Dynamical breaking of shift-symmetry in supergravity-based inflation[†]

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The observations of the cosmic microwave background (CMB) temperature anisotropies[1,2)] now strongly support the occurrence of primordial inflation in the early Universe. The observed temperature anisotropy can be well fitted by the primordial perturbations generated during inflation and the anticorrelation of the temperature (T) and E-mode polarization at large angular scale suggests that the primordial perturbations have been stretched on superhorizon scales[1,2)]. In addition, very recently, BICEP2 reported the detection of the primordial tensor perturbations through the B-mode polarization as[3)]

$$r = 0.20^{+0.07}_{-0.05} \text{ (68\%CL)}, \tag{1}$$

where r is the tensor-to-scalar ratio. To explain this large tensor-to-scalar ratio is challenging for cosmology and particle physics because of the Lyth bound[4)]: one would expect a super-Planckian excursion of the inflaton field in order to generate large r.

Generally speaking, the super-Planckian excursion of the inflaton is problematic from the effective field theory (EFT) point of view. In particular, within string theory there are many scales, the string scale, M_s, the compactification scale, M_c and the derived 4 dimensional Planck scale, with a spectrum, $M_s \leq M_c \leq M_p$. Beyond M_s there are quantum corrections not only to the inflaton potential but also to the inflaton kinetic term which can lead to various complications. Even if we assume that we have only one fundamental scale, such as M_p, there are many issues pertaining to the validity of an EFT when the field's VEV goes beyond M_p. In principle, a gauge singlet inflaton can couple to many degrees of freedom, including the Standard Model and the hidden sector degrees of freedom. Typically, the individual inflaton's couplings to matter has to be smaller than 10^{-3} to maintain the flatness of the inflaton potential and also to match the density perturbations created during inflation.

In spite of all these challenges, we wish to ask the question - whether can we explain *at least* a such small inflaton couplings to matter, and large inflaton's VEV during inflation within an EFT approach by invoking some symmetry such as *shift-symmetry*, $\phi \to \phi' = \phi + c$, where ϕ is the inflaton and c is a constant. Within EFT, one has to ensure that the inflaton's and *all other field's* kinetic terms are small, and here we simply assume so in some patch of the Universe just to be within the EFT regime. Such a *shift-symmetry* has been for the first time introduced in the context of chaotic inflation in supergravity (SUGRA)[5,6)]. However, based on the same token if *shift-symmetry* remains unbroken inflation would never occur in our patch of the universe. The *shift-symmetry* has to be broken, but in such a way that the breaking remains *soft*, which could be understood via some dynamics of the fields. A hard breaking can be introduced[5,6)], but the predictions can be lost or one has to resort to some anthropic arguments.

The purpose of this work is to illustrate a concrete model of dynamical shift symmetry breaking. We showed that it is indeed possible to break the *shift-symmetry* dynamically within 4 dimensional supergravity prior to a long phase of inflation. Thanks to the *shift-symmetry*, the leading contribution to the inflaton potential is free from the dangerous exponential factor even after its breaking, which is the main obstacle to realizing the super-Planckian inflation in supergravity. In our simple mode, the resulting effective inflaton potential schematically takes the form $V_{\text{eff}}(\phi_{\text{inf}}) \sim \cos \dfrac{\phi_{\text{inf}}}{\mu}$ with μ being the dynamical symmetry breaking scale. This potential can induce an inflationary epoch with the inflaton excursion $\Delta\phi_{\text{inf}} \sim \mu$. Unfortunately, in this model, it is difficult to realize the super-Planckian inflation $\Delta\phi_{\text{inf}} > M_p$ as long as the dynamical symmetry breaking scale μ is sub-Planckian. We hope to extend our simple model to realize the super-Planckian inflation, in near future.

References

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