

Opening up window of post-inflationary QCD axion

The QCD axion cosmology depends crucially on whether the QCD axion is present during inflation or not. We point out that contrary to the standard criterion, the Peccei-Quinn (PQ) symmetry could remain unbroken during inflation, even when the axion decay constant, f_a , is (much) above the inflationary Hubble scale, H_I . This is achieved through the heavy-lifting of the PQ scalar field due to its leading non-renormalizable interaction with the inflaton, encoded in a high-dimensional operator which respects the approximate shift symmetry of the inflaton. The mechanism opens up a new window for the post-inflationary QCD axion and significantly enlarges the parameter space, in which the QCD axion dark matter with $f_a > H_I$ could be compatible with high-scale inflation and free from constraints on axion isocurvature perturbations. There also exist non-derivative couplings, which still keep the inflaton shift symmetry breaking under control, to achieve the heavy-lifting of the PQ field during inflation.

Additionally, by introducing an early matter domination era, more parameter space of high f_a could yield the observed DM abundance.

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