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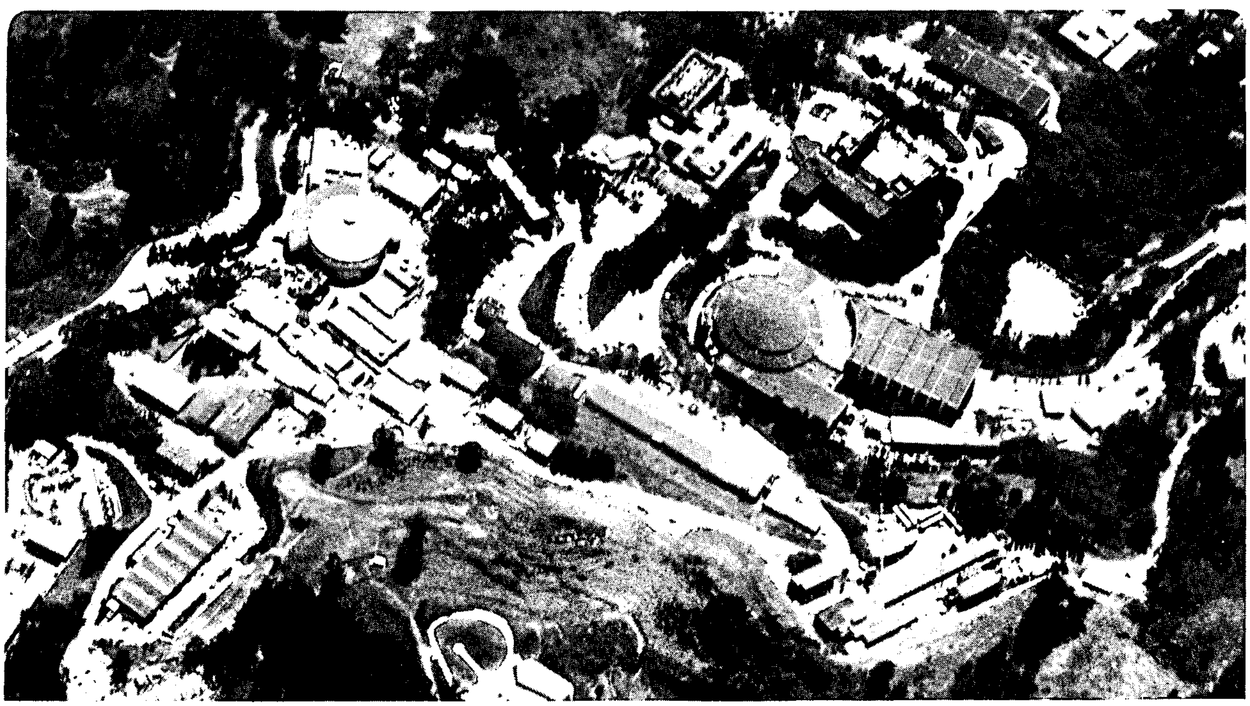

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GAUGINO MASSES IN SUPERSTRING INSPIRED MODELS*

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Contributions to the masses of the gauginos in models arising as low energy limits of superstring theories are considered.

*This work was done in collaboration with P. Binétruy and I. Hinchliffe

Low-energy models based on superstring theories have received much attention in the last several years. This is due to the fact that if 10-dimensional superstring models based on the gauge group $E_8 \times E_8$ are compactified, it is possible to obtain a low energy theory with a spectrum of quark and lepton fields compatible with that observed.[1] After compactification, the theory is described by an unbroken N=1 supersymmetry and a gauge group of the form K x G. G describes the interactions of the observable world of quarks and leptons which are singlets under K. Fields in the adjoint of K are singlets under G and form a hidden sector. The sectors K and G are coupled only by gravitational interactions.

Our model is completely determined by the gauge fields kinetic term, the Kähler potential $\mathcal{G}$, and the effective superpotential W. With these three ingredients, we are left with the standard N=1 theory of supergravity coupled to ordinary matter.

One field of particular relevance for our results is the dilaton field common to all superstring theories.[2] As a result of compactification, the dilaton combines with some fields related to the Kähler structure to form the scalar component, S, of a chiral supermultiplet $\mathcal{S}$. This field couples in identical ways to the gauge multiplets of the two sectors,

$$\mathcal{L} = \tfrac{1}{4} \int d^2\theta \; S W^{\alpha} W_{\alpha} + \text{h.c.} \qquad (1)$$

where we use a superfield notation in which W^{α} denotes both the K and G gauge supermultiplets.

A simple truncation of the string theory which is believed to reproduce the basic properties of compactification on a Calabi-Yau manifold gives for the Kähler potential,

$$\mathcal{G} = -\ln(S+S^*) - 3\ln(T+T^* - 2\sum_i |\phi_i|^2) + \ln|W|^2 \qquad (2)$$

where T is another combination of the dilaton and fields related to the Kähler structure, and the ϕ_i are the scalar fields of the observable sector. The superpotential W is a function of degree three or higher of the ϕ_i fields only.

If the gauge group K becomes strong at some scale Λ, then a condensate of the gauginos of the group K can occur. A non-zero gravitino mass $m_{3/2}$ is generated, along with a non-zero cosmological constant. After integrating out the gaugino condensates in the hidden sector, we are left with the effective superpotential,[3]

$$W = c + h e^{-3S/2b_o} \qquad (3)$$

where b_o is the coefficient of the one loop beta function of the hidden sector , h and c are constants, and we set $\phi_i = 0$ in what follows.

The observable sector of this model is unaware of supersymmetry breaking at this order. The scalar masses in the observable sector remain zero, as do the gaugino masses. Even one loop corrections fail to generate non-zero scalar masses.[4] The low energy gauge symmetry in these models is broken only if some scalar mass-squared becomes negative. Since the renormalization group equations for scalar and gaugino masses are coupled, a non-zero gaugino mass can trigger the symmetry breaking process. In this paper we investigate the masses of gauginos at one loop.[5]

The first contribution is from loops involving gravitinos, which will be present in any theory coupled to supergravity.[6] The diagrams of Fig. 1 give an equal contribution to all gaugino masses. Both the logarithmic and quartic divergences cancel and the result is a finite contribution to gaugino masses,

$$m_1 = \frac{2m_{3/2}^3}{\pi M_p^2} . \quad (4)$$

We turn now to the contributions specific to the models which are believed to arise from superstring theories. The first contribution involves χ, the spin ½ partner of S. The contributions to the gaugino masses are given, as in the gravitino case, by the tadpole and gauge loop diagrams of Fig. 1 with ψ_μ replaced by χ. Again the divergences cancel and we are left with the finite contribution,

$$m_2 = \frac{m_{3/2}^3 \omega^3}{\pi M_p^2} \quad (5)$$

where $\omega \equiv \frac{3}{b_o}$ Re <S> and b_o is the one-loop beta function of the hidden sector K.

Finally there are contributions to the gaugino masses involving the scalar field S. These are more difficult to evaluate since the S field kinetic term is not canonical and, as in the non-linear σ-model, cannot be put in canonical form by a redefinition of the fields,

$$\mathcal{L}_{K.E.} = \frac{1}{4(\mathrm{Re}S)^2} \partial_\mu S \partial^\mu S^* . \quad (6)$$

Our result must not depend on the particular parametrization that we choose for our fields. The simplest way to achieve this is to keep the field redefinition invariance explicit at each order of the quantum expansion. The procedure for doing this is explained in Ref. (5).

We evaluate the Feynman diagrams of Fig. 2 to obtain the contribution of the S scalars to the gaugino masses. The quadratic divergences cancel between these contributions leaving a residual logarithmic divergence. This divergence is cut off at the scale of the gaugino condensate in the hidden sector (Λ). Above this scale supersymmetry is unbroken and the S scalar is massless. The result is,

$$m_3 = \frac{m_{3/2}^3 \,\omega(\omega-3)}{2\pi M_p^2} \,[4\omega \,\ell n\, \Lambda/m_{3/2} + (1+\omega^2)\,\ell n\left|\frac{1-\omega}{1+\omega}\right| - 2\omega\,\ell n\,(1-\omega^2)] . \quad (7)$$

The total contribution to gaugino masses at one loop is therefore given by Eqs. (4, 5 and 7),

$$m_{1/2} = \frac{m_{3/2}^3}{\pi M_p^2} \{2+\omega^3+\omega(\omega-3)(2\omega\,\ell n\,\frac{\Lambda}{m_{3/2}} + \tfrac{1}{2}(1+\omega^2)\ell n\left|\frac{1-\omega}{1+\omega}\right| - \omega \ell n(1-\omega^2))\} . \quad (8)$$

It is non-zero and gives an equal contribution for all the gauginos in the observable sector.

All masses in the observable sector-gauginos and, through the coupled renormalization group equations, scalars - scale like $m_{3/2}^3 / M_p^2$. Radiative corrections from the Yukawa couplings of the quark, lepton, and Higgs fields induce a negative value of the mass-squared of the Higgs doublet. The requirement that the Higgs vacuum expectation value be stable with respect to higher order corrections fixes the value of $m_{1/2}$ to be of order M_W. We are then led to a value of $m_{3/2}$ of order 10^{13} GeV.

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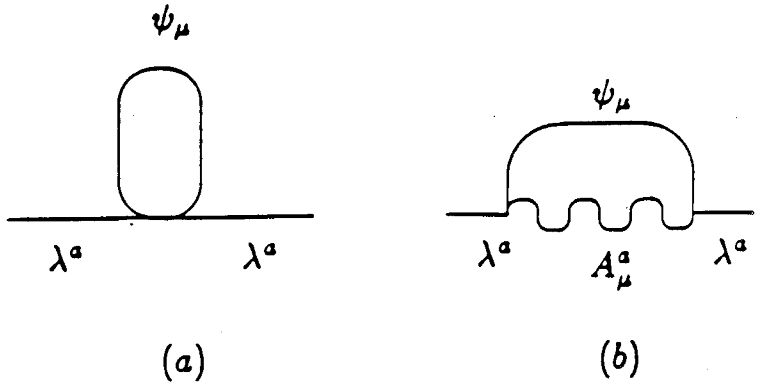

Figure 1. Contribution to gaugino masses from the spin-3/2 graviton, ψ_μ. A^a is the gauge boson associated with the gaugino, λ^a.

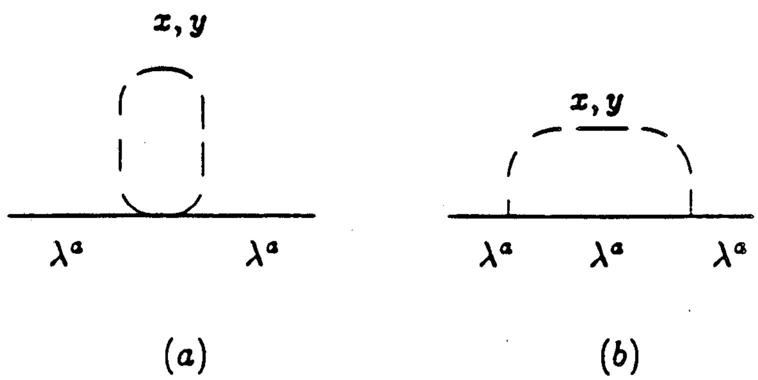

Figure 2. Contribution to gaugino masses from the S scalar. x=Re S and y=Im S.

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