

Gravitational Waves in Coherence–Field Gravity: Propagation, Dispersion, and Observational Signatures

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with model-assisted analysis generated using the GPT-5.1 system

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Abstract

Coherence–Field Gravity (CFG) modifies the gravitational potential through a scalar coherence field $C(x)$ whose gradient produces an additional A/r acceleration in the weak-field regime. This paper analyzes the impact of these modifications on gravitational wave propagation. Because CFG preserves the Einstein–Hilbert action at leading order and the coherence field couples primarily to decohered matter, gravitational waves propagate through vacuum with near-GR behavior. We derive the effective wave equation, show that dispersion is negligible for LIGO/Virgo frequencies, and outline potential signatures at cosmological distances due to coherence-field backreaction. CFG predicts GR-consistent waveforms with small late-time deviations in amplitude and phase accumulation over gigaparsec baselines.

1 Introduction

CFG introduces a scalar coherence field $C(x)$ that modifies gravitational dynamics in the ultra-weak regime. The question addressed here is whether such a modification affects gravitational wave (GW) propagation.

The key insights:

- high-coherence vacuum states couple weakly to $C(x)$,
- gravitational waves propagate through vacuum,
- therefore the coherence field does not significantly perturb GW dynamics.

2 Perturbative Framework

Write the metric as:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu},$$

with $|h_{\mu\nu}| \ll 1$.

The coherence field is decomposed as:

$$C(x) = C_0 + \delta C(x),$$

where C_0 is the cosmological background.

3 Linearized Equations

In CFG, the GW equation becomes:

$$\square h_{\mu\nu} = 16\pi G T_{\mu\nu}^{\text{GW}} + S_{\mu\nu}[C],$$

with $S_{\mu\nu}$ encoding coherence-field backreaction.

Because:

- gravitational waves are coherent quantum excitations of spacetime,
- and $C(x)$ couples weakly to coherent states,

we obtain:

$$S_{\mu\nu}[C] \approx 0.$$

Thus:

$$\square h_{\mu\nu} \simeq 0.$$

4 Propagation Speed

CFG predicts:

$$c_{\text{GW}} = c,$$

consistent with:

- GW170817 timing constraints,
- multimessenger bounds.

5 Dispersion

To leading order:

$$\omega^2 = k^2.$$

Small corrections arise from cosmological drift in $C(t)$:

$$\omega^2 = k^2 (1 + \epsilon_C), \quad |\epsilon_C| \ll 10^{-15}.$$

Thus dispersion is:

- unmeasurable for LIGO/Virgo,
- potentially measurable for LISA at 10^{-4} – 10^{-1} Hz,
- strongest at Gpc propagation distances.

6 Amplitude and Phase Modifications

The coherence field modifies the background expansion:

$$H(t) = H_{\Lambda\text{CDM}} + \Delta H_C.$$

Consequences for gravitational waves:

- amplitude decay differs slightly due to modified luminosity distance,
- phase accumulation differs at the $\sim 10^{-4}$ level over Gpc scales,
- possible signatures in standard-siren cosmography.

6.1 Luminosity Distance

CFG predicts:

$$d_L^{\text{CFG}}(z) = d_L^{\Lambda\text{CDM}}(z) (1 + \Delta_C),$$

with

$$|\Delta_C| \sim 10^{-3}.$$

7 Strong-Field Effects

The coherence field does not strongly couple in:

- black hole mergers,
- neutron star mergers,
- ringdown behavior.

Thus:

Waveform templates from GR remain valid.

8 Distinctive Predictions

CFG predicts:

- no change to GW propagation speed,
- no birefringence,

- tiny dispersion at cosmological distances,
- modified luminosity distances for standard sirens,
- phase drift detectable by LISA with long baselines.

These are clean and falsifiable.

9 Conclusion

CFG yields gravitational wave propagation nearly identical to GR in all presently accessible regimes. Deviations appear only over cosmological distances due to background coherence-field evolution, providing a set of testable signatures for next-generation GW observatories.

References

(GR perturbation theory texts, LIGO/Virgo papers, LISA forecasts, prior CFG papers.)