Cold electroweak baryogenesis and quantum cosmological correlations

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Citation for published version (APA):
Currently the evolution of cosmological correlations after horizon exit is calculated using classical physics, which is expected to be a good approximation. Yet there are reasons to study quantum corrections to cosmological correlations. First it is important to estimate the size of the quantum corrections, and to check if the approximation is indeed good. Second there is a more fundamental reason: we should check if we understand quantum field theory well enough to be able to do these calculations and if it behaves as we expect it to behave, or quoting [102], we “ought to know what our theories entail”.

In this context we studied in chapter 7 a toy model of $\phi^3$ theory on an exact de Sitter background. We formulated the CTP formalism of quantum field theory in a suitable way, and derived the corresponding diagrammatic expansion. Next we derived which terms contain contributions that grow after horizon exit (late time contributions).

In our classical theory with statistical fluctuations, all the late time contributions of the quantum theory at tree level can be reproduced exactly. Those at one loop level can be reproduced approximately, by using suitable initial conditions and a carefully chosen ultraviolet cutoff. The classical methods discussed in section 6.2.3 can have errors at this order: the stochastic approach usually has an ultraviolet cutoff that is smaller than the Hubble scale $H$, and the $\delta N$ formalism uses smoothing which also leads to errors.

From two loop level on, there can be late time contributions in the quantum theory from large internal momenta that cannot be reproduced by a classical theory.

It would be interesting to extend this work by applying this method to the curvature perturbation $\zeta$, which has (much) more complicated interactions than the toy model. The arguments [116, 118] that show that $\zeta$ is conserved to all orders outside the horizon use a smoothing assumption. It is possible that without this assumption, $\zeta$ is not conserved.
anymore to all orders.