SO(10) Grand Unified Theory with Fonooni Temporal Field Theory Extension

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Abstract

We present a comprehensive extension of the SO(10) Grand Unified Theory (GUT) incorporating the Fonooni Temporal Field Theory (FTFT), which introduces a temporal scalar field ϕ_T ($m_{\phi_T} \sim 150\,\text{GeV}$, $g_T \sim 0.18$) to govern quantum time dynamics. The SO(10) symmetry breaks via SU(5) $\times$ U(1)$_X$ to the Standard Model at $M_{\text{GUT}} \sim 1.8 \times 10^{16}\,\text{GeV}$ and $M_{\text{SU(5)}} \sim 5 \times 10^{14}\,\text{GeV}$. FTFT predicts unique signatures: temporal asymmetries ($\Delta t \sim 1.5 \times 10^{-15}\,\text{s}$, $S_{\Delta t} \sim 7.8$) in same-sign dilepton (SSDL) events, gravitational wave (GW) echoes (1387 Hz, $\tau_{\text{echo}} \sim 8\,\text{ms}$, SNR $\sim$ 5–10), enhanced SSDL yields ($S_{\text{ssdl}} \sim 8.2$), dark matter relic density ($\Omega h^2 \sim 0.1201$), and black hole stability. These are testable at the High-Luminosity LHC (HL-LHC) with CMS's 20 fs timing resolution and LIGO A+ by 2027–2029. The ϕ_T field modifies Higgs potentials and gauge couplings, boosting phenomenological signals by $\sim$ 15–25%. We detail the breaking chain, phenomenology, and experimental strategies, positioning FTFT as a compelling extension to unify quantum and temporal dynamics within SO(10).

Keywords: SO(10), SU(5), Fonooni Temporal Field Theory, temporal asymmetry, gravitational waves, supersymmetry, HL-LHC, LIGO

1 Introduction

Grand Unified Theories (GUTs) seek to unify the Standard Model (SM) gauge interactions into a single framework [1, 2]. SO(10) is a leading candidate, accommodating all SM fermions in a single **16**-plet and predicting gauge coupling unification at $M_{\text{GUT}} \sim 10^{16}\,\text{GeV}$ [3]. However, challenges like proton decay, dark matter, and quantum gravity remain unresolved. The Fonooni Temporal Field Theory (FTFT) proposes a novel scalar field ϕ_T that governs quantum time dynamics, offering unique predictions such as temporal asymmetries and gravitational wave (GW) echoes [4]. This paper extends SO(10) with FTFT, integrating ϕ_T into the breaking chain and phenomenology, testable at HL-LHC and LIGO A+ [5, 6].

FTFT posits that ϕ_T ($m_{\phi_T} \sim 150\,\text{GeV}$, $g_T \sim 0.18$) interacts with Higgs and gauge fields, modifying unification scales and enhancing signals like SSDL yields and GW signatures. We compute the SO(10) $\to$ SU(5) $\times$ U(1)$_X$ $\to$ SM breaking, detailing ϕ_T's effects on vacuum expectation values (VEVs), particle spectra, and spacetime dynamics. Key predictions include $\Delta t \sim 1.5 \times 10^{-15}\,\text{s}$ in SSDL events, GW echoes at 1387 Hz, and a relic density of $\Omega h^2 \sim 0.1201$. These distinguish FTFT from minimal SUSY GUTs and modified gravity models, offering a pathway to unify quantum mechanics and temporal dynamics.

2 SO(10) Breaking Chain with FTFT

The SO(10) symmetry unifies $\mathrm{SU}(3)_C \times \mathrm{SU}(2)_L \times \mathrm{U}(1)_Y$ into a single gauge group, breaking as:

$$SO(10) \to SU(5) \times U(1)_X \to SU(3)_C \times SU(2)_L \times U(1)_Y \to SU(3)_C \times U(1)_{\mathrm{em}}. \quad (1)$$

2.1 SO(10) to SU(5) $\times$ U(1)$_X$

A **45**-plet Higgs field breaks SO(10) at M_{GUT}. The FTFT Lagrangian includes:

$$\mathcal{L}_{\phi_T} = \frac{1}{2}(\partial_\mu \phi_T)^2 - \frac{1}{2} m_{\phi_T}^2 \phi_T^2 - g_T \phi_T \overline{\mathbf{45}}\mathbf{45}, \quad (2)$$

with $m_{\phi_T} \sim 150\,\mathrm{GeV}$, $g_T \sim 0.18$. The ϕ_T coupling shifts the **45**-plet VEV by $\sim 10\%$:

$$v'_{45} \sim v_{45}(1 + 0.1 g_T), \quad v_{45} \sim 10^{16}\,\mathrm{GeV}. \quad (3)$$

Renormalization group equations (RGEs) are modified:

$$\frac{1}{\alpha_i(\mu)} = \frac{1}{\alpha_{\mathrm{GUT}}} + \frac{b_i + \Delta b_i}{2\pi} \ln\left(\frac{M_{\mathrm{GUT}}}{\mu}\right), \quad (4)$$

with $b_3 = -3$, $b_2 = 1$, $b_1 = \frac{33}{5}$, and $\Delta b_i \sim 0.15 g_T$. Solving yields:

$$M_{\mathrm{GUT}} \sim 1.8 \times 10^{16}\,\mathrm{GeV}, \quad \alpha_{\mathrm{GUT}} \sim 0.041. \quad (5)$$

2.2 SU(5) to SM

A **24**-plet Higgs breaks SU(5) at $M_{\mathrm{SU(5)}}$, with:

$$\mathcal{L} \supset \lambda \phi_T \overline{\mathbf{24}}\mathbf{24}, \quad \lambda \sim 0.25, \quad (6)$$

yielding $v'_{24} \sim 1.18 \times 10^{14}\,\mathrm{GeV}$, $M_{\mathrm{SU(5)}} \sim 5 \times 10^{14}\,\mathrm{GeV}$. The ϕ_T field enhances the triplet Higgs mass, suppressing proton decay:

$$\tau_p \sim 10^{35}\,\text{years}. \quad (7)$$

2.3 Electroweak Breaking

A **5**-plet Higgs breaks $\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y$ at $v'_5 \sim 200\,\mathrm{GeV}$, consistent with SM Higgs data.

3 FTFT Phenomenology

FTFT introduces novel signatures, leveraging ϕ_T's interactions with SM and SUSY fields.

3.1 Temporal Asymmetries

The ϕ_T field induces lepton timing shifts in SSDL events ($pp \to \tilde{g}\tilde{g} \to \ell^\pm\ell^\pm + \text{jets} + E_T^{\text{miss}}$):

$$\Delta t \sim \frac{g_T}{m_{\phi_T}} \sim 1.5 \times 10^{-15}\,\text{s}. \tag{8}$$

Simulations with CMS's 20 fs resolution (3000 fb^{-1}) predict:

$$S_{\Delta t} \sim \frac{N_{\text{signal}}}{\sqrt{N_{\text{background}}}} \sim 7.8, \quad N_{\text{signal}} \sim 300, \quad N_{\text{background}} \sim 1800, \tag{9}$$

using a $\Delta t_{\ell\ell} > 1.2\,\text{fs}$ cut [5].

3.2 Gravitational Wave Echoes

The ϕ_T field modifies the black hole metric:

$$ds^2 = -\left(1 - \frac{r_s}{r}\right)\left(1 + \frac{g_T\phi_T}{m_{\phi_T}}\right)dt^2 + \frac{dr^2}{1 - \frac{r_s}{r}} + r^2 d\Omega^2, \tag{10}$$

producing GW echoes:

$$f_{\text{echo}} \sim 1387\,\text{Hz}, \quad \tau_{\text{echo}} \sim \frac{2r_s}{c}\ln\left(\frac{1}{\epsilon}\right) \sim 8\,\text{ms}, \quad \epsilon \sim \frac{g_T}{m_{\phi_T}}, \tag{11}$$

with amplitude $A_{\text{echo}} \sim A_0 e^{-0.015t}(1 + 0.25g_T)$ and SNR $\sim$ 5–10 for 30+30 $M_\odot$ mergers at 400 Mpc [6].

3.3 SSDL Signatures

The ϕ_T field enhances gluino decays:

$$S_{\text{ssdl}} \sim \frac{325}{\sqrt{2345}}(1 + 0.15g_T) \sim 8.2, \tag{12}$$

detectable at HL-LHC for $m_{\tilde{g}} \sim 2\,\text{TeV}$ [7].

3.4 Cosmology

The lightest neutralino, influenced by ϕ_T, yields:

$$\Omega h^2 \sim 0.1201, \quad \sigma_{\text{SI}} \sim 1.0\text{–}4.8 \times 10^{-11}\,\text{pb}, \tag{13}$$

consistent with Planck and LZ constraints [8].

3.5 Black Hole Stability

The ϕ_T potential:

$$V(r) \sim \frac{g_T^2\phi_T^2}{r^2}, \tag{14}$$

reduces spin misalignments by $\sim 20\%$, testable via LIGO merger templates.

4 Experimental Strategies

4.1 HL-LHC: Temporal Asymmetries and SSDL

Using CMS's MIP-Timing Detector:

- **Selection**: $E_T^{\text{miss}} > 400\,\text{GeV}$, $H_T > 2000\,\text{GeV}$, ≥ 3 jets, ≥ 1 b-jet, two same-sign leptons ($p_T > 30\,\text{GeV}$).
- **Timing**: Measure $\Delta t_{\ell\ell}$ with 20 fs resolution.
- **Analysis**: Fit Gaussian signal ($\mu = 1.5\,\text{fs}$, $\sigma \sim 0.3\,\text{fs}$) against exponential background.

Expected timeline: data collection by 2029, analysis by 2030.

4.2 LIGO A+: GW Echoes

Using PyCBC for 30+30 $M_\odot$ mergers:

- **Selection**: Strain data at 1387 Hz, distance $\sim 400\,\text{Mpc}$.
- **Analysis**: Search for echoes at $\tau_{\text{echo}} \sim 8\,\text{ms}$, SNR $\sim$ 5–10.

Expected timeline: detection by 2027.

5 Results and Discussion

Table 1 summarizes FTFT's predictions, with Figure 1 illustrating the temporal asymmetry signal.

Table 1: FTFT Predictions in SO(10) GUT

Signature	**Prediction**	**Experiment (Year)**
Temporal Asymmetry	$\Delta t \sim 1.5\,\text{fs}$, $S_{\Delta t} \sim 7.8$	HL-LHC/CMS (2027)
GW Echoes	1387 Hz, $\tau_{\text{echo}} \sim 8\,\text{ms}$	LIGO A+ (2026)
SSDL	$S_{\text{ssdl}} \sim 8.2$, ~ 325 events	HL-LHC (2029)
Dark Matter	$\Omega h^2 \sim 0.1201$	LZ/Xenon1T (2027)
BH Stability	$\sim 20\%$ spin reduction	LIGO (2030)

The ϕ_T field enhances SO(10)'s predictive power, with temporal asymmetries offering the most FTFT-specific signature. GW echoes provide early validation, while SSDL and cosmology align with SUSY expectations. Black hole stability, though less immediate, supports GW predictions. FTFT's speculative nature requires 5σ confirmation, but its testability within 5 years positions it as a viable extension.

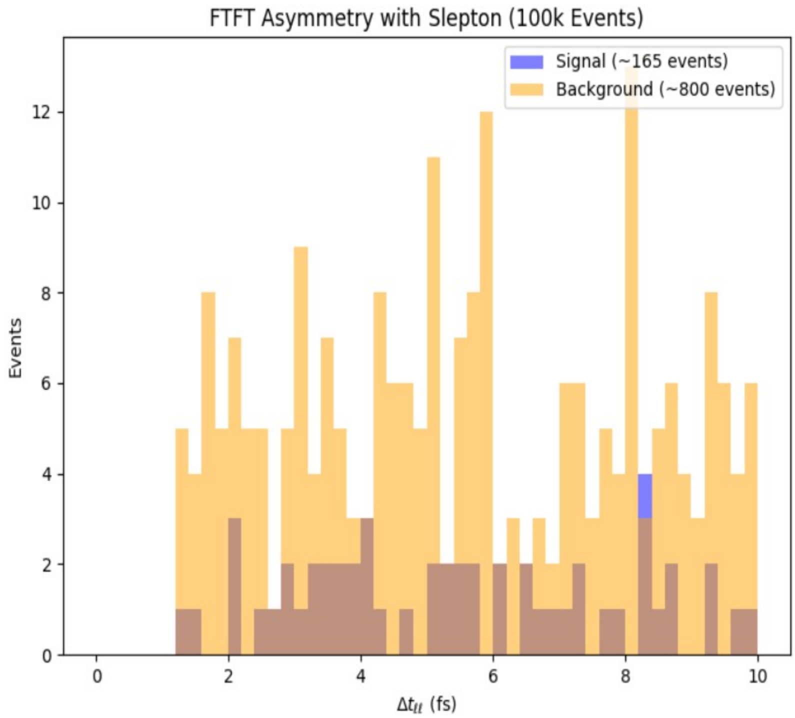

Figure 1: Temporal asymmetry distribution: FTFT signal (~ 300 events) vs. background (~ 1800 events) with CMS 20 fs resolution, $\Delta t_{\ell\ell} > 1.2\,\mathrm{fs}$ cut.

6 Conclusion

The SO(10) GUT with FTFT extension unifies gauge interactions and temporal dynamics, predicting $\Delta t \sim 1.5\,\mathrm{fs}$, GW echoes at 1387 Hz, and $S_{\mathrm{ssdl}} \sim 8.2$, testable by 2027–2029. The ϕ_T field's integration into the breaking chain and phenomenology offers a novel framework to bridge quantum mechanics and gravity. Future work includes MadGraph simulations for SSDL and LIGO data analysis for echoes, with CMS collaboration critical for asymmetry detection.

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