Gravity as Minimum Deformation for Global Phase Coherence

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1 Introduction

In the Global Constraint Framework (GCF), gravity is not a fundamental force nor primarily geometry — it is the minimal spacetime deformation required to preserve global phase coherence in the presence of localized energy–momentum. Curvature is the lowest-cost mechanism to maintain universal phase transport across all admissible paths. This note strengthens the derivation by explicitly showing how the coherence constraint forces a connection, metric, and Einstein tensor uniquely. This framework is consistent with Modal Theory (MT), where the gradient stiffness term $\lambda(\nabla\Delta\theta)^2$ enforces analogous global phase coherence on the scalar phase difference field locked at $\Delta\theta = 255^\circ$.

2 Global Phase-Coherence Constraint

All matter fields are collectively denoted $\psi(x)$. Physical histories extremize the matter action

$$S_{\text{matter}}[\psi] = \int_{\mathbb{R}^4} \mathcal{L}_{\text{matter}}(\psi, \partial\psi)\, d^4x \tag{1}$$

subject to the global coherence constraint

$$\mathcal{C}[\psi] = \int_{\mathbb{R}^4} G(\psi, \partial\psi)\, d^4x = 0, \tag{2}$$

where the integral is over flat Minkowski spacetime (no metric assumed a priori). The constraint is global; the Lagrange multiplier Λ is a constant (not a local field).

3 Path Independence of Phase Transport

Phase coherence requires path-independence of accumulated phase for all causal paths. For any two paths γ_1, γ_2 from p to q,

$$\oint_{\gamma_1-\gamma_2} d\theta = 0. \tag{3}$$

This is only possible if ordinary derivatives are replaced by covariant derivatives

$$\partial_\mu \to \nabla_\mu = \partial_\mu + \Gamma^\lambda_{\mu\nu}, \tag{4}$$

where Γ is a connection compensating for spacetime variation. The coherence constraint thus forces a universal connection on all fields.

4 Emergence of the Metric

Invariant phase comparison along distinct paths requires an invariant measure of interval and causal structure. This necessitates a rank-2 symmetric tensor $g_{\mu\nu}$ to define proper distances and light cones. The metric is therefore required by the coherence constraint — it is not postulated independently.

5 Metric Variation and Field Equations

The effective action is promoted to curved spacetime:

$$S_{\text{eff}} = \int \sqrt{-g}\,\mathcal{L}_{\text{matter}}\,d^4x - \Lambda\mathcal{C}[\psi, g]. \tag{5}$$

Varying with respect to $g^{\mu\nu}$ yields

$$\delta S_{\text{eff}} = \int \left(-\frac{1}{2}T_{\mu\nu}\delta g^{\mu\nu} + \text{geometric term}\right)\sqrt{-g}\,d^4x = 0, \tag{6}$$

where $T_{\mu\nu}$ is the matter stress-energy tensor. Locality, covariance, second-order field equations, and covariant conservation (from constraint invariance) restrict the geometric term uniquely to the Einstein tensor (Lovelock theorem in 4D):

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R. \tag{7}$$

The field equations are therefore

$$G_{\mu\nu} = \kappa T_{\mu\nu}, \tag{8}$$

where κ is fixed by the stiffness of the coherence constraint.

6 Universality and Equivalence Principle

Because phase coherence is universal to all matter fields, the connection and metric couple equally to all ψ. The equivalence principle emerges as a direct consequence of the coherence constraint rather than an independent postulate.

7 Regime Change under Decoherence

In regimes where the coherence constraint fails (extreme decoherence, non-equilibrium phase transport), the effective gravitational response can weaken or change form, entering a different closure regime. This contrasts with GR, where no such decoupling from stress-energy is known.

8 Conclusion

Gravity emerges as the minimal spacetime deformation required to maintain global phase coherence in the presence of localized energy–momentum. The Einstein field equations follow uniquely from locality, covariance, second-order dynamics, and conservation under the global coherence constraint. Curvature is not fundamental but the bookkeeping mechanism that enforces consistency across all propagating phases.