Quantum incompleteness of inflation

Inflation is most often described using quantum field theory (QFT) on a fixed, curved spacetime background. Such a description is valid only if the volume of the background is so large that its moduli do not fluctuate quantum mechanically. However, if we trace an inflating universe back to early times, the volume of any comoving region becomes exponentially small. Hence, quantum fluctuations in the trajectory of the background cannot be neglected. Here, we develop a path integral description of flat, inflating patch, coupling the background moduli to gravitational waves treated at leading (quadratic) order. We show this description fails at small values of the initial scale factor, because *two* background classical solutions contribute significantly to the gravitational path integral. The interplay of the two solutions leads to a failure of QFT in curved spacetime, causing the fluctuations to be unstable and out of control. We show how the problem may be alleviated by a careful quantum choice of the initial, inflating patch. However in order to recover the traditional result, one must prescribe not only the inflating background, but stable, Bunch-Davies fluctuations by hand, which is a serious fine tuning. Our work shows in detail how, even if $H \ll M_{Pl}$, new physics is required to explain the initial quantum state of the universe.