Non-Tachyonic Semi-Realistic Non-Supersymmetric Heterotic String Vacua

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Motivation

Seek string models which closely resemble the MSSM with

- 4D $N = 1$ theory

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  - $N = 1 \rightarrow N = 0$

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- 4D $N = 1$ theory
  - $N = 1 \rightarrow N = 0$
  - See also talks by S. Groot Nibbelink, E. Mavroudi
- with SM gauge group embedding
- 3 chiral generations of quarks and leptons
- minimum of 1 Higgs doublet pair

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- ROME: $N = 1 \to N = 0$

The Free Fermionic Construction

A general boundary condition basis vector is of the form

$$\alpha = \left\{\psi^{1,2}, \chi^i, y^i, \omega^i | \overline{y}^i, \overline{\omega}^i, \overline{\psi}^{1,\ldots,5}, \overline{\eta}^{1,2,3}, \overline{\phi}^{1,\ldots,8}\right\}$$

where $i = 1, \ldots, 6$

- $\overline{\psi}^{1,\ldots,5}$ - $SO(10)$ gauge group
- $\overline{\phi}^{1,\ldots,8}$ - $SO(16)$ gauge group

The Very Simple Rules

- The ABK Rules

  [*Antoniadis*, *Bachas*, *Kounnas*, 1987]

- One-Loop Phases
  - $C\begin{pmatrix} b_i \\ b_j \end{pmatrix} = \pm 1$ or $\pm i$

- Virasoro Level-Matching Condition
  - $M_L^2 = -\frac{1}{2} + \frac{\alpha_L^2}{8} + \sum v_L = -1 + \frac{\alpha_R^2}{8} + \sum v_R = M_R^2$

$$SO(16) \times SO(16) \xrightarrow{\textit{tachyonic state(s) produced}} \text{untwisted sector}$$

[*Alvarez-Gaume*, *Ginsparg*, *Moore*, *Vafa*, 1986]

The SUSY generator S
Guarantees The Untwisted Tachyon Is Projected OUT.

However...

Problem: There is an abundance of sectors in the 3 generation semi-realistic models that can potentially give rise to tachyonic states.

An Explicit Non-Supersymmetric Tachyon-Free Model

$$
\begin{aligned}
1 &= \{\psi^\mu, \chi^{1,..,6}, y^{1,\dots,6}, \omega^{1,\dots,6} | \overline{y}^{1,\dots,6}, \overline{\omega}^{1,\dots,6}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^{1,2,3}, \overline{\phi}^{1,\dots,8}\} \\
S &= \{\psi^\mu, \chi^{1,..,6}\} \\
b_1 &= \{\psi^\mu, \chi^{1,2}, y^{3,\dots,6} | \overline{y}^{3,\dots,6}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^1\} \\
b_2 &= \{\psi^\mu, \chi^{3,4}, y^{1,2}, \omega^{5,6} | \overline{y}^{1,2}, \overline{\omega}^{5,6}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^2\} \\
b_3 &= \{\psi^\mu, \chi^{5,6}, \omega^{1,\dots,4} | \overline{\omega}^{1,\dots,4}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^3\}
\end{aligned}
$$

$$
\begin{aligned}
\alpha &= \{y^{1,\dots,6}, \omega^{1,\dots,6} | \overline{\omega}^1, \overline{y}^2, \overline{\omega}^3, \overline{y}^{4,5}, \overline{\omega}^6, \overline{\psi}^{1,2,3}, \overline{\phi}^{1,\dots,4}\} \\
\beta &= \{y^2, \omega^2, y^4, \omega^4 | \overline{y}^{1,\dots,4}, \overline{\omega}^5, \overline{y}^6, \overline{\psi}^{1,2,3}, \overline{\phi}^{1,\dots,4}\} \\
\gamma &= \{y^1, \omega^1, y^5, \omega^5 | \overline{\omega}^{1,2}, \overline{y}^3, \overline{\omega}^4, \overline{y}^{5,6}, \overline{\psi}^{1,2,3} = \tfrac{1}{2}, \\
&\qquad\qquad\qquad\qquad \overline{\eta}^{1,2,3} = \tfrac{1}{2}, \overline{\phi}^{2,\dots,7} = \tfrac{1}{2}\}
\end{aligned}
$$

The Non-Supersymmetric Choice of GGSO Phases

$$
\begin{array}{c c}
 & \begin{array}{cccccccc} 1 & S & b_1 & b_2 & b_3 & \alpha & \beta & \gamma \end{array} \\
\begin{array}{c} 1 \\ S \\ b_1 \\ b_2 \\ b_3 \\ \alpha \\ \beta \\ \gamma \end{array} &
\left(\begin{array}{cccccccc}
1 & 1 & -1 & -1 & -1 & 1 & 1 & i \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 \\
-1 & -1 & -1 & -1 & -1 & -1 & -1 & i \\
-1 & -1 & -1 & -1 & -1 & -1 & -1 & i \\
-1 & -1 & -1 & -1 & -1 & -1 & 1 & i \\
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 \\
1 & -1 & 1 & -1 & 1 & -1 & -1 & 1
\end{array}\right)
\end{array}
$$

The Observable Sector

$$\begin{array}{c} SO(10) \\ \Big\downarrow \alpha,\ \beta \\ SO(6) \times SO(4) \\ \Big\downarrow \gamma \\ SU(3)_C \times U(1)_C \times SU(2)_L \times SU(2)_R \end{array}$$

The Hidden Sector

$$
\begin{array}{c}
SO(16) \\
\Big\downarrow{\scriptstyle \alpha,\ \beta} \\
SO(8) \times SO(8) \\
\Big\downarrow{\scriptstyle \gamma} \\
U(1) \times SU(3)_{H_1} \times U(1)_{H_1} \times SU(3)_{H_2} \times U(1)_{H_2} \times U(1)
\end{array}
$$

No More SUSY

3 Types of Sectors

- Sectors that respect SUSY
- Sectors that exhibit SUSY breaking explicitly

  For a given sector
  $$\rho \in \Xi$$
  SUSY partners would be obtained from
  $$S + \rho$$
  But
  $$(\rho)_L^2 = 4, \qquad (S+\rho)_L^2 = 8$$
- Sectors with equal number of bosons and equal number of fermions but with **different gauge charges**

$n_b = n_f \Rightarrow \Lambda$ is exponentially suppressed.

Talk by E. Mavroudi

[*Abel*, *Dienes*, *Mavroudi*, 2015]

However, in our non-tachyonic, non-supersymmetric model there is a mismatch.

Having said that, we believe we can engineer our way to tackle this problem.

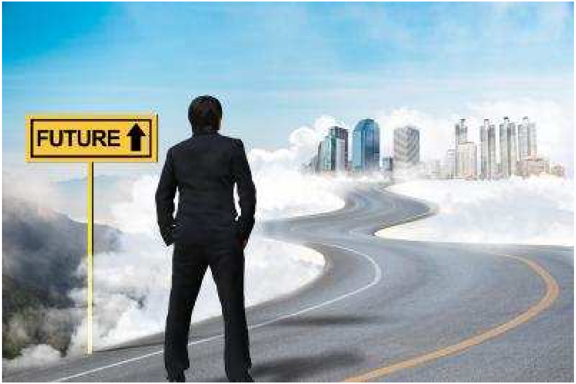
Summary

- Generically models without SUSY have tachyons
- We found a non-supersymmetric semi-realistic model

Furthermore

- This model is tachyon-free (all tachyons are projected out)
- Various Types of Sectors

Future Work



- Searching For Semi-Realistic Models With Exponentially Suppressed Cosmological Constant
- Cancellation of Non-Vanishing Vacuum Energy Tadpole Against $U(1)_A$ Tadpole

GRACIAS POR TU ATENCIÓN