An Update on Supersymmetric String Landscape

KEK-PH 2018 Workshop, 2018 Feb. 16

Taizan Watari (Kavli IPMU, Tokyo)

anything to learn about particle physics from string theory?

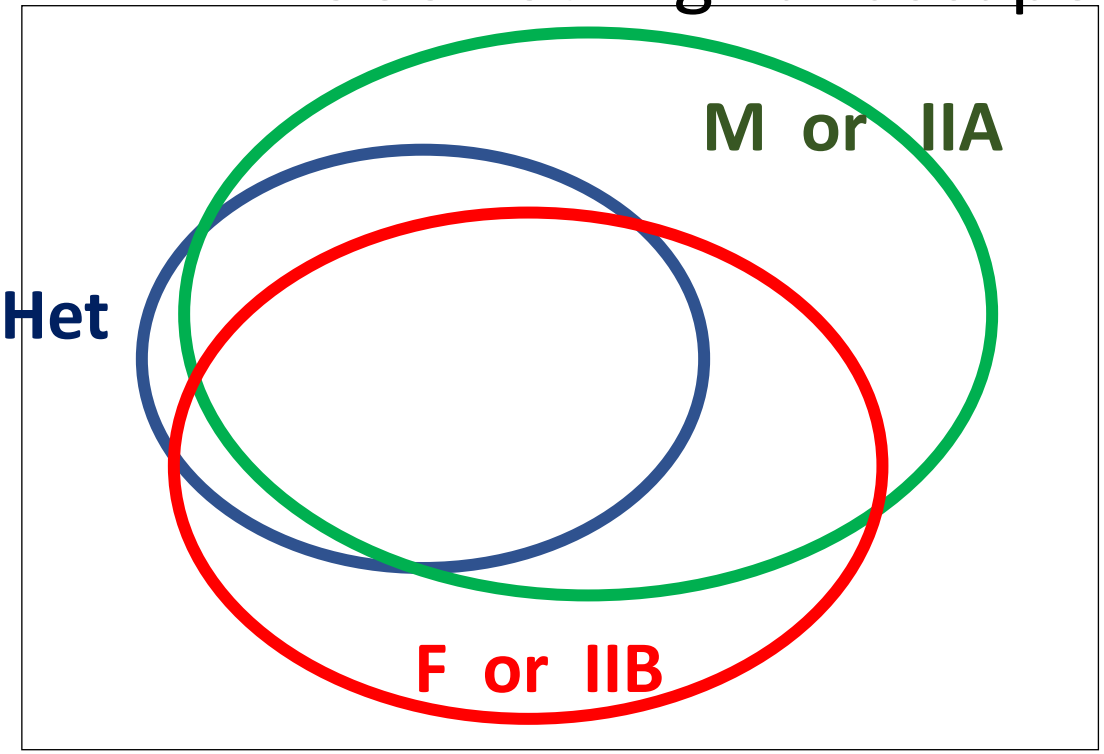
- Enhanced rate of proton decay. Friedman Witten ‘02
- RH neutrino mass somewhat below the GUT scale. Tatar Tsuchiya TW ‘09
- Electron mass not larger than Planck scale.

- Landscape (ensemble) of meta-stable vacua early 00’s ~
  - Eternal inflation prior to slow-roll inflation
  - Ensembles subject to selection
  - Theoretical foundation to “naturalness” ???

From the perspectives of string theorists…

- Studying string landscape:
  - just an intellectual curiosity. (like geography, zoology, etc)
    - typical greetings: “hello” and “Ni-hao”
    - tallest man on earth <= 2.5m
  - use the statistics for the basis of naturalness
    - based on String Theory after 90’s
  - probe into where the “String Theory after 90’s” fails badly.

D=4 N=1 SUSY String Landscape



- Study F-theory SUSY vacua
  - up-type Yukawa in SU(5) GUT Tatar TW '06
  - powerful machinery alg. geom.

- Fix a topology of the internal 6D mfd.
  - Flux introduces 10^{500} vacua.

  - gravitino mass: $\propto dm_{3/2}\ m_{3/2}$.
  - In Type IIB: also distrib. formula $10^{500}\ \det[R+\omega]$. Ashok Douglas '03, Denef Douglas '04

- **Not understood in 00's**: how gauge group (brane config) is determined

Virtually no question of practical interest can be asked back then.

Part I

Fix a topology of the internal 6dim. manifold.

- F-theory version of the Ashok-Denef-Douglas formula:

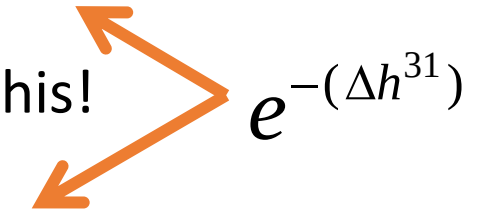
Denef '08
Braun Kimura TW '14,
Braun TW '14

$$e^{(2+2h^{31}+h_H^{22})/6}\det[R+\omega] \approx e^{h^{31}}\det[R+\omega]. \qquad h^{31} = \dim(\mathcal{M}).$$

- Lesson 1: #[flux vacua] $10^{100,000}$

record high $h^{31} \sim 3\times 10^5$ Taylor Wang '15
(for one topology)

- Lesson 2: vacua w/ non-Abelian gauge group: VERY rare.
  - small value of dark energy 10^{-120} is not as serious a problem as this!
- Lesson 3: vacua w/ U(1) gauge group is MUCH MORE rare.

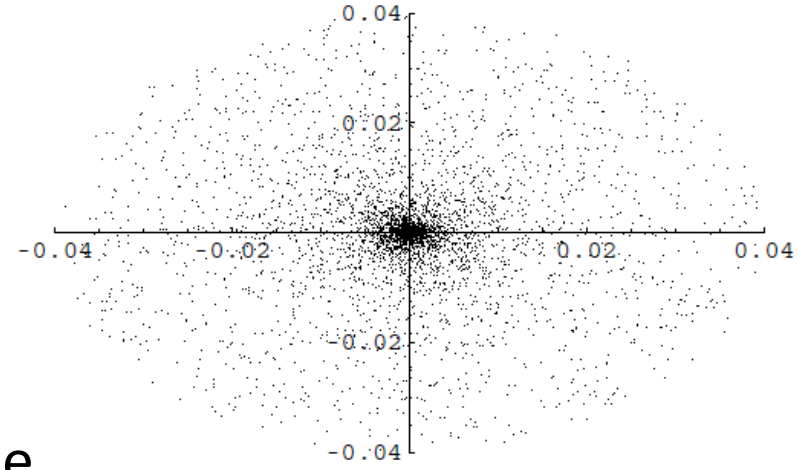


Braun TW '14,, TW '15

Part I

Fix a topology of the internal 6dim. manifold.

taken from Giryavets et.al. th/0404243

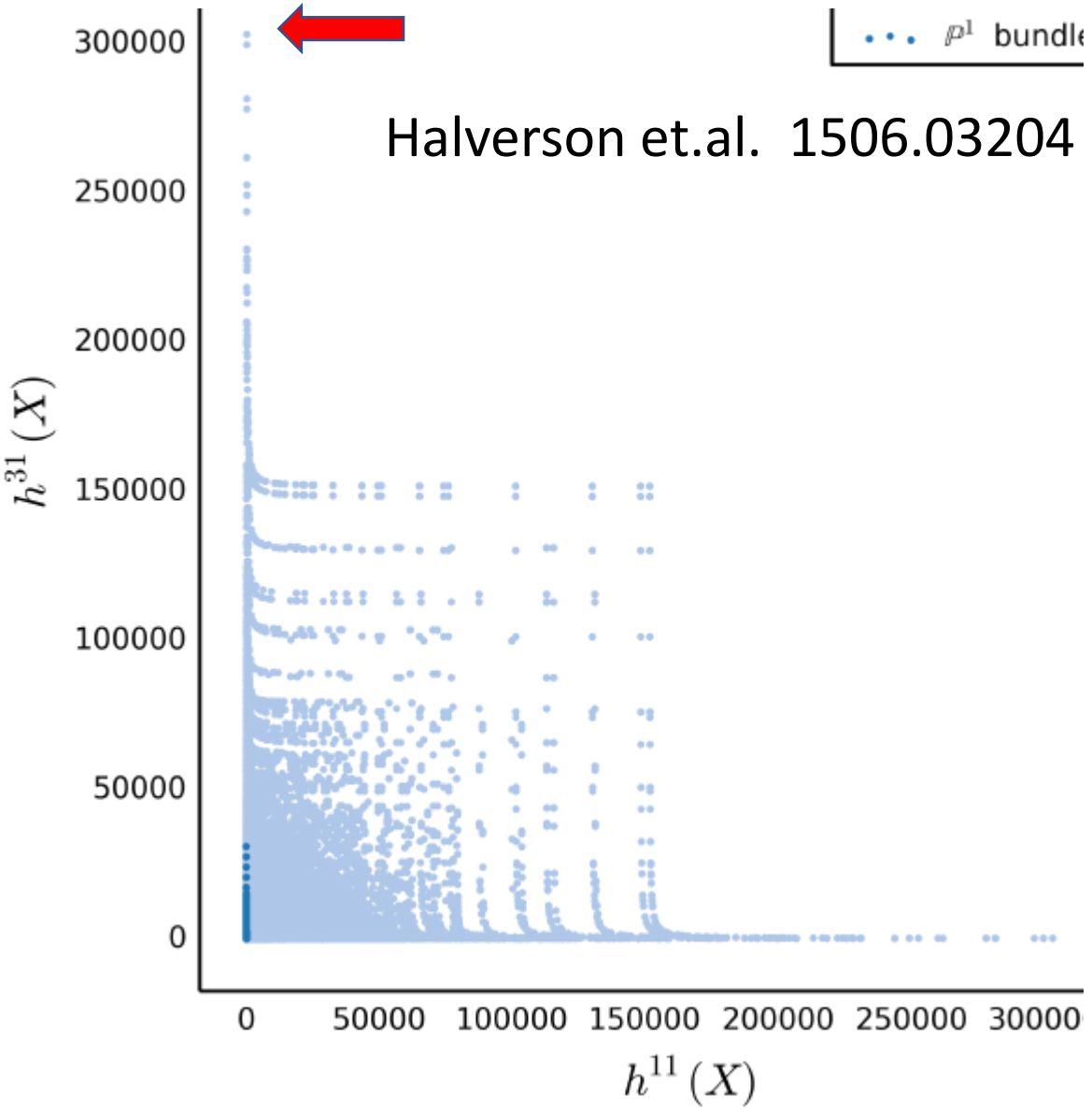


- distribution $\propto \det[R+\omega]$
  - accumulation locus (see ⟶) iff 4-cycles have logarithmic monodromy. Eguchi Tachikawa '06
  - Lesson 4: U(1) symmetry breaking parameter: YES in codimension- (Δh^{31}) subspace
  - Lesson 5: hierarchical Yukawa from localized wavefunctions: Arkani-Hamed Schmaltz '01
    - F-theory implementation: $\mathrm{Im}(\tau) \sim O(100)$ for localization. Hall Salem TW '07
    - turns out that $e^{2\pi i\tau}$ is the natural coordinates on the mod. space. Hayashi et.al. '09
    - ⟹ unless there is log monodromy around $e^{2\pi i\tau} = 0$, the AS idea has no gain, in fact.

Part II

6dim. internal manifolds with diff. topology

- the zoo of internal manifolds



Part II

6dim. internal manifolds with diff. topology

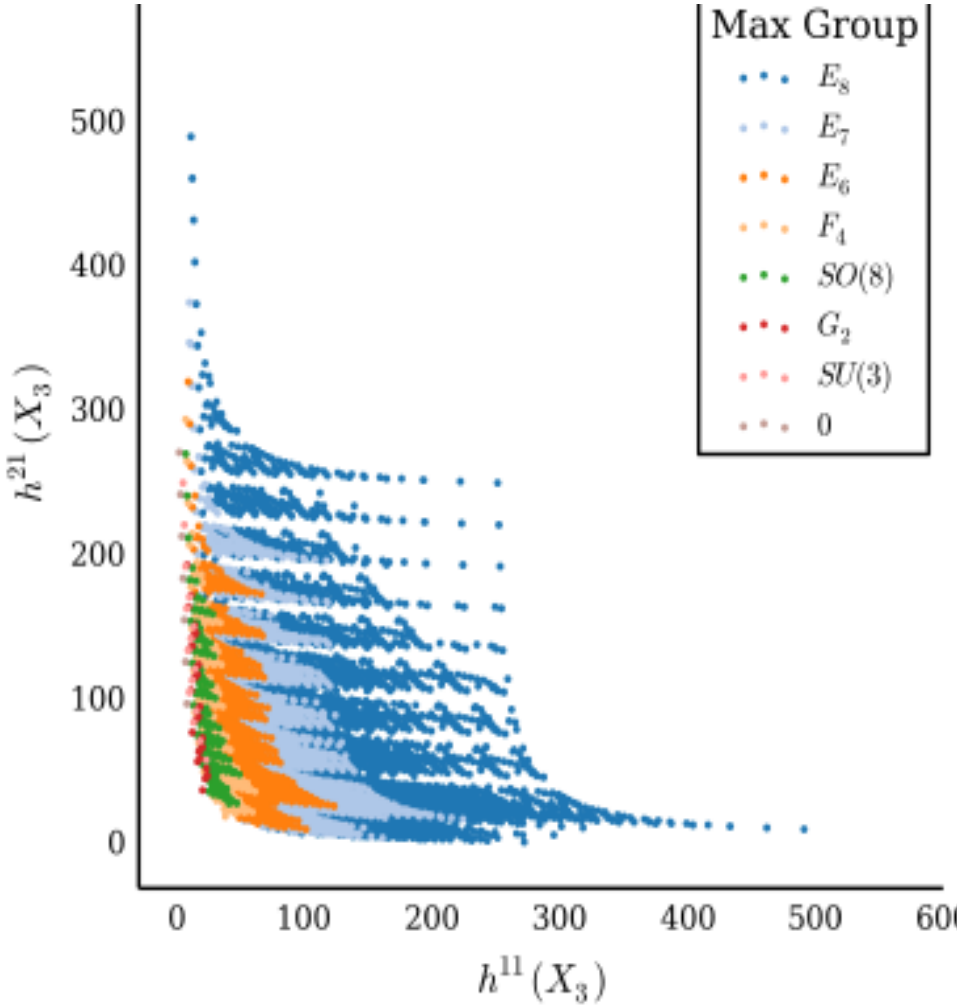
Halverson et.al. 1506.03204

- the zoo of internal manifolds
- for many of them, there are unavoidable stacks of 7-branes ➡ non-Abelian gauge grps
  - often in the form of product of non-Abelians.

v.s.

Halverson et.al. ‘17

- Unavoidable non-Abelinas relevant to us??
  - the MSSM has flat directions (deformat’n DOFs)



Summary

- 4D N=1 SUSY String Landscape being studied well using F-theory
  - tremendous number of flux vacua,
  - tremendous rarity of flux vacua with higher rank gauge group
  - techniques developed and available to study distribution of couplings in the effective theory
    - U(1) symmetry breaking parameter,
    - Yukawa hierarchy
  - often unavoidable stack of branes leading to product of non-Abelian gauge groups