The $\not\mu$SSM and a 125 GeV Higgs? RIP*

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Based on work done with Linda Carpenter
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The Model -$\not{\mu}SSM$ Nelson, Rius, Sanz, Unsal - hep-ph/0206102

Assume all masses arise directly from EWSB or SUSY breaking. Thus the superpotential contains no μ-term. However, in the MSSM with $\mu = 0$ the upper bound on the lightest chargino mass is m_W. Thus, introduce an SU(2) adjoint, A, and SM singlet, S allowing for Dirac gaugino masses.

$$W = W_{\text{Yukawa}} + \lambda_A H_u A H_d + \lambda_S S H_u H_d$$

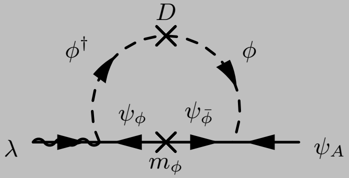
$$m_{\text{MSSM}} = \begin{array}{c} \\ W^- \\ h_d^- \end{array} \begin{array}{c} \begin{array}{cc} W^+ & h_u^+ \end{array} \\ \begin{pmatrix} \tilde{m} & \sqrt{2} m_W s_\beta \\ \sqrt{2} m_W c_\beta & 0 \end{pmatrix} \end{array}$$

$$m_{\not{\mu}\text{SSM}} = \begin{array}{c} \\ A^- \\ W^- \\ h_d^- \end{array} \begin{array}{c} \begin{array}{ccc} A^+ & W^+ & h_u^+ \end{array} \\ \begin{pmatrix} 0 & \tilde{M}_A & \sqrt{2}\lambda h_d^0 \\ \tilde{M}_A & \tilde{m} & \sqrt{2} m_W s_\beta \\ -\sqrt{2}\lambda h_u^0 & \sqrt{2} m_W c_\beta & 0 \end{pmatrix} \end{array}$$

Generating Dirac Masses - Supersoft

We will assume ~~SUSY~~ is communicated to the SM via GMSB. Dirac gaugino masses will then be generated through supersoft operators.

$$W = y\bar{\phi}A\phi + m_\phi \bar{\phi}\phi$$



$$W_{\text{ssoft}} \quad = \quad \zeta \frac{W'_\alpha W_j^\alpha A_j}{\Lambda} + \zeta' \frac{W'_\alpha W'^\alpha A_j A^j}{\Lambda^2}$$

Fox, Nelson, Weiner - hep-ph/0206096

- ζ will give positive mass^2 to the real parts of A and S
- ζ' will give mass^2 of opposite signs to the real and imaginary parts of A and S
- ⋆ One needs to consider messenger sectors with parity violation

Generating Dirac Masses - Supersoft

Once the hidden sector U(1) obtains a D-term

$$
\begin{aligned}
W_{\text{ssoft}} &= \zeta_A \frac{W'_\alpha W^\alpha_j A_j}{\Lambda} + \zeta'_A \frac{W'_\alpha W'^\alpha A_j A^j}{\Lambda^2} + \zeta_S \frac{W'_\alpha W^\alpha S}{\Lambda} + \zeta'_S \frac{W'_\alpha W'^\alpha S^2}{\Lambda^2} \\
&\to \zeta_A \frac{\theta_\alpha D' W^\alpha_j A_j}{\Lambda} + \zeta'_A \frac{\theta_\alpha \theta^\alpha D'^2 A_j A^j}{\Lambda^2} + \zeta_S \frac{\theta_\alpha D' W^\alpha S}{\Lambda} + \zeta'_S \frac{\theta_\alpha \theta^\alpha D'^2 S^2}{\Lambda^2}
\end{aligned}
$$

Where ζ' generates holomorphic mass terms for A and S

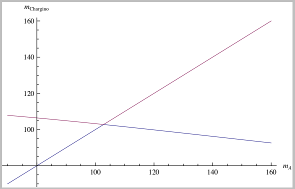
$$V = (b_S S^2 + b_A A^2 + \text{h.c.})$$

And ζ generate the Dirac gaugino mass and shift to MSSM D-terms

$$
\begin{aligned}
D_2 &= m_{DA}(A + A^\dagger) + \Sigma_i g M_i^\dagger T M_i \\
D_1 &= m_{DS}(S + S^\dagger) + \Sigma_i g' q_i M_i^\dagger T M_i
\end{aligned}
$$

Back to Charginos

$$m_{\not\mu\mathrm{SSM}} = \begin{array}{c} \\ A^- \\ W^- \\ h_d^- \end{array} \begin{array}{c} \begin{array}{ccc} A^+ & W^+ & h_u^+ \end{array} \\ \begin{pmatrix} 0 & \tilde{M}_A & \sqrt{2}\lambda h_d^0 \\ \tilde{M}_A & 0 & \sqrt{2}m_W s_\beta \\ -\sqrt{2}\lambda h_u^0 & \sqrt{2}m_W c_\beta & \tilde{\mu} \end{pmatrix} \end{array}$$



In the $\tan\beta \to \infty$ limit

- $\tilde{\mu} = 0$ - One of the two lightest chargino masses increases with $\tilde{M}_A$ while the other decreases.
- $\tilde{\mu} \neq 0$ - For large $\tilde{M}_A$, the lightest two chargino masses $\sim \tilde{\mu}$

So, it would seem we still need a non-zero $\tilde{\mu}$ term to push up the chargino masses.

VEVs for A and S

A vev for S and A will introduce an effective μ-term.

$$W \supset \lambda_A H_u A H_d + \lambda_S S H_u H_d$$

However, we need $\langle A_0 \rangle \sim 0$ due electroweak precision measurements. Additionally the minimization condition along the S direction tells us that a large vev for S implies a large vev for A.

$$2[b_S + 2m_{DS}^2 + m_{S2}^2 + 2\frac{y^2 m_Z^2}{g^2 + g'^2}]S = -4\frac{y\lambda m_Z^2}{g^2 + g'^2} A_0 + g' m_{DS}^2 \left[(h_d^0)^2 - (h_u^0)^2 \right]$$

A VEV for S and More Operators

To get around this we want a way to force the extrema condition in the S direction to be non-linear in S. Thus, add a cubic term to the potential

$$V \supset \kappa S^3$$

On can imagine generating this term from a superpotential term

$$W \supset \zeta_\kappa \frac{W'W'S^3}{\Lambda^3}$$

Furthermore, one will generate trilinear scalar couplings for fields which couple to the messenger sector.

$$W \supset \zeta_{SH} \frac{W'W'SH_uH_d}{\Lambda^3}, \zeta_{SA} \frac{W'W'H_uAH_d}{\Lambda^3}$$

Where Does All This Leave Us

- For tan$\beta \sim 3$ we can find a point where the lightest chargino (mostly charged higgsino) is 145GeV and the lightest neutralino (mix of wino, singlet and neutral higgsinos) is 102GeV. Unfortunately, the higgs mass in this model is 162GeV.
- For a larger tan$\beta \sim 200$ we can get a higgs mass of roughly 125 GeV however the lightest chargino is 24GeV and the lightest neutralino is 0.5GeV.