Supersymmetry-Breaking Models of Inflation

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August, 1997

Abstract

We consider dynamical models of supersymmetry breaking which naturally incorporate cosmological inflation. The inflaton plays an inevitable role in dynamical SUSY breaking and the hierarchical scales of inflation and SUSY breaking are simultaneously realized through a single dynamics.
Supersymmetry, if present in nature, is broken at low energy so that the observed particles do not have superpartners with the same masses. Spontaneous SUSY breaking at low energy may be realized through dynamics of nonabelian gauge theory. The vector-like model of dynamical SUSY breaking [1] provides one of the simplest models that serve as realistic SUSY-breaking sectors [2] of the SUSY standard model.

In this paper, we provide a slight modification of the vector-like model of dynamical SUSY breaking, which naturally incorporates cosmological inflation of the hybrid type [3]. The inflaton plays an inevitable role in dynamical SUSY breaking and the hierarchical scales of inflation and SUSY breaking are simultaneously realized through a single dynamics.

Let us consider a SUSY SU(2) gauge theory with four doublet chiral superfields $Q_i$ and six singlet ones $Y^a$ and $Z$. Here $i$ and $a$ denote the flavor indices ($i = 1, \cdots, 4; a = 1, \cdots, 5$). Without a superpotential, this model has a flavor SU(4)$_F$ symmetry. We impose a flavor SP(4)$_F$ symmetry on our model, where we adopt a notation SP(4)$_F \subset$ SU(4)$_F$. The superpotential of our model is given by

$$W = W_Y + W_Z; \quad W_Y = \lambda_Y Y^a (QQ)_a, \quad W_Z = \frac{\lambda_Z}{M^{2(n-1)}} Z (QQ)^n,$$

where $\lambda_Y$ and $\lambda_Z$ denote coupling constants of order one and $(QQ)_a$ and $(QQ)$ denote a five-dimensional representation and a singlet of SP(4)$_F$, respectively, in the gauge invariants $Q_i Q_j$, which constitute a six-dimensional representation of SU(4)$_F$. We take the reduced Planck scale $M$ as a natural cutoff in supergravity, which is assumed in our construction.

SUSY breaking is realized in the present model with the same dynamics investigated in Ref.[1]. Indeed, for $n = 1$, the model is none other than the vector-like model of dynamical SUSY breaking. We henceforth put $n > 1$ to achieve a hierarchical structure of the physical scales in the model.\footnote{If one would like to avoid a nonrenormalizable interaction in the superpotential $W$, one may consider the case $n = 1$ with a tiny coupling $|\lambda_Z| \ll 1$.}

The SUSY-breaking scale is given by $F_Z \simeq \lambda_Z \Lambda^{2n} / M^{2(n-1)}$, where $\Lambda$ is a dynamical scale of the SU(2) gauge interaction. Note that the superpotential $W_Y$ plays a crucial role to cause dynamical SUSY breaking in the present model.

In a regime $|Y^a| \gg \Lambda$, the effective superpotential of the model is given by
and the effective Kähler potential is approximately canonical. Hence the effective potential is almost flat along $Y^a$ with $V_{\text{eff}} \simeq |\lambda_Y \Lambda^2|^2$. This is appropriate for inflationary dynamics.\(^2\) In fact, the radiative and supergravity corrections to the effective potential allow the field space $|Y^a| \leq M$ to possess a region large enough which satisfies the slow-roll condition for inflation \([3, 5]\). The point is that the scale of inflation can be much larger than that of the SUSY breaking in our model, which is suitable for realistic primordial inflation. It is remarkable that the model for SUSY breaking automatically contains an inflationary sector $W_Y$ in the present construction.

In the above model, the singlet $Z$ contains a light scalar component compared with the SUSY-breaking scale. We may make it heavier through radiative corrections \([6]\) by means of a superpotential

$$W'_{Z} = Z[n \lambda Z M^2 (n-1) (QQ)^n - \lambda X X^2] + \frac{f (QQ)^m Z' X}{M^{2n-1}}$$

instead of $W_Z$ in the superpotential $W$, where we have introduced additional singlets $X$ and $Z'$.

We finally consider a variant of the above model which incorporates ‘new inflation’ rather than SUSY breaking. Let us take a superpotential

$$W''_{Z} = \frac{\lambda Z}{M^{2(n-1)}} (QQ)^n Z - \frac{f}{M^2} Z^5$$

instead of $W_Z$ in the superpotential $W$. Then the sector given by $W_Y$ may yield ‘pre-inflation’ \([7]\), which dynamically realizes the initial condition for ‘new inflation’ \([8]\) of the inflaton $Z$.\(^3\) The point here is again that the scale of ‘pre-inflation’ can be much larger than that of ‘new inflation’ in the model, which leads to the initial condition for realistic ‘new inflation’.

We have presented a few models with two hierarchical scales of physical interest generated naturally by a single dynamics. Along similar lines of construction, we may consider various models with two or more physical scales with large hierarchy.

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\(^2\)A similar dynamics was considered in Ref.\([5]\) to generate a flat potential for inflation.

\(^3\)We considered the case $n = 2$ as a dynamical model of ‘new inflation’ in Ref.\([7]\), which is to be supplemented by a separate sector of ‘pre-inflation’. We here claim that the dynamical model for ‘new inflation’ automatically contains a ‘pre-inflation’ sector in itself, and thus it requires no additional sector of ‘pre-inflation’.
Acknowledgement

The author would like to thank T. Yanagida for valuable discussions.

References


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