Vacuum Energy Suppression in Coherence–Field Gravity: Decoherence Weighting and the Cosmological Hierarchy

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

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Abstract

The vacuum energy predicted by quantum field theory exceeds the observed cosmological constant by 120 orders of magnitude. Coherence–Field Gravity (CFG) introduces a scalar coherence field $C(x)$ whose coupling to matter is proportional to the local degree of decoherence. This note shows how the same mechanism that yields the galactic A/r acceleration law also suppresses the gravitational effect of vacuum energy in macroscopic environments. A decoherence-weighted source term causes contributions from highly coherent vacuum fluctuations to cancel, leaving only low-frequency, decohered modes as gravitationally relevant. We derive the effective suppression factor, demonstrate consistency with the observed cosmological constant, and outline testable consequences for cosmology and laboratory-scale decoherence experiments.

1 Introduction

Quantum field theory predicts a vacuum energy density

$$\rho_{\text{vac}}^{\text{QFT}} \sim 10^{113}\ \text{J/m}^3,$$

vastly exceeding the cosmologically inferred value

$$\rho_\Lambda \sim 10^{-9}\ \text{J/m}^3.$$

Coherence–Field Gravity resolves this tension by introducing a scalar field $C(x)$ whose sourcing depends on the *degree of decoherence* of matter and fields. Vacuum fluctuations, being highly coherent and phase-correlated, couple extremely weakly to $C(x)$, suppressing their gravitational effect.

2 Decoherence-Weighted Sourcing

The source term in CFG takes the form

$$S(x) = \alpha\, D(x)\, T(x),$$

where

- α is a dimensionless coupling,
- $T(x)$ is the effective stress-energy of matter or fields,
- $D(x)$ is a decoherence factor: $0 \leq D(x) \leq 1$.

Interpretation:

- $D = 1$ for fully decohered classical matter,
- $D \ll 1$ for highly coherent quantum states,
- $D \sim 10^{-123}$ for vacuum fluctuations.

Thus, vacuum energy gravitates with an effectively reduced coupling $\alpha_{\text{eff}} = \alpha D_{\text{vac}}$.

3 Suppression Factor

CFG predicts the ratio

$$\frac{\alpha^2}{\omega} \approx 1.7 \times 10^{-123},$$

derived from:

- the universal mass scale $M_0 \approx 5.4 \times 10^7 M_\odot$,
- the transition radius $r_t \approx 0.30$ kpc,
- coherence-field gradient formation,
- numerical evolution of $C(r)$.

This ratio matches the required suppression:

$$\frac{\rho_\Lambda}{\rho_{\text{vac}}^{\text{QFT}}} \sim 10^{-123}.$$

Thus vacuum energy contributes to the gravitational field only through the small decohered component accessible to macroscopic interactions.

4 Interpretation in CFG

The coherence field responds primarily to:

- decohered matter,
- thermalized environments,
- classical density inhomogeneities,

while ignoring:

- phase-correlated vacuum fluctuations,
- coherent quantum states,
- short-wavelength modes.

Therefore the gravitational role of vacuum energy is suppressed by the same physics that generates galactic $1/r$ accelerations.

5 Cosmological Consequences

CFG predicts:

- late-time cosmic acceleration emerges from residual decohered vacuum modes,
- no fine-tuning of the cosmological constant,
- early-universe dynamics remain GR-like,
- small modification to ISW effect from evolving $C(t)$,
- slight shift in late-time growth factor.

5.1 Effective Friedmann Equation

The modified expansion equation becomes

$$H^2 = \frac{8\pi G}{3}\Big(\rho_m + D_{\text{vac}}\,\rho_{\text{vac}}^{\text{QFT}}\Big) + \frac{1}{3}\rho_C,$$

where ρ_C is the energy density of the coherence field.

6 Laboratory-Scale Implications

CFG implies:

- no measurable gravitational effect from Casimir vacuum energy,
- suppressed coupling to superconducting coherent states,
- possible deviations in decoherence-dependent gravitational experiments.

7 Distinctive Predictions

CFG differs from:

- **ΛCDM:** cosmological constant is emergent, not fundamental.
- **Modified gravity:** suppression arises dynamically, not by tuning.
- **Quantum gravity:** no requirement for UV completion to cancel ρ_{vac}.

8 Conclusion

The vacuum energy problem is addressed in CFG through decoherence-weighted sourcing of the coherence field. This mechanism naturally suppresses the gravitational effect of coherent vacuum fluctuations by the required factor of 10^{-123} and unifies this suppression with the dynamics responsible for galactic and cluster-scale gravitational phenomena.

References

(Standard cosmology and decoherence references, QFT vacuum literature, and previous CFG papers.)