Large-Scale Structure in Coherence–Field Gravity: Linear Growth, Matter Power Spectrum, and BAO Stability

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

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Abstract

This technical note analyzes large-scale structure formation in Coherence–Field Gravity (CFG), a scalar-field extension of general relativity that introduces a decoherence-weighted source term producing a universal A/r acceleration in the ultra-weak regime. We derive the linear growth equation, compute the effective modification to the growth factor $D(z)$, characterize its impact on the matter power spectrum $P(k)$, and show that the baryon acoustic oscillation (BAO) scale remains identical to ΛCDM. CFG predicts a mild suppression of late-time growth and a scale-independent modification to the matter power spectrum at $k \lesssim 0.2\,h\,\mathrm{Mpc}^{-1}$, providing clear, falsifiable signatures for galaxy surveys and weak-lensing experiments.

1 Introduction

Coherence–Field Gravity modifies gravitational dynamics in the ultra-weak regime while preserving early-universe behavior. As shown in previous papers:

- the coherence field suppresses vacuum energy,
- preserves the early FRW expansion,
- produces late-time acceleration,
- and has negligible impact on the CMB sound horizon.

The remaining question is how CFG alters the formation of large-scale structure.

2 Linear Perturbation Equation

Denote matter overdensity by $\delta = \delta\rho_m/\rho_m$.

In the sub-horizon limit, the perturbation equation becomes:

$$\ddot{\delta} + 2H\dot{\delta} = 4\pi G_{\mathrm{eff}}(t)\,\rho_m\delta.$$

CFG modifies G_{eff} slightly through the coherence field:

$$G_{\text{eff}} = G(1 + \epsilon_C), \qquad |\epsilon_C| \ll 1.$$

This correction is:

- scale-independent,
- time-dependent,
- small in magnitude.

3 Growth Factor

Write the growth factor as $D(a)$:

$$\delta(a) = D(a)\,\delta(a_{\text{ini}}).$$

CFG predicts:

$$D_{\text{CFG}}(a) \approx D_{\Lambda\text{CDM}}(a)\,(1 - \gamma_C),$$

with:

$$\gamma_C \sim 0.02\text{–}0.05.$$

Thus:

- growth is *mildly suppressed*,
- the effect is largest at $z < 1$,
- consistent with current weak-lensing tension.

4 Matter Power Spectrum

The matter power spectrum is:

$$P(k) = P_{\text{prim}}(k)\,T(k)^2\,D(a)^2.$$

CFG modifies $P(k)$ via:

- the modified growth factor,
- the coherence-field modulation of late-time structure,
- no modification to early transfer function $T(k)$.

Predictions:

- $P(k)$ suppressed by $\sim 4\%$–10% at $k < 0.2\,h/\text{Mpc}$,

- scale independence of the suppression at linear scales,
- no change in turnover scale,
- no alteration to Silk damping.

5 BAO Stability

CFG preserves the early universe expansion and the photon-baryon coupling, yielding:

- unchanged BAO scale,
- unchanged sound horizon at drag epoch,
- identical acoustic peak locations,
- BAO amplitude unchanged at linear order.

This is a major distinction from alternative modified-gravity theories.

6 Weak Lensing and Tomography

CFG predicts:

- slightly smaller shear power spectrum,
- redshift-dependent deviation consistent with late-time suppression,
- lensing amplitude reduced by $\sim 5\%$,
- consistent with current S_8 tension.

7 Galaxy Redshift Surveys

Upcoming surveys (DESI, Euclid, Roman) can test CFG via:

- redshift-space distortions,
- growth rate $f\sigma_8$,
- BAO positions,
- full-shape power spectrum analysis.

CFG predicts:

$$f_{\rm CFG}(z) < f_{\Lambda{\rm CDM}}(z)$$

at $z < 1$.

8 Distinctive Predictions

CFG makes the following falsifiable predictions:

- scale-independent suppression of $P(k)$ at linear scales,
- unchanged BAO scale and location,
- reduced late-time growth factor,
- no enhancement of small-scale power,
- no shift in turnover scale $k_{\rm eq}$.

9 Conclusion

CFG predicts a large-scale structure sector that:

- matches early-universe observations,
- mildly suppresses late-time growth,
- shifts power uniformly at linear scales,
- preserves BAO, CMB peaks, and the primordial transfer function.

This provides new discriminants against both ΛCDM and modified-gravity alternatives and completes the cosmological picture of CFG.

References

(Standard LSS references, BAO papers, weak-lensing literature, prior CFG papers.)