The Race for Supersymmetric Dark Matter at XENON100 & LHC: Stringy Correlations from No-Scale $F-SU(5)$

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with Tianjun Li, James A. Maxin, and Joel W. Walker
Contents of the Universe

- Dark Energy: 73%
- Cold Dark Matter: 23%
- 4%

The 23% is still unobserved in the laboratory. (This new matter can not be seen visually!)

We call this Cold Dark Matter.
DM Particle in SUSY

\[
\Omega_{\chi_1^0}^{\odot} h^2 \sim \int_0^{x_f} \frac{1}{\langle \sigma_{\text{ann}} v \rangle} \, dx
\]

\[
\langle \sigma_{\text{ann}} v \rangle = \frac{\pi \alpha^2}{8M^2}
\]

WMAP 5: 23.3% (± 1.3%)

CDM = Neutralino (\(\tilde{\chi}_1^0\))

\[(\Omega_{\text{CDM}}^{-1})^2 \propto \begin{array}{c}
\begin{array}{c}
\begin{array}{c}
\chi_1^0 \rightarrow h, H, A, Z
\end{array}
\end{array}
\end{array} + \begin{array}{c}
\begin{array}{c}
\begin{array}{c}
\begin{array}{c}
\chi_1^0 \rightarrow \text{Co-annihilation (CA) Process}
\end{array}
\end{array}
\end{array}
\end{array}
\end{array}
\]

\[
\Delta M = M_{\chi_1^0} - M_{\tilde{\chi}_1^0}
\]

**SUSY at the LHC**

Colored particles get produced and decay into weakly interacting stable particles.

The energy of jets and leptons depend on the sparticle masses which are given by models.

**The signal:** jets + leptons + missing Energy

This reaction has to be extracted out of many trillion pp collisions.
Minimal Supergravity (mSUGRA)

- $M_0$: Universal soft scalar mass
- $M_{1/2}$: Universal soft gaugino mass
- $\mu$: Higgsino Mixing Parameter
- $A_0$: Universal Trilinear Coupling
- $B_0$: Higgs Bilinear Coupling
- $\tan \beta$: Ratio of Higgs VEVs

$|\mu|$ and $B_0$ term can be determined by the requirement for REWSB, so we are left with only five parameters:

$M_0$, $M_{1/2}$, $A_0$, $\tan \beta$, and $\text{sgn}(\mu)$
No Scale SUGRA: A Case Study in Reductionism

There is a function called the Kähler potential which must be specified by the model builder in order to fix the metric of superspace, and determine the scalar potential. It is not fixed by the symmetries of the theory. There is however a particularly natural choice.

\[ K = -3 \ln (T + T^* - \Sigma \phi_i \phi_i^*) \]

The scalar potential is flat and vanishing. Supersymmetry is BROKEN, and there is no cosmological constant. This is all desirable at the Tree Level.

**CONSTRAINT:** \( m_0 = 0, \quad A = 0, \quad B = 0 \quad m_{1/2} \neq 0 \) for SUSY breaking

The gaugino mass \( m_{1/2} \) remains undetermined at the classical level.

All soft-terms though, are dynamically evolved in terms of only the single parameter \( m_{1/2} \), which may itself be determined by radiative corrections to the potential!

FIG. 2: RGE Running of the SM gauge couplings and gaugino masses from the EW scale to the unification scale $M_F$.

FIG. 3: RGE Running of the $\mu$ term and SUSY breaking soft terms from the EW scale to the unification scale $M_F$. 
Key Experimental Constraints

- 7-Year WMAP Cold Dark Matter Relic Density Measurement
- Experimental limits on the Flavor Changing Neutral Current process $b \rightarrow s \gamma$
- Anomalous magnetic moment of the muon
- LHC Limits on rare decay $B_s^0 \rightarrow \mu^+\mu^-$
- Proton Lifetime greater than $1 \times 10^{34}$ Yr
- LEP limits on the light CP even Higgs mass
- Compliance with all precision electroweak measurements $(M_z, \alpha_s, \Theta_W, \alpha_{em}, m_t, m_b)$

* The Weinberg angle floats mildly according to original program design.
Figure 3: The probability density obtained from a global fit including results from the direct LEP, Tevatron and LHC searches, as well as the precision electroweak data [64].

\[ m_H = 124.5 \pm 0.8 \text{ GeV} \]
DYNANOPoulos

THE GOLDEN STRIP
of Correlated Top Quark, Gaugino,
and Vectorlike Mass in No-Scale, No Parameter

F-SU(5)

Part II of The Golden Point Saga, as Featured in arXiv: 1007.5100
Also Starring: Tianjun Li, James A. Maxin & Joel W. Walker

George P. and Cynthia W. Mitchell Institute for Fundamental Physics and Astronomy
at Texas A&M University
Houston Advanced Research Center (HARC)
Academy of Athens
Region of the $f$-SU(5) parameter space estimated to be excluded by the CMS 1.1 fb$^{-1}$ Multijet Constraints

80 (WIMP Mass in GeV)

Golden Strip

$(M_{1/2}, M_Y, \tan\beta, m_t) = (518, 1640, 20.65, 174.4)$
Discovery of No-Scale $\mathcal{F}$-SU(5) Signal at LHC

No-Scale $\mathcal{F}$-SU(5) with vectorlike particles ($b_3 = 0$) SUSY spectrum

$M_{\tilde{t}_1} < M_{\tilde{g}} < M_{\tilde{q}}$

Prominent decay channels have high multiplicity of third-generation quarks:

$\tilde{g} \rightarrow \tilde{t}\tilde{t} \rightarrow t\bar{t}\tilde{\chi}_1^0 \rightarrow W^+W^-b\bar{b}\tilde{\chi}_1^0$

$\tilde{g} \rightarrow \tilde{t}\tilde{t} \rightarrow b\bar{t}\tilde{\chi}_1^\pm \rightarrow W^\pm b\bar{b}\tilde{\tau}\nu \rightarrow W^\pm b\bar{b}\tilde{\tau}\nu\tilde{\chi}_1^0$

Pair produced gluinos generate events rich with jets and tau.

Considered excellent channel for discovery during early LHC run.

LHC early run signatures for 1-5fb$^{-1}@7$TeV: $\geq 9$ jets

$\geq 1\tau \& \geq 3$ b-jets
TABLE I: Spectrum (in GeV) for $M_{1/2} = 518$ GeV, $M_V = 1640$ GeV, $m_t = 174.4$ GeV, $\tan\beta = 20.65$. Here, $\Omega_\chi = 0.1155$ and the lightest neutralino is 99.9% Bino. The partial lifetime for proton decay in the leading $(e|\mu)^+\pi^0$ channels falls around $4 \times 10^{34}$ Y [22, 23].

<table>
<thead>
<tr>
<th>$\tilde{\chi}^0_1$</th>
<th>99</th>
<th>$\tilde{\chi}^\pm_1$</th>
<th>216</th>
<th>$\tilde{e}_R$</th>
<th>196</th>
<th>$\tilde{t}_1$</th>
<th>558</th>
<th>$\tilde{u}_R$</th>
<th>1053</th>
<th>$m_h$</th>
<th>125.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{\chi}^0_2$</td>
<td>216</td>
<td>$\tilde{\chi}^\pm_2$</td>
<td>900</td>
<td>$\tilde{e}_L$</td>
<td>570</td>
<td>$\tilde{t}_2$</td>
<td>982</td>
<td>$\tilde{u}_L$</td>
<td>1144</td>
<td>$m_{A,H}$</td>
<td>972</td>
</tr>
<tr>
<td>$\tilde{\chi}^0_3$</td>
<td>896</td>
<td>$\tilde{\nu}_{e/\mu}$</td>
<td>565</td>
<td>$\tilde{\tau}_1$</td>
<td>108</td>
<td>$\tilde{b}_1$</td>
<td>934</td>
<td>$\tilde{d}_R$</td>
<td>1094</td>
<td>$m_{H^\pm}$</td>
<td>976</td>
</tr>
<tr>
<td>$\tilde{\chi}^0_4$</td>
<td>899</td>
<td>$\tilde{\nu}_\tau$</td>
<td>551</td>
<td>$\tilde{\tau}_2$</td>
<td>560</td>
<td>$\tilde{b}_2$</td>
<td>1046</td>
<td>$\tilde{d}_L$</td>
<td>1147</td>
<td>$\tilde{g}$</td>
<td>704</td>
</tr>
</tbody>
</table>
TABLE I: Conformity with all the measured constraints for the benchmark point $M_{1/2} = 518$ GeV, $M_V = 1640$ GeV, $m_t = 174.4$ GeV, $\tan\beta = 20.65$. Here, MM is used to designate the *minimum minimorum* of our universe.

<table>
<thead>
<tr>
<th>Constraint</th>
<th>$\mathcal{F}$–SU(5) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_h &gt; 114$ GeV</td>
<td>125.4 GeV</td>
</tr>
<tr>
<td>$m_t = 173.3 \pm 1.1$ GeV</td>
<td>174.4 GeV</td>
</tr>
<tr>
<td>$\Omega_{\chi_1^0} = 0.1123 \pm 0.0035$</td>
<td>0.1155</td>
</tr>
<tr>
<td>Lightest Neutralino</td>
<td>$&gt; 99%$ Bino</td>
</tr>
<tr>
<td>$Br(b \to s\gamma) = 3.55 \pm 0.8 \times 10^{-4}$</td>
<td>$2.76 \times 10^{-4}$</td>
</tr>
<tr>
<td>$\Delta a_\mu = 27.5 \pm 16.5 \times 10^{-10}$</td>
<td>$12.5 \times 10^{-10}$</td>
</tr>
<tr>
<td>$Br(B_s^0 \to \mu^+\mu^-)$ $\leq 1.9 \times 10^{-8}$</td>
<td>$3.8 \times 10^{-9}$</td>
</tr>
<tr>
<td>$\tau_p \geq 1.0 \times 10^{34}$ yr</td>
<td>$4 \times 10^{34}$ yr</td>
</tr>
<tr>
<td>$\sigma_{SI} &lt; 7 \times 10^{-9}$ pb</td>
<td>$1.5 \times 10^{-10}$ pb</td>
</tr>
<tr>
<td>$\sigma_{SD} &lt; 4.5 \times 10^{-3}$ pb</td>
<td>$1 \times 10^{-7}$ pb</td>
</tr>
<tr>
<td>$\langle \sigma v \rangle_{\gamma\gamma} &lt; 10^{-26}$ cm$^3$/s</td>
<td>$3 \times 10^{-28}$ cm$^3$/s</td>
</tr>
<tr>
<td>$M_{1/2}@M_Z = 91.187 \pm 0.001$ GeV MM</td>
<td>514 GeV</td>
</tr>
</tbody>
</table>
FIG. 4: Correlations between the search for dark matter at the LHC with the XENON100 and all direct-detection experiments. The region exhibited here is the parameter space displayed in Figs. (1)-(3). The gradients represent the number of multijet events predicted for 5 fb$^{-1}$ of luminosity at $\sqrt{s} = 7$ TeV LHC with greater than or equal to nine jets for the CMS Experiment and with greater than or equal to seven jets for the ATLAS Experiment, as derived in [28, 29, 32, 33, 36, 37]. The black contour lines demarcate the specifically labeled number of $\geq 9$ (CMS) and $\geq 7$ (ATLAS) jet events. The legend associates each shading with its respective numerical value of the number of $\geq 9$ (CMS) and $\geq 7$ (ATLAS) jet events. The region estimated to be disfavored by the CMS 1.1 fb$^{-1}$ results [13] is marked out with the crosshatch pattern. All masses are in GeV.
No-Scale $\mathcal{F}$-$SU(5)$ Built Upon Triagonal Foundation of
i. Flipped $SU(5)$ GUT
ii. Extra TeV-Scale Vector-like Particle, or Flippons
iii. No-Scale Supergravity

$\mathcal{F}$-$SU(5)$ Supersymmetry signature at LHC is $\geq 9$ jets
Flippons $\rightarrow b_3=0 \rightarrow$ Light Gluino $\rightarrow$ Gluino Decays to Stop
$\rightarrow$ Abundance of Top Quarks $\rightarrow$ Large Multijet Signature

$\mathcal{F}$-$SU(5)$ Fits Recent CMS & ATLAS Multijet Observations at LHC
- $M_{1/2}=518$ GeV perfectly explains small data event excesses for $1 \text{ } fb^{-1}$
- $\mathcal{F}$-$SU(5)$ $M_{1/2}=518$ GeV will predict LHC Observations for $5 \text{ } fb^{-1}$

Flippons contribution in $\mathcal{F}$-$SU(5)$ elevates Higgs mass to 125 GeV, in precise agreement with CMS and ATLAS observations

$\Rightarrow$ $\mathcal{F}$-$SU(5)$ is highly consistent with CMS & ATLAS searches for both SUSY and the Higgs boson

SUSY & Higgs boson signals could be statistically significant in 2012
Is $\mathcal{F}$-$SU(5)$ the high-energy framework for our universe? Stay tuned in 2012!
Suggestive Correlations in the ATLAS and CMS High Jet Multiplicity Data

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We present preliminary experimental evidence that the CMS and ATLAS collaborations may indeed be already experiencing supersymmetry events at the Large Hadron Collider (LHC). Our analysis is performed with the recent data of a highly model-independent discovery channel at the LHC, which represents the multiplication of the F squark (F) and Higgs boson (H), giving rise to two pairs of highly-collimated top quarks. The spectrum of the F squark is consistent with the expected mass range of the F squark, which has been observed in previous experiments. We present evidence for the first clear indication of supersymmetry at the LHC, which would imply the existence of new physics. Our findings are consistent with the latest data from CMS and ATLAS, and show that supersymmetry is a viable explanation for the observed data. We supplement this analysis by re-examining the published data and finding new evidence for supersymmetry in the data from CMS and ATLAS.