Flavour-Messenger Unification

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May 21, 2013

Thanks

- Tomasz Jelinski, Stefan Pokorski, Krzysztof Turzynski

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  E. Witten, Phys. Lett. B 91 (1980) 81; Z. G. Berezhiani,Phys. Lett. B 150 (1985) 177; A. Davidson and K. C. Wali,Lett. 58 (1987) 2623; J. Hisano, H. Murayama and T. Yanagida, Phys. Rev.D 49(1994) 4966; K. S. Babu and S. M. Barr, Phys. Rev. Lett. 75 (1995) 2088 [hep-ph/9503215]; Z. G. Berezhiani, Phys Lett. B 355 (1995) 178 [arXiv:hep-ph/9505384]; M. Malinsky, Phys. Rev. D 77 (2008) 055016 [arXiv:0710.0581 [hep-ph]]; Q. Shafi and Z. Tavartkiladze, Phys. Lett. B 459 (1999) 563 [hep-ph/9904249]; N. Oshimo, Phys. Rev. D 80 (2009) 075011 [arXiv:0907.3400 [hep-ph]].
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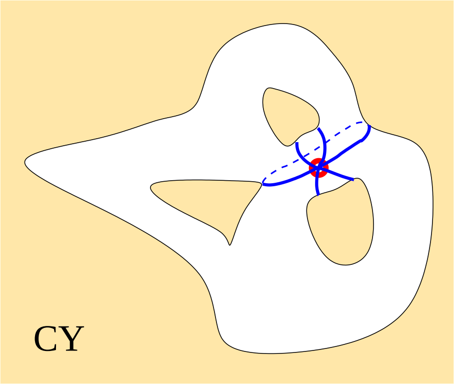
String unification (F-theory)



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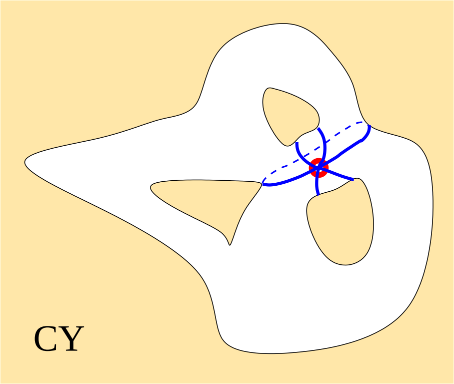

SM $\subset$ SUSY SU(5)

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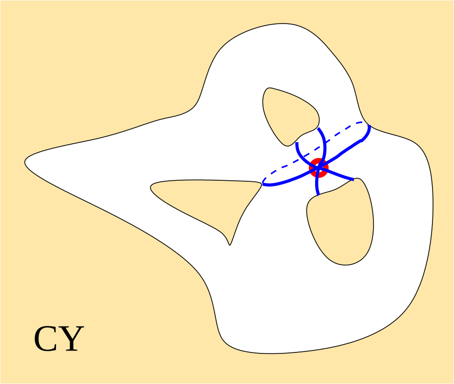

SM $\subset$ SUSY SU(5)

$+$ messengers Y : $5 \oplus 10$

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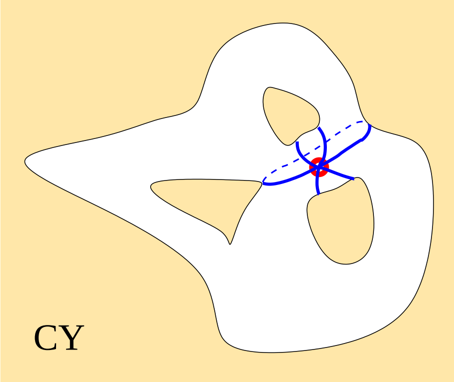
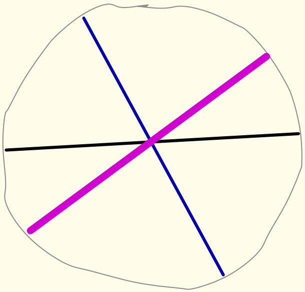


SM $\subset$ SUSY SU(5)

+ messengers Y : $5 \oplus 10$

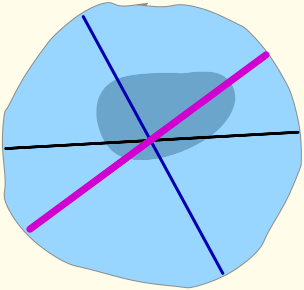
+ hidden sector X

Brane intersection



Brane intersection

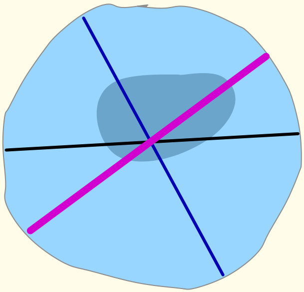
fluxes on branes:



Brane intersection

fluxes on branes:

fluxes $\supset U_Y(1)$ flux



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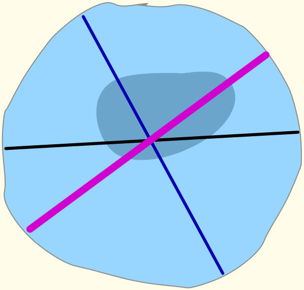
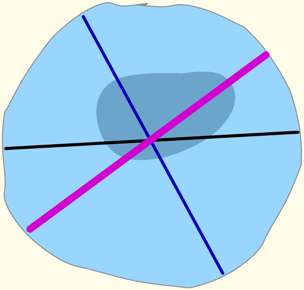


(1) break SU(5)$\rightarrow$ SM

Brane intersection

fluxes on branes:

fluxes $\supset U_Y(1)$ flux



(1) break SU(5)$\rightarrow$ SM

(2) chiral 3 families

Brane intersection

fluxes on branes:

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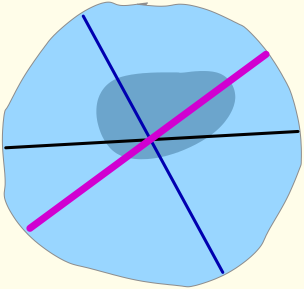

(1) break SU(5)$\rightarrow$ SM

(2) chiral 3 families

(3) Yukawas texture

pattern of Yukawas

$$y_u^{ij} Q_L^i u_R^j H_u + y_d^{ij} Q_L^i d_R^j H_d + y_l^{ij} L^i e_R^j H_d$$

No flux

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

pattern of Yukawas

$$y_u^{ij} Q_L^i u_R^j H_u + y_d^{ij} Q_L^i d_R^j H_d + y_l^{ij} L^i e_R^j H_d$$

Flux

$$y_{NC} \sim \begin{pmatrix} \epsilon^8 & \epsilon^6 & \epsilon^4 \\ \epsilon^6 & \epsilon^4 & \epsilon^2 \\ \epsilon^4 & \epsilon^2 & 1 \end{pmatrix} + \Phi_0 \begin{pmatrix} \epsilon^6 & \epsilon^4 & \epsilon^2 \\ \epsilon^4 & \epsilon^2 & 0 \\ \epsilon^2 & 0 & 0 \end{pmatrix} + \dots$$

pattern of Yukawas

$$y_u^{ij} Q_L^i u_R^j H_u + y_d^{ij} Q_L^i d_R^j H_d + y_l^{ij} L^i e_R^j H_d$$

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$$\Phi_0 = \Phi_0(flux) \Rightarrow y_u \neq y_d \neq y_l$$

pattern of Yukawas

$$y_u^{ij} Q_L^i u_R^j H_u + y_d^{ij} Q_L^i d_R^j H_d + y_l^{ij} L^i e_R^j H_d$$

Flux

$$y_{NC} \sim \begin{pmatrix} \epsilon^8 & \epsilon^6 & \epsilon^4 \\ \epsilon^6 & \epsilon^4 & \epsilon^2 \\ \epsilon^4 & \epsilon^2 & 1 \end{pmatrix} + \Phi_0 \begin{pmatrix} \epsilon^6 & \epsilon^4 & \epsilon^2 \\ \epsilon^4 & \epsilon^2 & 0 \\ \epsilon^2 & 0 & 0 \end{pmatrix} + \dots$$

quarks up $m_1 : m_2 : m_3 = \epsilon^8 : \epsilon^4 : 1, \ (\Phi_0 = 0)$ OK
$m_1 : m_2 : m_3 = \epsilon^6 : \epsilon^3 : 1, \ (\Phi_0 = \epsilon^1)$ NO,
leptons $\epsilon^{6.5} : \epsilon^{2.5} : 1$,
quarks down $\epsilon^{4.5} : \epsilon^{2.5} : 1$, $\epsilon \sim 0.2$

E_8/Z_3

	Minimal							Extra		
	$10_M,\ Y_{10}$	$\overline{5}_M,\ Y_{\overline{5}}$	5_H	$\overline{5}_H$	$Y^a_{\overline{10}}$	X	N	$10_{(1)}$	Y_5	D
$U(1)_{PQ}$	$+1$	$+1$	-2	-2	$+3$	-4	-3	0	$+3$	-1
$U(1)_\chi$	-1	$+3$	$+2$	-2	$+1$	0	-5	$+4$	-3	$+5$

$$X(Y_{\overline{5}}5 + Y_{10}Y_{\overline{10}}) + X(\overline{5}_M 5 + 10_M Y_{\overline{10}})$$

E_8/Z_3

	Minimal						Extra
	10_M	$\bar{5}_M$, $Y_{\bar{5}}$	5_H	$\bar{5}_H$	X	N	Y_5
$U(1)_{PQ}$	$+1$	$+1$	-2	-2	-4	-3	$+3$
$U(1)_\chi$	-1	$+3$	$+2$	-2	0	-5	-3

$$X(Y_{\bar{5}} + a_i \bar{5}'^i_M)5$$

this coupling desides that messenger is $(Y_{\bar{5}} + a_i \bar{5}'^i_M)$

pattern of Yukawas

$$y_u^{ij} Q_L^i u_R^j H_u + \tilde{y}_d^{iJ} Q_L^i d_R^J H_d + \tilde{y}_l^{iJ} e_R^i L^J H_d$$

$$J = 1, \ldots 4$$

$$\tilde{y}_{NC} \sim \begin{pmatrix} \epsilon^{10} & \epsilon^8 & \epsilon^6 & \epsilon^4 \\ \epsilon^8 & \epsilon^6 & \epsilon^4 & \epsilon^2 \\ \epsilon^6 & \epsilon^4 & \epsilon^2 & 1 \end{pmatrix} + \Phi_0 \begin{pmatrix} \epsilon^8 & \epsilon^6 & \epsilon^4 & \epsilon^2 \\ \epsilon^6 & \epsilon^4 & \epsilon^2 & 0 \\ \epsilon^4 & \epsilon^2 & 0 & 0 \end{pmatrix} + \ldots$$

$$\Phi_0 = \Phi_0(flux) \Rightarrow \tilde{y}_d \neq \tilde{y}_l$$

modified Yukawas: leptons

$\Phi_0 = 0$

$$y_l = \begin{pmatrix} y_{14} a_1^* \epsilon^4 & y_{14} a_2^* \epsilon^4 + y_{12}\epsilon^8 & y_{14} a_3^* \epsilon^4 + y_{13}\epsilon^6 \\ y_{24} a_1^* \epsilon^2 & y_{24} a_2^* \epsilon^2 + y_{22}\epsilon^6 & y_{24} a_3^* \epsilon^2 + y_{23}\epsilon^4 \\ a_1^* y_{34} & a_2^* y_{34} + y_{32}\epsilon^4 & a_3^* y_{34} + y_{33}\epsilon^2 \end{pmatrix}$$

modified Yukawas: leptons

$\Phi_0 = 0$

$$\begin{aligned} y_3 &\approx a_3^* y_{34} + y_{33}\,\epsilon^2 \\ y_2 &\approx \frac{(y_{24}y_{33} - y_{23}y_{34})a_2\epsilon^4}{a_3^* y_{34} + y_{33}\,\epsilon^2} \\ y_1 &\approx \frac{\det(y_d)}{(y_{24}y_{33} - y_{23}y_{34})a_2\epsilon^4} \end{aligned}$$

$a_3 \sim \epsilon^{2.5},\ a_2 \sim \epsilon^3,\ a_1 \sim \epsilon^{3.5}$

modified Yukawas: quarks d

$\Phi_0 = \epsilon$

$$y_d = \begin{pmatrix} y_{11}\epsilon^8 + y_{14}a_1^*\epsilon^3 & y_{12}\epsilon^6 + y_{14}a_2^*\epsilon^3 & y_{13}\epsilon^5 + y_{14}a_3^*\epsilon^3 \\ y_{21}\epsilon^6 + y_{24}a_1^*\epsilon^2 & y_{22}\epsilon^5 + y_{24}a_2^*\epsilon^2 & y_{23}\epsilon^3 + y_{24}a_3^*\epsilon^2 \\ y_{31}\epsilon^5 + y_{34}a_1^* & y_{32}\epsilon^3 + y_{34}a_2^* & y_{33}\epsilon^2 + y_{34}a_3^* \end{pmatrix}$$

modified Yukawas: quarks d

$\Phi_0 = \epsilon$

$$
\begin{aligned}
y_3 &\approx a_3^* y_{34} + y_{33}\,\epsilon^2 \\
y_2 &\approx \frac{a_2 y_{23} y_{34} \epsilon^3 + y_{32} y_{33} \epsilon^6}{y_3} \\
y_1 &\approx \frac{\det(y_d)}{a_2 y_{23} y_{34} \epsilon^3 + y_{32} y_{33} \epsilon^6}
\end{aligned}
$$

$a_3 \sim \epsilon^2,\ a_2 \sim \epsilon^{3.5},\ a_1 \sim \epsilon^4$

Yukawas: RG

	m_u [MeV]	m_c [MeV]	m_t [GeV]	m_d [MeV]	m_s [MeV]	m_b [GeV]	m_e [MeV]	m_μ [MeV]	m_τ [GeV]
$MSSM, \Lambda = 10^3$	1.15	560	161	2.20	42.0	2.23	0.41	88.3	1.50
$MSSM$	0.55	270	106	0.79	15.1	0.89	0.29	62.0	1.06
$y_{34} = 0.6, M = 10^{13}$	0.55	268	107	0.84	16.0	0.96	0.31	66.2	1.16
$y_{34} = 1.5, M = 10^7$	0.51	250	112	1.39	26.6	1.82	0.52	112	2.48

Table : One-loop fermion masses at Λ_{GUT} for different values of the messenger-matter mixing y_{34} and the messenger mass M. The initial values of the masses at 1 TeV are given in the first row.