Title: Supersymmetric U(1)\' Models

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Abstract: Extension of the minimal supersymmetric standard model (MSSM) that include a U(1)\' gauge symmetry are motivated by top-down constructions and offer an elegant solution to the MSSM mu problem. In this talk I will describe some of the opportunities that such models offer, such as a new mechanism for mediation of supersymmetry breaking, as well as some of the challenges in constructing viable supersymmetric U(1)\' models.

Supersymmetric $U(1)'$ Models

Gil Paz

Institute *for* Advanced Study, Princeton

In collaboration with
Paul Langacker, Lian-Tao Wang and Itay Yavin

PRL **100** 041802 (2008) [arXiv:0710.1632]
PRD **77** 085033 (2008) [arXiv:0801.3693]
arXiv:0811.1196 [to appear in PLB]

Motivation

- High(er) energy models (e.g. superstring constructions) often involves extra $U(1)'$

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- Mediation mechanism of SUSY breaking determines the low energy phenomenology

Reminder

- MSSM superpotential

$$W = y_u H_u Q u^c + y_d H_d Q d^c + y_e H_d L e^c + \mu H_u H_d$$

- Soft susy breaking Lagrangian (schematically)

$$\begin{aligned}
\mathcal{L}_{\rm soft} \quad \ni \quad & -\frac{1}{2} m^2 \phi\, \phi^\dagger && \text{(scalar masses)} \\
& -\frac{1}{2} M\, \tilde{\lambda}\, \tilde{\lambda} && \text{(gaugino masses)} \\
& -\frac{1}{6} A\, \phi_i\, \phi_j\, \phi_k && \text{(A terms)} \\
& -\frac{1}{2} b\, \phi_i\, \phi_j \\
& + \quad h.c.
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- Why should SUSY-conserving μ be related to SUSY-breaking m^2 and b ?

  Large $\tan\beta$ limit: $M_Z^2 = -2(m_{H_u}^2 + |\mu|^2) + ...$

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- $U(1)'$ models offer a solution

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$$W = y_u H_u Q u^c + y_d H_d Q d^c + y_e H_d L e^c + \lambda S H_u H_d$$

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\end{aligned}$$

- $\mu_{\rm eff} = \lambda \langle S \rangle$ can be related to SUSY-breaking m^2 and b

Motivation

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- Mediation mechanism of SUSY breaking determines the low energy phenomenology
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Outline

- Z' mediation - A new mediation mechanism of SUSY breaking
  - General features
  - Specific implementation

    Paul Langacker, GP, Lian-Tao Wang, Itay Yavin

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- General issues with SUSY $U(1)'$ models
  - Accidental symmetries
  - Vacuum structure

    Paul Langacker, GP, Itay Yavin arXiv:0811.1196 [to appear in PLB]

Z' Mediation of SUSY Breaking

Paul Langacker, GP, Lian-Tao Wang, Itay Yavin

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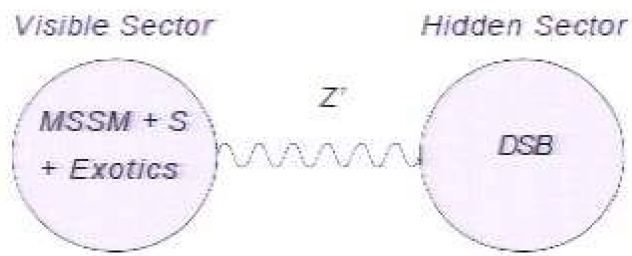
Sectors

- No direct renormalizable interaction between visible and hidden sector fields

- **Both** are charged under $U(1)'$



- At Λ_S the Z'-ino becomes massive. For $X = M + \theta^2 F$

$$M_{\tilde{Z}'} \sim \frac{g_{z'}^2}{16\pi^2}\frac{F}{M}$$

- How are MSSM fields affected?

Reminder

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Masses

- Gaugino $\tilde{\lambda}_i$ decouple when $g_i \to 0$

  $\Rightarrow$ To "feel" SUSY breaking all masses must be $\propto g_{z'}^2$

- Scalar masses

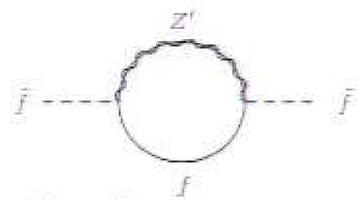
$$m_{\tilde{f}_i}^2 \propto g_{z'}^2$$

- $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauginos' masses must be also $\propto g_a^2$

$$M_a \propto g_{z'}^2 g_a^2$$

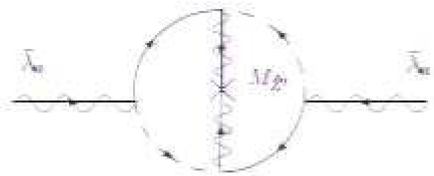
Masses

- Scalars get a mass at one loop



$$m^2_{\tilde{f}_i} \sim \frac{g^2_{z'} Q^2_{f_i}}{16\pi^2} M^2_{\tilde{Z}'} \log\left(\frac{\Lambda_S}{M_{\tilde{Z}'}}\right)$$

- $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauginos get a mass at two loops



$$M_a \sim \frac{g^2_{z'} g^2_a}{(16\pi^2)^2} M_{\tilde{Z}'} \log\left(\frac{\Lambda_S}{M_{\tilde{Z}'}}\right)$$

- Ratio of masses

$$\frac{m_{\tilde{f}_i}}{M_a} \sim \frac{M_{\tilde{Z}'}}{4\pi} \Big/ \frac{M_{\tilde{Z}'}}{(4\pi)^4} = (4\pi)^3 \sim 1000$$

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- LEP direct searches imply EW-ino mass > 100 GeV

  $\Rightarrow$ heavy scalars ~ 100 TeV $\Rightarrow M_{\tilde{Z}'} \sim 1000$ TeV

- Mini version of split-susy (Arkani-Hamed & Dimopoulos 2004)

  split susy scalar mass 10^9 GeV

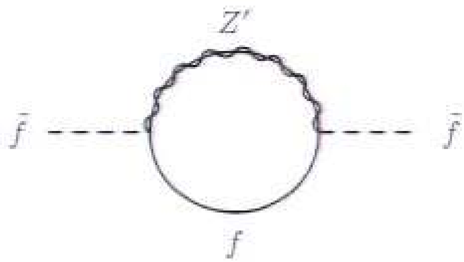
- Like split-susy no flavor or CPV problems due to heavy scalars
- Like split-susy need one fine-tuning to set EW breaking scale
- Unlike split-susy μ parameter scale set by $U(1)'$ breaking

Elements of Z' mediation

- To break the $U(1)'$ symmetry introduce SM singlet field (charged under $U(1)'$)
- $\mu\, H_u\, H_d \;\longrightarrow\; \lambda\, S\, H_u\, H_d \Rightarrow$ Large μ term
- Include exotic matter $\sum_i Y_i\, S\, X_i\, X_i^c$
  - Cancel anomalies associated with $U(1)'$
  - Drive S negative

Driving S negative

- Scalar mass RGE has contributions from various diagrams



$$\Rightarrow \quad \frac{dm_S^2}{dt} = -8g_{z'}^2 Q_S^2 M_{\tilde{Z}'}^2$$

$$\Rightarrow \quad \frac{dm_S^2}{dt} = 4\lambda^2(m_S^2 + m_{H_u}^2 + m_{H_d}^2) + Y_i^2(m_S^2 + m_{X_i}^2 + m_{X_i^c}^2)$$

- At $t = 0$ gauge term drives m_S positive

  As t becomes more negative m_i grow and at some point m_S goes negative

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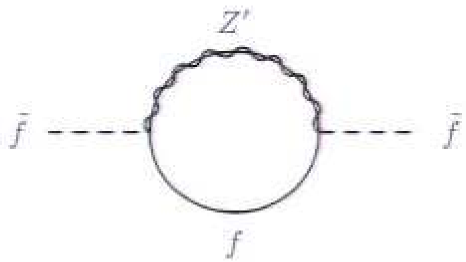

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$$+ \quad Y_i^2 (m_S^2 + m_{X_i}^2 + m_{X_i^c}^2)$$

- At $t = 0$ gauge term drives m_S positive

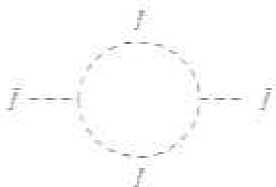
  As t becomes more negative m_i grow and at some point m_S goes negative

Driving S negative

- A term is also generated

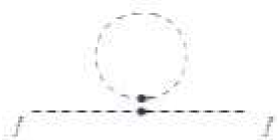
$$\Rightarrow \qquad \frac{dA}{dt} = 4\lambda M_{\tilde{Z}'} g_{z'}^2 (Q_i^2 + Q_j^2 + Q_k^2)$$

- A term contribution to m_S RGE can be neglected



$$\Rightarrow \qquad \frac{dm_S^2}{dt} \propto A^2 \propto g_{z'}^4$$

- For $U(1)$ there is also



$$\Rightarrow \qquad \frac{dm_S^2}{dt} = 2g_{z'}^2 Q_S \mathrm{Tr}(Q_j\, m_j^2)$$

Does not contribute

Higgs mass matrix

- Scalar S potential

$$V(S) \quad = \quad \underset{\text{Rad. Gen.}}{\underset{\uparrow}{m_s^2|S|^2}} \quad + \quad \underset{D\text{ term}}{\underset{\uparrow}{\tfrac{1}{2}g_{z'}^2 Q_S^2 |S|^4}}$$

- VEV of S

$$\langle S\rangle = \left|\frac{m_S}{g_{z'}Q_S}\right|$$

- Higgs mass matrix

1) "M" terms: $m_{H_u}^2$, $m_{H_d}^2$ from RGEs

2) F terms: $\lambda^2 S^2 H_i^2 \Rightarrow \lambda^2 \langle S\rangle^2$

3) D terms: $\frac{1}{2}g_{z'}^2(Q_2 H_u^2 + Q_1 H_d^2 + Q_S S^2)^2 \quad \Rightarrow \quad g_{z'}^2 \langle S\rangle^2 Q_S Q_i$

4) A terms: $ASH_uH_d \quad \Rightarrow \quad A\langle S\rangle H_uH_d$

Higgs mass matrix

- Higgs mass matrix

$$\mathcal{M}_H^2 = \begin{pmatrix} m_2^2 & -A_H \langle S \rangle \\ -A_H \langle S \rangle & m_1^2 \end{pmatrix}$$

$$m_2^2 = m_{H_u}^2 + g_{z'}^2 Q_S Q_2 \langle S \rangle^2 + \lambda^2 \langle S \rangle^2$$
$$m_1^2 = m_{H_d}^2 + g_{z'}^2 Q_S Q_1 \langle S \rangle^2 + \lambda^2 \langle S \rangle^2$$

- To generate Λ_{EW} must fine-tune linear combination of H_i to be much lighter than natural scale
- Typically find solutions by tuning $|m_2^2| \ll m_1^2 \sim g_{z'}^2 M_{\tilde{Z}'}^2 / 16\pi^2$
- $\tan\beta \approx m_1^2 / A_H \langle S \rangle \sim 10 - 100$
- Get single SM-like Higgs scalar, with mass ~140 GeV.
- Remaining Higgs particles are at $\sim$ 100 TeV

"Beyond MSSM" Masses

"Beyond MSSM" particles:

- Exotic superfield

$$W \ni \sum_i Y_i \, S \, X_i \, X_i^c$$

  Exotic superfield mass: $Y_i \langle S \rangle \quad \surd$

- Z' superfield
  - $\tilde{Z}'$ gaugino: $\quad M_{\tilde{Z}'} \quad \surd$
  - Z' gauge boson $\quad$?

- S superfield
  - scalar $\quad \langle S \rangle \quad \surd$
  - fermion - Singlino - $\widetilde{S}$ $\quad$?

Non-scalar masses

- As a result of S getting a VEV, Z' gauge boson gets a mass from $U(1)$ Higgs mechanism

$$M_{Z'} = \sqrt{2} g_{z'} |Q_S| \langle S \rangle$$

- The singlino $\widetilde{S}$ receives a mass via mixing with $\tilde{Z}'$

$$\mathcal{L} = -\sqrt{2} g_{z'} (S\, Q_S\, \widetilde{S}) \tilde{Z}'$$

Singlino Z'-ino mass matrix

$$\mathcal{M}_{SZ} = \begin{pmatrix} 0 & -\sqrt{2} g_{z'} Q_S \langle S \rangle \\ -\sqrt{2} g_{z'} Q_S \langle S \rangle & M_{\tilde{Z}'} \end{pmatrix}$$

Eigenvalues given by usual seesaw formula

$$\mathcal{M}^{(1)}_{SZ} = -\frac{M^2_{Z'}}{M_{\tilde{Z}'}} \qquad \mathcal{M}^{(2)}_{SZ} = M_{\tilde{Z}'}$$

General features - Summary

- High energy spectrum $g_{z'} \sim \lambda \sim (0.1 - 1)$:

  Z'-ino mass $M_{\tilde{Z}'} \sim 1000$ TeV

  Typical scalar mass $m_{\tilde{f}_i} \sim 100$ TeV

  $\langle S \rangle \sim M_{\tilde{Z}'}/4\pi \sim 100$ TeV

  $\mu = \lambda \langle S \rangle \sim 10 - 100$ TeV

  Exotic superfield mass $Y_i \langle S \rangle \sim 10 - 100$ TeV

  $M_{Z'} = \sqrt{2} g_{z'} Q_S \langle S \rangle \sim 10 - 100$ TeV

  $M_{\tilde{S}} = \frac{M_{Z'}}{M_{\tilde{Z}'}} M_{Z'} \sim 1 - 10$ TeV

- Low energy spectrum

  SM + Higgs + $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauginos

General features - Summary

- Interesting case for $g_{z'} \ll \lambda$

$$|M_{H_u}|^2 \sim \frac{g_{z'}^2 M_{\tilde{Z}'}^2}{16\,\pi^2} \text{ tuned against } \lambda^2 \langle S \rangle^2$$

$$\Rightarrow \langle S \rangle \sim \frac{g_{z'}}{\lambda} \frac{M_{\tilde{Z}'}}{4\pi}$$

$$M_{\tilde{S}} \sim \frac{g_{z'}^2 Q_S^2 \langle S \rangle^2}{M_{\tilde{Z}'}} \sim g_{z'}^2 \frac{g_{z'}^2}{16\,\pi^2} M_{\tilde{Z}'}$$

  - Very light singlino $M_{\tilde{S}} \sim \left(10^{-3} - 10^{-5}\right) M_{\tilde{Z}'}$

  - Z' gauge-boson, $M_{Z'} \sim g_{z'} Q_S \langle S \rangle$, in this case can be light enough to be produced @ LHC

- Low energy spectrum

  SM + Higgs + $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauginos +

  + Singlino and even Z'

Specific Models

- The free parameters are: $g_{z'}$, λ, Y_i, $U(1)'$ charges, $M_{\tilde{Z}'}$, and SUSY breaking scale Λ_S
- Minimal choice (leads to a light wino, $M_2 < M_{1,3}$):
  - 3 families of colored exotics (D)
  - 2 families of uncolored $SU(2)_L$ singlet families (E)

  both have $U(1)_Y$ charge
- Superpotential

$$W = \lambda\, S\, H_u\, H_d + y_D\, S\, D\, D^c + y_E\, S\, E\, E^c + \text{quark} + \text{lepton}$$

- Taking $Q_1 = 1$, Q_2 and Q_Q are free parameters

  (other charges are determined by anomalies)
- Other constraints
  - $U(1)'$ spontaneously broken by radiative corrections
  - Allow appropriate fine tuning to break EW symmetry
  - Check for color or charge breaking minima

RGE running

- Very different scales

  Ideal approach: integrate out different fields at each scale

  Highly non trivial task

  e.g integrate out heaviest particle $\tilde{Z}'$

  $\Rightarrow$ different RGEs for Yukawas and quartic couplings ("SUSY breaking")

- Simplified treatment: integrate out heavy scalars and $\tilde{Z}'$ at the same scale

  disadvantage: multiple RGE threshold corrections

  Two regions $M_{\tilde{Z}'} < \mu < \Lambda_S$ and $\mu < M_{\tilde{Z}'}$

RGE running

- $M_{\tilde{Z}'} < \mu < \Lambda_S$: use usual soft SUSY RGEs

  one loop RGEs for: gauge and Yukawas, $M_{\tilde{Z}'}$ and $m_{\tilde{f}_i}$, and A terms

  two loop RGEs for gaugino masses

- $\mu < M_{\tilde{Z}'}$: SM + Higgs + gauginos

  one loop RGEs: SM Higgs and quartic, Yukawas, gauge and gaugino mass

  + Threshold corrections e.g.

$$m_H^2(\mu \approx m_{\tilde{f}_i}) = min(\mathcal{M}_H^2) - \frac{3Y_t^2}{16\,\pi^2} m_{\tilde{f}_i}^2$$

Five Benchmark Models

All mass units are GeV $M_{\tilde{Z}'}$ fixed at 1000 TeV

	1	2	3	4	5
Q_2	$-\frac{1}{4}$	$-\frac{1}{4}$	$-\frac{1}{4}$	$-\frac{1}{2}$	$-\frac{1}{2}$
Q_Q	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	-2	-2
$g_{z'}$	0.45	0.23	0.23	0.06	0.04
λ	0.5	0.8	0.8	0.3	0.3
Y_D	0.6	0.7	0.8	0.4	0.6
Y_E	0.6	0.6	0.6	0.1	0.1
$\langle S \rangle$	2×10^5	7×10^4	6×10^4	2×10^5	8×10^4
$\tan\beta$	20	29	33	45	60
M_1	2700	735	650	760	270
M_2	710	195	180	340	123
M_3	4300	1200	1100	540	200
m_H	140	140	140	140	140
$m_{\tilde{Q}_3}$	1×10^5	5×10^4	4×10^4	8×10^4	4×10^4
$m_{\tilde{L}_3}$	3×10^5	10^5	10^5	2×10^4	10^5
$m_{3/2}$	890	3600	810	3	0.1
$m_{\tilde{S}}$	4300	230	160	31	4
$m_{Z'}$	7×10^4	1.5×10^4	1.3×10^4	5600	2100

Scalar Potentials and Accidental Symmetries in Supersymmetric $U(1)'$ Models

Paul Langacker, GP, Itay Yavin

arXiv:0811.1196 [to appear in PLB]

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Scalar Potentials

and

Accidental Symmetries

in

Supersymmetric $U(1)'$ Models

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Gauge Unification?

- $U(1)'$ symmetry $\Rightarrow$ new anomaly cancellation condition

  $\Downarrow$

  Introduce new "exotic" matter
  - X_i charged under SM and $U(1)'$
  - SM singlet(s) S_i give mass to X_i: $SX_iX_i^c \in W$
- Problem: Typically exotics spoil MSSM unification
- Solutions:
  - Give up unification
  - Embed $G_{\rm SM} \times U(1)'$ inside a larger group such as E_6

    $\Rightarrow$ need extra "Higsses" that reintroduce μ problem

    [Langacker and J. Wang '98]
  - Add complete $SU(5)$ multiplets of exotic matter

SM Singlets

- Adding complete $SU(5)$ multiplets of exotic matter

  $\Downarrow$

  Must introduce more than one singlet field

  [Erler '00, Morrissey and Welsh '05]

- Singlet fields should:
  1. Break $U(1)'$ symmetry
  2. Generate effective μ term for H_u and H_d
  3. Give mass to exotic matter

Generic Problems with Multiple Singlets

- $U(1)' +$ gauge unification $\Rightarrow$ Multiple singlet fields
- Problem 1: Accidental global symmetries:

  Once broken lead to axion-like bosons
- Problem 2: Generating required vacuum structure:

  Exotics might remain massless

Accidental Global Symmetries

- Consider only D-terms and soft masses in scalar potential

$$V(S_1, ..., S_N) = \sum_i m_i^2 |S_i|^2 + \frac{g_{z'}^2}{2} \left(\sum_i Q_i |S_i|^2 \right)^2 .$$

- N scalar fields $\Rightarrow$ N phases

  one linear combination "eaten" by Z' gauge boson

  $\Rightarrow N-1$ "accidental" global symmetries

  If all spontaneously broken, get $N-1$ massless Nambu-Goldstone bosons

- Global symmetries anomalous under $G_{\rm SM}$

  $\Rightarrow$ one linear combination is an axion with mass $\Lambda^2_{\rm QCD}/f$

  Other bosons are massless excluded!

- Even axion problematic: For $f \sim 100$ TeV, mass ~ 100 eV

  Experimental constraint: Axion mass should be ≤ 10 meV

Breaking the Accidental Global Symmetries

- Only way out, explicitly break the $N-1$ global symmetries

  Need $N-1$ linearly independent terms in the superpotential
- Ideally use only cubic terms: $S_i S_j S_k, S_i^2 S_j \in W$

  unlike bilinear terms $\mu S_i S_j \in W$ do not require mass scale μ
- Can we use only cubic terms?

Interlude: Linear Equations over Finite Algebraic Field

- Given k singlets with $U(1)'$ charges $Q_1 ... Q_k$

  find l singlet fields with charges $Q_{k+1} ... Q_{k+l}$ $\quad N = k + l$

  such that $Q_1 ... Q_{k+l}$ are the solution on $k + l - 1$ linear equations

  $S_i S_j S_m \Rightarrow Q_i + Q_j + Q_m = 0$ or $S_i^2 S_j \Rightarrow 2Q_i + Q_j = 0$

- In matrix form:

$$\begin{pmatrix} 1 & 1 & 1 & 0 & ... & 0 \\ 2 & 1 & 0 & 0 & ... & 0 \\ . & & & & & \\ . & & & & & \\ . & & & & & \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} Q_1 \\ Q_2 \\ . \\ . \\ . \\ Q_N \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ . \\ . \\ . \\ 0 \end{pmatrix}$$

- Consider equations over $\mathbb{F}_3$, **Algebraic** field with 3 elements: $\{0, 1, 2\}$

  or $Q_i \rightarrow Q_i$ mod 3

Interlude: Linear Equations over Finite Algebraic Field

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Linear Equations over Finite Algebraic Field

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- In general assumption is not correct

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- Does this reintroduce the μ problem?

  NO!
- μ problem: have μ in $\mu H_u H_d \in W$ at the same scale

  as the soft parameters $(b, m^2_{H_u}, m^2_{H_d})$
- Here not using μ term to generate vacuum structure

  Need μ to give mass larger than MeV
- Term can arise from Giudice-Masiero mechanism $\mu \sim F/M_P$

Example: Erler's Model

- MSSM + Exotics: two pairs of $\mathbf{5}+\mathbf{5}^*$: (D_i, L_i) and (D_i^c, L_i^c), $i = 1, 2$

  need two singlets: S, S_D with charges $Q_S = 1 \quad Q_{S_D} = 3/2$

  S generates μ term and give mass to L, L_c, S_D give mass to D, D^c

- Using only cubic terms requires 4 extra singlets

  The superpotential terms are:

$$S_1 S_1 S_2,\ S_2 S_3 S_D,\ S_1 S_4 S_D,\ S S_3 S_3, S S S_4$$

- With bilinears can do with only 2 extra singlets

$$\mu S S_1 + y_1 S_1 S_2 S_D + y_2 S S_2 S_2 \in W$$

  New singlets' charges $Q_{S_1} = -1 \quad Q_{S_2} = -1/2$

Generating required vacuum structure

- Need to give vacuum expectation value (vev) to multiple scalars. How?
- No "rigorous" proofs but the big picture is:
- Easier to analyze by ignoring F terms for now

$$V(S_1, ..., S_N) = \sum_i m_i^2 |S_i|^2 + \frac{g_{z'}^2}{2} \left(\sum_i Q_i |S_i|^2 \right)^2 .$$

- Reasonable to assume some m_i^2 are driven negative by RGEs
- Consider two cases
  1. Only one fields develop a vev
  2. "Flat" direction
- First case:
  - If for only one field $m_i^2 < 0$, it will develop a vev
  - If multiple fields have $m_i^2 < 0$,
    only the field with largest $|m_i^2/Q_i|$ develop a vev

"Flat" direction

- Assume that for two fields with opposite charges S_i and S_j

  $|Q_j|m_i^2 + |Q_i|m_j^2 < 0$

  $\Rightarrow$ "runaway" direction: $V \to -\infty$, for $|Q_i||S_i|^2 = |Q_j||S_j|^2 \to \infty$
- Adding F terms stabilize the vevs at finite values

  $\Rightarrow$ Generate vevs for S_i and S_j
- After "vacuum insertion" A terms can generate linear terms

  in the potential for other fields: $A\,|S_i|\,|S_j|\,S_m \in V$

  $\Rightarrow$ generate vev for S_m
- This case is phenomenologically favorable

Example: Erler's Model

- Recall superpotential

$$\mu S S_1 + y_1 S_1 S_2 S_D + y_2 S S_2 S_2 \in W$$

and charges: $Q_{S_1} = -1 \quad Q_{S_2} = -1/2 \quad Q_S = 1 \quad Q_{S_D} = 3/2$

- We need S and S_D to develop a vev

For simplicity ignore μ term and assume $y_1 \ll y_2, g_{z'}$

Scalar potential ("turning off" A terms)

$$V(S, S_D, S_1, S_2) = \sum_i m_i^2 |S_i|^2 + \frac{g_{z'}^2}{2}\left(\sum_i Q_i |S_i|^2\right)^2 + |y_2|^2 |S_2|^4$$

- Flat direction for S_2 and S_D, assume

$|Q_{S_1}| m_{S_D}^2 + |Q_{S_D}| m_{S_1}^2 > 0$ and $|Q_{S_2}| m_{S_D}^2 + |Q_{S_D}| m_{S_2}^2 < 0$

- The vevs are

$$|S_D|^2 = -\frac{4}{9}\frac{m_{S_D}^2}{g_{z'}^2} - \frac{1}{18 y_2^2}\left(3m_{S_2}^2 + m_{S_D}^2\right) \qquad |S_2|^2 = -\frac{1}{6y_2^2}\left(3m_{S_2}^2 + m_{S_D}^2\right)$$

Notice $|S_i| \propto 1/y_2^2$ remnant of the flat direction

Example: Erler's Model

- S_2 and S_D have vevs
- Recall superpotential

$$\mu S S_1 + y_1 S_1 S_2 S_D + y_2 S S_2 S_2 \in W$$

- "Turn on" A term for $S S_2 S_2$

  linear term for S: $A\, S |S_2|^2 \in V$

  $\Rightarrow$ generate vev for S

- Final result: both S and S_D have vevs $\surd$

Future Directions

- Other Z' mediation models

  Models with gauge unification?

  Implement Erler's model [In progress]

  Models with wino/bino LSP?

- Combine with other mediation mechanisms

  e.g. anomaly mediation [In progress]

- Incorporate in other top-down models

- Models of the hidden sector

Conclusions

- Motivated by top-down constructions:

  New mechanism for mediation of SUSY breaking

  via a U(1)' gauge interaction

- Specific implementation
  - heavy sfermions, Higgsinos, exotics $\sim$ 10 - 100 TeV
  - Light gauginos $\sim 100 - 1000$ GeV, of which the lightest can be wino-like and a light Higgs $\sim$ 140 GeV

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- $U(1)' +$ gauge unification $\Rightarrow$ Multiple singlet fields

  Generic problems:

- accidental symmetries $\Rightarrow$ light bosons
  - Solution: explicitly breaking via SP terms

    Cubic might not be feasible, bilinears ok

- Vacuum structure: multiple scalar vevs
  - Solution: lifted flat direction: two scalar vevs

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- More work to be done!