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Two or three things particle physicists (mis)understand about (pre)heating

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Abstract

The transition from the end of inflation to a hot, thermal Universe—commonly referred to as (re)heating—is a critical yet often misunderstood phase in early-Universe cosmology. This review aims to provide a comprehensive, conceptually clear, and accessible introduction to the physics of (re)heating, tailored to the particle physics community. We critically examine the standard Boltzmann approach, emphasizing its limitations in capturing the intrinsically non-perturbative and non-linear dynamics that dominate the early stages of energy transfer. These include explosive particle production, inflaton fragmentation, turbulence, and thermalization—phenomena often overlooked in perturbative treatments. We survey a wide range of theoretical tools, from Boltzmann equations to lattice simulations, clarifying when each is applicable and highlighting scenarios where analytic control is still feasible. Special attention is given to model-dependent features such as preheating, the role of fermions, gravitational couplings, and the impact of multifield dynamics. We also discuss exceptional cases—including Starobinsky-like models and instant preheating—where reheating proceeds through analytically tractable channels without requiring full non-linear simulations. Ultimately, this review serves both as a practical guide and a cautionary tale, advocating for a more nuanced and physically accurate understanding of this pivotal epoch within the particle physics community.
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