Novel perspectives in string phenomenology

- 1989 – $\cdots$ Minimal Standard Heterotic String Models $\cdots$
- 2003 – $\cdots$ Classification of fermionic $Z_2 \times Z_2$ orbifolds $\cdots$
- 2019 – $\cdots$ 10D tachyonic vacua $\longrightarrow$ phenomenology?

  (AEF, EPJ C79 (2019) 703)
- Phenomenological aspects of non–geometric backgrounds

With: Kounnas, Rizos, $\cdots$, Percival, Matyas, Hurtado, $\cdots$

Corfu Summer Institute 2019, Corfu, 12 September 2019

Fermionic $Z_2 \times Z_2$ orbifolds

'Phenomenology of the Standard Model and Unification'

- Minimal Superstring Standard Model — NPB 335 (1990) 347 (with Nanopoulos & Yuan)
- Top quark mass $\sim$ 175–180GeV — PLB 274 (1992) 47
- Generation mass hierarchy — NPB 407 (1993) 57
- CKM mixing — NPB 416 (1994) 63 (with Halyo)
- Stringy seesaw mechanism — PLB 307 (1993) 311 (with Halyo)
- Gauge coupling unification — NPB 457 (1995) 409 (with Dienes)
- Proton stability — NPB 428 (1994) 111
- Squark degeneracy — NPB 526 (1998) 21 (with Pati)
- Moduli fixing — NPB 728 (2005) 83
- Classification — 2003 – $\cdots$ (with Kounnas, Rizos & ... Harries, Percival)

Other approaches

Geometrical

Greene, Kirklin, Miron, Ross (1987)
Donagi, Ovrut, Pantev, Waldram (1999)
Blumenhagen, Moster, Reinbacher, Weigand (2006)
Heckman, Vafa (2008)
....

Orbifolds

Ibanez, Nilles, Quevedo (1987)
Bailin, Love, Thomas (1987)
Kobayashi, Raby, Zhang (2004)
Lebedev, Nilles, Raby, Ramos-Sanchez, Ratz, Vaudrevange, Wingerter (2007)
Blaszczyk, Groot–Nibbelink, Ruehle, Trapletti, Vaudrevange (2010)
....

Other CFTs

Gepner (1987)
Schellekens, Yankielowicz (1989)
Gato–Rivera, Schellekens (2009)
....

Orientifolds

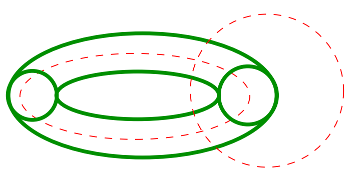
Cvetic, Shiu, Uranga (2001)
Ibanez, Marchesano, Rabadan (2001)
Kiristis, Schellekens, Tsulaia (2008)
....

Free Fermionic Construction

Left-Movers: $\psi^{\mu}_{1,2}, \quad \chi_i, \quad y_i, \; \omega_i \quad (i=1,\cdots,6)$

Right-Movers

$$\bar\phi_{A=1,\cdots,44} = \begin{cases} \bar y_i \; , \; \bar\omega_i & i=1,\cdots,6 \\ & \\ \bar\eta_i & U(1)_i \quad i=1,2,3 \\ \bar\psi_{1,\cdots,5} & SO(10) \\ \bar\phi_{1,\cdots,8} & SO(16) \end{cases}$$



$$V \longrightarrow V \qquad\qquad f \longrightarrow -e^{i\pi\alpha(f)} f$$

$$Z = \sum_{\substack{all\ spin\\ structures}} c\binom{\vec\alpha}{\vec\beta} \, Z\binom{\vec\alpha}{\vec\beta}$$

Models $\longleftrightarrow$ Basis vectors $+$ one–loop phases

Old School:

The NAHE set : $\{ \mathbf{1}, S, b_1, b_2, b_3 \}$

$N = 4 \rightarrow 2 \quad 1 \quad 1$ vacua

$Z_2 \times Z_2$ orbifold compactification

$\Longrightarrow$ Gauge group $SO(10) \times SO(6)^{1,2,3} \times E_8$

beyond the NAHE set Add $\{\alpha, \beta, \gamma\}$ $e.g.$ FNY model

number of generations is reduced to three

$$SO(10) \longrightarrow SU(3) \times SU(2) \times U(1)_{T_{3_R}} \times U(1)_{B-L}$$

$$U(1)_Y = \frac{1}{2}(B-L) + T_{3_R} \in SO(10) \; !$$

$$SO(6)^{1,2,3} \longrightarrow U(1)^{1,2,3} \times U(1)^{1,2,3}$$

Classification of fermionic $Z_2 \times Z_2$ orbifolds (Modern School)

Basis vectors:

$$1 = \{\psi^\mu,\ \chi^{1,\dots,6}, y^{1,\dots,6}, \omega^{1,\dots,6} \mid \bar{y}^{1,\dots,6}, \bar{\omega}^{1,\dots,6}, \bar{\eta}^{1,2,3}, \bar{\psi}^{1,\dots,5}, \bar{\phi}^{1,\dots,8}\}$$

$$S = \{\psi^\mu, \chi^{1,\dots,6}\},$$

$$z_1 = \{\bar{\phi}^{1,\dots,4}\},$$

$$z_2 = \{\bar{\phi}^{5,\dots,8}\},$$

$$e_i = \{y^i, \omega^i | \bar{y}^i, \bar{\omega}^i\},\ i = 1, \dots, 6, \qquad N = 4 \text{ Vacua}$$

$$b_1 = \{\chi^{34}, \chi^{56}, y^{34}, y^{56} | \bar{y}^{34}, \bar{y}^{56}, \bar{\eta}^1, \bar{\psi}^{1,\dots,5}\}, \qquad N = 4 \to N = 2$$

$$b_2 = \{\chi^{12}, \chi^{56}, y^{12}, y^{56} | \bar{y}^{12}, \bar{y}^{56}, \bar{\eta}^2, \bar{\psi}^{1,\dots,5}\}, \qquad N = 2 \to N = 1$$

$$\alpha = \{\bar{\psi}^{4,5}, \bar{\phi}^{1,2}\} \qquad \& \quad SO(10) \to SO(6) \times SO(4) \times \cdots$$

$$\beta = \{\bar{\psi}^{1,\cdots,5} \equiv \tfrac{1}{2}, \cdots\} \qquad \& \quad SO(10) \to SU(5) \times U(1) \times \cdots$$

Independent phases $c\begin{bmatrix} vi \\ v_j \end{bmatrix} = \exp[i\pi(v_i|v_j)]$: upper block

$$
\begin{array}{c}
\\ 1 \\ S \\ e_1 \\ e_2 \\ e_3 \\ e_4 \\ e_5 \\ e_6 \\ z_1 \\ z_2 \\ b_1 \\ b_2 \\ \alpha
\end{array}
\begin{array}{c}
\begin{array}{ccccccccccccc}
1 & S & e_1 & e_2 & e_3 & e_4 & e_5 & e_6 & z_1 & z_2 & b_1 & b_2 & \alpha
\end{array} \\
\left(
\begin{array}{ccccccccccccc}
-1 & -1 & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm \\
 & & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 \\
 & & & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm \\
 & & & & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm \\
 & & & & & \pm & \pm & \pm & \pm & \pm & \pm & \pm & \pm \\
 & & & & & & \pm & \pm & \pm & \pm & \pm & \pm & \pm \\
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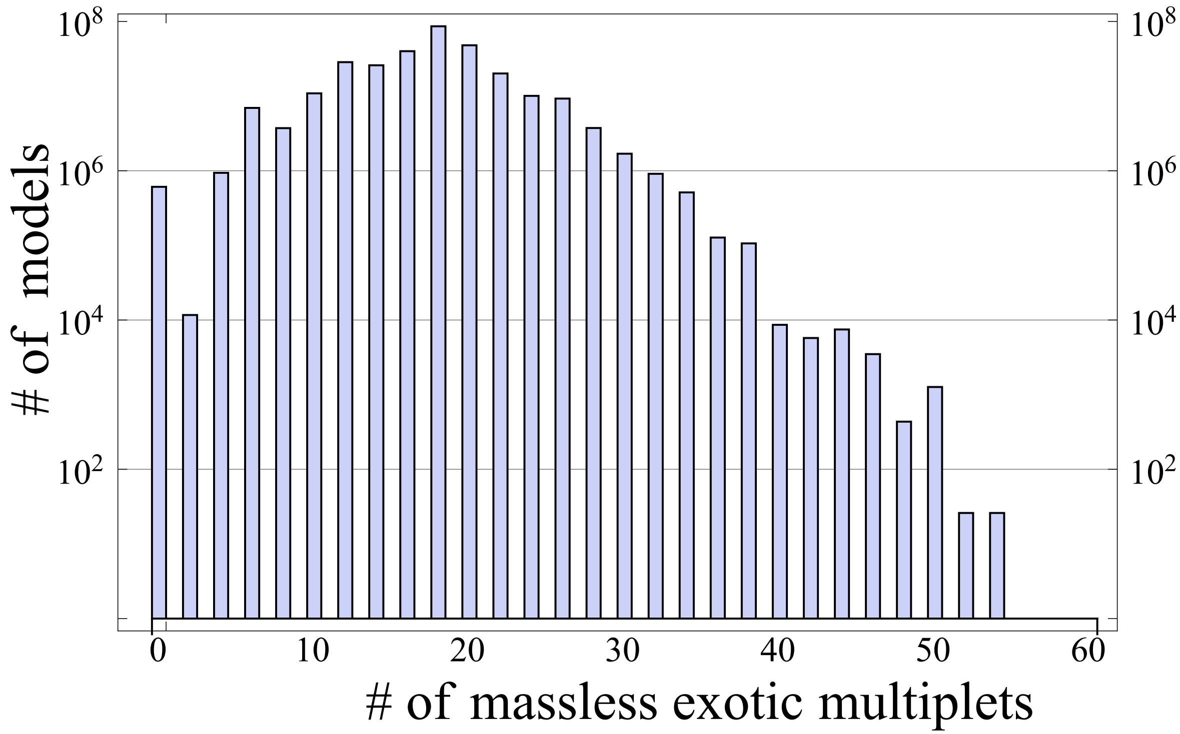
 & & & & & & & & & & & \pm & \pm \\
 & & & & & & & & & & & -1 & \pm \\
 & & & & & & & & & & & &
\end{array}
\right)
\end{array}
$$

A priori 66 independent coefficients $\rightarrow$ 2^{66} distinct vacua

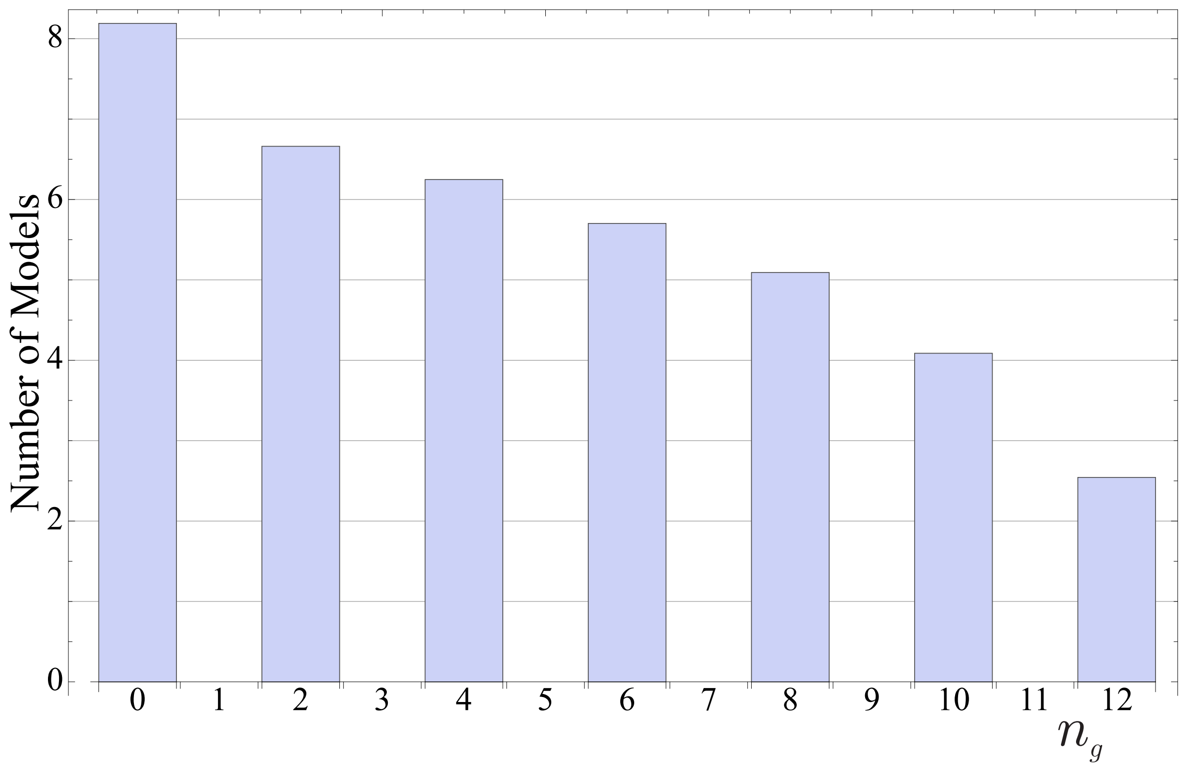
Pati–Salam class: with Assel, Christodoulides, Kounnas, Rizos

RESULTS: of random search of over 10^{11} vacua



Number of 3-generation models versus total number of exotic multiplets flipped $SU(5)$ class: with Sonmez, Rizos

RESULTS: of random search of over 10^{12} vacua



Number of exophobic models versus the number of generations

Standard-like Model class: with Sonmez, Rizos NPB 927 (2018) 1

RESULTS: random search of over 10^{11} vacua $\Rightarrow$ few 3 gen models

- Adaptation of the methodology:

- Two stage process;

- Random fertile $SO(10)$ models; Fertility conditions

- Complete SLM classification of fertile cores.

10^{7} Three generation SLMs with standard light and heavy Higgs spectrum

Left-Right Symmetric class: with Harries, Rizos NPB 936 (2018) 472

with fertility conditions: with Percival, Rizos work in progress

Starting with: $$Z^{+}_{10d} = (V_8 - S_8)\left(\overline{O}_{16} + \overline{S}_{16}\right)\left(\overline{O}_{16} + \overline{S}_{16}\right),$$

using the level–one $SO(2n)$ characters

$$O_{2n} = \frac{1}{2}\left(\frac{\theta_3^n}{\eta^n} + \frac{\theta_4^n}{\eta^n}\right), \qquad V_{2n} = \frac{1}{2}\left(\frac{\theta_3^n}{\eta^n} - \frac{\theta_4^n}{\eta^n}\right),$$

$$S_{2n} = \frac{1}{2}\left(\frac{\theta_2^n}{\eta^n} + i^{-n}\frac{\theta_1^n}{\eta^n}\right), \qquad C_{2n} = \frac{1}{2}\left(\frac{\theta_2^n}{\eta^n} - i^{-n}\frac{\theta_1^n}{\eta^n}\right).$$

where

$$\theta_3 \equiv Z_f\begin{pmatrix}0\\0\end{pmatrix} \qquad \theta_4 \equiv Z_f\begin{pmatrix}0\\1\end{pmatrix} \qquad \theta_2 \equiv Z_f\begin{pmatrix}1\\0\end{pmatrix} \qquad \theta_1 \equiv Z_f\begin{pmatrix}1\\1\end{pmatrix}$$

Apply $g = (-1)^{F+F_{z_1}+F_{z_2}}$

$$\begin{aligned} Z^{-}_{10d} = & \Big[\, V_8\left(\overline{O}_{16}\overline{O}_{16} + \overline{S}_{16}\overline{S}_{16}\right) - S_8\left(\overline{O}_{16}\overline{S}_{16} + \overline{S}_{16}\overline{O}_{16}\right) \\ + & \; \underline{O_8\left(\overline{C}_{16}\overline{V}_{16} + \overline{V}_{16}\overline{C}_{16}\right)} - C_8\left(\overline{C}_{16}\overline{C}_{16} + \overline{V}_{16}\overline{V}_{16}\right)\Big]. \end{aligned}$$

In fermionic language: $\{\ \mathbf{1}\ , z_1\ , z_2\ \}$

where $z_1 = \{\bar\psi^{1,\cdots,5}, \bar\eta^{1,2,3}\}$; $z_2 = \{\bar\phi^{1,\cdots,8}\}$ $\Rightarrow$ $S = \mathbf{1} + z_1 + z_2$

$c\binom{z_1}{z_2} = +1 \implies E_8 \times E_8$; $c\binom{z_1}{z_2} = -1 \implies SO(16) \times SO(16)$

non-SUSY string phenomenology

Alternatively: Apply $g = (-1)^{F+F_{z_1}}$

$$Z^{-}_{10d} = (V_8\overline{O}_{16} - S_8\overline{S}_{16} + O_8\overline{V}_{16} - C_8\overline{C}_{16})\,(\overline{O}_{16} + \overline{S}_{16}) ,$$

$O_8\overline{V}_{16}\overline{O}_{16} \implies$ tachyon

In fermionic language: $\{\ \mathbf{1}\ ,\ z_2\ \}$ $\implies$ No S

A tachyon free model

$$
\begin{aligned}
1 &= \{\psi^\mu,\ \chi^{1,\dots,6}, y^{1,\dots,6}, \omega^{1,\dots,6} | \bar{y}^{1,\dots,6}, \bar{\omega}^{1,\dots,6}, \bar{\eta}^{1,2,3}, \bar{\psi}^{1,\dots,5}, \bar{\phi}^{1,\dots,8}\}, \\
b_1 &= \{\psi^\mu, \chi^{1,2}, y^{3,\dots,6} | \overline{y}^{3,\dots,6}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^{1}\} \\
b_2 &= \{\psi^\mu, \chi^{3,4}, y^{1,2}, \omega^{5,6} | \overline{y}^{1,2}, \overline{\omega}^{5,6}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^{2}\} \\
b_3 &= \{\psi^\mu, \chi^{5,6}, \omega^{1,\dots,4} | \overline{\omega}^{1,\dots,4}, \overline{\psi}^{1,\dots,5}, \overline{\eta}^{3}\} \\
\alpha &= \{y^{1,\dots,6}, \omega^{1,\dots,6} | \overline{\omega}^{1}, \overline{y}^{2}, \overline{\omega}^{3}, \overline{y}^{4,5}, \overline{\omega}^{6}, \overline{\psi}^{1,2,3}, \overline{\phi}^{1,\dots,4}\} \\
\beta &= \{y^{2}, \omega^{2}, y^{4}, \omega^{4} | \overline{y}^{1,\dots,4}, \overline{\omega}^{5}, \overline{y}^{6}, \overline{\psi}^{1,2,3}, \overline{\phi}^{1,\dots,4}\} \\
\gamma &= \{y^{1}, \omega^{1}, y^{5}, \omega^{5} | \overline{\omega}^{1,2}, \overline{y}^{3}, \overline{\omega}^{4}, \overline{y}^{5,6}, \overline{\psi}^{1,\dots,5} = \frac{1}{2}, \overline{\eta}^{1,2,3} = \frac{1}{2}, \overline{\phi}^{2,\dots,5} = \frac{1}{2}\}
\end{aligned}
\tag{1}
$$

with a suitable set of GGSO projection coefficients

- Tachyon free six generation SLM model with suitable Higgs spectrum
- Reduction to three generation $\longrightarrow$ S–like vector on the left
- Connection with MSDS vacua in two dimensions ? (Kounnas & Florakis)

$Z_2 \times Z_2$ orbifolds

torus: One complex parameter $Z = Z + n\, e_1 + m\, e_2$

$T^2 \times T^2 \times T^2 \longrightarrow$ Three complex coordinates z_1 , z_2 and z_3

Z_2 orbifold : $Z = -Z + \sum_i m_i e_i \longrightarrow$ 4 fixed points

$$Z = \{ \; 0 \; , \; 1/2\, e_1 \; , \; 1/2\, e_2 \; , \; 1/2\,(e_1 + e_2) \; \}$$

$$\frac{T^2 \times T^2 \times T^2}{Z_2 \times Z_2}$$

$\alpha : (z1, z2, z3) \rightarrow (-z1, -z2, +z3) \rightarrow 16$

$\beta : (z1, z2, z3) \rightarrow (+z1, -z2, -z3) \rightarrow 16$

$\alpha\beta : (z1, z2, z3) \rightarrow (-z1, +z2, -z3) \rightarrow 16$

48

↓

$\gamma : (z1, z2, z3) \rightarrow (z1+1/2, z2+1/2, z3+1/2) \longrightarrow$ 24

Correspondence with $Z_2 \times Z_2$ orbifold

NAHE $\oplus$ $(z_1 = \{\bar\psi^{1,\cdots,5}, \bar\eta^1, \bar\eta^2, \bar\eta^3\} = 1) \quad \rightarrow \quad \{1, S, z_1, z_2, b_1, b_2\}$

Gauge group: $SO(4)^3 \times E_6 \times U(1)^2 \times E_8$ and 24 generations.

toroidal compactification

$$g_{ij} = \begin{pmatrix} 2 & -1 & 0 & 0 & 0 & 0 \\ -1 & 2 & -1 & 0 & 0 & 0 \\ 0 & -1 & 2 & -1 & 0 & 0 \\ 0 & 0 & -1 & 2 & -1 & -1 \\ 0 & 0 & 0 & -1 & 2 & 0 \\ 0 & 0 & 0 & -1 & 0 & 2 \end{pmatrix} \qquad b_{ij} = \begin{cases} g_{ij} & i < j \\ 0 & i = j \\ -g_{ij} & i > j \end{cases}$$

$R_i \quad \rightarrow$ the free fermionic point $\rightarrow$ G.G. $SO(12) \times E_8 \times E_8$

mod out by a $Z_2 \times Z_2$ with standard embedding

$\Rightarrow$ Exact correspondence

In the realistic free fermionic models

$$c\binom{z_1}{z_2} = +1 \quad \rightarrow \quad -1 \qquad \longrightarrow \qquad \text{Wilson line in toroidal language}$$

Then $\{\vec{1}, \vec{S}, \vec{z}_1, \vec{z}_2\} \rightarrow$ N=4 SUSY and

$$SO(12) \times SO(16) \times SO(16)$$

apply $b_1 \times b_2 \quad \rightarrow \quad Z_2 \times Z_2 \quad \rightarrow$ N=1 SUSY and

$$SO(4)^3 \times SO(10) \times U(1)^3 \times SO(16)$$

b_1, b_2, b_3 $\Rightarrow (3 \times 8) \cdot 16$ of $SO(10)_O$

$b_1 + 2\gamma$, $b_2 + 2\gamma$, $b_3 + 2\gamma$ $\Rightarrow (3 \times 8) \cdot 16$ of $SO(16)_H$

$Z_2 \times Z_2$ at the free fermion point

Question:

$$\frac{T^6}{Z_2 \times Z_2} \;\rightarrow\; 48 \;\text{ fixed points} \qquad\qquad \frac{SO(12)}{Z_2 \times Z_2} \;\rightarrow\; 24 \;\text{ fixed points}$$

$$Z_2 \;\text{ shift } \;: 48 \;\longleftrightarrow\; 24$$

Is this the same model? In general, no.

Starting from:

$$Z_+ = (V_8 - S_8) \left(\sum_{m,n} \Lambda_{m,n} \right)^{\otimes 6} (\bar{O}_{16} + \bar{S}_{16}) \, (\bar{O}_{16} + \bar{S}_{16}) \ ,$$

where as usual, for each circle,

$$p^i_{\mathrm{L,R}} = \frac{m_i}{R_i} \pm \frac{n_i R_i}{\alpha'} \, ,$$

and

$$\Lambda_{m,n} = \frac{q^{\frac{\alpha'}{4} p^2_{\mathrm{L}}} \, \bar{q}^{\frac{\alpha'}{4} p^2_{\mathrm{R}}}}{|\eta|^2} \, .$$

Add shifts : (A_1, A_1, A_1) , (A_3, A_3, A_3)

($48 \rightarrow 24$ yes)
($SO(12)$? no)

Uniquely: $A_2 : X_{\mathrm{L,R}} \to X_{\mathrm{L,R}} + \frac{1}{2}\left(\pi R \pm \frac{\pi\alpha'}{R}\right)$ NG shifts

$$g \;:\; (A_2, A_2, 0)\,,$$

$$h \;:\; (0, A_2, A_2)\,,$$

where each A_2 acts on a complex coordinate

($48 \to 24$ yes)

($SO(12)$? yes)

$$R = \sqrt{\alpha'}$$

Moduli $\rightarrow$ WS Thirring interactions $(R-\frac{1}{R})J_L^i(z)\bar{J}_R^j(\bar{z}) = (R-\frac{1}{R})y^i\omega^i\bar{y}^j\bar{\omega}^j$

To identify the untwisted moduli in the free fermionic models

$\rightarrow$ find the operators of the form

$$J_L^I(z)\bar{J}_R^J(\bar{z})$$

that are allowed by the orbifold (fermionic) symmetry group

$$Z_2 \times Z_2 \qquad \{\ 1\ ,\ S\ ,\ \xi_1\ ,\ \xi_2\ \}\ +\ \{\ b_1\ ,\ b_2\ \}$$

$$\rightarrow\ \ SO(4)^3 \times E_6 \times U(1)^2 \times E_8$$

The Thirring interactions that remain invariant are

$$J_L^{1,2}\bar{J}_R^{1,2} \quad ; \quad J_L^{3,4}\bar{J}_R^{3,4} \quad ; \quad J_L^{5,6}\bar{J}_R^{5,6}$$

$$y^{1,2}\omega^{1,2}\bar{y}^{1,2}\bar{\omega}^{1,2} \quad ; \quad y^{3,4}\omega^{3,4}\bar{y}^{3,4}\bar{\omega}^{3,4} \quad ; \quad y^{5,6}\omega^{5,6}\bar{y}^{5,6}\bar{\omega}^{5,6}$$

These moduli are always present in symmetric $Z_2 \times Z_2$ orbifolds in realistic models

$$\{\,1\,,\ S\,,\ \xi_1\,,\ \xi_2\,\}\ \oplus\ \{\,b_1\,,\ b_2\,\}\ \oplus\ \{\,\alpha\,,\ \beta\,,\ \gamma\}$$

$$N=4 \qquad\qquad N=1$$

$$E_8\times E_8 \qquad\qquad Z_2\times Z_2$$

new feature Asymmetric orbifold

the key focus: boundary conditions of the internal fermions

$$\{\,y\,,\ \omega\ \mid\ \bar{y}\,,\ \bar{\omega}\,\}$$

WS fermions that have same B.C. in all basis vectors are paired

pairing of LR fermions $\longrightarrow$ Ising model $\longrightarrow$ symmetric real fermions

pairing of LL & RR fermions $\longrightarrow$ complex fermions $\longrightarrow$ asymmetric

STRING DERIVED STANDARD-LIKE MODEL (PLB278)

	ψ^μ	χ^{12}	χ^{34}	χ^{56}	$y^{3,\ldots,6}$	$\bar{y}^{3,\ldots,6}$	$y^{1,2},\omega^{5,6}$	$\bar{y}^{1,2},\bar{\omega}^{5,6}$	$\omega^{1,\ldots,4}$	$\bar{\omega}^{1,\ldots,4}$	$\bar{\psi}^{1,\ldots,5}$	$\bar{\eta}^1$	$\bar{\eta}^2$	$\bar{\eta}^3$	$\bar{\phi}^{1,\ldots,8}$
1	1	1	1	1	1,...,1	1,...,1	1,...,1	1,...,1	1,...,1	1,...,1	1,...,1	1	1	1	1,...,1
S	1	1	1	1	0,...,0	0,...,0	0,...,0	0,...,0	0,...,0	0,...,0	0,...,0	0	0	0	0,...,0
b_1	1	1	0	0	1,...,1	1,...,1	0,...,0	0,...,0	0,...,0	0,...,0	1,...,1	1	0	0	0,...,0
b_2	1	0	1	0	0,...,0	0,...,0	1,...,1	1,...,1	0,...,0	0,...,0	1,...,1	0	1	0	0,...,0
b_3	1	0	0	1	0,...,0	0,...,0	0,...,0	0,...,0	1,...,1	1,...,1	1,...,1	0	0	1	0,...,0

	ψ^μ	χ^{12}	χ^{34}	χ^{56}	y^3y^6	$y^4\bar{y}^4$	$y^5\bar{y}^5$	$\bar{y}^3\bar{y}^6$	$y^1\omega^5$	$y^2\bar{y}^2$	$\omega^6\bar{\omega}^6$	$\bar{y}^1\bar{\omega}^5$	$\omega^2\omega^4$	$\omega^1\bar{\omega}^1$	$\omega^3\bar{\omega}^3$	$\bar{\omega}^2\bar{\omega}^4$	$\bar{\psi}^{1,\ldots,5}$	$\bar{\eta}^1$	$\bar{\eta}^2$	$\bar{\eta}^3$	
α	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1 1 1 0 0	0	0	0	1 1
β	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	1	1 1 1 0 0	0	0	0	1 1
γ	0	0	0	0	0	1	0	1	0	1	0	1	1	0	0	0	$\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$ 0 1

Asymmetric $BC \Rightarrow$ all untwisted moduli are projected out!

all $y_i\omega_i\bar{y}_i\bar{\omega}_i$ are disallowed

can be translated to asymmetric bosonic identifications

$$X_L + X_R \rightarrow X_L - X_R$$

moduli fixed at enhanced symmetry point

Twisted moduli

(2,2) $b_j \oplus b_j + \xi_2 \quad \longrightarrow \quad (16 \oplus 10 + 1) + 1 = 27 + 1 \Rightarrow$ twisted moduli

(2,0) $b_j + b_j + 2\gamma \quad \longrightarrow 16_{SO(10)} + 16_{SO(16)}$

all twisted moduli are projected out

MINIMAL DOUBLET HIGGS CONTENT (EJPC50)

	ψ^μ	χ^{12}	χ^{34}	χ^{56}	y^3y^6	$y^4\bar{y}^4$	$y^5\bar{y}^5$	$\bar{y}^3\bar{y}^6$	$y^1\omega^5$	$y^2\bar{y}^2$	$\omega^6\bar{\omega}^6$	$\bar{y}^1\bar{\omega}^5$	$\omega^2\omega^4$	$\omega^1\bar{\omega}^1$	$\omega^3\bar{\omega}^3$	$\bar{\omega}^2\bar{\omega}^4$	$\bar{\psi}^{1,\dots,5}$	$\bar{\eta}^1$	$\bar{\eta}^2$	$\bar{\eta}^3$	$\bar{\phi}$
α	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1 1 1 0 0	1	0	0	1 1 0
β	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	1	1 1 1 0 0	0	1	0	0 0 1
γ	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	$\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	0 0 0

(With Elisa Manno and Cristina Timirgaziu)

SYMMETRIC $\leftrightarrow$ ASYMMETRIC

with respect to b_1 & b_2

$h_1,\ \bar{h}_1,\ D_1,\ \bar{D}_1$, $h_2,\ \bar{h}_2,\ D_2,\ \bar{D}_2$ are projected out

$h_3,\ \bar{h}_3$ remain in the spectrum

$$\lambda_t Q_3 t_3^c \bar{h}_3 \ \text{ with } \ \lambda_t\ O(1)$$

No Phenomenologically viable flat directions

Cleaver, Faraggi, Manno, Timirgaziu, PRD 78 (2008) 046009

Classification of F and D flat directions in EMT reduced Higgs model

No D flat direction which is F-flat up to order eight in the superpotential

no stringent flat directions to all orders

Suggesting no supersymmetric flat directions in this model (class of models)

implying no supersymmetric moduli

only remaining perturbative moduli is the dilaton

quasi–realistic model: SLM; 3 gen; $SO(10)$ embed; Higgs & $\lambda_t \sim 1$; ...

vanishing one–loop partition function, perturbatively broken SUSY

Fixed geometrical, twisted and SUSY moduli

Conclusions

- DATA $\longrightarrow$ UNIFICATION
- STRINGS THEORY $\longrightarrow$ GAUGE & GRAVITY UNIFICATION
- STRINGS PHENOMENOLOGY $\longrightarrow$ AT ITS INFANCY

  STILL LEARNING HOW TO WALK

- 10D vacua without S–SUSY generator
- Role of non–geometric backgrounds?
- String Phenomenology $\longrightarrow$ Physics of the third millenium

  $e.g.$ Aristarchus to Copernicus