# Signals of Dynamical Supersymmetry Breaking in a Hidden Sector

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## ABSTRACT

If supersymmetry is dynamically broken in a hidden sector, the gauginos typically have unacceptably small masses. This situation can be corrected if a non-Abelian gauge interaction becomes strong at a scale of order 1 TeV and induces dynamical gaugino masses. We discuss the typical signals of this scenario at present and future colliders.

If supersymmetry (SUSY) breaking is communicated from a hidden sector to the visible sector by supergravity, then the squarks and sleptons acquire masses suppressed by one power of the Planck scale: $\Lambda_{\rm SB}^2/M_P$ , where $\Lambda_{\rm SB}$ is the SUSY breaking scale. Therefore, SUSY is relevant at the electroweak scale provided $\Lambda_{\rm SB} \sim 10^{11}$ GeV. The gauginos get masses of order $\Lambda_{\rm SB}(\Lambda_{\rm SB}/M_P)^n$, where $n$ is the lowest dimension of the gauge invariant operators from the hidden sector [1]. Current limits on the gluino mass require $n = 1$, i.e. there should be a gauge singlet in the hidden sector. However, the hierarchy between $\Lambda_{\rm SB}$ and $M_P$ requires dynamical SUSY breaking, and the majority of the models of this type cannot accommodate gauge singlets [1, 2] (possible exceptions may be found in [3]). Furthermore, mass terms for gauge singlets can be forbidden only by global symmetries, which are expected to be violated by Planck scale effects [4]. Thus, any gauge singlet is likely to have a mass of order $M_P$, so that a VEV of order $\Lambda_{\rm SB}$ would require an unacceptable amount of fine tuning. Note that this problem is more severe than the existence of light singlets under the Standard Model (SM) gauge group (as the ones used to generate a $\mu$ term), which may be protected by discrete gauge symmetries.

Therefore, hidden sector models may be realistic only if an additional source of gaugino masses is provided. This can be done, without reintroducing a hierarchy problem, if new gauge interactions become strong at a scale $\Lambda_{\rm G} \sim 1$ TeV. The idea is to produce dynamical masses for some fields whose spectrum is non-supersymmetric due to the usual supergravitational interactions, and then to feed these dynamical masses into one-loop gaugino masses. A specific example is constructed in ref. [5]. Here we discuss the signatures of this class of models at present and future colliders.

A striking feature of this scenario, as opposed to the usual supergravity (SUGRA) models which are not concerned with the mechanism for dynamical SUSY breaking, is that the gaugino masses fall off at large momenta. As a result, the radiative corrections to the squark and slepton masses coming from gauge interactions are small. This can be seen by evaluating the one-loop gluino contribution to the squark self energy shown in Fig. 1.

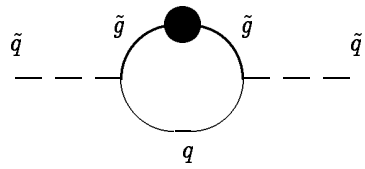


Fig. 1. Gluino-quark contribution to the squark mass. The • is the dynamical gluino mass.

The quadratic divergence is cancelled by two other one-loop diagrams, involving a gluon and the same squark, respectively. The dynamical gluino mass, represented by a • in Fig. 1, can be approximated by a momentum independent mass, $M_3$, which vanishes at energies above $\Lambda_{\rm G}$. Therefore, the one-loop integral should be cut-off at $\Lambda_{\rm G}$, and the result is

$$\delta M_{\tilde{q}}^2 \approx \frac{8}{3\pi}\alpha_s(\Lambda_{\rm G}) M_3^2 \log\left(\frac{\Lambda_{\rm G}}{M_3}\right) , \qquad (1)$$

where $\alpha_s(\Lambda_{\rm G}) \approx 0.1$ is the QCD coupling constant at the scale $\Lambda_{\rm G}$. As we will argue below, the squark mass, $M_{\tilde{q}}$, is significantly larger than $M_3$, implying $\delta M_{\tilde{q}}^2 \ll M_{\tilde{q}}^2$. Similarly, the gaugino contributions to the slepton masses are small.

An equivalent description of these radiative corrections can be given in terms of the renormalization group evolution: the running of the squark and slepton masses from $\Lambda_{\rm SB}$ down to $\Lambda_{\rm G}$ is not affected to leading order by gauge interactions. Hence, if the Kahler potential is minimal, then the squarks and sleptons are almost degenerate at the electroweak scale. The only exceptions are the stops, which are lighter due to the large radiative corrections induced by the top Yukawa coupling.

Since the scale of SUSY breaking in the spectrum of the fields carrying the new gauge interactions is of order 1 TeV, we expect the squarks and sleptons to be rather heavy, in the 0.5 – 1 TeV range. The gluino mass, $M_3$, is suppressed by a factor of $\alpha_s(\Lambda_{\rm G})$ times some group factor that arises from the coupling to the fields with dynamical masses. Therefore, $M_3 \sim 100 - 300$ GeV is the typical range.

The Majorana masses for the $U(1)_Y$ gaugino, $M_1$, and $SU(2)_W$ gaugino, $M_2$, are proportional to the hypercharge and weak coupling constants ($\alpha_1$ and $\alpha_2$), respectively, provided that the superfields responsible for these masses transform non–trivially under the SM group. The usual relations from GUT theories will not hold in general because the gaugino masses also depend on the SM charges of the fields carrying the new gauge interactions. In the model presented in ref. [5], the gaugino mass ratios are given by

$$M_3 : M_2 : M_1 \quad = \quad \frac{1}{3}t(R_3)\alpha_s(\Lambda_{\rm G}) : \frac{1}{2}t(R_2)\alpha_2(\Lambda_{\rm G})$$

$$: t(R_1)\alpha_1(\Lambda_G) \ , \qquad (2)$$

where $t(R_k)$, $k = 1, 2, 3$, are the indices of the color, weak and hypercharge representations of the fields with dynamical masses. It appears naturally that the inequalities $M_1 < M_2 < M_3$ remain true, with $M_1$ of order 30 GeV and $M_2$ of order 100 GeV. On the other hand, if the chiral superfields responsible for the Majorana masses are weak singlets, which is the most economical alternative, then $M_2 = 0$.

Consider a typical set of parameters in the visible sector:

$$\begin{aligned} M_1 = 50 \text{ GeV} \ , \ M_2 = 100 \text{ GeV} \ , \ M_3 = 200 \text{ GeV} \ , \\ \tan\beta = 5 \ , \ \mu = 180 \text{ GeV} \ , \ M_{\tilde{Q}} \simeq M_{\tilde{\ell}} = 800 \text{ GeV} \ , \\ m_A = 900 \text{ GeV} \ , \ M_{\tilde{t}_1} = 560 \text{ GeV} \ , \ M_{\tilde{t}_2} = 570 \text{ GeV} \ . \end{aligned} \qquad (3)$$

The lightest particles are then the neutralinos $(\tilde{N}_1, \tilde{N}_2, \tilde{N}_3, \tilde{N}_4) = (39, 75, 190, 225)$ GeV, charginos $(\tilde{C}_1, \tilde{C}_2) = (69, 225)$ GeV, the gluino $\tilde{g} = 249$ GeV, and the Higgs $h$ = 104 GeV. The largest cross sections at a hadron collider are $\tilde{C}_1\tilde{N}_2$, $\tilde{C}_1\tilde{C}_1$ and $\tilde{g}\tilde{g}$ production, with $\tilde{C}_1 \to W^*\tilde{N}_1$, $\tilde{N}_2 \to Z^*\tilde{N}_1$, and $\tilde{g} \to \tilde{C}_i/\tilde{N}_i jj$. The expected signatures are trilepton, dilepton, and 4 jet events plus missing $E_T$. LEP2 would be sensitive to chargino pair production. Despite the fact that the soft parameters of the model have quite a different origin, the phenomenology looks very similar to a SUGRA model. Of course, the usual relationship between the neutralino/chargino masses and the gluino mass is modified, giving a possible handle on the underlying theory.

An alternative possibility is the set of parameters (3) but with

$$M_2 = 0 \ , \ \tan\beta = 1.5 \ , \ \mu = -50 \text{ GeV} \ . \qquad (4)$$

This corresponds to the case when the fields responsible for the Majorana masses are SU(2)$_W$ singlets. The values of $\tan\beta$ and $\mu$ are chosen to give compatibility with LEP limits. The mass spectrum is then $(\tilde{N}_1, \tilde{N}_2, \tilde{N}_3, \tilde{N}_4) = (31, 47, 88, 115)$ GeV, $(\tilde{C}_1, \tilde{C}_2) = (53, 112)$ GeV, $\tilde{g} = 249$ GeV, and $h$ = 73 GeV. The largest cross sections at a hadron collider are $\tilde{N}_1\tilde{N}_1$, $\tilde{N}_1\tilde{N}_2$, $\tilde{C}_1\tilde{C}_1$, $\tilde{N}_1\tilde{C}_1$ and $\tilde{g}\tilde{g}$ production. As before, $\tilde{C}_1 \to W^*\tilde{N}_1$, but there is a sizable branching fraction for $\tilde{N}_2 \to \gamma\tilde{N}_1$, giving a possible signal of $\gamma$ and missing $E_T$. The usual trilepton signature would be absent. LEP2 would be sensitive to chargino and neutralino pair production, the latter giving a striking $\gamma$ plus missing $E$ signal.

So far we have seen that the potential signals of hidden sector dynamical SUSY breaking at the existing colliders and their upgraded versions are related only to the gaugino and Higgs sectors, and are peculiar only for a class of models. However, if squark and slepton production will be possible at the next generation of colliders, then the spectrum of these particles will provide an important test of hidden sector dynamical SUSY breaking. The reason is that in most models of SUSY breaking [6] the squarks are significantly heavier than the sleptons, while the models discussed here predict approximate squark-slepton degeneracy.

At even higher energies it will be possible to probe the strongly coupled sector responsible for gaugino masses. If pseudo Goldstone bosons result from the strong dynamics, then they will be the first particles beyond the minimal supersymmetric SM to be seen. In the model discussed in [5] the chiral symmetry of the fields carrying the new strong interaction is spontaneously broken leading to three Goldstone bosons. This chiral symmetry is also explicitly broken such that the Goldstone bosons get masses of order 1 TeV. Since the new non-Abelian gauge interactions become strong at a scale of order 1 TeV, scaling from QCD suggests that the lightest composite states beyond the Goldstone bosons will have masses in the 5 – 10 TeV range. In conclusion, if SUSY is dynamically broken in a hidden sector, a very rich phenomenology will emerge at future colliders.

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# I. REFERENCES

[1] I. Affleck, M. Dine and N. Seiberg, Nucl. Phys. **B 256** (1985) 557.

[2] I. Affleck, M. Dine and N. Seiberg, Phys. Rev. Lett. **52** (1984) 1677; Phys. Lett. **B 137** (1984) 187; Phys. Lett. **B 140** (1984) 59;
Y. Meurice and G. Venziano, Phys. Lett. **B 141** (1984) 69;
D. Amati, K. Konishi, Y. Meurice, G. C. Rossi and G. Venziano, Phys. Rep. **162** (1988) 170;
K. Intriligator, N. Seiberg and S. H. Shenker, Phys. Lett. **B 342** (1995), hep-ph/9410203;
M. Dine, A. E. Nelson, Y. Nir and Y. Shirman, Phys. Rev. **D 53** (1996) 2658, hep-ph/9507378;
E. Poppitz and S. P. Trivedi, Phys. Lett. **B 365** (1996) 125, hep-th/9507169;
C. Csaki, L. Randall and W. Skiba, report no. MIT-CTP-2532 (1996), hep-th/9605108;
C.-L. Chou, hep-th/9605119;
E. Poppitz, Y. Shadmi and S. P. Trivedi, report no. EFI-96-24 (1996), hep-th/9606184;
C. Csaki, L. Randall, W. Skiba and R. G. Leigh, report no. MIT-CTP-2543 (1996), hep-th/9607021;
C. Csaki, W. Skiba and Schmaltz, report no. MIT-CTP-2543, BU-HEP-96-23 (1996), hep-th/9607210;
K. Intriligator and S. Thomas, report no. SLAC-PUB-7143 (1996), hep-th/9608046.

[3] A. E. Nelson, Phys. Lett. **B 369** (1996) 277, hep-ph/ 9511350;
K. Izawa and T. Yanagida, Prog. Theor. Phys. **B 95** (1996) 829, hep-th/9602180;
K. Intriligator and S. Thomas, Nucl. Phys. **B 473** (1996) 121, hep-th/9603158.

[4] S. Giddings and A. Strominger, Nucl. Phys. **B 307** (1988) 854;
S. Coleman, Nucl. Phys. **B 310** (1988) 643;
G. Gilbert, Nucl. Phys. **B 328** (1988) 159.

[5] B. A. Dobrescu, Phys. Rev. **D 53** (1996) 6558, hep-ph/9510424.

[6] For a review, see M. E. Peskin, report no. SLAC-PUB-7133 (1996), hep-ph/9604339.