Atmospheric Newtonian noise in torsion-balance measurements of the gravitational constant G

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Measurements of Newton's gravitational constant remain limited by environmental and apparatus-dependent systematics whose treatment is often less explicit than that of instrumental noise. Among these, atmospheric density fluctuations generate unshieldable gravity gradients that couple directly to torsion-balance observables as atmospheric Newtonian noise. Here, we develop a GUM-consistent framework for propagating this contribution through the torque estimator into the uncertainty budget of torsion-balance measurements. We derive closed-form spatial transfer functions for two benchmark geometries: a two-mass dumbbell, which provides an upper-coupling reference, and a perfectly symmetric cross, which serves as an idealized rejection limit and exposes the trade-off between suppressing low-order environmental coupling and preserving signal response. We also separate stationary correlated inputs from non-stationary baseline drift, using the Ornstein–Uhlenbeck process only as a benchmark for the former. Atmospheric pressure benchmarks indicate that the resulting background contribution is below present reference uncertainty levels, but can become relevant as systematic floors approach the part-per-million regime. This framework provides a practical route for incorporating site-specific environmental gravity gradients into future torsion-balance uncertainty budgets [1].

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