$SO(10)$ heterotic M-theory vacua

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Nonperturbative flipped $SU(5)$ vacua in heterotic M-theory
Nucl. Phys. **B641** (2002) 111

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Yukawa couplings in SO(10) heterotic M-theory vacua
Nucl. Phys. **B659** (2003) 224

Plan

1. Heterotic M-theory

2. $SO(10)$ heterotic M-theory vacua

3. Future directions

Heterotic M-theory

1. Compactify (11-D SUGRA limit of) M-theory on $S^1/\mathbb{Z}_2$

2. Anomaly cancellation $\to$ E_8 vector supermultiplet on fixed planes

   - gluinos *same* chirality $\to N = 1$

   - *opposite* $\to N = 0$

3. Compactify $N = 1$ theory $\to$ *heterotic M-theory*

   - This talk: $M^{11} = M^4 \times Z \times S^1/\mathbb{Z}_2$

$SO(10)$ **Heterotic M-theory vacua**

1. $M^{11} = M^4 \times Z \times S^1/\mathbb{Z}_2$
   - Z *torus* fibered Calabi-Yau 3-fold
   - $\pi_1(Z) = \mathbb{Z}_2 \longrightarrow$ Wilson breaking
2. $N_{gen} = 3$
3. M5-branes in bulk space
   - span M^4
   - wrap holomorphic curves in Z
4. Potentially viable Yukawa's

$M^{11} = M^4 \times Z \times S^1/\mathbb{Z}_2$

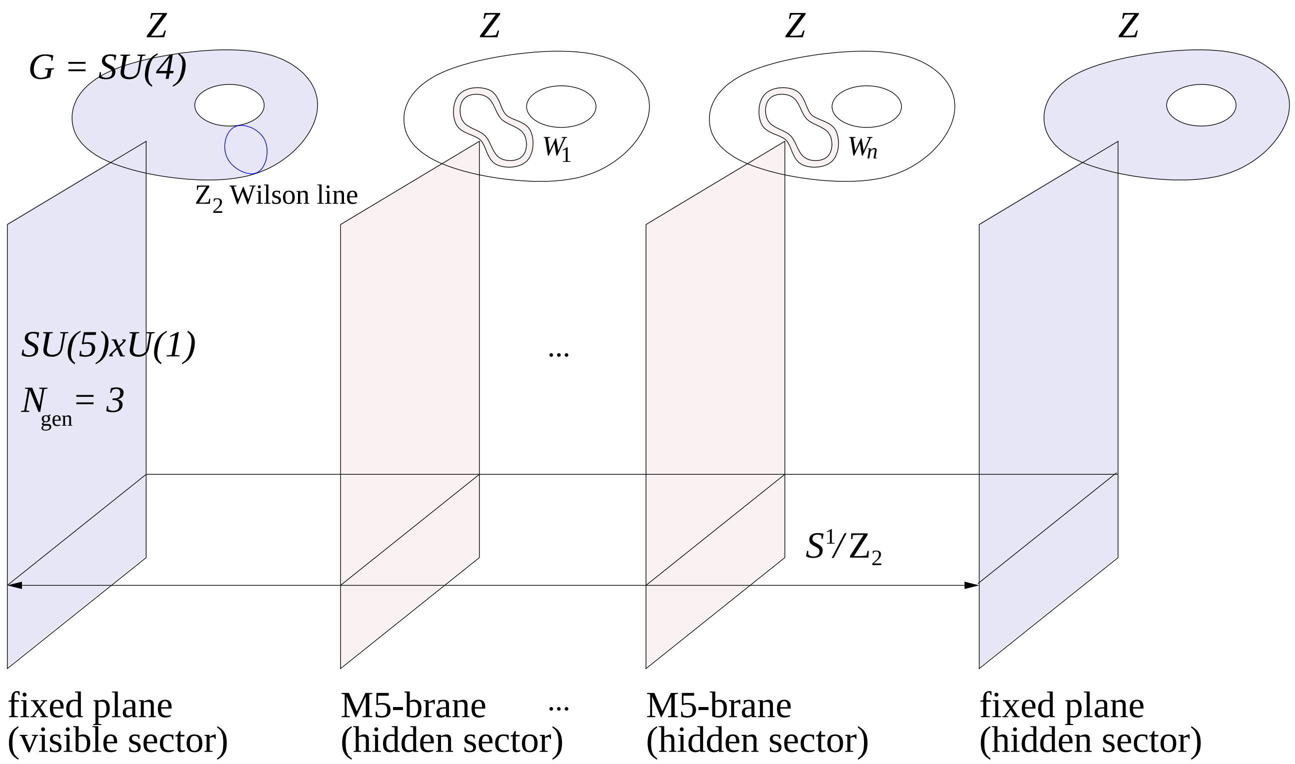
- $G \subseteq E_8$ survives on Z
  E_8 breaks to $G \times H$

G	GUT H	
$SU(3)$	E_6	
$\mathbf{SU(4)}$	$\mathbf{SO(10)}$	Faraggi, Garavuso & Isidro
$SU(5)$	$SU(5)$	Donagi, Ovrut, Pantev & Waldram

- Donaldson-Uhlenbeck-Yau theorem

  Solution to $D^A F_{AB} = 0$
  subject to $F_{ab} = F_{\overline{a}\overline{b}} = g^{a\overline{b}} F_{a\overline{b}} = 0$
  $\Longleftrightarrow$
  Semistable holomorphic vector bundle
  V_Z over Z with structure group $G_{\mathbb{C}}$

- $\mathbb{Z}_2$ Wilson line breaking of H
  e.g. $SO(10) \longrightarrow SU(5) \times U(1)$



Heterotic M-theory brane-world

$$H = SO(10) \xrightarrow{\mathbb{Z}_2} SU(5) \times U(1)$$

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Rules

1. Construct $Z = X/\tau_X$

   - Z *torus* fibered with $\pi_1(Z) = \mathbb{Z}_2$

   - X smooth, *elliptically* fibered with base $B =$ del Pezzo, Hirzebruch, Enriques

   - τ_X freely acting involution on X

2. Construct V_Z over Z
   with structure group $G_{\mathbb{C}} = SU(n)_{\mathbb{C}}$

3. $N_{gen} = \frac{1}{2}\int_Z c_3(V_{Z1}) = 3$

4. $[W_Z] = c_2(TZ) - c_2(V_{Z1}) - c_2(V_{Z2})$

5. $\beta_i^{(0)} = 0$ Arnowitt & Dutta (2001)

Matter Yukawa couplings

$$\mathcal{L}_{kin} \sim Z_{IJ}\partial_\mu C^I \partial^\mu \overline{C}^J$$

$$W_{Yuk} \sim Y_{IJK} C^I C^J C^K$$

Diagonalize & rescale Z_{IJ} to unit matrix:

$$C^I \to (US)_{IJ} C'^J$$

$$Z_{IJ} \sim G_{IJ} - \frac{\epsilon}{2\mathcal{V}} \tilde{\Gamma}^i_{IJ} \sum_{n=0}^{N+1} (1 - z_n)^2 \beta_i^{(n)}$$

zeroth order background:

$$M^{11} = M^4 \times Z \times S^1/\mathbb{Z}_2$$

Results

- Faraggi, Garavuso & Isidro (2002)

  $\exists\ B =$ Hirzebruch F_2 solutions

  $\nexists\ B =$ Del Pezzo solutions

  Overlap with *free-fermionic* models

- Faraggi & Garavuso (2003)

  $\nexists\ B =$ Hirzebruch solutions

  $\exists\ B =$ Del Pezzo dP_7 solutions

  Nonperturbative extension of
  top quark Yukawa coupling calculation
  in realistic free-fermionic models
  (Faraggi 91, 96 & 97)

Future Directions

1. $N = 0$ S-dual?

2. Adaptation of rules

3. Further nonperturbative extensions