Distributions of Three Generation Models in Type IIB Chiral Flux Vacua

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1. Introduction

Type IIB compactification on $T^6/(\mathbb{Z}_2 \times \mathbb{Z}'_2)$

Fluxes $\{a^0, a^i, b_i, b_0\}$, N_{flux}

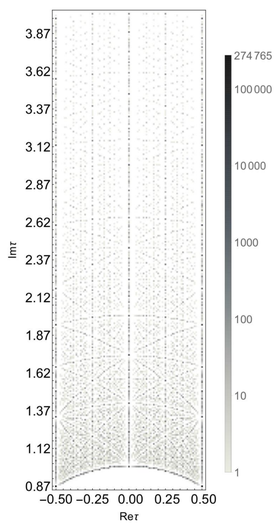
⇒ many VEVs of complex structure (τ)

The distribution of complex structure moduli VEVs clusters at fixed points of modular symmetry of torus.

($\tau = i, \omega, i\infty$ with $\omega = \frac{-1+\sqrt{3}i}{2}$, $\mathbb{Z}_3$ fixed point : $\tau = \omega$)

Especially, $\mathbb{Z}_3$ fixed point has the largest part in the distribution

We investigate the distribution of 3-generation models in the flux landscape



$\mathbb{Z}_3$: 40.3%

The numbers of stable flux vacua on the fundamental domain of τ

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2. Distribution of g−generation models (MSSM)

The background $U(1)_a$ gauge field strength F_a on $(T^2)_i$,

$$\frac{m_a^i}{2\pi}\int_{T_i^2} F_a^i = n_a^i,$$

m_a^i : wrapping number on $(T^2)_i$
n_a^i : units of magnetic flux on $(T^2)_i$

The number of chiral zero-modes on T^6

$$I_{ab} = \prod_{i=1}^{3}(n_a^i m_b^i - n_b^i m_a^i),$$

This is Index theorem and the number of independent wave functions is known to be determined by 2 factors of D-branes

D-brane configuration leading to MSSM like model

N_α	Gauge group	(n_α^1, m_α^1)	(n_α^2, m_α^2)	(n_α^3, m_α^3)
$N_a = 6$	$SU(3)_C$	(1,0)	$(g, 1)$	$(g, -1)$
$N_b = 2$	$USp(2)_L$	(0,1)	$(1, 0)$	$(0, -1)$
$N_c = 2$	$USp(2)_R$	(0,1)	$(0, -1)$	$(1, 0)$
$N_d = 2$	$U(1)_d$	(1,0)	$(g, 1)$	$(g, -1)$

The magnetic flux g on the second and third tori determines the generations of quark and lepton chiral multiplets in the visible sector

- D3-brane charge conservation

$$D3: \sum_a N_a n_a^1 n_a^2 n_a^3 + \frac{1}{2}N_{\text{flux}} = 16,$$

- The existence of magnetized D9-branes in the hidden sector

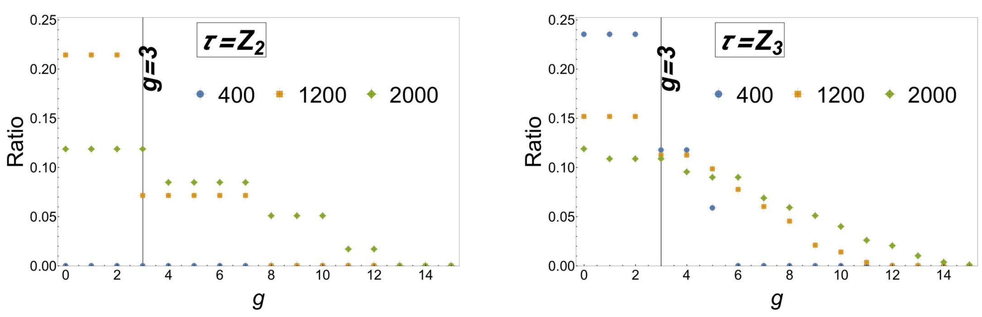
$$8g^2 = -Q_{D3}^{\text{hid}} + 16 - \frac{N_{\text{flux}}}{2},$$

(Q_{D3}^{hid} : D3-brane charge induced by the magnetic flux on D9-branes)

We freely change the value of Q_{D3}^{hid} to reveal the mutual relation between the generation number and the flux quanta

The numbers of flux vacua as a function of the generation number g at $\tau = i$ and $\tau = \omega$ respectively

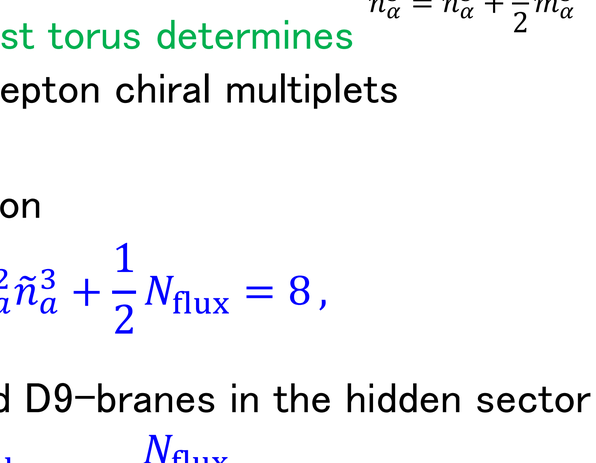
We change the maximum value of Q_{D3}^{hid} ($|Q_{D3}^{\text{hid}}| = 400, 1200, 2000$)



The small generation number is favored in the string landscape

The numbers of stable flux vacua with $g = 3$ generation of quarks/leptons on the fundamental domain of τ

MSSM-like models are still peaked at the $\mathbb{Z}_3$ fixed point



3. Distribution of g−generation models (Pati-Salam)

D-brane configuration leading to Pati-Salam-like model

N_α	Gauge group	(n_α^1, m_α^1)	(n_α^2, m_α^2)	$(\tilde{n}_\alpha^3, m_\alpha^3)$
$N_a = 8$	$U(4)_C$	$(0, -1)$	$(1, 1)$	$(1/2, 1)$
$N_b = 4$	$U(2)_L$	$(g, 1)$	$(1, 0)$	$(1/2, -1)$
$N_c = 4$	$U(2)_R$	$(g, -1)$	$(0, 1)$	$(1/2, -1)$

$\tilde{n}_\alpha^3 = n_\alpha^3 + \frac{1}{2}m_\alpha^3$

The magnetic flux g on the first torus determines the generations of quark and lepton chiral multiplets in the visible sector

- D3-brane charge conservation

$$D3: \sum_a N_a n_a^1 n_a^2 \tilde{n}_a^3 + \frac{1}{2}N_{\text{flux}} = 8,$$

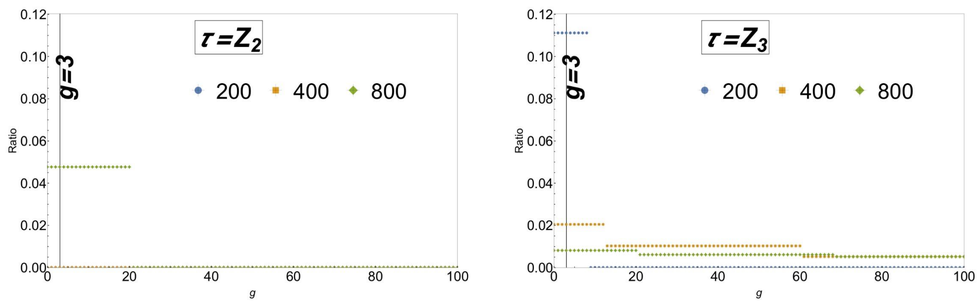
- The existence of magnetized D9-branes in the hidden sector

$$2g = -Q_{D3}^{\text{hid}} + 8 - \frac{N_{\text{flux}}}{2},$$

(Q_{D3}^{hid} : D3-brane charge induced by the magnetic flux on D9-branes)

The numbers of flux vacua as a function of the generation number g at $\tau = i$ and $\tau = \omega$ respectively

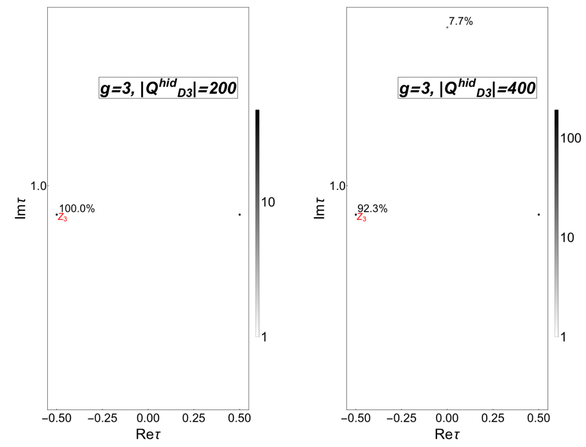
We change the maximum value of Q_{D3}^{hid} ($|Q_{D3}^{\text{hid}}| = 200, 400, 800$)



The small generation number is also favored in the string landscape

The numbers of stable flux vacua with $g = 3$ generation of quarks/leptons on the fundamental domain of τ.

Pati-Salam like models are still peaked at the $\mathbb{Z}_3$ fixed point



4. Summary

D-brane configurations leading to MSSM-like model and Pati-Salam like model

The magnetic flux g determines the generations of quark and lepton in the visible sector (Index theorem)

By tadpole cancellation conditions, the moduli distribution are related with the generation number

→ the string landscape leads to small generation number