New AdS_4 vacua in string theory
and their conformal field theory duals

Alessandro Tomasiello

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Introduction

This talk is about supersymmetric AdS_4 vacua.

We don't live in AdS_4; nor is supersymmetry unbroken. But:

- Possible dual CFT3 description. has become possible very recently!

- Useful first step. $\Lambda > 0$ difficult to achieve! [deWit, Smit, Hari Dass '87; Maldacena, Nuñez '00]

... and with unbroken susy, impossible:

[for susy vacua: superpotential
$$V \sim (|\cancel{DW}|^2 - |W|^2)$$
]

Hence we will break susy when we make Λ positive.

Examples:

[Kachru,Kallosh,Linde,Trivedi'03]

Step 1. $\mathrm{AdS}_4 \times \mathrm{CY}_6$ in IIB

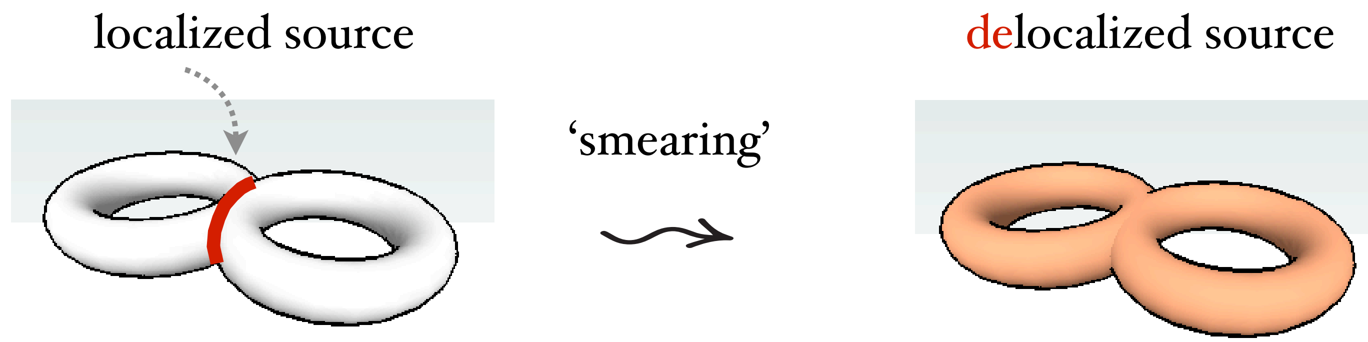
using
- quantum corrections (brane instantons)
- O3, D3, D7

Step 2. using D3-$\overline{\text{D3}}$ pairs

[deWolfe, Giryavets, Kachru, Taylor'05]

Step 1. $\mathrm{AdS}_4 \times \mathrm{CY}_6$ in IIA

using
- classical ingredients
- [smeared!] O6



Step 2. Not easy (no-go, in some sense)

[Hertzberg, Kachru, Taylor, Tegmark'07]

Can we avoid instantons and orientifolds?

[deWit, Smit, Hari Dass '87;
Maldacena, Nuñez '00]

don't apply to $\Lambda < 0$

One construction existed ("Freund-Rubin"):

- works for infinitely many spaces
  (but not just any space)

- for each space, one vacuum (or two)

...until now:

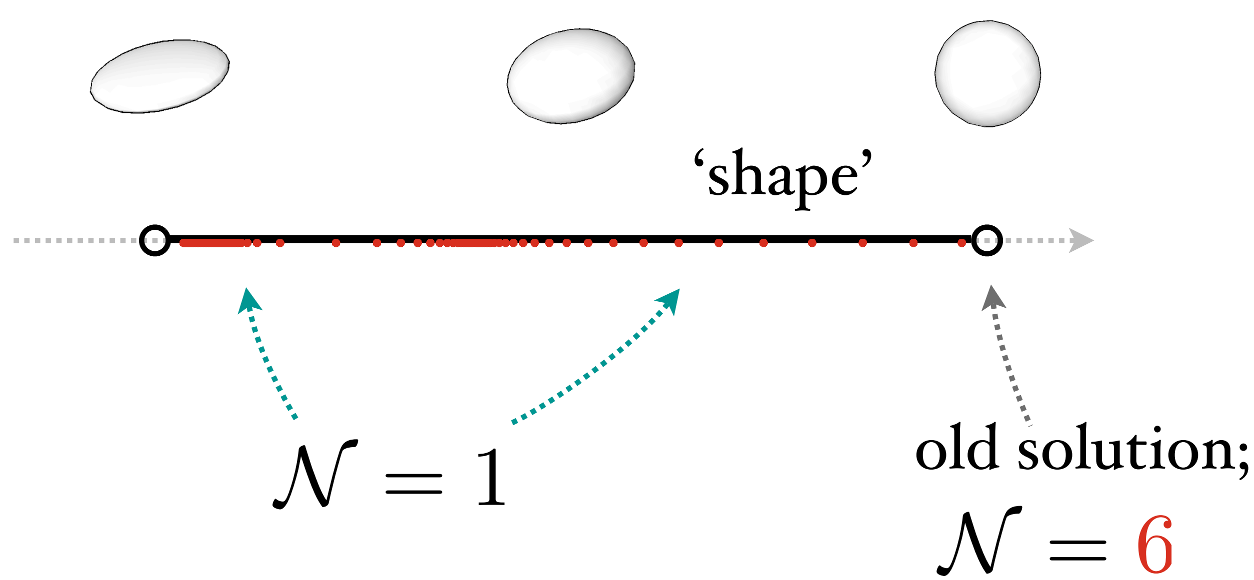
This talk: new class of AdS_4 vacua

[AT '07]

- no orientifolds, no brane instantons
- all moduli stabilized (not there to begin with!)
- infinitely many

$AdS_4 \times \mathbb{CP}^3$
vacua in IIA

a rich 'discretuum'
of vacua
with same topology



[sample]

Freund-Rubin:

- works for infinitely many spaces
  (but not just any space)

- for each space, one vacuum (or two)

My new construction:

- so far, only two internal spaces:

  $$\mathbb{CP}^3 \; , \quad \frac{\mathrm{SU}(3)}{\mathrm{U}(1)\times\mathrm{U}(1)} \; ;$$

  I have a conjecture for infinitely many more!

- for each space, infinitely many vacua

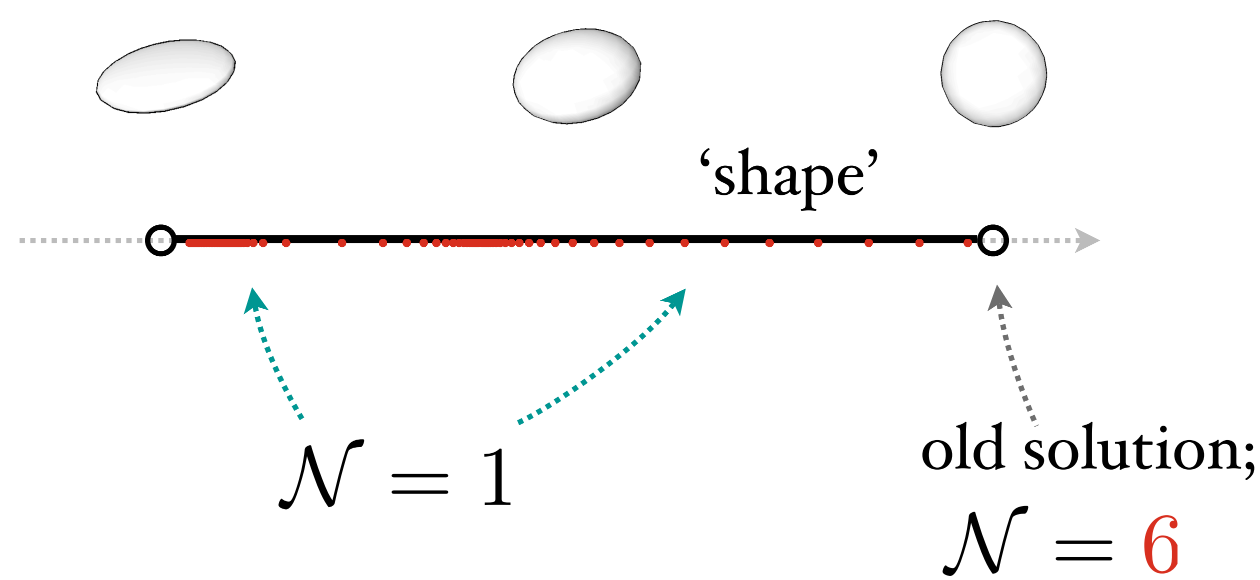
- Bonus: AdS4 / CFT3

a dual was found for the ‘old solution’:
Chern-Simons + matter

[Aharony, Bergman, Jafferis, Maldacena ‘08....]

Finally, AdS4 / CFT3 duals with Lagrangian description.

I will present an idea for the dual to the other vacua.



Plan

- General considerations about supersymmetry
- Some geometry of $\mathbb{CP}^3$
- Finding the new vacua
- Sketch of CFT duals

Supersymmetry

In general:

Conditions for susy solutions $\Longleftrightarrow$ Geometrical problem

[Graña, Minasian, Petrini, AT '05, '06]

a refinement of 'generalized complex geometry' [Hitchin '02, Gualtieri '04]

In particular:

- For all $\Lambda = 0$ vacua, M_6 is 'generalized complex'
- For all $\Lambda < 0$ vacua, M_6 is 'generalized half-flat'

essentially all known vacua in ‘$\mathrm{SU}(3)$ structure’ class

earlier analyzed by [Lüst,Tsimpis‘04]

$$J \wedge \Omega = 0$$

$$\Omega \wedge \overline{\Omega} = i J^3$$

[break local $\mathrm{SO}(6)$ to $\mathrm{SU}(3)$]

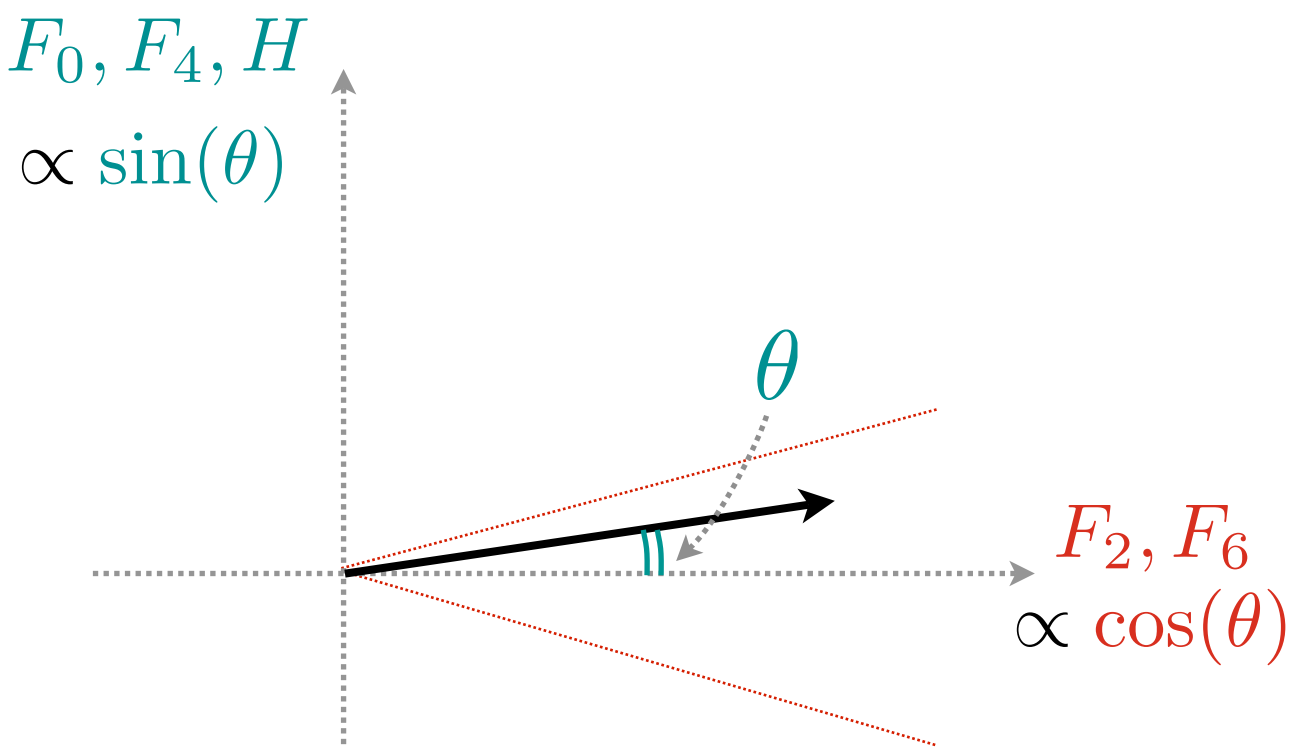
the general geometrical method boils down to

geometry is supersymmetric $\Longleftrightarrow$

$$dJ \propto \mathrm{Re}\Omega$$

$$\Delta \mathrm{Re}\Omega \propto \mathrm{Re}\Omega$$

Susy then also determines the fluxes:



[F_k are internal fluxes]

[Lüst,Tsimpis‘04]

so, morally: $\tan(\theta) \sim F_0/F_6$

actually, F_2 has also a term of norm

$$\propto 1 - 16\sin^2(\theta)$$

⇨

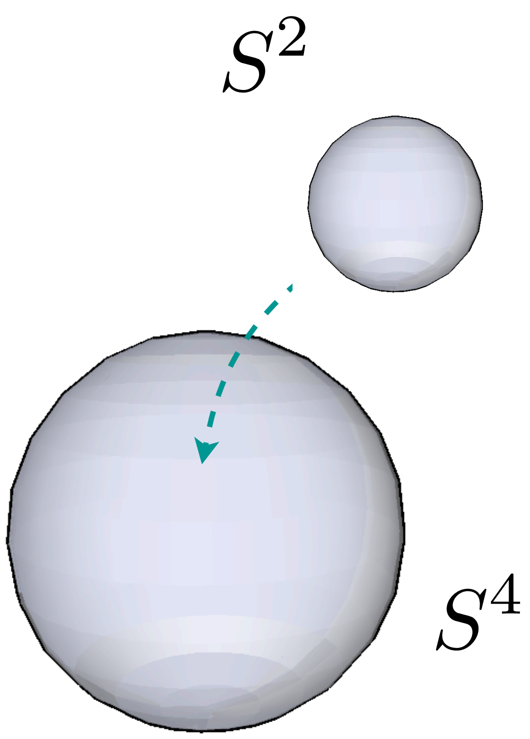
$$|\sin(\theta)| < \frac{1}{4}$$

[limit not valid with sources; more on this shortly]

Some geometry of $\mathbb{CP}^3$

- topology

$\mathbb{CP}^3$ is a sphere fibration:



cohomology:

h^0	h^1	h^2	h^3	h^4	h^5	h^6
1	0	1	0	1	0	1

- “Isn’t $c_1 \neq 0$?”

  Actually there is another (almost) complex structure, with $c_1 = 0$

  ‘not integrable’: but this is what susy requires

- Metric:

overall size

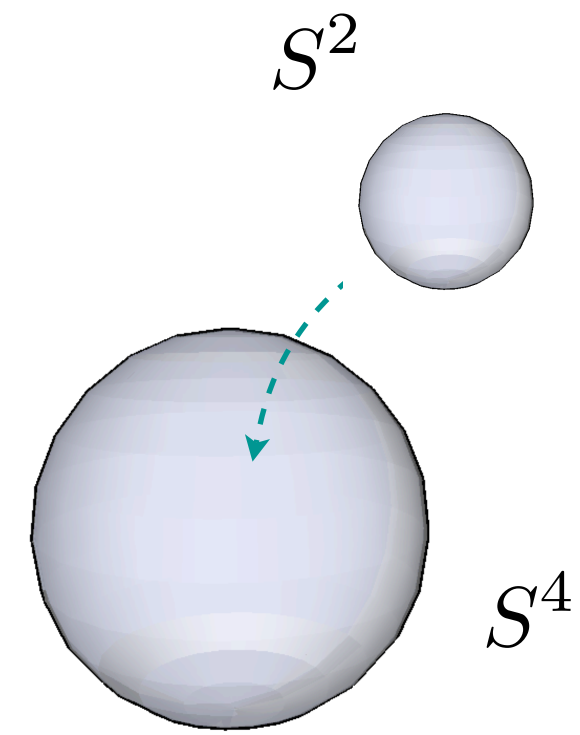
S^2

fibration is nontrivial

$$ds^2 = R^2(g_{ij}(dx^i + A^i)(dx^j + A^j) + \frac{1}{\sigma} ds^2_{S^4})$$

few parameters to begin with:

‘stabilizing moduli’ will be easy



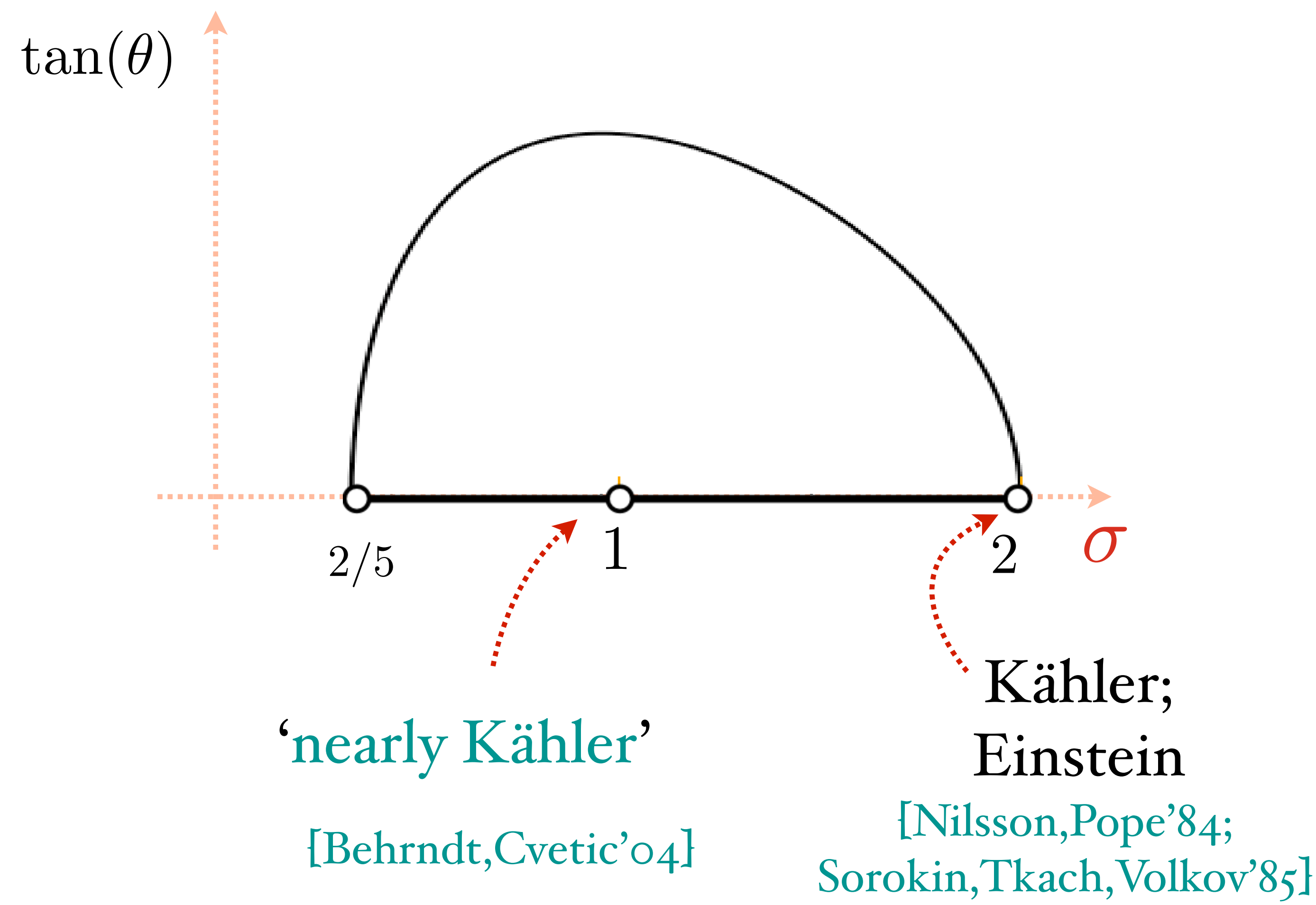
The new vacua

[AT '08]

susy reduces to...

$$\tan(\theta) = \frac{\sqrt{(\sigma - \frac{2}{5})(2-\sigma)}}{\sigma + 2}$$

recall: "F_0/F_6" "shape"



Flux quantization

- Bianchi: $d(e^{-B\wedge}F)_k = 0$

$$\|\|$$

$$d\tilde{F}_k = 0 \quad \Rightarrow \quad \int_{\text{k-cycle}} \tilde{F}_k = n_k$$

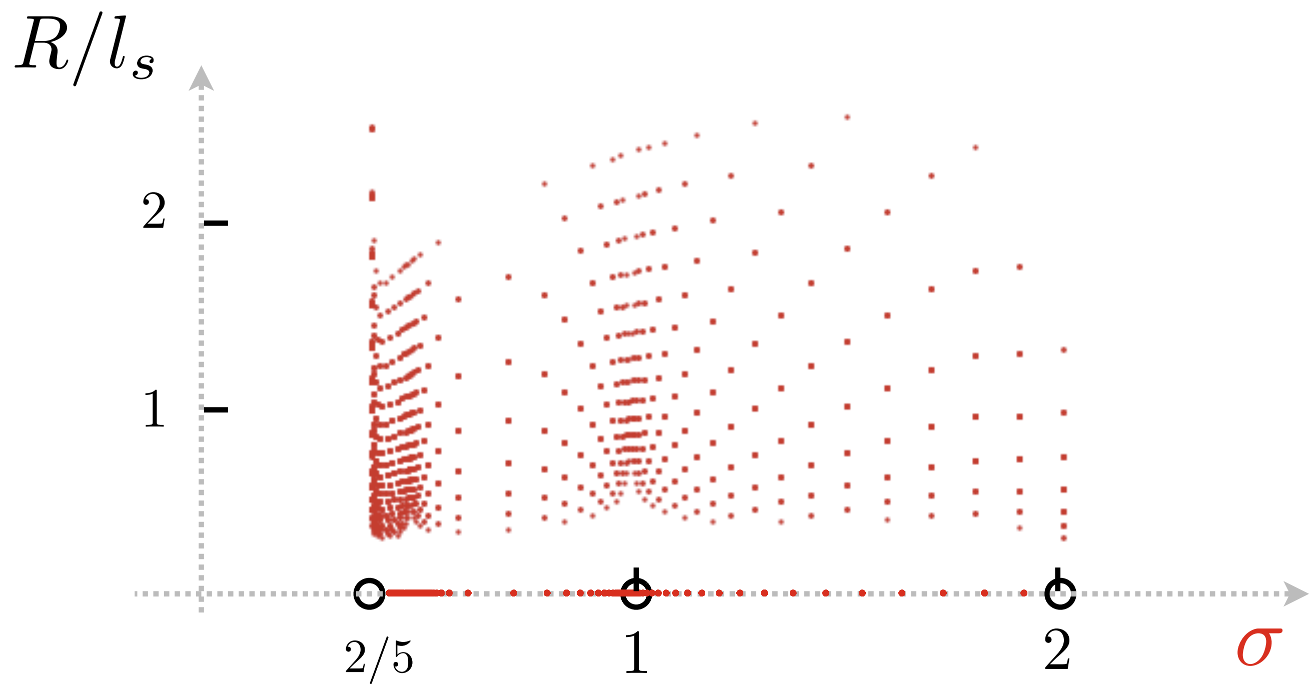
$$k = 0, 2, 4, 6$$

[internal fluxes]

four equations for:

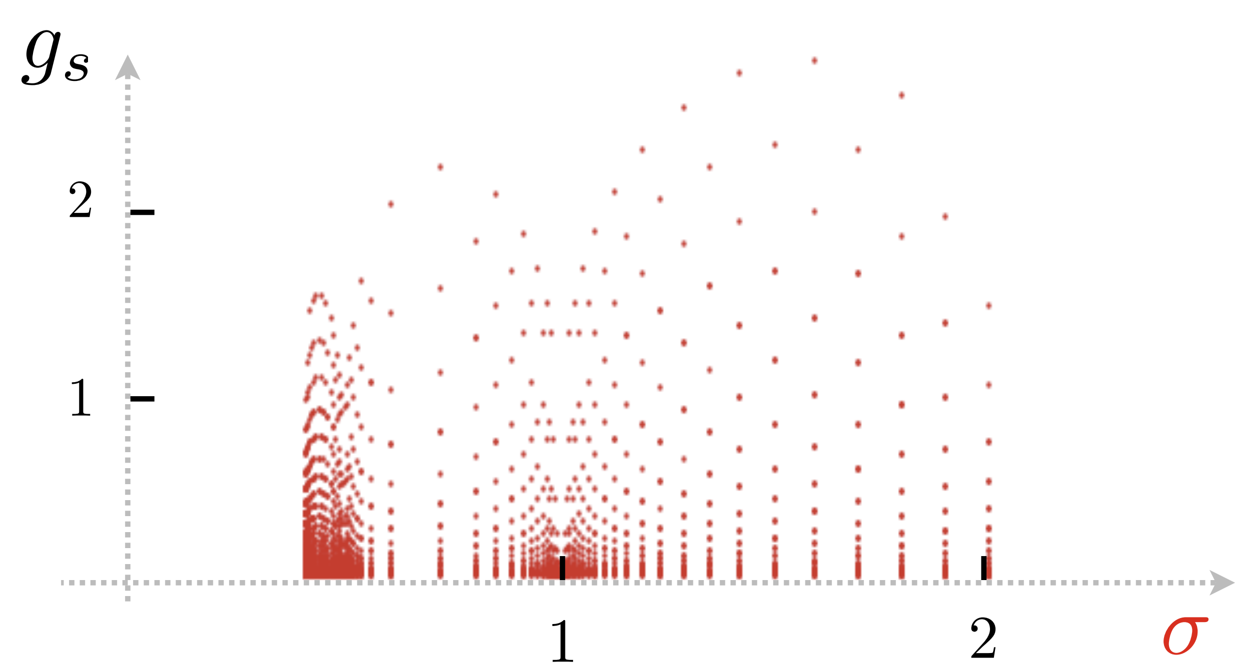
R	B
[size]	[NSNS]
g_s	σ
[coupling]	[shape]

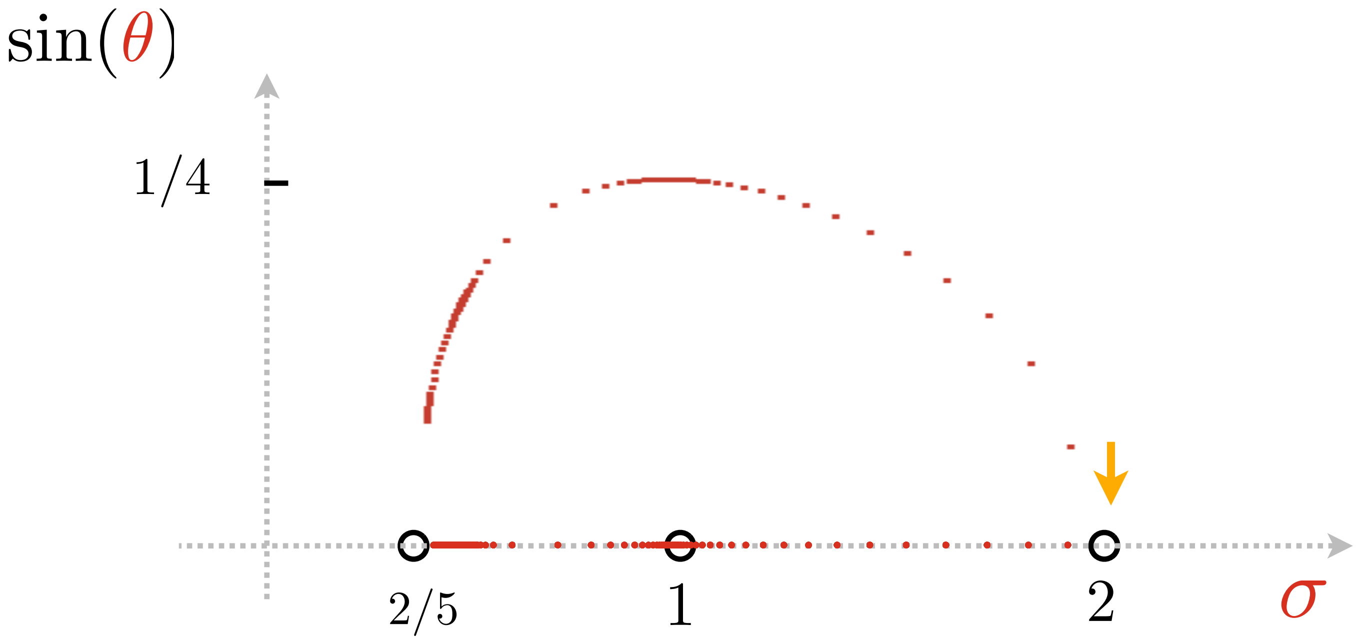
these parameters are discretized

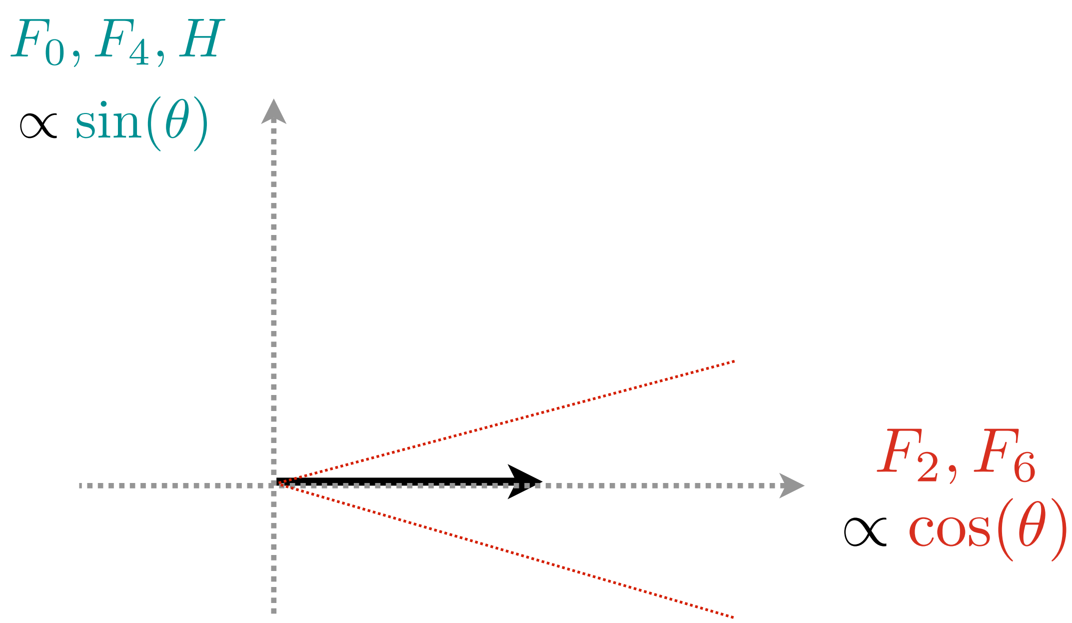


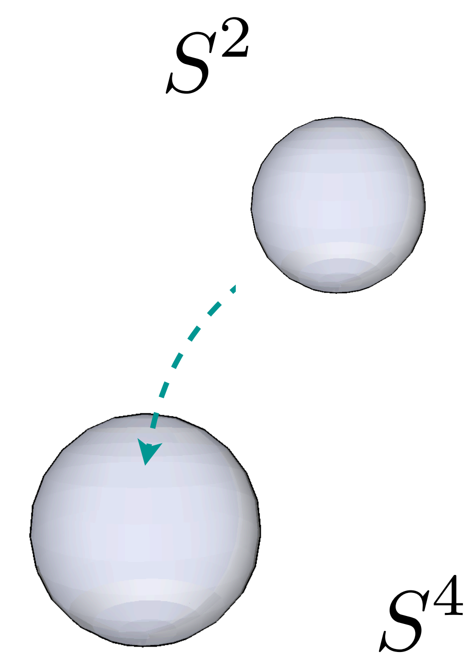
- for each of these σ s, can achieve $R \gg l_s$ and $g_s \ll 1$ parametrically
- reasonable cuts on KK scale make them finite

agreement with general conjecture
by [Acharya, Douglas '06]









generically all fluxes are on.

AdS$_4$/CFT$_3$

3d CFTs not as well understood as in 4d and 2d.

- in 2d the conformal group is ∞-dimensional; not in 3d

- in 4d, gauge couplings run logarithmically; (using NSVZ β-function)
  can choose coefficient to be zero

in 3d gauge couplings are dimensionful.

Recently: [Aharony, Bergman, Jafferis, Maldacena'08]

$\mathcal{N} = 6$ superconformal Chern-Simons

+ quartic superpotential

dual to

$\mathrm{AdS}_4 \times (S^7/\mathbb{Z}_k)$

or $\mathrm{AdS}_4 \times \mathbb{CP}^3$

What about the other vacua on $\mathbb{CP}^3$?

[Aharony, Bergman, Jafferis, Maldacena '08]

$\mathcal{N} = 6$ superconformal Chern-Simons

CS level k | CS level $-k$

+ quartic superpotential

dual to

old solution, $\mathcal{N} = 6$

Proposal:

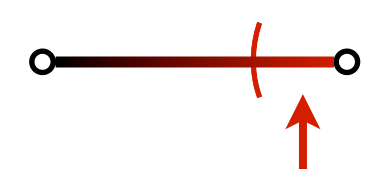
[Gaiotto, AT: work in progress]

$\mathcal{N} = 1$ superconformal Chern-Simons

CS level k | CS level k'

+ quartic superpotential

dual to



new vacua

[our duality better and better justified close to $\mathcal{N} = 6$ solution]

Conclusions

- New AdS solutions under control and with no moduli
- Complexity of vacua not exclusive to Calabi-Yau's
- New perspectives in CFT_3