To Split Or Not To Split

Part I

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Why **SUSY** is the most compelling framework for physics beyond the SM (@ TeV scale)

- The only known perturbative solution to the hierarchy problem
- May implement the WIMP miracle
- Predict gauge coupling unification
The LEP legacy:

1 – No SUSY particles below ~100 GeV
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2 – SM Higgs > 114.4 GeV

\[ \delta v^2 \propto m_s^2 \]

\[ \delta m_h^2 \propto v^2 \log m_s^2 \]

The little hierarchy problem
⇒ need to go beyond the MSSM
Tevatron:

1 – Pushed the bounds on sparticles to few hundred GeV in several models
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2 – Killed last corners of “natural” MSSM
    (e.g. hidden Higgs $h \rightarrow \chi_0 \chi_0 \rightarrow \gamma \gamma GG$
    w/ $m_H \sim 95$ GeV)
1 – Very strong bounds on colored particles
LHC-7

2 – An awkward Higgs mass
What the LHC has done to SUSY?

**Pre-LEP**

\[
\begin{align*}
\bar{g} &\rightarrow \tilde{t}_2 \tilde{b}_2 \\
\tilde{d}_L \tilde{u}_L &\rightarrow \tilde{u}_R \tilde{d}_R \\
\tilde{N}_4 &\rightarrow \tilde{C}_2 \\
\tilde{N}_3 &\rightarrow \tilde{C}_2 \\
\tilde{N}_2 &\rightarrow \tilde{C}_1 \\
\tilde{N}_1 &\rightarrow \tilde{C}_1
\end{align*}
\]

**Post-LHC7**

\[
\begin{align*}
\bar{g} &\rightarrow \tilde{t}_2 \tilde{b}_2 \\
\tilde{d}_L \tilde{u}_L &\rightarrow \tilde{u}_R \tilde{d}_R \\
\tilde{e}_L &\rightarrow \tilde{\nu}_e \\
\tilde{\tau}_2 &\rightarrow \tilde{\nu}_\tau \\
\tilde{\bar{e}}_R &\rightarrow \tilde{\nu}_\tau \\
\tilde{\bar{e}}_R &\rightarrow \tilde{\tau}_1
\end{align*}
\]
How well SUSY unifies?

@1-loop
How well SUSY unifies?

@2-loop
How well SUSY unifies?

SM

MSSM

@2-loop x9!

@2-loop
At the Crossroads

- Split Supersymmetry
- Standard Model
- Multiverse
- Naturalness
- Large Extra Dimensions
- Supersymmetry
- Technicolor
What naturalness wants

1 – light $\mu$-term (<~ 250 GeV)
2 – light stops (<~400 GeV)
3 – not too heavy gluino (<~2 TeV)

What simple model building likes

1 – degenerate squarks
2 – hierarchish colored/uncolored spectrum
3 – some very light sparticle
Lesson #1: Gluino Sucks

\[ \partial_t m_s^2 = -\frac{32 \alpha_s}{3 \frac{\pi}{4}} |M_3|^2 + \ldots \]
Lesson #2: The Higgs needs a fix

- Singlet (perturbative coupling may still work)
- Extra gauge group (U(1)')
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Lesson #3: Yukawa running

Running from high scales with universal squark masses:

\[ m_{\text{stop}} \sim \frac{1}{2} m_{\text{squarks}} \]
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Lesson #3: Yukawa running

Running from high scales with universal squark masses:

\[ m_{\text{stop}} \sim \frac{1}{2} m_{\text{squarks}} \]

Lesson #4: Universal gaugino masses

\[ M_3 \sim \frac{\alpha_3}{\alpha_1} M_1 \sim 7 M_1 \]
Scenario #1: Universal squark masses

Best solution to flavor problem is still MFV-like scalar spectrum
(as in gauge/gaugino mediation, anomaly mediation, etc...)
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The Clash:
- Very strong bounds on first gen. squarks!
- Light stop required by naturalness!
**Scenario #1: Universal squark masses**

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*The Clash:*
- Very strong bounds on first gen. squarks!
- Light stop required by naturalness!

**option #1:** big RGE running \( (m_{squarks} \sim 2 \, m_{stop}) \)

**option #2:** small running w/ good boundary conditions

\[
m_s^2 = m_0^2 (1+c \, |Y|^2)
\]
One of the last natural SUSY model?

1) MSSM
2) Singlet (to raise Higgs mass and to solve $\mu$-problem)
3) Low scale gauge mediation (to minimize gluino effects)
4) Non universal gaugino masses
   (to avoid too heavy colored particles)
5) Direct coupling Singlet-Mediators
   (to generate negative singlet mass squared and A-terms)
6) Direct coupling Higgs-Mediators
   (to generate extra negative contribution to stop mass and A-terms)
A working spectrum?

- squarks (>~1.2 TeV)
- gluino (>~1 TeV)
- stop 2 (~500)
- neutralinos (>400)
- stop 1 (~200)
- gravitino (~0)
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1) Is it really natural? 2) How easy is to model build?
**Scenario #2: Split families models**

- **1st- 2nd family**
- **gluino**
- **3rd family**
- **higgsinos**

The 3rd generation is different

E.g. first two generation couple more strongly to SUSY breaking

*Dimopoulos Giudice '95, Pomarol Tommasini '95*

*...Craig Dimopoulos Gherghetta '12*
Split Families Models

to be discovered soon!
Scenario #3: Exotic: RPV, photini, ...

RPV: Graham, Kaplan, Rajendran, Saraswat '12

Photini: Baryakhtar, Craig, Van Tilburg '12