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Curvature Perturbations from Entropy Production on Cosmic Trajectories

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Inflation provides a dynamical mechanism to produce the primordial density perturbations that seed the formation of structure in the Universe through gravitational collapse. However, during the inflationary phase, the Universe is in a nearly homogeneous and low-entropy state, which must eventually give rise to the dense thermal plasma of the standard hot big bang. This transition, known as (p)reheating, is a necessary ingredient in inflationary theory. Microscopic models of this transition typically lead to strong instabilities and the eventual onset of highly complex, nonlinear mode-mode coupled behavior.

I will introduce a novel viewpoint on preheating dynamics —the ballistic approximation —where the derivatives coupling nearby points in spacetime (separated by less than Hubble scales) are ignored and individual points in spacetime evolve independently. Remarkably, this approximation captures the relevant dynamics obtained in full lattice simulations, at a tiny fraction of the compuational cost. We define a nonlinear generalization of the comoving curvature perturbation that applies on subhorizon as well as superhorizon scales. Absent couplings between trajectories, this quantity is conserved, and the production of curvature fluctuations can be identified with entropy generation. I will argue that the production of curvature perturbations from end-of-inflation dynamics is ubiquitous, rather than occurring in only a few highly specialized models. Furthermore, our formalism can be extended to study the effects of particle production and evolution on nontrivial potential surfaces during inflation, thus providing a unifying description of both the inflationary and early post-inflationary Universe.

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