Mass scale of vector like matter and superpartners from IR fixed point predictions of gauge and top Yukawa couplings

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MSSM with a vector like family

- Vector like fermions introduced for a variety of phenomenological studies
  - \( g-2 \)
  - Higgs mass
  - \( U(1)' \) physics
  - Flavor anomalies

- In my talk:
  - Extend the MSSM with a vector like family
  - Offers phenomenologically interesting GUT scenario, mass scales for vector like matter and superpartners inferred from IR fixed points in the model

\[
W \supset M_Q Q \bar{Q} + M_U U \bar{U} + M_E E \bar{E} + M_L L \bar{L} + M_D D \bar{D} + M_N N \bar{N}
\]

\[
10 \oplus \bar{10} \hspace{2cm} 5 \oplus \bar{5} \hspace{2cm} 1 \oplus \bar{1}
\]
Gauge couplings with VF

\[
\frac{d\alpha_i}{dt} = \beta(\alpha_i) = \frac{\alpha_i^2}{2\pi} b_i
\]

\[
b_i = \left(\frac{33}{5}, 1, -3\right) + n_5(1, 1, 1) + 3n_{10}(1, 1, 1)
\]

**Complete vectorlike Family:**

\[
b_i = \left(\frac{53}{5}, 5, 1\right)
\]

\[
n_5 = n_{10} = 1
\]

**All three couplings become asymptotically divergent**

\[
\alpha_i^{-1}(M_Z) = \frac{b_i}{2\pi} \ln \frac{M_G}{M_Z} + \alpha^{-1}(M_G)
\]

\[
\Rightarrow \quad \frac{\alpha_i(M_Z)}{\alpha_j(M_Z)} \sim \frac{b_j}{b_i}
\]

Two parameter free predictions
Weinberg angle

\[ \sin^2 \theta_W \equiv \frac{\alpha'}{\alpha_2 + \alpha'} \approx \frac{b_2}{b_2 + b'} = 0.2205 \]
Weinberg angle

\[ \sin^2 \theta_W \equiv \frac{\alpha'}{\alpha_2 + \alpha'} \approx \frac{b_2}{b_2 + b'} = 0.2205 \]

Correct EW scale value

For \( \alpha_G \geq 0.3 \) & superpartners above 1 TeV, suggests VL matter ~ multi-TeV scale
Mass scale for vector like fermions

\[ \alpha_G = 0.3 \quad M_{SUSY} = 3 \text{ TeV} \]

\[ \log_{10} M_{VF} [\text{GeV}] \]

\[ \log_{10} M_G [\text{GeV}] \]

\[ \alpha_1 \sim 10\% \]
\[ \alpha_2 \sim 10\% \]
\[ \alpha_3 \sim 10\% \]
\[ \text{All} \sim 10\% \]
\[ \text{All} \sim 5\% \]
\[ \text{All} \sim 1.5\% \]

Shows huge range of parameters
results in observed pattern of gauge couplings
Mass scale for vector like fermions

\[ \alpha_G = 0.3 \]

\[ \alpha_G = 0.4 \]

\[ \alpha_G = 0.2 \]
For any $\alpha_G \geq 0.3$, VF or SUSY expected within 1.7 TeV (2.5 TeV) based on all gauge couplings within 1.7% (5%) from observed values at EW scale

Interesting tension in parameter space, in a region that can be tested in the near future
Fixed point for the top Yukawa

\[ W \supset Y_U H_u Q\bar{U} + Y_D H_u \bar{Q} D \]

\[ \beta_{y_t}^{(1)} = y_t \left( 6y_t^2 + 3Y_U^2 + 3Y_D^2 - \frac{16}{3} g_3^2 - 3g_2^2 - \frac{13}{15} g_1^2 \right) \]
Fixed point predictions for the top Yukawa

\[ \alpha_G = 0.3 \]

For \[ m_t = y_t v \sin \beta \] to produce \[ \alpha_3 \] also gives robust prediction for top-yukawa.
Conclusions

• Extending the MSSM with a complete vector like family offers an interesting SUSY GUT scenario:
  • Many features of the model highly insensitive to details at the GUT scale
  • Both VF and SUSY scales can be inferred by comparing to EW data and collider limits
  • Fixed points of Gauge couplings and top-quark Yukawa coupling all point ~ multi-TeV VF & SUSY scales (favored by Higgs mass)

• More specific spectrum can be studied by introducing specific SUSY breaking scenario, GUT scale model etc. Results presented here can be used to understand the implications of such a model

Thanks!