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Dynamical Supersymmetry Breaking in Vector-Like Gauge Theories

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We provide vector-like gauge theories which break supersymmetry dynamically.

There is a piece of folklore which holds that voctor-like gauge theories cannot break supersymmetry dynamically. In this paper, we point out remarkable exceptions to this piece of folklore.

Let us consider a supersymmetric $SU(2)$ gauge theory with four doublet chiral superfields Q_i. We also introduce six singlet chiral superfields $Z^{ij}=-Z^{ji}$. Here i and j denote the flavor indices ($i, j=1, \cdots, 4$).

The tree-level superpotential of our model is given by**)

$$W_{\text{tree}}=\lambda_{ij}^{kl}Z^{ij}Q_kQ_l\,, \tag{1}$$

where the λ_{ij}^{kl} denote generic coupling constants with $\lambda_{ij}^{kl}=-\lambda_{ji}^{kl}=-\lambda_{ij}^{lk}$. The peculiarity of this superpotential resides in the fact that it raises all the D-flat directions in the doublets Q_i, which is a necessary condition for supersymmetry to break down.[1] Of course, supersymmetry remains unbroken perturbatively in this model.

The exact effective superpotential of the model, which takes into account the full nonperturbative effects, may be written in terms of gauge-invariant low-energy degrees of freedom[2]

$$V_{ij}=-V_{ji}\sim Q_iQ_j \tag{2}$$

as follows:

$$W_{\text{eff}}=X(\text{Pf}\,V_{ij}-\Lambda^4)+\lambda_{ij}^{kl}Z^{ij}V_{kl}\,, \tag{3}$$

where X is an additional chiral superfield, PfV_{ij} denotes the Pfaffian of the antisymmetric matrix V_{ij}, and Λ is a dynamical scale of the $SU(2)$ gauge interaction.[2),3)] This is none other than a superpotential of the O'Raifeartaigh type.[4] Namely, this effective superpotential yields conditions for supersymmetric vacua

$$\text{Pf}\,V_{ij}=\Lambda^4\,,\quad \lambda_{ij}^{kl}V_{kl}=0\,, \tag{4}$$

which cannot be satisfied simultaneously as long as $\Lambda\neq 0$. Therefore we conclude that supersymmetry is dynamically broken in our model.

We note that this conclusion is not in contradiction with the index argument.[5]

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**) This tree-level superpotential is natural since it possesses two global symmetries. One is an axial $U(1)$ symmetry associated with a Q_i phase transformation and the other is an anomaly-free R symmetry.

The doublets Q_i cannot be decoupled by means of mass terms $m^{ij}Q_iQ_j$, since the apparent masses may be absorbed in the shifts of the singlets Z^{ij}.

It is straightforward to generalize the above model to an $Sp(N)$ gauge theory[6] with $2(N+1)$ chiral superfields in the $2N$ representation. Here we adopt the notation $Sp(1)=SU(2)$.

These vector-like models might serve as a supersymmetry-breaking mechanism in the hidden[7] or visible sector.

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