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# False and genuine decoherence of primordial perturbations

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Quantum fluctuations of the metric are amplified during inflation, producing the macroscopic perturbations observed in the late universe. To clarify whether these fluctuations retain their quantum coherence, we investigate the decoherence of superhorizon modes induced by gravitational nonlinearities. We show that cubic gravitational couplings, constrained by the soft theorem, lead to IR and UV divergences in the decoherence rate at one loop. These divergences originate from deep IR fluctuations, which appear as background modes to a local observer, and from violent zero-point fluctuations in the deep UV. We argue that these divergences are unobservable, as they vanish when proper observables are considered. To incorporate the observer's perspective, we propose using an effective quantum state, defined in terms of actual observables, as a more appropriate probe of quantum coherence. Based on this framework, we evaluate the finite decoherence rate induced by the superhorizon environment during inflation and in the late universe.

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