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Unified Covariant GUP and Momentum-Space Geometry

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We present a unified theoretical framework that combines a covariant Generalized Uncertainty Principle with a dynamical momentum-space geometry. Using normal-coordinate methods, we show that the extrinsic curvature of constant-momentum hypersurfaces induces covariant deformations of the canonical commutators, yielding noncommutative position operators. Simultaneously, the momentum-space metric is elevated to a dynamical field governed by an Einstein–Hilbert–type action. When coupled to quantum matter fields, this construction produces systematically modified kinetic operators and dispersion relations within a self-consistent, covariant setting.

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