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Posted Date: 26 January 2026

doi: 10.20944/preprints202503.1613.v2

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Gravitational Wave Propagation, Polarization Anomalies, and Informational Coherence in the Unified Theory of Informational Spin (TGU) – v2

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Abstract

This work presents an updated and consolidated formulation of gravitational wave (GW) propagation within the Unified Theory of Informational Spin (TGU). Extending previous results, we formalize gravitational waves as phase-coherent excitations propagating through a structured informational substrate rather than a purely geometric vacuum. A refined operational form of the coherence-modulation equation is introduced, distinguishing amplitude-integrated effects from polarization-dependent anisotropies. Numerical simulations based on GW150914-like events demonstrate that informational coherence gradients produce measurable amplitude modulation and polarization ratios unattainable within General Relativity (GR). These effects are shown to be falsifiable with current and next-generation interferometers (LIGO–Virgo–KAGRA, Einstein Telescope). The TGU is positioned as a phenomenological propagation framework fully compatible with GR at emission while extending gravitational physics through environmental coherence effects.

Keywords: gravitational waves; informational coherence; unified theory of informational spin; polarization anomalies; LIGO; Virgo; KAGRA; Einstein telescope; cosmology

1. Introduction

Gravitational waves constitute one of the most precise probes of spacetime dynamics. Within General Relativity (GR), their generation and propagation are governed entirely by spacetime geometry, with amplitude and polarization fixed by source parameters and luminosity distance.

However, accumulating observational tensions — including discrepancies in inferred distances, effective masses, and cosmological parameters — motivate the exploration of propagation effects beyond purely geometric descriptions.

The Unified Theory of Informational Spin (TGU) proposes that spacetime possesses an underlying *informational coherence structure*, influencing the propagation of physical fields without altering their local generation. In this framework, gravitational waves propagate as phase-coherent informational excitations, sensitive to coherence gradients along their path.

This paper presents a revised and operationally grounded formulation of gravitational wave propagation in TGU, supported by numerical simulations and explicit falsification criteria.

2. Conceptual Framework of the TGU

2.1. Spacetime as an Informational Substrate

In TGU, spacetime is modeled as a structured informational field characterized by a scalar coherence function

$$\varepsilon(r, \theta) \in (0, 1]. \tag{1}$$

This function quantifies the local capacity of spacetime to preserve phase coherence of propagating fields:

- $\varepsilon = 1$: fully coherent substrate,
- $\varepsilon < 1$: partial decoherence,
- $\nabla\varepsilon \neq 0$: informational gradients.

Gravitation emerges geometrically at emission (GR-compatible), while propagation is governed by coherence transport.

2.2. Informational Coherence and Gravitational Waves

Gravitational waves are interpreted as coherent phase oscillations embedded in the informational substrate. Unlike GR, where the vacuum is inert, TGU predicts that propagation depends on the informational integrity of the medium traversed.

3. Gravitational Wave Propagation in TGU

3.1. Separation of Physical Regimes

A key refinement introduced in this version is the separation of two physically distinct regimes: amplitude-integrated propagation and polarization-dependent anisotropies.

3.2. Regime I: Amplitude-Integrated Propagation

For integrated observables such as strain amplitude and signal-to-noise ratio (SNR), the effective modulation is given by

$$h_{\text{obs}} = h_{\text{GR}} \cdot \varepsilon_{\text{eff}}^{-1/2}, \quad (2)$$

where ε_{eff} is the path-averaged informational coherence.

This effect leads to apparent amplitude enhancement without violating local energy conservation, effectively renormalizing the inferred luminosity distance.

3.3. Regime II: Polarization-Dependent Modulation

For polarization modes, the TGU predicts

$$h_{+}^{\text{obs}} = h_{+}^{\text{GR}} \cdot \varepsilon_{+}^{-1/2}, \quad (3)$$

$$h_{\times}^{\text{obs}} = h_{\times}^{\text{GR}} \cdot \varepsilon_{\times}^{-1/2}, \quad (4)$$

with $\varepsilon_{+} \neq \varepsilon_{\times}$ in anisotropic coherence fields.

Such polarization ratios cannot be reproduced by any source geometry within GR and constitute a unique signature of the TGU.

4. Numerical Simulations

4.1. GW150914-like Event

Simulations were performed using parameters representative of the GW150914 event:

- Component masses $m_1 = 36 M_{\odot}$, $m_2 = 29 M_{\odot}$,
- Luminosity distance ~ 410 Mpc,
- Inspiral–merger chirp waveform.

4.2. Amplitude Modulation Results

Assuming a coherence value $\varepsilon = 0.8$, we obtain:

- GR SNR proxy: 1.89×10^{-25} ,
- TGU SNR proxy: 2.12×10^{-25} ,
- Boost factor: ~ 1.12 .

This modulation lies within current detector sensitivity and becomes decisive for third-generation observatories.

4.3. Polarization Anomaly Test

For a binary inclination of 30° and anisotropic coherence values $\varepsilon_+ = 0.95$ and $\varepsilon_\times = 0.85$, the polarization ratio exits the physically allowed GR domain.

No real inclination angle can reproduce the observed ratio, rendering the apparent inclination mathematically undefined. This constitutes an environmental signature independent of source geometry.

5. Falsifiability Criteria

The TGU is explicitly falsifiable through the following criteria:

1. If all observed polarization ratios can be mapped to physical inclinations within GR, the TGU is disfavored.
2. If polarization anomalies fail to correlate with large-scale structure or environmental coherence gradients, the TGU is ruled out.
3. If no coherence-dependent effects are observed across frequencies, the model is falsified.

6. Observational Prospects

While current LIGO–Virgo–KAGRA sensitivity is marginal for these effects, next-generation detectors such as the Einstein Telescope and Cosmic Explorer will enable polarization tomography and environmental coherence mapping.

7. Epistemological Status

The TGU does not replace General Relativity. GR governs local emission and dynamics, while the TGU governs propagation through structured spacetime. This separation mirrors dispersion theory in electrodynamics without modifying Maxwell's equations.

8. Conclusions

This revised formulation demonstrates that gravitational wave propagation may encode information about spacetime coherence. The TGU predicts measurable, falsifiable deviations from GR, with polarization anomalies providing a unique experimental window. Gravitational waves thus emerge as probes of the informational integrity of the universe.

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