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Stochastic inflation: key insights, latest advances and future directions

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During inflation, quantum vacuum fluctuations are stretched beyond the Hubble radius, modifying the large-scale dynamics of the universe. Although typically negligible in the perturbative regime, this backreaction can become significant in regimes leading to primordial black hole (PBH) formation, where large density fluctuations arise, and which are the standard framework for addressing loop corrections. The combination of stochastic inflation and delta N formalisms provides an efficient non-perturbative framework to track these large fluctuations.

After reviewing the key results of stochastic inflation—particularly its prediction of heavy non-Gaussian tails in the curvature perturbation distribution—I will show how large fluctuations are spatially correlated in the presence of quantum diffusion during inflation, computing real-space correlation functions in the stochastic-delta N formalism.

To this end, I will show how the relationship between field values and physical distances is encoded in the recursive geometry of a stochastically inflating universe, allowing the consistent inclusion of volume-weighting effects. This approach is the first step in reconstructing the power spectrum and examining potential quantum diffusion corrections at cosmic microwave background (CMB) scales.

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