SUSY flavor structure of generic 5D supergravity models

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Introduction

Motivation

- Mass Hierarchy

$m_u \sim 1.7-3.3\times10^{-3}$ [GeV]	$m_d \sim 4.1-5.8\times10^{-3}$ [GeV]
$m_c \sim 1.27$ [GeV]	$m_s \sim 1.01\times10^{-1}$ [GeV]
$m_t \sim 1.72\times10^{2}$ [GeV]	$m_b \sim 4.19$ [GeV]

- SUSY flavor problem
  in the gravity-mediated SUSY breaking scenario
- Tachyonic squark and slepton problem
  in the 5D SUGRA on S^1/Z_2

Set-up

5D conformal SUGRA on S^1/Z_2 $\quad (0\le y\le L)$

$$ds^2 = e^{2\sigma(y)}\eta_{\mu\nu}dx^\mu dx^\nu - dy^2$$

5D superconformal multiplet	$N=1$ decomposition	Z_2-parity
Weyl multiplet (gravity)	$\mathbf{E_W}=(E_W, L^\alpha_E, V_E)$	$(+,-,+)$
U(1) Vector multiplet (moduli)	$\mathbf{V}^{I'}=(V^{I'},\Sigma^{I'};(I'=1,2,3))$	$(-,+)$
Vector multiplet (gauge)	$\mathbf{V}^{I''}=(V^{I''},\Sigma^{I''})$	$(+,-)$
Hypermultiplet (compensator)	$\mathbf{H}^{a=1}=(\Phi^1,\Phi^2)$	$(-,+)$
Hypermultiplet (matter)	$\mathbf{H}^{a\ge2}=(\Phi^{2a-1},\Phi^{2a})$	$(-,+)$

T. Kugo and K. Ohashi, Prog. Theor. Phys. 108 (2002) 203

(i) off-shell dimensional reduction
(ii) Super conformal gauge-fixing

H. Abe and Y. Sakamura, Nucl. Phys. B796 (2008) 224

4D Poincare SUGRA

Moduli Multiplets$\cdots T^{I'} = 2\int_0^L dy\Sigma^{I'}(y)$

Visible sector contents

MSSM matter contents

(V_1,V_2,V_3) : gauge vector multiplets
$(\mathcal{Q}_i,\mathcal{U}_i,\mathcal{D}_i)$: quark chiral multiplets
$(\mathcal{L}_i,\mathcal{E}_i)$: lepton chiral multiplets
$(\mathcal{H}_u,\mathcal{H}_d)$: Higgs chiral multiplets,

Yukawa couplings(at only the y=0 brane)

$$y^u_{ij} = \frac{\lambda^u_{ij}}{\sqrt{<\hat{Y}_{\mathcal{H}_u}\hat{Y}_{\mathcal{Q}_i}\hat{Y}_{\mathcal{U}_j}>}} \qquad \hat{Y}(\tilde{c}^{I'}_\alpha) = \frac{1-e^{-2\tilde{c}^{I'}_\alpha}}{2\tilde{c}^{I'}_\alpha}$$

Moduli couplings($\tilde{c}^{I'}_\alpha$) ⟹ The Hierarchial Structures

$\tilde{c}^{I'}_\alpha = (c_{\alpha I'} - k_{I'}/2)\mathrm{Re} < T^{I'} >$
$c_{\alpha I'}$...hypermultiplets charge for $\mathbf{V}^{I'}$
$k_{I'}$....compensator multiplets charge for $\mathbf{V}^{I'}$

Yukawa Couplings

Moduli couplings($\tilde{c}^{I'}_\alpha$)

$\tilde{c}^{I'=1}_{\mathcal{Q}_i}=(1.2,\ 1.2,\ 0.5)$ $\tilde{c}^{I'=2}_{\mathcal{Q}_i}=(-7.9,-5.9,\ 0)$ $\tilde{c}^{I'=3}_{\mathcal{Q}_i}=(1.2,\ 1.2,\ 0)$	$\tilde{c}^{I'=1}_{\mathcal{L}_i}=(1.2,\ 1.2,\ 1.2)$ $\tilde{c}^{I'=2}_{\mathcal{L}_i}=(-6.9,-6.9,-4.9)$ $\tilde{c}^{I'=3}_{\mathcal{L}_i}=(1.2,\ 1.2,\ 1.2)$	$\tilde{c}^{I'=1}_{\mathcal{H}_u}=1.0$ $\tilde{c}^{I'=2}_{\mathcal{H}_u}=0$ $\tilde{c}^{I'=3}_{\mathcal{H}_u}=0$
$\tilde{c}^{I'=1}_{\mathcal{U}_i}=(1.2,\ 1.2,\ 0.5)$ $\tilde{c}^{I'=2}_{\mathcal{U}_i}=(-10.4,-5.9,\ 0)$ $\tilde{c}^{I'=3}_{\mathcal{U}_i}=(1.2,1.2,0)$	$\tilde{c}^{I'=1}_{\mathcal{E}_i}=(1.2,\ 1.2,\ 1.2)$ $\tilde{c}^{I'=2}_{\mathcal{E}_i}=(-9.4,-3.9,-3.9)$ $\tilde{c}^{I'=3}_{\mathcal{E}_i}=(1.2,\ 1.2,\ 1.2)$	$\tilde{c}^{I'=1}_{\mathcal{H}_d}=1.2$ $\tilde{c}^{I'=2}_{\mathcal{H}_d}=-3.4$ $\tilde{c}^{I'=3}_{\mathcal{H}_d}=1.2$
$\tilde{c}^{I'=1}_{\mathcal{D}_i}=(1.2,\ 1.2,\ 1.2)$ $\tilde{c}^{I'=2}_{\mathcal{D}_i}=(-6.4,-6.9,-4.9)$ $\tilde{c}^{I'=3}_{\mathcal{D}_i}=(1.2,\ 1.2,\ 1.2)$	$\tilde{c}^{I'=1}_{X}=8.7$ $\tilde{c}^{I'=2}_{X}=1.2$ $\tilde{c}^{I'=3}_{X}=1.2$	

	Sample values	Observed (central values)
$(m_u,m_c,m_t)/m_t$	$(1.4\times10^{-5}, 7.38\times10^{-3}, 1.0)$	$(1.5\times10^{-5}, 7.37\times10^{-3}, 1.0)$
$(m_d,m_s,m_b)/m_b$	$(1.2\times10^{-3}, 2.41\times10^{-2}, 1.0)$	$(1.2\times10^{-3}, 2.54\times10^{-2}, 1.0)$
$(m_e,m_\mu,m_\tau)/m_\tau$	$(2.871\times10^{-4}, 5.955\times10^{-2}, 1.0)$	$(2.871\times10^{-4}, 5.959\times10^{-2}, 1.0)$
$\lvert V_{CKM}\rvert$	$\begin{pmatrix}0.97324 & 0.2298 & 0.00337\\ 0.2297 & 0.97235 & 0.042\\ 0.00637 & 0.0417 & 0.999112\end{pmatrix}$	$\begin{pmatrix}0.97428 & 0.2253 & 0.00347\\ 0.2252 & 0.97345 & 0.041\\ 0.00862 & 0.0403 & 0.999152\end{pmatrix}$

K. Nakamura et al. [Particle Data Group Collaboration], J. Phys. G G37, 075021 (2010)

Hidden(Mediation) sector contents

Hidden sector : X **(chiral multiplet from a 5D Hypermultiplet)**
Mediation sector : $T^{I'}(I'=1,2,3)$ **(moduli multiplets from 5D Vector multiplets)**

Norm function $\hat{N}(\mathrm{Re}\,T) = (\mathrm{Re}\,T^1)(\mathrm{Re}\,T^2)(\mathrm{Re}\,T^3)$

Soft terms

$$\mathcal{L}_{\rm soft} = -\sum_{Q_I} m^2_{Q_I}|Q_I|^2 - \frac{1}{2}\sum_r M_r \mathrm{tr}(\lambda^r\lambda^r) - \sum_{IJK} y_{IJK}A_{IJK}Q_IQ_JQ_K - B\mu H_uH_d$$

$M_r =< F^A\partial_A \ln(\mathrm{Re}\ f^r_{eff}) >$
$m^2_{Q_I} = -< F^A\bar{F}^{\bar{B}}\partial_A\partial_{\bar{B}}\ \ln Y_{Q_I} >$
$A_{IJK} = F^A\partial_A \ln\ (Y_IY_JY_K)$

V. S. Kaplunovsky and J. Louis, Phys. Lett. B 306 (1993) 269

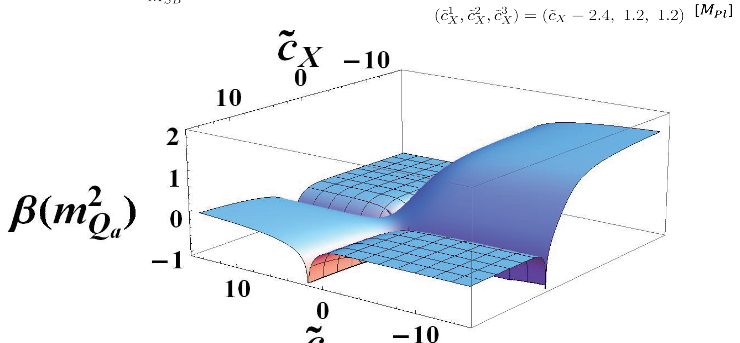
SUSY breaking parameters

Typical scale of SUSY breaking $\quad M_{SB} \equiv (K_{X\bar{X}})^{1/2}|F^X|$

Ratios of the strength between Hidden and Mediation sector $\quad \alpha_{I'} \equiv \frac{(K_{T'\bar{T}'})^{1/2}|F^{T'}|}{(K_{X\bar{X}})^{1/2}|F^X|}$

The Structure of soft mass

$$\beta(m^2_{Q_a}) = \log_{10}\frac{\sqrt{|m^2_{Q_a}|}}{M_{SB}},\ \alpha_1=\alpha_3=1/4\pi^2, \alpha_2=1/2\pi^2,\ (\tilde{c}^1_{Q_a},\tilde{c}^2_{Q_a},\tilde{c}^3_{Q_a}) = (1.2,\ \tilde{c}_{Q_a}-2.4,\ 1.2)$$
$$(\tilde{c}^1_X,\tilde{c}^2_X,\tilde{c}^3_X) = (\tilde{c}_X-2.4,\ 1.2,\ 1.2)\ [M_{Pl}]$$

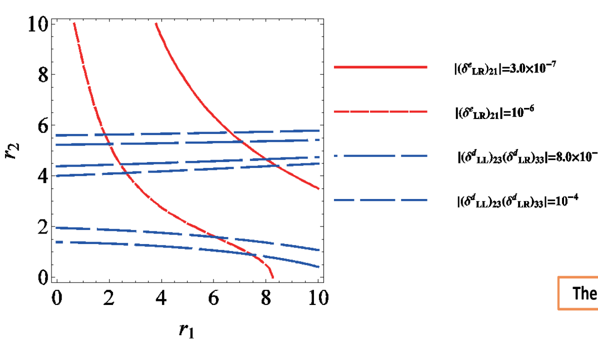


A mesh describes the region $m^2_{Q_a} > 0$

Conclusion

We can avoid the SUSY flavor problem and tachyonic sfermion problem while realize the hierarchial structures of the Yukawa couplings.

$M_{SB}=100$[GeV], $\alpha_1=1,\ \alpha_2=1/2,\ \alpha_3=1/4\pi^2,\ M_3(\mathrm{GUT})=343$[GeV], $\tan\beta=4$



$\alpha_2 << 1$ ⟹

The allowed region($\mu \to e+\gamma$) is much wider

$M_{SB}=200$[GeV], $\alpha_1=1/2,\ \alpha_2=1/8\pi^2,\ \alpha_3=1/4\pi^2,\ M_3(\mathrm{GUT})=383$[GeV], $\tan\beta=4$