controlled temporal quantization effects. FTFT is constructed to be compatible with existing experimental tests of gravity and particle physics while making concrete, falsifiable predictions in high-energy and strong-gravity regimes.

This manuscript collects the minimal FTFT action adopted in phenomenological work (Nov 2025), derives the equations of motion used in simulations, summarizes constraints (especially from GW170817), and updates the temporal scalar mass to $m_{\phi_T} = 152$ GeV based on recent collider hints. The presentation is self-contained and intended to serve as the definitive reference for the FTFT program.

2 Minimal FTFT Lagrangian

Our working, minimal FTFT Lagrangian is:

$$\begin{aligned}\mathcal{L}_{\rm FTFT} = \frac{M_{\rm Pl}^2}{2}R - \frac{1}{2}\partial_\mu\phi_T\partial^\mu\phi_T - \frac{1}{2}m_{\phi_T}^2\phi_T^2 - \xi\,\phi_T^2 R - g_T\,\phi_T\,T^\mu{}_\mu \\ + \lambda_{\rm NL}\,\phi_T(x)\int d^4y\,\mathcal{K}_\ell(x-y)\,\phi_T(y)\,T^\mu{}_\mu(y) + \mathcal{L}_{\rm SM}[g_{\mu\nu},\psi],\end{aligned} \tag{1}$$

with a normalized Gaussian kernel

$$\mathcal{K}_\ell(x-y) = \frac{1}{\pi^2\ell^4}\exp\left[-(x-y)^2/\ell^2\right], \qquad \int d^4z\,\mathcal{K}_\ell(z) = 1. \tag{2}$$

Key parameter benchmarks used throughout:

$$m_{\phi_T} = 152\text{ GeV}, \qquad g_T \lesssim 10^{-6}, \qquad \xi \sim 10^{-2}, \qquad \lambda_{\rm NL} \sim 10^{-3}, \qquad \ell \sim 10^{-18}\text{ m}.$$

This Lagrangian is intentionally portal-free (no direct $\phi_T^2 H^\dagger H$ term): that choice keeps electroweak parameters safe and concentrates FTFT effects into trace- and curvature-mediated channels and nonlocal temporal correlations.

3 Equations of motion

Varying the total action $S = \int d^4x\sqrt{-g}\,\mathcal{L}_{\rm FTFT}$ yields the scalar and gravitational equations used in phenomenology.

3.1 Temporal scalar EOM

$$(\Box + m_{\phi_T}^2)\,\phi_T(x) + 2\xi\,R(x)\,\phi_T(x) = g_T\,T^\mu{}_\mu(x) - \lambda_{\rm NL}\int d^4y\,\mathcal{K}_\ell(x-y)\,\phi_T(y)\,T^\mu{}_\mu(y). \tag{3}$$

3.2 Modified Einstein equations

The metric variation produces:

$$M_{\mathrm{Pl}}^2 G_{\mu\nu} = T_{\mu\nu}^{\mathrm{SM}} + T_{\mu\nu}^{\phi_T} + \Delta_{\mu\nu}[\xi, \phi_T] - \lambda_{\mathrm{NL}}\, \mathcal{N}_{\mu\nu}, \tag{4}$$

with

$$T_{\mu\nu}^{\phi_T} = \partial_\mu \phi_T \partial_\nu \phi_T - \frac{1}{2} g_{\mu\nu} \left[(\partial \phi_T)^2 + m_{\phi_T}^2 \phi_T^2 \right], \tag{5}$$

and the nonminimal-coupling geometric terms

$$\Delta_{\mu\nu}[\xi, \phi_T] = \xi \Big[2\phi_T^2 G_{\mu\nu} + (g_{\mu\nu}\Box - \nabla_\mu \nabla_\nu)\phi_T^2 \Big], \tag{6}$$

and $\mathcal{N}_{\mu\nu}$ the metric variation of the nonlocal integral (explicit form given in Appendix A). The trace of (4) together with (3) is convenient for screening analyses.

4 Momentum-space representation and form factors

For analytic estimates, transform (3) to momentum space (flat background approximation):

$$\tilde{K}(k) = e^{-k^2\ell^2}, \qquad \left(-k^2 + m_{\phi_T}^2\right) \tilde{\phi}_T(k) + 2\xi\, \widetilde{(R\phi_T)}(k) = g_T \tilde{T}(k) - \lambda_{\mathrm{NL}} \int \frac{d^4q}{(2\pi)^4} \tilde{K}(k-q)\, \tilde{\phi}_T(q)\, \tilde{T}(k-q).$$

When sources vary slowly on scale ℓ and ϕ_T is small this simplifies to a Yukawa-like propagator with momentum-dependent self-energy from the nonlocal term.

5 Observational constraints

5.1 GW170817 and gravitational-wave speed

The near-coincident arrival of GWs and photons from GW170817 constrains modifications of GW propagation: $|c_g - c|/c \lesssim 10^{-15}$. In FTFT tensor modes remain minimally coupled in the infrared; with $m_{\phi_T} \gtrsim 100$ GeV and $g_T \lesssim 10^{-6}$ the scalar cannot significantly modify the GW dispersion relation in the LIGO/Virgo frequency band. Thus FTFT is consistent with multimessenger bounds.

5.2 Electroweak precision and Higgs-portal absence

Because the minimal Lagrangian contains no direct Higgs portal, tree-level shifts of the Higgs vev are absent. The leading universal effect comes from nonminimal coupling and scales as

$$\frac{\delta v}{v} \sim -\xi \frac{\langle \phi_T \rangle^2}{M_{\mathrm{Pl}}^2},$$

which for $\langle \phi_T \rangle \sim \mathcal{O}(10^2$ GeV$)$ and $\xi \sim 10^{-2}$ is $\mathcal{O}(10^{-35})$ — entirely negligible. Precision electroweak bounds are therefore satisfied.

5.3 Fifth-force and equivalence-principle tests

The scalar mediates an attractive Yukawa-like potential with an additional Gaussian smearing. The effective coupling at macroscopic distances behaves as

$$g_T^{\mathrm{eff}}(r) \simeq g_T\, e^{-m_{\phi_T} r}\, e^{-r^2/\ell^2},$$

so for $m_{\phi_T} \gtrsim 100$ GeV and $\ell \sim 10^{-18}$ m, macroscopic fifth forces are exponentially suppressed. Combined with $g_T \lesssim 10^{-6}$ this is consistent with Eöt-Wash and MICROSCOPE constraints.

6 Updated mass: $m_{\phi_T} = 152$ GeV

Motivated by accumulating collider hints (narrow excesses in diphoton and related channels around 150–155 GeV), FTFT adopts

$$\boxed{m_{\phi_T} = 152 \text{ GeV}}$$

as the updated benchmark. This mass sits naturally in the allowed window, remains heavy enough to decouple astrophysically, and can produce a narrow collider resonance through loop- and trace-induced couplings.

7 Phenomenological predictions

7.1 Collider signatures

Primary collider signatures for the minimal FTFT setup are:

- A **narrow diphoton resonance** near 152 GeV, with small cross-section proportional to g_T^2 and SM loop factors.
- Suppressed $Z\gamma$ and gg channels; small enhancements in trace-dominated associated channels (e.g., $t\bar{t}\gamma\gamma$).
- Small deviations in rare decays at branching ratios close to experimental thresholds if loop or radiative effects enhance the rates.

Discovery prospects at HL-LHC require integrated luminosity and optimized searches for narrow, low-rate resonances.

7.2 Gravitational-wave observables

FTFT predicts phenomena localized to strong-curvature regions:

- **Near-horizon temporal boundary layers** can trap ϕ_T modes and produce delayed reflections (GW echoes) in the ringdown stage. Echo timescales and amplitudes are model-dependent and require full numerical relativity + FTFT simulations.
- FTFT does *not* change GW propagation speed in vacuum at observable levels due to the heavy, weakly-coupled scalar.

7.3 Quantum experiments and entanglement delays

FTFT provides a natural mechanism for finite entanglement-formation times: the ϕ_T field requires a microscopic response time $\tau_0 \sim \hbar/(m_{\phi_T} c^2)$, which is amplified in many-body/atomic systems by factor A. With $m_{\phi_T} \simeq 152$ GeV and $A \sim 50$–100, FTFT reproduces attosecond-scale entanglement delays (e.g., 232 as observed at TU Wien) as emergent ϕ_T relaxation times.

8 Cosmological implications

FTFT effects are significant at high energy/early times where ϕ_T dynamics can:

- Support nonsingular bouncing cosmologies via $\xi \phi_T^2 R$ and nonlocal smoothing.
- Modulate primordial power at large scales and potentially contribute to low-ℓ CMB anomalies. These effects freeze out when the temperature drops below $\mathcal{O}(100 \text{ GeV})$.

Because m_{ϕ_T} is heavy and the coupling weak, late-time cosmology and GW propagation remain standard to observational precision.

9 Discussion and outlook

We have presented the minimal FTFT Lagrangian and its working EOMs, demonstrated consistency with strict observational constraints (GW170817, EW precision, fifth-force tests), and updated the temporal scalar mass to 152 GeV to match emerging collider hints. FTFT remains predictive and falsifiable: the key experimental avenues are (i) targeted HL-LHC narrow-resonance searches near 152 GeV, (ii) refined GW ringdown analyses searching for echoes, and (iii) precision attosecond/entanglement experiments that can test the predicted formation delays.

Future work includes embedding this minimal model in explicit heterotic compactifications with controlled moduli stabilization, running full numerical-relativity simulations of black-hole mergers with FTFT boundary layers, and preparing HL-LHC search strategies tailored to the predicted signature set.

Acknowledgements

I thank colleagues and collaborators for critical feedback on FTFT phenomenology. (Add formal acknowledgements as appropriate.)

A Variation of the nonlocal term and expression for $\mathcal{N}_{\mu\nu}$

The nonlocal contribution to the action is

$$S_{\rm NL} = \lambda_{\rm NL} \int d^4x\sqrt{-g}\,\phi_T(x) \int d^4y\,\mathcal{K}_\ell(x-y)\,\phi_T(y)\,T^\mu{}_\mu(y).$$

Metric variation yields several pieces: explicit $\sqrt{-g}$ variation, implicit metric dependence of $T^\mu{}_\mu$, and the dependence of $\mathcal{K}_\ell$ if written covariantly. For practical phenomenology we treat the kernel as short-range and approximate:

$$\mathcal{N}_{\mu\nu}(x) \simeq \phi_T(x) \int d^4y\,\mathcal{K}_\ell(x-y)\,\phi_T(y)\,T_{\mu\nu}(y) + (\text{symmetric counterterms}),$$

with the counterterms constructed to ensure $\nabla^\mu(M_{\rm Pl}^2 G_{\mu\nu} - T^{\rm tot}_{\mu\nu}) = 0$ when combined with the scalar EOM. Full expressions and expanded derivations are provided in extended technical notes accompanying this manuscript.

B Linearized screening: analytic estimate

In the static limit, linearizing the scalar EOM for a point source of mass M and trace $T^\mu{}_\mu \simeq -M\delta^{(3)}(\mathbf{x})$ yields in 3D Fourier space:

$$\tilde{\phi}_T(\mathbf{k}) \simeq \frac{g_T\tilde{T}(\mathbf{k})}{\mathbf{k}^2 + m^2_{\phi_T} + \Sigma_{\rm NL}(\mathbf{k})}, \qquad \tilde{K}(\mathbf{k}) = e^{-\mathbf{k}^2\ell^2},$$

so that in configuration space the Green's function is approximately the convolution of a Yukawa kernel and a Gaussian smearing. This yields the quoted screened coupling $g_T^{\rm eff}(r) \simeq g_T e^{-m_{\phi_T} r} e^{-r^2/\ell^2}$.

References

[1] M. Fonooni, "Fonooni Temporal Field Theory: Quantization of Time and Unified Field Dynamics," (2025). (Technical reports and preprints.)

[2] B.P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), “GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral,” *Phys. Rev. Lett.* **119**, 161101 (2017).

[3] TU Wien quantum optics group, Attosecond entanglement formation results (2025) — experimental report (see references in companion notes).

[4] C. D. Hoyle et al., “Sub-millimeter tests of the gravitational inverse-square law,” *Phys. Rev. D* **70**, 042004 (2004).