A new flavour imprint of SU(5)-like Grand Unification and its LHC signature

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Sommaire

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$\{Q_i, U_i, E_i\} \in \mathbf{10_i}$, $\{L_i, D_i\} \in \mathbf{\bar{5}_i}$
- The Higgs sector requires special care, $H_1, H_2 \equiv (H_d, H_u)$ must be embed in $\mathbf{5_i}$ and $\mathbf{\bar{5}_i}$ respectively

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Conclusion

Proton lifetime assumed to be long enough so that I can have the opportunity to give this talk.

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3. In the MSSM, similar relation holds between soft terms: $m_L^2 = m_D^2$, $m_Q^2 = m_U^2 = m_E^2$, $a_d = a_l^t$

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How stable $a_u = a^t_u$ and $m^2_Q = m^2_U$ remains upon RG flow?

$\rightarrow$ SPheno (v3.2.4), two-loop RGE code: $O(\%)$, only sizable discrepancy between m^2_{Q33} and m^2_{U33}.

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Let us reorganize the up-squark mass term such that:

$$\mathcal{L} \supset \tilde{u}^\dagger \mathcal{M}^2_{\tilde{u}} \tilde{u} \equiv \Phi^\dagger \mathcal{M}^2 \Phi = \left(\hat{\phi}^\dagger, \phi^\dagger\right) \begin{pmatrix} \hat{M}^2 & \tilde{M}^2 \\ \tilde{M}^{2\dagger} & M^2 \end{pmatrix} \begin{pmatrix} \hat{\phi} \\ \phi \end{pmatrix}$$

$\hat{\phi}$: heavy states, ϕ: Light states.

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$\hat{\phi}$: heavy states, ϕ: Light states.
→ The up-squark sector of the Lagrangian will have the form:

$$\mathcal{L} \supset \left|D\Phi\right|^2 - \Phi^\dagger \mathcal{M}^2 \Phi + \left(\mathcal{O}\phi + \hat{\mathcal{O}}\hat{\phi} + \mathrm{h.c.}\right),$$

with $\hat{\mathcal{O}}$, $\mathcal{O}$: Interactions with others fields used to probe the up-squark sector

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$$\begin{aligned}\mathcal{L}_{\mathrm{eff}} &= \left|D\phi\right|^2 \\ &+ \left(\mathcal{O} - \hat{\mathcal{O}}\left(\hat{M}^{-2} - \hat{M}^{-4}\partial^2\right)\tilde{M}^2 - \frac{\mathcal{O}}{2}\tilde{M}^{2\dagger}\hat{M}^{-4}\tilde{M}^2\right)\phi + \mathrm{h.c.} \\ &- \phi^\dagger\left(M^2 - \tilde{M}^{2\dagger}\hat{M}^{-2}\tilde{M}^2 - \frac{1}{2}\left\{\tilde{M}^{2\dagger}\hat{M}^{-4}\tilde{M}^2, M^2\right\}\right)\phi\,.\end{aligned}$$

Expanded to $E^2\hat{M}^{-2}$ and where $\{,\}$ is the anti-commutator.

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Assumptions

1. Unobserved squarks heavy enough for $\mathcal{L}_{eff}$ to make sense.
2. Stop production occurs through flavour diagonal processes.
3. R-parity conserving scenarios with a $\tilde{\chi}_1^0$ LSP.

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  1. $\hat{\mathcal{O}} \propto (u_L, c_L, -4\, u_R, -4\, c_R)\, \tilde{B}$
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At first order in $\mathcal{L}_{eff}$, the flavour-violating couplings:

$$\tilde{B}\begin{pmatrix} \frac{m_{13}^2}{\Lambda_1^2}u_L + \frac{m_{23}^2}{\Lambda_2^2}c_L - 4\frac{m_{34}^2}{\Lambda_1^2}u_R - 4\frac{m_{35}^2}{\Lambda_2^2}c_R \\ \frac{m_{16}^2}{\Lambda_1^2}u_L + \frac{m_{26}^2}{\Lambda_2^2}c_L - 4\frac{m_{46}^2}{\Lambda_1^2}u_R - 4\frac{m_{56}^2}{\Lambda_2^2}c_R \end{pmatrix} R(\tilde{\theta})\begin{pmatrix}\tilde{t}_1 \\ \tilde{t}_2\end{pmatrix}$$

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Where $\Lambda_1^2 \equiv m_{11,44}^2$ and $\Lambda_2^2 \equiv m_{22,55}^2$

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$$\begin{aligned} N_{L,Y} \ \propto\ & \left(\sigma_{\tilde{t}_1} c_{\tilde{\theta}}^2 + \sigma_{\tilde{t}_2} s_{\tilde{\theta}}^2\right)\left(m_{13}^4 \Lambda_1^{-4} + m_{23}^4 \Lambda_2^{-4}\right) \\ & + \left(\sigma_{\tilde{t}_1} s_{\tilde{\theta}}^2 + \sigma_{\tilde{t}_2} c_{\tilde{\theta}}^2\right)\left(m_{16}^4 \Lambda_1^{-4} + m_{26}^4 \Lambda_2^{-4}\right) \\ & + 2 c_{\tilde{\theta}} s_{\tilde{\theta}} \left(\sigma_{\tilde{t}_1} - \sigma_{\tilde{t}_2}\right)\left(m_{13}^2 m_{16}^2 \Lambda_1^{-4} + m_{23}^2 m_{26}^2 \Lambda_2^{-4}\right). \end{aligned}$$

with $\sigma_{\tilde{t}_i} = \sigma(pp \to \tilde{t}_i \tilde{t}_i^*)$

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- The normalisation of $N_{Y,L}$ is not needed, only ratios involved.
- The stops mixing angle can be arbitrary.

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- $\tilde{t}_{1,2}$ can only decay into $\tilde{\chi}_1^0 \sim \tilde{B}$, $\mathcal{O} \propto (t_L, -4\, t_R)\, \tilde{B}$.

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Two non-trivial relations:

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$$b=\frac{1}{2}\left(\frac{m_{13}^2 m_{16}^2}{\Lambda_1^4}+\frac{m_{23}^2 m_{26}^2}{\Lambda_2^4}+\frac{m_{34}^2 m_{46}^2}{\Lambda_1^4}+\frac{m_{35}^2 m_{56}^2}{\Lambda_2^4}\right)$$

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- If the SU(5) hypothesis is not true, both relations will be not satisfied.
- Again, only ratios involved, no crucial dependency upon the overall normalisation.

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- These tests are particularly simple, involved only ratios of number of events and hence do not depend on the exact form of the total cross sections.
- Though, charm tagging techniques and top polarimetry will be crucial ingredients to make them reality.

Conclusions:

- We have pointed out the existence of new MSSM/SU(5) induced symmetry relations.
- These relations stay confined within the up-squark sector and hence are less spoiled by RGE running while being insensitive to GUT threshold corrections.
- We have built a new two light stops effective theory as a tool to put our SU(5) tests in practice.
- These tests are particularly simple, involved only ratios of number of events and hence do not depend on the exact form of the total cross sections.
- Though, charm tagging techniques and top polarimetry will be crucial ingredients to make them reality.
- Stay tuned for more evolved tests involving Bayesian statistic, coming up this summer ☺ or this fall ☹.

Thank you for your attention.

Any Questions?