Higgsino-less Bino Dark Matter

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Based on:

Marcela Carena, R. J. Hernandez-Pinto and A. M., arXix:1105.xxxx

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Dark Matter and MSSM

- WMAP/SDSS has measurement the relic abundance to be

$$\Omega_{CDM} h^2 = 0.113 \pm 0.0035$$

- The most studied symmetry principle that can lead to such a stable dark matter particle is supersymmetry.

- Gravity-mediated MSSM models $\Rightarrow$ typically Bino LSP.

- To generate the thermal relic abundance and not requiring light sfermions $\Rightarrow$ large Higgsino component in the LSP.

- Large Higgsino component $\Rightarrow$ large direct detection cross-sections.

How is this dark matter phenomenology modified in BMSSM?

Effective Operators

- $D = 6$ gauge Higgs mixing operators

$$\mathcal{L} \supset \frac{d_1}{4M^2} H_u H_d W^{(1)\alpha} W^{(1)}_\alpha \Big|_{\theta\theta} + \frac{d_2}{4M^2} H_u H_d W^{(2)\alpha} W^{(2)}_\alpha \Big|_{\theta\theta} + \frac{d_{12}}{2M^2} W^{(1)\alpha} H_u W^{(2)}_\alpha H_d \Big|_{\theta\theta} + \text{h.c.}$$

- Assuming F-term SUSY breaking, effective D-term spurion terms

$$\frac{1}{4} \int d^2\theta \left(\frac{d_1}{M} \mathcal{W}^\alpha W^{(1)}_\alpha H_u H_d + \frac{d_{12}}{M} \mathcal{W}^\alpha H_u W^{(2)}_\alpha H_d \right) + \text{h.c.}$$

can be removed by the shift of the U(1) vector super-field.

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Modified Gauge Sector couplings and Masses

- d_1, d_2 and d_{12} at the only additional parameters.
- Leads to modified gauge boson mass

$$\begin{aligned} m_W^2 &= \frac{1}{4} g_2^2 v^2 \\ m_Z^2 &= \frac{1}{4}(g_1^2 + g_2^2)\, v^2 \left(1 - \frac{v^2 s_{2\beta}}{2M^2} t_{\theta_W} \Re(d_{12})\right) \end{aligned}$$

where

$$\frac{\Delta v}{v} = \frac{v^2 s_{2\beta}}{4M^2} t_{\theta_W} \Re(d_{12}).$$

- Hence Peskin-Takeuchi electroweak parameters get the tree-level corrections

$$\begin{aligned} \alpha \Delta T^{Tree} &= \frac{v^2}{2M^2} s_{2\beta} t_{\theta_W} \Re(d_{12}) \\ \alpha \Delta S^{Tree} &= -\frac{v^2 s_{2\beta}}{M^2} \Re(d_{12}) t_{\theta_W}^{-1} \left(1 - 2s_{\theta_W}^2 - 2s_{\theta_W}^4\right) \end{aligned}$$

contd...

- Corrections are independent of d_1 and d_2.

- Electroweak precision constraints are small for large $\tan\beta$ and imaginary d_{12}.

- Corrections to S and T are correlated $\Rightarrow \left|\frac{\Delta S^{tree}}{\Delta T^{tree}}\right| \approx 2.9$

Modifications to the Neutralino Mass Matrix

- Kinetic mixing terms and mass terms lead to

$$\mathbf{M}_{\tilde{\chi}^0} \;=\; \mathbf{M}^0_{\tilde{\chi}^0} + \frac{v^2}{M^2}\Delta_{\tilde{\chi}^0}$$

where in the limit $\tan\beta \to \infty$

$$\Delta^{11}_{\tilde{\chi}^0} \to \tfrac{1}{2}\mu^* d_1,\ \Delta^{12}_{\tilde{\chi}^0} \to \tfrac{1}{4}\mu^* d_{12},\ \Delta^{22}_{\tilde{\chi}^0} \to \tfrac{1}{2}\mu^* d_2,$$
$$\Delta^{13}_{\tilde{\chi}^0} \to \tfrac{1}{4} m_Z s_{\theta_W}\left[d_1 - \tfrac{d_{12}}{2} t^{-1}_{\theta_W}\right],\ \Delta^{23}_{\tilde{\chi}^0} \to -\tfrac{1}{4} m_Z c_{\theta_W}\left[d_2 - \tfrac{d_{12}}{2} t_{\theta_W}\right]$$

- These operators induce large Bino-Wino mixing in the limit of large μ and $\tan\beta$.

Modifications to the Chargino Mass Matrix

- Similarly kinetic mixing and mass terms lead to

$$\mathbf{M}_{\tilde{\chi}^\pm} = \mathbf{M}^0_{\tilde{\chi}^\pm} + \frac{v^2}{M^2}\Delta_{\tilde{\chi}^\pm}$$

where in the limit $\tan\beta \to \infty$

$$\Delta^{11}_{\tilde{\chi}^\pm} \to \frac{1}{2}\mu^* d_2, \; \Delta^{21}_{\tilde{\chi}^\pm} \to -\frac{1}{8}\sqrt{2} m_W d_{12} t_{\theta_W}$$

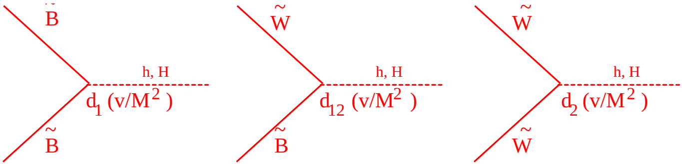
- Corrections to the Wino element of the neutralino and chargino get the same correction.

Neutralino and Chargino Couplings

- Explicit changes to the $g_{\chi_0\chi_0 Z}$ $g_{\chi_\pm\chi_\pm Z}$ $g_{\chi_0\chi_0\gamma}$, $g_{\chi_0\chi_\pm W_\mp}$ are $\propto \sin 2\beta$.

- However modification of composition can lead to large effect especially for $g_{\chi_0\chi_\pm W_\mp}$.

- Additional contribution to $g_{h\chi_0\chi_0}$ and $g_{H\chi_0\chi_0}$ due to

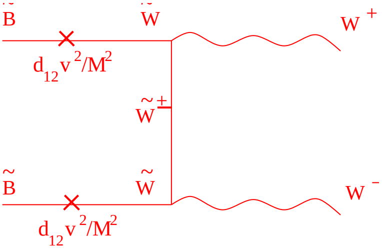


but not for $g_{A\chi_0\chi_0}$

Relic Density

- Assuming no coannihilation, mostly Bino LSPs with small Higgsino components typically over close the universe.
- The d_{12}-term can induce a larger Wino component while still having small a small Higgsino component.
- For $m_{\chi_1^0} \geq m_W$ the annihilation cross-section into W^+W- is

$$\langle \sigma v^2_{\chi_0} \rangle_0 \propto \frac{v^4 d_{12}^2}{M^4 (M_2 - M_1)^2}$$



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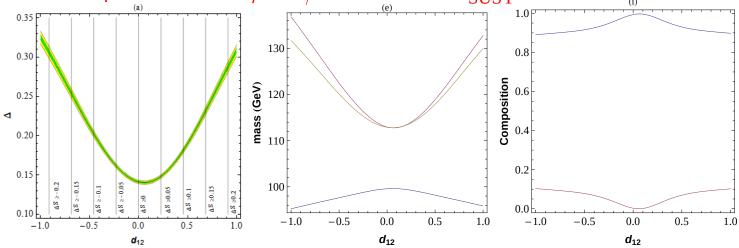
$M_1 = 100$ GeV, $\tan\beta = 60$ and $M_{\text{SUSY}} = 800$ GeV.



- Large values of d_{12} allow for larger splittings and smaller coannihilation effects.

The Higgsino-less Bino Parametric Scenario

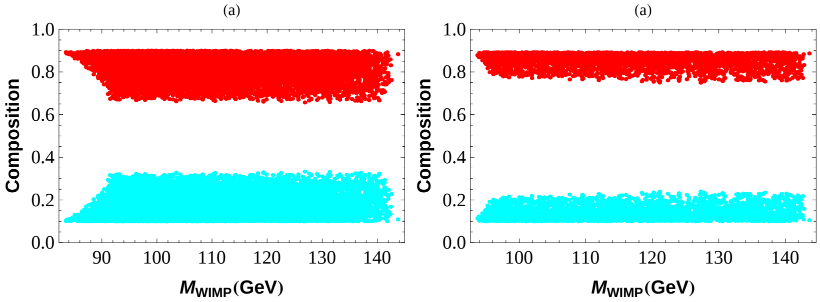
- Similar to the "Well-Tempered" Wimp we choose

  $$|N^{11}|^2 \geq 0.5,\ |N^{12}|^2 \geq 0.1,\ |N^{13}|^2 \text{ and } |N^{14}|^2 \leq 0.01$$

- Imposed these constraints on the parameter scan

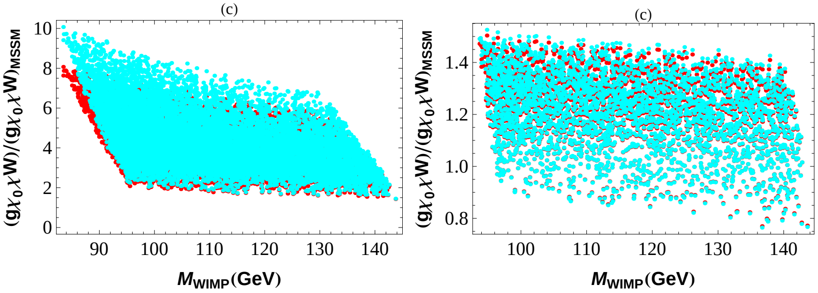
$$M_2 \subset [100, 150]\ \text{GeV};\ \ M_1 \subset [80, M2 - 5]\ \text{GeV};$$

$$\mu = 800\ \text{GeV}\ d_1 = 0;\ \ d_2 = 0;\ \ d_{12} = [-1, 1],\ M = 1\ \text{TeV}$$



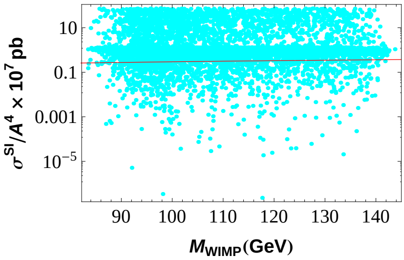
- Large tan β leads to greater Wino component in the LSP due to S-parameter constraint.

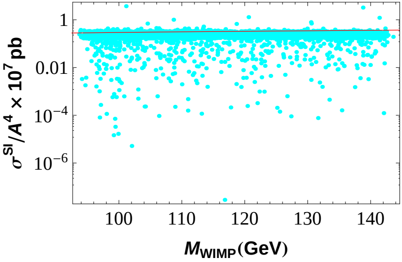
Neutralino-Chargino W Couplings



- As expect large modification of $g_{\chi_0 \chi_\pm W^\mp}$ due to enhanced Wino component in the LSP.

Direct Detection



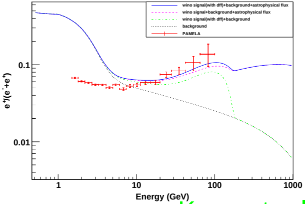


- Direct detection limits mostly due to H^0 exchange

$\propto \tan^2\beta/m_A^2$.

- Scanned over $m_A \in [100, 500]$ GeV.

Indirect Detection: Experiments



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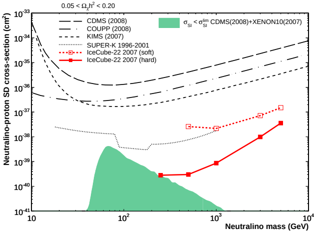
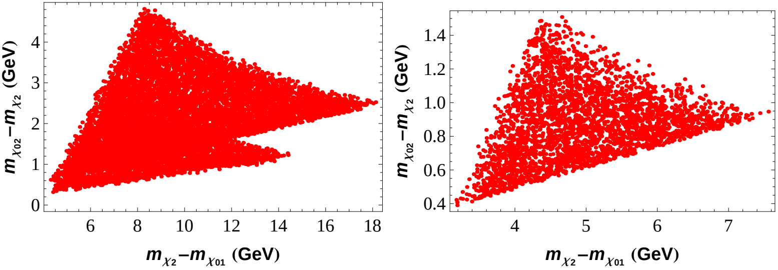


Abbasi et. al. '09

- A boost factor of $\sim 10^{-3}$ needed to explain PAMELA $\Rightarrow$ limits from FERMI/LAT are relatively weak.
- As $m_{\chi_0} \lesssim 150$ limits, present limits from ICECUBE are relatively weak.
- Limits from Super-Kamiokande $\gtrsim 10^{-6}$ pb so are weaker than direct detection constraints.

Collider Searches



- Inverted mass hierarchy between $\chi^1_\pm$ and χ^2_0 with a few GeV splitting.
- $m_{\chi^1_\pm} - m_{\chi^1_0} \sim 10$ GeV.
- Small splittings $\longrightarrow$ soft leptons and jets.
- Discovery of the scenario at the LHC is quite challenging.
- Large d_{12} allows for larger splittings $\Rightarrow$ improved reach at LHC.

Conclusions

- We consider additional $D = 6$ gauge Higgs mixing operators.

- These operators give corrections to electroweak precision observables.

- These operators do not modify Higgs physics significantly once electroweak precision constraints are imposed.

- These operators can induce significant modifications to neutralino and chargino sectors and lead to significant modifications of MSSM phenomenology.

- Larger D=6 operator contributions allows for less degenerate mass spectrum and better LHC discovery prospects.