Neutrinos, Cosmological Constant, and Number Theory

Grant-in-aid Program “Neutrinos”

2019 workshop at Iga-Ueno

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Symmetries behind the Scenes

- track records
  - isotropic and homogeneous universe
  - electroweak unification
  - $U(N_F)\times U(N_F)$ and $U(1)_L$ as accidental symm.

- more symmetries in phys. beyond the SM?

- adopted as a strategic hypothesis since 80's.

String theory provides a perspective on low-energy eff. field theory models

- more than 10^{10^5} vacua, however,
  - almost any gauge group,
  - any number of generations,
- not sure what to learn from that.

- are discrete symmetries quite common ?
  - more things to think before final words

String theory as a stage of all things

- in contrast with local effective field theory

$$\mathcal{L}_{Particle} + \mathcal{L}_{Inflation} + \mathcal{L}_{DarkEnergy} + \cdots$$

- one chosen geometry of the internal space determines all aspects of the eff. theory model.

analogy: amino-acid sequence of a protein
determines all the excitation spectra
in microwave, IR, and magnetic resonance.

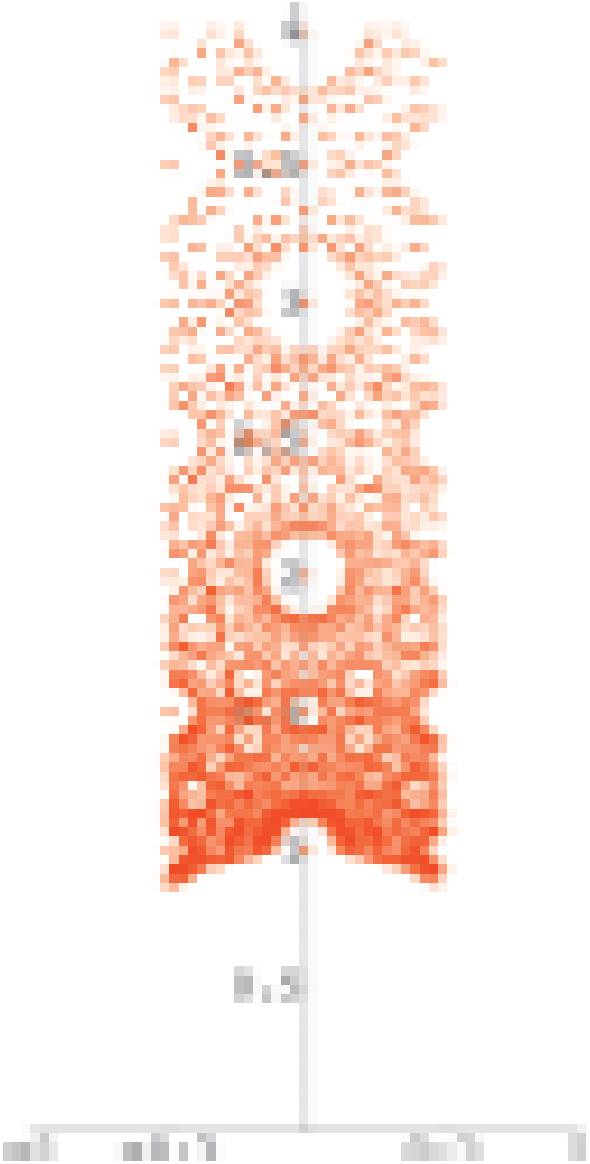
- Assume supersymmetric compactification

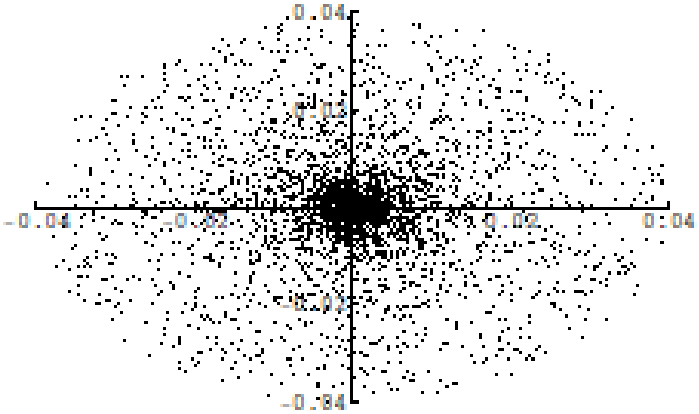
  == SUSY breaking much below the GUT scale

$\Rightarrow$ Right-handed Neutrinos $\simeq$ coordinates of the moduli space of compactification

discrete symmetry is in eff. theory $\Leftrightarrow$ scalar RH nu vac. is in a symmetric locus of the moduli space

- Two competing arguments
  - discrete symm unlikeley, vs likely.
- Cosmological Constant is typically $-M_{Pl}^4$





In another set-up
(hep-th/0404243
Giryavets et.al.)

A number-theoretical solution to the small c.c. / gravitino mass,

and its Consequences

based on

Phys. Rev. D96 (’17) 106001

+ another work in progress

with K. Kanno (U. Tokyo)

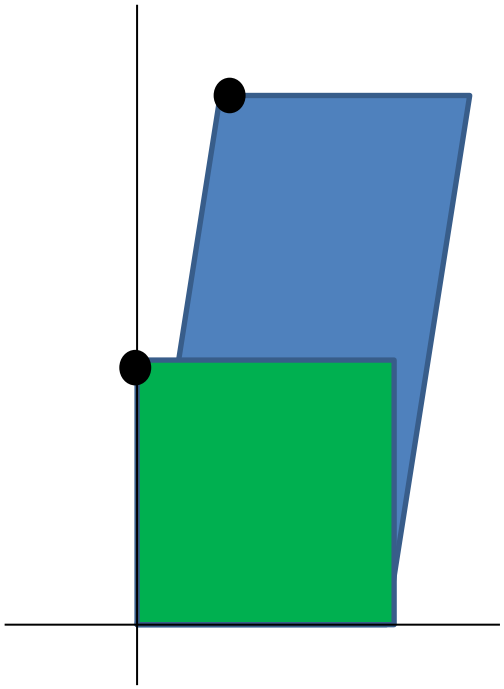
$$c.c. \sim -M_{Pl}^4 \left| \frac{\sum_i n_i \Pi_i}{(\sum_j \Pi_j^\dagger \Pi_j)^{1/2}} \right|^2 .$$

$n_i \in \mathbb{Z}.$

Π_i vac. exp. val. of geom. moduli

$$\sum_i n_i \Pi_i \sim 0???$$

e.g., Π of parallelograms



- An idea:

De Wolfe et.al. '05
Kanno TW '17

  – for example.

$$\Pi_0 = 1,\ \Pi_1 = e^{\pi i/3},\ \Pi_2 = e^{2\pi i/3},$$

$$1 \cdot \Pi_0 - 1 \cdot \Pi_1 + 1 \cdot \Pi_2 = 0.$$

$$\dim_{\mathbb{Q}} \mathbb{Q}(\Pi's) < \infty.$$ (algebraic)

  – algebraic Π_i : more likely to be a potential minimum.

- An internal manifold with number-theoretical characterization may be behind the small value of the cosmological constant.
  - translating observational clues not into symmetry and its breaking parameter, but to something else.
  - any consequences???

e.g., about discrete symmetries??
in particle spectrum ??

F-theory on internal spaces with cpx multiplication

Kanno , TW
in progress

- once an internal space X is given

→ gauge group, matter spectrum, interactions, symmetry — determined

- systematic construction of such an X: not easy.
  - easiest: $X = (K3 \times K3)/Z_2.$ (Borcea—Voisin)

→ small c.c., + accidental discrete symmetry
but no Yukawa couplings

  - other constructions??

messages

- rethinking process about guiding principles in physics beyond the Standard Model, using string theory.

- string theory as a stage of all things.
  - incl. cosmological const.
  - provides a way to see things differently from local effective field theory