Orbifold Blow-ups without breaking hypercharge

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Based on:

M. Blaszczyk, S. Groot Nibbelink, M. Ratz, F. Ruehle, M. Trapletti and P. V.: arXiv:09xx.xxxx

Outline

Motivation

- Heterotic orbifold MSSMs
- Study their connection to Calabi-Yau compactifications
- What is generic to orbifold MSSMs?

Orbifold MSSMs

Orbifold MSSMs

$\mathbb{Z}_6$-II Mini-Landscape

$\mathcal{O}(100)$ $\mathbb{Z}_6$-II orbifold models with

- $SU(3) \times SU(2) \times U(1)_Y$ times hidden sector
- 3 generations of quarks and leptons + vector-like exotics
- exotics decouple
- (potentially) realistic flavor structure, e.g. heavy top

O. Lebedev, H. P. Nilles, S. Raby, S. Ramos-Sanchez, M. Ratz, P. V., A. Wingerter 2006, 2007

- see talks by:
  R. Kappl, H. P. Nilles, S. Ramos-Sanchez and M. Ratz

Relation to other Constructions

- Can these models be obtained from a CY construction?

  $\Rightarrow$No, at least not easily!

  $\Rightarrow$ talks by M. Trapletti and S. Groot Nibbelink
- $\mathbb{Z}_6$-II Mini-Landscape at special (symmetry enhanced) point in moduli space:
  - Wilson line breaks GUT to SM (locally) at fixed points
  - In full blow-up, SM gauge group (e.g. hypercharge) broken at these fixed points
  - (fixed points with only SM charged states $\Rightarrow$ blow-up mode breaks SM)
- Important: full blow-up of Mini-Landscape models not necessary

Full Blow-up possible?

Can MSSM orbifold models have a corresponding CY description in principle?

or

Can MSSM orbifold models be blown-up completely?

Non-local GUT Breaking

Non-local GUT Breaking

Non-local GUT Breaking

- One possibility: GUT broken to SM non-locally: freely acting orbifold
- In this talk: $\mathbb{Z}_2 \times \mathbb{Z}_2$ orbifold with freely acting twists

  R. Donagi and K. Wendland 2008
- Gauge coupling unification and M_{GUT} vs. M_{string} (anisotropic compactification $\Rightarrow$ talk by R. Kappl on gauge-top unification)

  A. Hebecker and M. Trapletti 2004

$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

(1-1) $\mathbb{Z}_2 \times \mathbb{Z}_2$ orbifold by Donagi, Wendland:

- $T^6 = T^2 \times T^2 \times T^2$ spanned by orthogonal lattice e_i, $i = 1, \ldots, 6$
- $\mathbb{Z}_2 \times \mathbb{Z}_2$ generated by

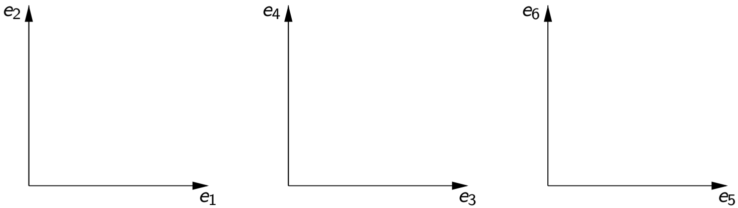
$$\begin{aligned} v_1 &= \left(0, \frac{1}{2}, -\frac{1}{2}\right) \\ v_2 &= \left(-\frac{1}{2}, 0, \frac{1}{2}\right) \end{aligned}$$

- freely acting twist: $\tau = \left(\frac{1}{2}e_2, \frac{1}{2}e_4, \frac{1}{2}e_6\right)$

R. Donagi and K. Wendland 2008

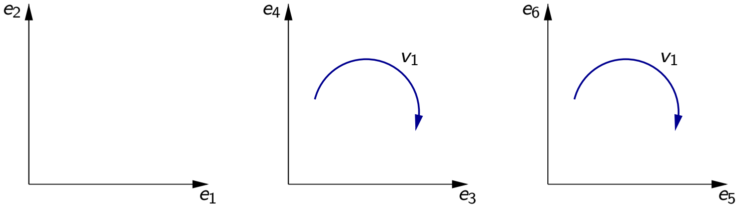
$\mathbb{Z}_2 \times \mathbb{Z}_2$ orbifold with freely acting twist

T^6 torus



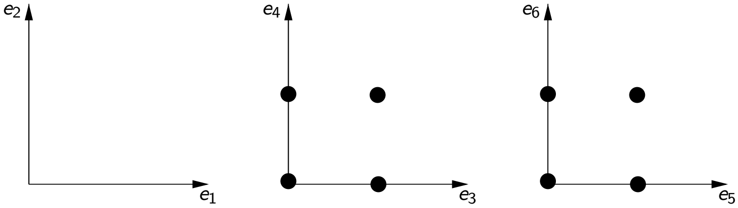
$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

twist v_1 acting on T^6 torus



$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

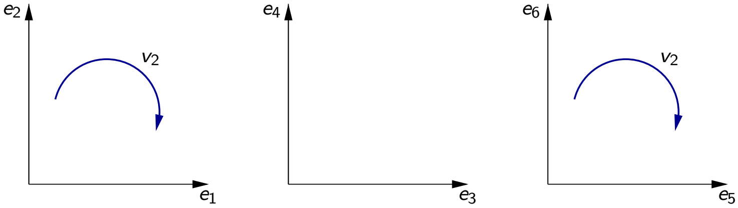
twist v_1 acting on T^6 torus



$\Rightarrow$ 16 fixed points

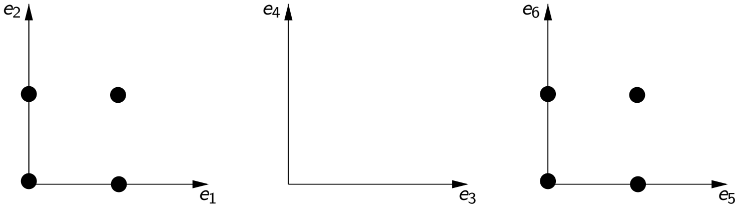
$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

twist v_2 acting on T^6 torus



$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

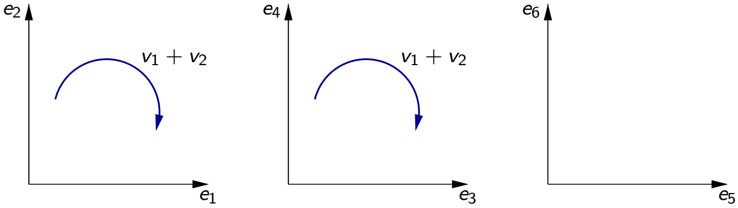
twist v_2 acting on T^6 torus



$\Rightarrow$ 16 fixed points

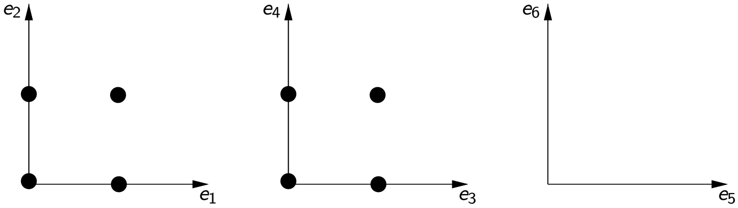
$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

twist $v_1 + v_2$ acting on T^6 torus



$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

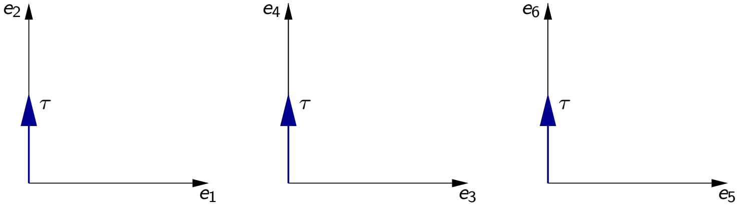
twist $v_1 + v_2$ acting on T^6 torus



$\Rightarrow$ 16 fixed points

$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

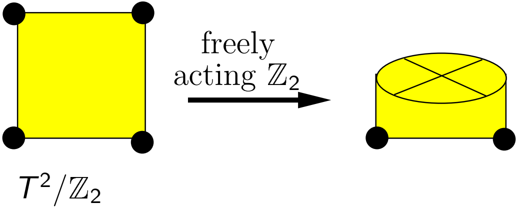
freely acting twist τ acting on T^6 torus



$\Rightarrow$ half the number of fixed points: $(16+16+16)/2 = 24$

$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

action of freely acting twist in 2d:



$\Rightarrow$ half the number of fixed points: $4/2 = 2$

$\mathbb{Z}_2 \times \mathbb{Z}_2$ Orbifold with Freely Acting Twist

- setup:

$\mathbb{Z}_2 \times \mathbb{Z}_2$ orbifold with 6 generations of SU(5)

$\downarrow$ freely acting $\mathbb{Z}_2$

3 generations of $SU(3) \times SU(2) \times U(1)$

- where freely acting Wilson line induces GUT breaking
- Potentially: one SM singlet per fixed point $\Rightarrow$ full blow-up

Example 1

- Shifts and Wilson lines

$$
\begin{aligned}
V_1 &= \left(\frac{1}{4}, -\frac{1}{4}, -\frac{1}{4}, \frac{1}{4}, -\frac{3}{4}, -\frac{3}{4}, \frac{1}{4}, \frac{1}{4}, 1, 0^7\right)\\
V_2 &= \left(\frac{3}{4}, \frac{1}{4}, -\frac{1}{4}, \frac{1}{4}, \frac{1}{4}, -\frac{3}{4}, \frac{1}{4}, \frac{1}{4}, 1, 0^7\right)\\
A_1 &= 0\\
A_2 &= \left(-\frac{5}{4}, \frac{3}{4}, -\frac{3}{4}, \frac{9}{4}, -\frac{7}{4}, -\frac{3}{4}, \frac{5}{4}, -\frac{3}{4}, -\frac{1}{4}, \frac{11}{4}, \frac{3}{4}, -\frac{3}{4}, -\frac{7}{4}, -\frac{3}{4}, \frac{5}{4}, \frac{3}{4}\right)\\
A_3 &= \left(-1, -1, 0, -2, 0, -2, 2, -3, -\frac{7}{4}, -\frac{1}{4}, \frac{3}{4}, -\frac{1}{4}, -\frac{5}{4}, \frac{1}{4}, \frac{1}{4}, \frac{5}{4}\right)\\
A_5 &= \left(\frac{1}{4}, \frac{9}{4}, -\frac{13}{4}, \frac{11}{4}, \frac{3}{4}, \frac{11}{4}, -\frac{1}{4}, -\frac{1}{4}, \frac{3}{4}, \frac{1}{4}, -\frac{11}{4}, -\frac{3}{4}, -\frac{3}{4}, -\frac{1}{4}, -\frac{5}{4}, \frac{3}{4}\right)\\
A_6 &= A_4 = A_2
\end{aligned}
$$

Example 1

- 4d gauge group: SU(5) × U(1)^4 × [SU(4)^2 × U(1)^2]
- massless spectrum

15	(5, 1, 1)	9	($\overline{5}$, 1, 1)
6	($\overline{10}$, 1, 1)	56	(1, 1, 1)
12	(1, 4, 1)	12	(1, $\overline{4}$, 1)
12	(1, 1, 4)	12	(1, 1, $\overline{4}$)
2	(1, 6, 1)	2	(1, 1, 6)

- 6 generations of SU(5) ⇒ 3 generations SM by freely acting Wilson line $A_\tau = \frac{1}{2}A_2$
- one blow-up mode per fixed-point ⇒ potentially full blow-up
- however: unbroken U(1)$_{B-L}$ at low energies (cf. M. Ambroso and B. Ovrut 2009)

Example 2

- Shifts and Wilson lines

$$
\begin{aligned}
V_1 &= \left(\frac{1}{2}, \frac{1}{2}, 0^{14}\right) \\
V_2 &= \left(\frac{5}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{2}, \frac{1}{2}, 0^{6}\right) \\
A_1 &= 0 \\
A_2 &= \left(-1, -1, 0, -1, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{4}, \frac{3}{4}, -\frac{3}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, -\frac{3}{4}, \frac{1}{4}\right) \\
A_3 &= \left(1, -1, 0, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, 1, \frac{1}{4}, \frac{1}{4}, -\frac{3}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}, \frac{1}{4}\right) \\
A_5 &= \left(-\frac{1}{2}, \frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, 0, 0, 0, 0, \frac{1}{2}, \frac{1}{2}\right) \\
A_6 &= A_4 = A_2
\end{aligned}
$$

Example 2

- 4d gauge group: $\mathrm{SU}(5) \times \mathrm{U}(1)^4 \times [\mathrm{SU}(4)^2 \times \mathrm{U}(1)^2]$
- massless spectrum

15	$(5, 1, 1)$	9	$(\overline{5}, 1, 1)$
6	$(\overline{10}, 1, 1)$	52	$(1, 1, 1)$
6	$(1, 4, 1)$	6	$(1, \overline{4}, 1)$
8	$(1, 1, 4)$	8	$(1, 1, \overline{4})$
2	$(1, 1, 6)$		

- freely acting Wilson line $A_\tau = \frac{1}{2} A_2 \Rightarrow$ 3 generations SM
- properties (preliminary)
  - vector-like exotics decouple (at trilinear order)
  - Higgs-pair from untwisted sector: potentially $\mu \sim \langle W \rangle \sim m_{3/2}$
  - D_4 family symmetry: third generation: singlet; first/second: doublet
  - heavy top / all extra U(1)'s broken (at high scale)
  - however: 3 empty fixed points $\Rightarrow$ blow-up mode? $\Rightarrow$ full blow-up?

Conclusion

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Summary

- $\mathbb{Z}_6$-II Mini-Landscape at special (symmetry enhanced) point, but full blow-up not necessary
- $\mathbb{Z}_2 \times \mathbb{Z}_2$ with freely acting twist $\Rightarrow$ non-local GUT breaking
- Examples: promising models (potentially also in full blow-up)