FLAT DIRECTIONS IN SUSY GUTS \(^a\)

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It is shown that a realistic SUSY SU(6) GUT can dynamically generate the GUT scale and solve at the same time the doublet-triplet splitting problem. The cosmological implications of such a model are briefly reviewed.

1 Introduction

One of the main reasons to consider supersymmetry as a phenomenological viable model is the hierarchy problem: why is the Higgs boson so light, since it is naively believed that it should get a mass of the order of the next new scale, for example the grand unified scale or the Planck scale. Supersymmetry solves technically this problem, assuring that the boson-fermion cancellations in loop diagrams do not change considerably the scalar mass. There are however two remnants of the hierarchy problem still in susy models.

The first one is to understand, why mass scales in nature are so different, for example, why is \(M_{GUT} \ll M_{Planck}\), or why is \(M_W \ll M_{GUT}\).

The second one is how to achieve the mass splitting between Higgs SU(2) doublets and Higgs SU(3) triplets, which inevitably appear in any GUT.

This short paper deals with the above problems, as well as with cosmological implications. For a longer version see \(^1\).

\(^a\)Talk given by Borut Bajc at SUSY'01, Dubna, Russia
2 Flat directions

It has been shown long ago\footnote{\textsuperscript{3}} that flat directions in supersymmetric models can generate dynamically very different scales. The idea of such a mechanism, known also as dimensional transmutation or radiative symmetry breaking, is very simple: a) have a supersymmetric model with at least one flat direction; this flat direction is exact at any order of perturbation theory due to a supersymmetric non-renormalization theorem; b) break supersymmetry spontaneously or softly, in order to lift this flat direction; higher loop contributions to the effective potential can generate a nontrivial minimum; since these corrections are logarithmic in the flat direction field, this new minimum is exponentially far away from the original scale (for example the susy breaking scale or the soft mass term). In such a way one can reproduce with soft supersymmetry breaking the electroweak\footnote{\textsuperscript{3}} or the GUT\footnote{\textsuperscript{4}} scale from the Planck scale.

The simplest example of a GUT flat direction is given by

\begin{equation}
W = \lambda \text{Tr}(\Sigma^3),
\end{equation}

where $\Sigma$ is an adjoint of the gauge SU(6). The flat direction is

\begin{equation}
\Sigma = \sigma \text{diag}(1, 1, 1, -1, -1, -1).
\end{equation}

Such simple flat directions are present only in SU(2n) theories.

The solution (2) with arbitrary nonzero $\sigma$ breaks the original SU(6) gauge group to SU(3) $\times$ SU(3) $\times$ U(1). To break further one can use for example the Fayet-Iliopoulos D-term of an extra (anomalous) gauge U(1):

\begin{equation}
D_{U(1)} = q_H|H|^2 + q_{\bar{H}}|\bar{H}|^2 - \zeta,
\end{equation}

where $H$ and $\bar{H}$ are the fundamental and antifundamental representations of SU(6) and $q_H, q_{\bar{H}}$ have the same sign as $\zeta$. The supersymmetric solution

\begin{equation}
H = \bar{H} = \sqrt{\zeta/(q_H + q_{\bar{H}})} (0, 0, 0, 0, 0, 1)
\end{equation}

together with (2) clearly breaks the GUT into the standard model.

3 The doublet-triplet splitting

The previous example has unfortunately light Higgs triplets and heavy doublets, which is the opposite of what we want. To obtain the right pattern we need\footnote{\textsuperscript{2}} at least two adjoints ($A, A'$) and two singlets ($S, S'$):

\begin{equation}
W = \lambda \text{Tr}(A^2 A') + \lambda_S S \text{Tr}(AA') + \lambda_{S'} S' \text{Tr}(A'^2).
\end{equation}
The solution is given by $A$ in the $SU(4) \times SU(2) \times U(1)$ direction and proportional to an undetermined (flat direction) $S$ and a zero $A'$. Using again the D-term, one gets exactly two light Higgs doublets and heavy triplets.

4 Cosmology

At high enough temperature the $-T^4$ term dominates and the symmetry restoration takes place, since a large nonzero vev of the flat direction would diminish the number of light degrees of freedom. Due to the flatness of the potential, the critical temperature is only of order $(m_3/2M_{GUT})^{1/2}$, which is safe for the production of monopoles. Also, the phase transition is first order, reducing further the production rate. Of course, all this is relevant only if the phase transition really takes place, which is the subject of further studies.

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References

1. B. Bajc, I. Gogoladze, R. Guevara and G. Senjanović, hep-ph/0108196.
2. E. Witten, Phys. Lett. B 105, 267 (1981).
3. L. Alvarez-Gaume, J. Polchinski and M. B. Wise, Nucl. Phys. B 221, 495 (1983).
4. K. Tabata, I. Umemura and K. Yamamoto, Phys. Lett. B 127, 90 (1983); H. Goldberg, Phys. Lett. B 400, 301 (1997).
5. G. Dvali and S. Pokorski, Phys. Rev. Lett. 78, 907 (1997).
6. G. Dvali and L. Krauss, hep-ph/9811298; B. Bajc and G. Senjanović, Phys. Rev. D 61, 103506 (2000).
7. F. R. Klinkhamer, Phys. Lett. B 110, 203 (1982); P. Ginsparg, Phys. Lett. B 112, 45 (1982); S. Pi, Phys. Lett. B 112, 441 (1982).
8. K. Yamamoto, Phys. Lett. B 133, 315 (1983).

\footnote{An opposite behaviour is however possible due to different initial conditions.}