Low energy physics of a F-GUT model

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References

Based on work with : arXiv:1008.2254
and
work with T.Jelinski, K.Turzynski (to be published)

Beasly, Heckmann, Vafa: several papers in 2008/9,
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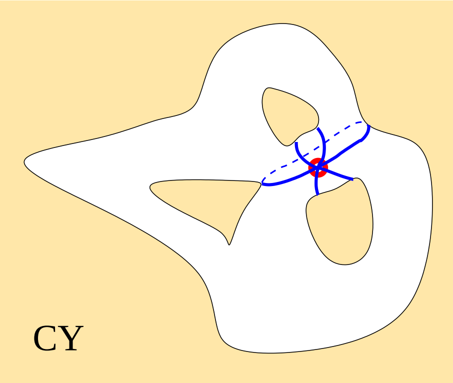
Blumenhagen, Braun, Weigand, ...
..... H.P. Nilles ....

Plan

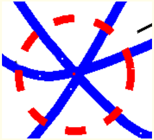
- Local F-GUTs
- Physics of the $\mathbb{Z}_3$ model
  - The model
  - constaints from B/L-violation
  - low energy phenomenology: soft masses

local F models

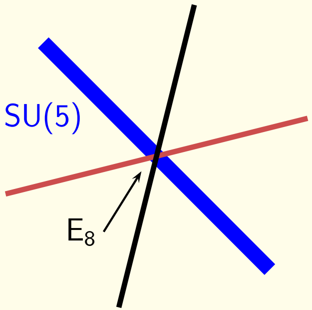
[Heckman-Vafa]

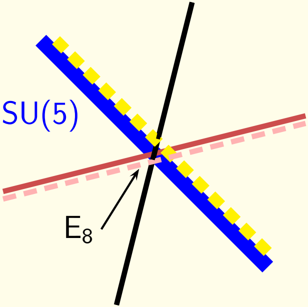


(1) we decouple gravity
(2) focuse on open string degrees of freedom

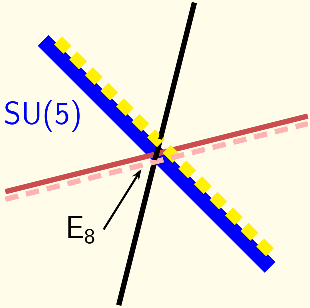


(3) D7 wrapped on cycles


SU(5)
E_8

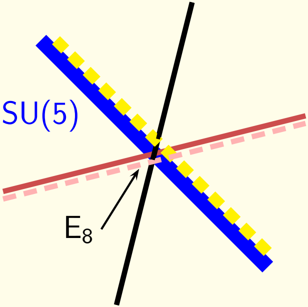


fluxes on branes:



fluxes on branes:

(1) break SU(5)$\longrightarrow$ SM
(2) chiral 3 families



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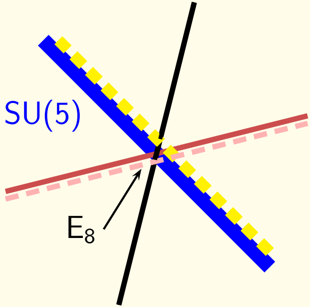
(3) removes $3 \in 5_H$



fluxes on branes:

(1) break SU(5)$\longrightarrow$ SM
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- states are classified by decompositon

$$E_8 \longrightarrow SU(5) \times SU(5)_{\perp}$$

E8$\rightarrow$ SU(5)$\times$ SU(5)$_\perp$

$$\mathbf{Adj(E8) = 248} \rightarrow$$

$$(24,1) \quad +(5,\overline{10}) \quad +(\overline{5},10) \quad +(10,5) \qquad +(1,24) \qquad +(\overline{10},\overline{5})$$

E8$\rightarrow$ SU(5)$\times$ SU(5)$_\perp$

$$\mathbf{Adj(E8) = 248} \rightarrow$$

$$\begin{array}{cccccc}
(24,1) & +(5,\overline{10}) & +(\overline{5},10) & +(10,5) & +(1,24) & +(\overline{10},\overline{5}) \\
\textit{gauge} & 5_H & \overline{5}_M,\ \overline{5}_H & 10_M & DM & Y_{\overline{10}} \\
 & Y_5 & Y_{\overline{5}} & Y_{10} & X \rightarrow \ \text{SUSY-B}, \ldots & \ldots. \\
 & & & & N_R,\ \text{R-neutrino} &
\end{array}$$

E8$\to$ SU(5)$\times$ SU(5)$_\perp$

$$\mathbf{Adj}(\mathbf{E8}) = \mathbf{248} \to$$

$(24,1)$	$+(5,\overline{10})$	$+(\overline{5},10)$	$+(10,5)$	$+(1,24)$	$+(\overline{10},\overline{5})$
gauge	5_H	$\overline{5}_M,\ \overline{5}_H$	10_M	DM	$Y_{\overline{10}}$
	Y_5	$Y_{\overline{5}}$	Y_{10}	$X \to$ SUSY-B, ...	....
				N_R, R-neutrino	

Yukawas: one needs to identify weights of SU(5)$_\perp$

$$SU(5) \times \frac{SU(5)_\perp}{\Gamma} \longrightarrow SU(5) \times U(1)^n_{anomalous \to\ global}$$

$\Gamma = \mathbb{Z}_2,\ \mathbb{Z}_3, S_3, \mathbb{Z}_2 \times \mathbb{Z}_2, Dih_4$

Minimal model

$\Gamma = Dih_4 \simeq \mathbb{Z}_2 \ltimes \mathbb{Z}_4$

Matter	$10_M, Y_{10}$	$Y_{\overline{10}}$	$\overline{5}_M$	5_H	$\overline{5}_H$	X	N_R
$U(1)_{PQ}$	$+1$	$+4$	$+2$	-2	-3	-5	0

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$5_H \longrightarrow (5_H)_2$

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$$10_M \sim Y_{10}$$

$$5_H \cdot (10_M, Y_{10}) \cdot (10_M, Y_{10})$$

$$\overline{5}_H \cdot \overline{5}_M \cdot (10_M, Y_{10})$$

Which fields are matter ? We need $\langle X \rangle$ in order to give mass to Y_{10}, $Y_{\overline{10}}$.

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$U(1)_{PQ}$	$+1$	$+4$	$+2$	-2	-3	-5	0

Messengers only one $Y_{\overline{10}}$

$$W \ni (10_M, Y_{10}) \; Y_{\overline{10}} \, X$$

$$\uparrow$$

Y_{10} - massive messenger

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Matter	$10_M, Y_{10}$	$Y_{\overline{10}}$	$\overline{5}_M$	5_H	$\overline{5}_H$	X	N_R
$U(1)_{PQ}$	$+1$	$+4$	$+2$	-2	-3	-5	0

μ-term

$$\frac{1}{\Lambda_{GUT}} X^\dagger \cdot 5_H \cdot \overline{5}_H \longrightarrow \quad W \ni \qquad \frac{F_X}{\Lambda_{GUT}} \, 5_H \cdot \overline{5}_H$$

$$\mu \sim 10^2 \ GeV$$

Minimal model

Matter	$10_M, Y_{10}$	$Y_{\overline{10}}$	$\overline{5}_M$	5_H	$\overline{5}_H$	X	N_R
$U(1)_{PQ}$	$+1$	$+4$	$+2$	-2	-3	-5	0

avoids dangerous

$$\overline{5}_M \cdot \overline{5}_M \cdot 10_M$$

no B/L-violation due to $U(1)_{PQ}$

Minimal model

Matter	$10_M, Y_{10}$	$Y_{\overline{10}}$	$\overline{5}_M$	5_H	$\overline{5}_H$	X	N_R
$U(1)_{PQ}$	$+1$	$+4$	$+2$	-2	-3	-5	0

Problems ????

$$W \ni \quad \overline{5}_M \cdot 5_H \cdot N + \Lambda_{GUT} N^2$$

$$+\overline{5}_M \cdot 5_H \; + \; N \; + \; N^3$$

if $\langle N \rangle \neq 0$ breaks $U(1)_{PQ}$ *to* B/L number–violation

$\Gamma = \mathbb{Z}_3$

	Minimal						
	$10_M,\ Y_{10}$	$\bar{5}_M$	5_H	$\bar{5}_H$	$Y^a{}_{\overline{10}}$	X	N
$U(1)_{PQ}$	$+1$	$+1$	-2	-2	$+3$	-4	-3
$U(1)_\chi$	-1	$+3$	$+2$	-2	$+1$	0	-5

Extra			
$10_{(1)}$	$Y_{\bar{5}}$	Y_5	$\overline{D}$
0	$+1$	$+3$	-1
$+4$	$+3$	-3	$+5$

Messengers

$$Y^a_{\overline{10}}, \quad Y_{10}, \quad 10_{(1)}$$
$$Y_5, \quad Y_{\overline{5}}$$

$$W \supset \underbrace{f_a Y^a_{\overline{10}}}_{Y_{\overline{10}}} Y_{10}\, X, \;\; Y_{\overline{5}} Y_5\, X, \;\; \underbrace{g_a Y^a_{\overline{10}}}_{\overline{10}_{(1)}} 10_{(1)}\, N$$

Phenomenology does not constrain $\langle X \rangle$, $\langle N \rangle$, $\langle \overline{D} \rangle$,
but
suppression of B/L-violation constraints $\langle F_N \rangle$, $\langle F_D \rangle$.

$\langle \mathbf{F_D} \rangle$

$$K \supset \frac{1}{\Lambda_{GUT}} \bar{5}_M 5_H \overline{D}^{\,+}$$

$$W \supset (\mu \bar{5}_H + \langle F_D \rangle \bar{5}_M)_2 (5_H)_2$$

with $\mu = F_X / \Lambda_{GUT}$. This can be put into canonical form $\mu' \bar{5}_H 5_H$ by a rotationIn consequence

$$y \frac{\langle F_D \rangle}{\mu'} 10_M \bar{5}_M (\bar{5}_M)_2 \supset \; QLd, \; LLe$$

[Dreiner] $F_D < 10^{-6} F_X$ (3rd family)

$\langle \mathbf{F_N} \rangle$

$$K \supset \frac{1}{\Lambda_{GUT}} \bar{5}_M \bar{5}_H^+ N$$

$$\rightarrow \ V \sim \frac{F_N F_H}{\Lambda_{GUT}} \tilde{\nu}_L \longrightarrow \ \tilde{\nu}_L \sim 10^2 \, GeV$$

But

$$\mathcal{L} \subset \tilde{\nu}_L \, \nu_L \, (\tilde{B}, \ \tilde{W}^0) \rightarrow \ m_\nu \sim \frac{\langle \tilde{\nu}_L \rangle^2}{m_W}$$

$\langle \mathbf{F_N} \rangle$

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But

$$\mathcal{L} \subset \tilde{\nu}_L \, \nu_L \, (\tilde{B}, \, \tilde{W}^0) \to \; m_\nu \sim \frac{\langle \tilde{\nu}_L \rangle^2}{m_W}$$

Conclusion: $\langle F_N \rangle = 0 = \langle F_D \rangle, \; \langle F_X \rangle \neq 0$

Other dangerous operators

$$W \supset \frac{\mu \langle \overline{D} \rangle}{\langle X \rangle^2} Y_5 10_M 10_M, \quad \frac{\langle \overline{D} \rangle}{\langle X \rangle} Y_{\overline{5}} 10_M \bar{5}_M$$

Integrating over the messengers we obtain

$$W \supset \underset{\uparrow}{\frac{\mu \langle \overline{D} \rangle^2}{\langle X \rangle^4}} \qquad \underset{\substack{\uparrow \\ QQQL,\ QQ\bar{D}\bar{E}}}{10_M 10_M 10_M \bar{5}_M}$$

Conclusion: Nothing dangerous.

Other dangerous operators

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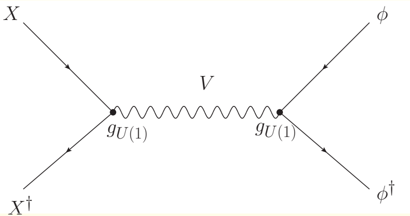
Integrating over the messengers we obtain

$$W \supset \underbrace{\frac{\mu\langle\overline{D}\rangle^2}{\langle X\rangle^4}}_{\sim 10^{-18}/\Lambda_{GUT}} \quad \underbrace{10_M 10_M 10_M \bar{5}_M}_{QQQL,\ QQ\bar{D}\bar{E}}$$

Conclusion: Nothing dangerous.

SUSY breaking terms

- 

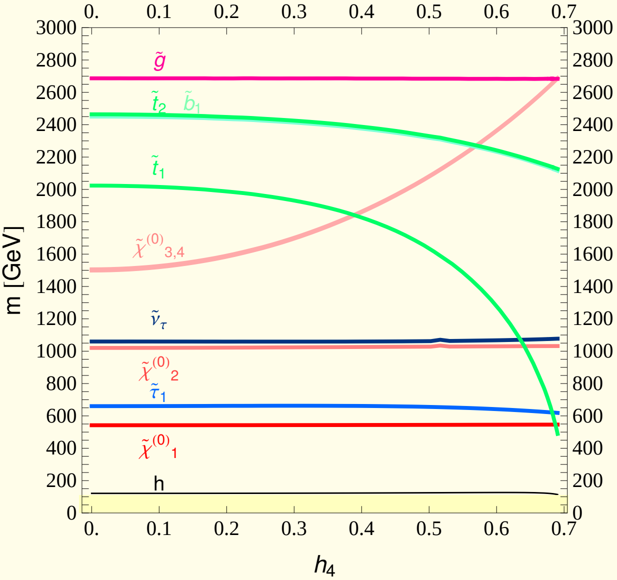
$$\delta K = \frac{XX^+}{\Lambda_{GUT}^2}\Phi_M \Phi_M^+ \rightarrow \text{ sfermions masses} \sim \delta m^2 \sim \frac{\langle F_X \rangle^2}{\Lambda_{GUT}^2}$$

- messenger exchange $\rightarrow$ gaugino masses
- vector multiplet loops $\rightarrow$ sfermion masses
- mixed messenger–vector multiplet loops

RG-soft masses

$$
\begin{aligned}
W \;=\;& h_1 H_u Y_Q Y_U + h_2 H_d Y_D Y_Q + h_3 H_d Y_L Y_E \\
&+ h_4 H_u Q Y_U + h_5 H_u U Y_Q + h_6 H_d Y_L E \\
&+ h_7 H_d Y_D Q + h_8 H_d D Y_Q + h_9 H_d L Y_E \\
&+ \text{mass terms for messengers} \\
&+ y_u H_u Q U + y_d H_d Q D + y_e H_d L E \\
&+ \mu H_u H_d
\end{aligned}
$$

RG-soft masses



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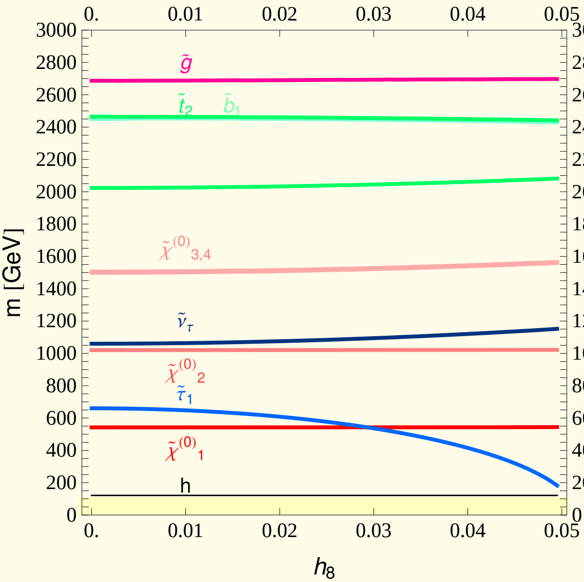

Conclusions

- $\Gamma = \mathbb{Z}_3$ is a nice F-GUT model
- no exotics at low energies
- no dangerous operators
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- other Γ's are similar ?