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Stochastic inflation in full general relativity

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In the context of inflation, we show how to account for quantum modes in general and numerical relativity on scales bigger than the Hubble radius, from where they behave classically and can grow non-perturbatively.

We provide a formulation of Stochastic Inflation in full general relativity that goes beyond the slow-roll and separate universe approximations. Starting from the initial conditions problem in numerical relativity, we show how gauge invariant Langevin source terms can be obtained for the complete set of Einstein equations in their ADM formulation by providing a recipe for coarse-graining the spacetime in any small gauge. These stochastic source terms are defined in terms of the only dynamical scalar degree of freedom in single-field inflation and all depend simply on the first two time derivatives of the coarse-graining window function, on the gauge-invariant mode functions that satisfy the Mukhanov-Sasaki evolution equation, and on the slow-roll parameters. Stochastic gravitons sources can also be accounted for.

We validate the efficacy of these Langevin dynamics directly using an example in uniform field gauge, obtaining the stochastic e-fold number without the need for a first-passage-time analysis. As well as investigating the most commonly used gauges in cosmological perturbation theory, we also derive stochastic source terms for the coarse-grained first-order BSSN formulation of Einstein's equations, which enables a well-posed implementation for 3+1 numerical relativity simulations.

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