SOME PHENOMENOLOGICAL ANALYSES IN STRING THEORY AND M-THEORY

David G. Cerdeño
Departamento de Física Teórica
Instituto de Física Teórica
Universidad Autónoma de Madrid

In collaboration with:
Emidio Gabrielli
Shaaban Khalil
Emilio Torrente-Lujan
Carlos Muñoz

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The MSSM can be built using D-brane configurations.

![Diagram: Dp3, Dp1, Dp2 with labels u^c, d^c, b, w, e^c, H2, H1, L_e, Dq, Q_u, U(3)_c, U(1), U(2)_L]

The SM gauge group can be embedded within

- the same set of D-branes
- different sets of D-branes

$U(1)_Y$ is in general a linear combination of the remaining $U(1)$ that reproduces the correct hypercharge for the matter.
\[ Y = c_3 \sqrt{6} Q_3 + c_2 \sqrt{4} Q_2 + \sqrt{2} Q_1 \]

(Antoniadis, Kiritsis, Tomaras '00)

From this ...

\[ \frac{1}{\alpha_Y(M_I)} = \frac{2}{\alpha_1(M_I)} + \frac{4c_2^2}{\alpha_2(M_I)} + \frac{6c_3^2}{\alpha_3(M_I)} \]

... and the usual RGE’s for gauge couplings

\[ \frac{1}{\alpha_j(M_I)} = \frac{1}{\alpha_j(M_Z)} + b_{j}^{ns} \frac{\ln M_s}{M_Z} + b_{j}^s \frac{\ln M_I}{M_s} \]

An expression for the string scale in terms of low-energy data \((\alpha_i(M_Z))\) is found, e.g.,

\[ \ln \frac{M_I}{M_s} = 33.09 - \frac{1.05}{\alpha_1(M_I)} - 1.22 \ln \frac{M_s}{M_Z} \]

0.07 \(\lesssim\) \(\alpha_1(M_Z)\) \(\lesssim\) 0.1 \(\rightarrow\) \(M_I \approx 10^{10-12}\) GeV

- This possibility also arises for other configurations, such as \(Dp_1 = Dp_3\) or considering the SM gauge group to be embedded within the same set of D-branes.

(Cerdeño, Gabrielli, Khalil, Muñoz, Torrente-Luján '01)
Soft SUSY-breaking terms

Under the assumption of dilaton/moduli supersymmetry-breaking, the structure of soft terms can be evaluated.

(Ibáñez, Muñoz, Rigolin ’99)

These are generically non-universal, e.g., for the case of gaugino masses:

\[
\begin{align*}
M_3 &= \sqrt{3} m_{3/2} \sin \theta , \\
M_2 &= \sqrt{3} m_{3/2} \Theta_1 \cos \theta , \\
M_Y &= \sqrt{3} m_{3/2} \alpha_Y (M_I) \left( \frac{2}{\alpha_1 (M_I)} \Theta_3 \cos \theta \\
&\quad + \frac{1}{\alpha_2 (M_I)} \Theta_1 \cos \theta + \frac{6 c_3^2}{\alpha_3 (M_I)} \sin \theta \right)
\end{align*}
\]

And also for the scalar masses and trilinear parameters.
Intermediate scales, together with non-universality of the soft terms may induce an increase of the interaction cross-section of supersymmetric dark matter (lightest neutralinos, $\tilde{\chi}_1^0$) in Earth detectors.

(Gabrielli, Khalil, Muñoz, Torrente-Luján ’00)

(Accomando, Arnowitt, Dutta, Santoso ’00)

(Arnowitt, Dutta ’01)

This is here the case and compatibility with DAMA is possible.

(Cerdeño, Gabrielli, Khalil, Muñoz, Torrente-Luján ’01)

(Cerdeño, Gabrielli, Muñoz ’02)
The GUT scale is identified with the Calabi-Yau compactification scale on the observable hyperplane, $V_O^{-1/6}$.

- Typically, $V_O^{-1/6} \approx 3 \times 10^{16}$ GeV.

  It can, however, be decreased under special circumstances.

  (Benakli ’99)
  (Cerdeño, Muñoz ’99)

- We have considered a compactification on a CY with only one modulus (or overall modulus), in order to obtain universal soft terms.

  The soft terms are calculated taking into account the effect of five-branes in the bulk.

  (Cerdeño, Muñoz ’02)
Being the soft terms universal and the initial scale for their running of the order of $10^{16}$ GeV, the predictions for $\sigma_{\chi_1^0-p}$ are below the present sensitivities.

No compatibility with DAMA is achieved.

(Cerdeño, Muñoz '02)
D-brane scenarios

- Intermediate scales, $\sim 10^{10-12}$ GeV, appear naturally in D-brane scenarios when low-energy experimental data are imposed.

- Non-universal soft terms are common in these scenarios.

- Interesting phenomenological implications, e.g., increasing the cross-section for dark matter detection is possible.

Heterotic M-theory

- We have considered high values for the scale $\sim 3 \times 10^{16}$ GeV, and universal soft terms.

- The predictions for dark matter detection are much smaller, e.g., compatibility with DAMA is not achieved.