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# STRING COMPACTIFICATIONS FROM TOP TO BOTTOM



Miguel Montero

IFT Madrid

June 3 2024



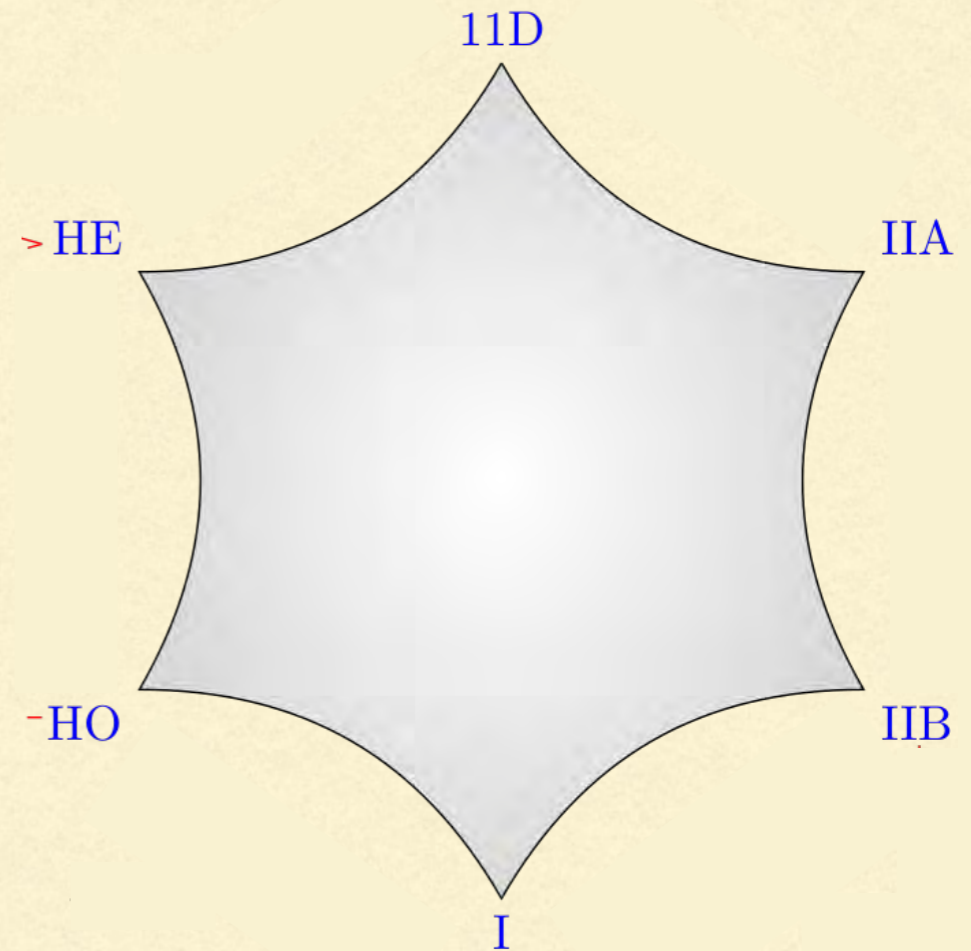
Strings 2024 @ CERN

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**dimensional** Minkowski  $\mathbb{R}^{9,1}$

(+ 11d M theory on  $\mathbb{R}^{10,1}$  )

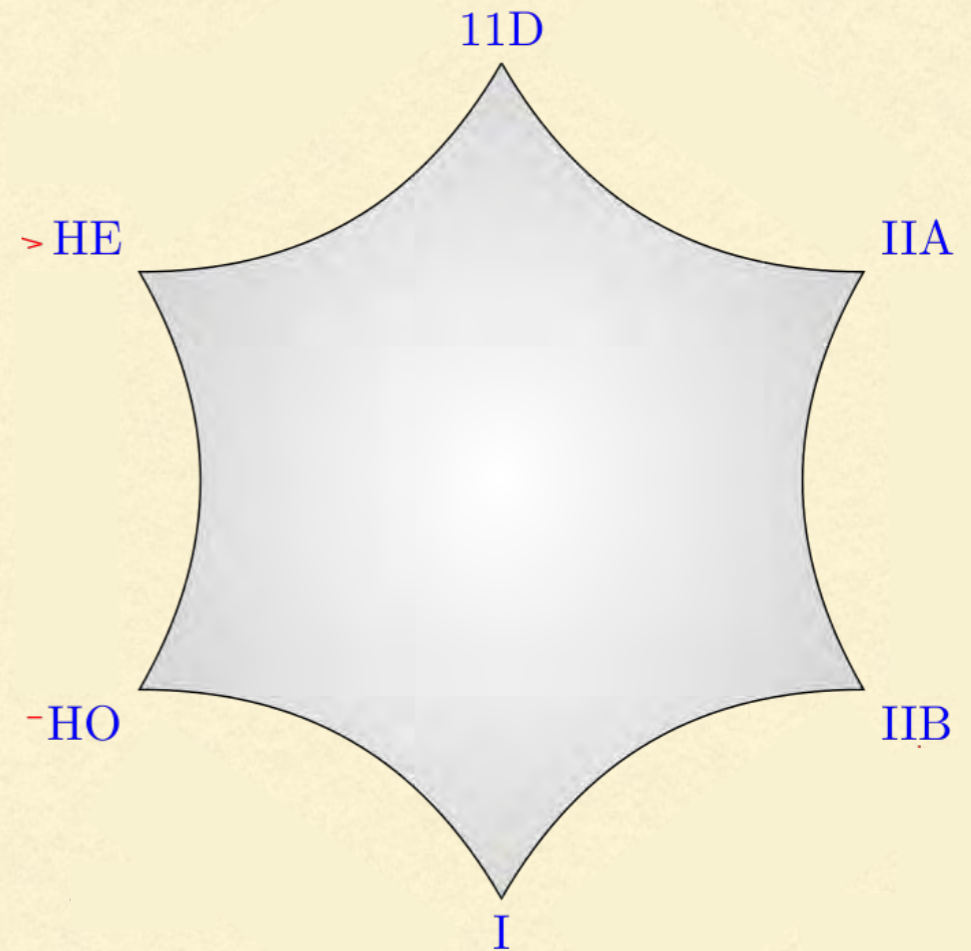


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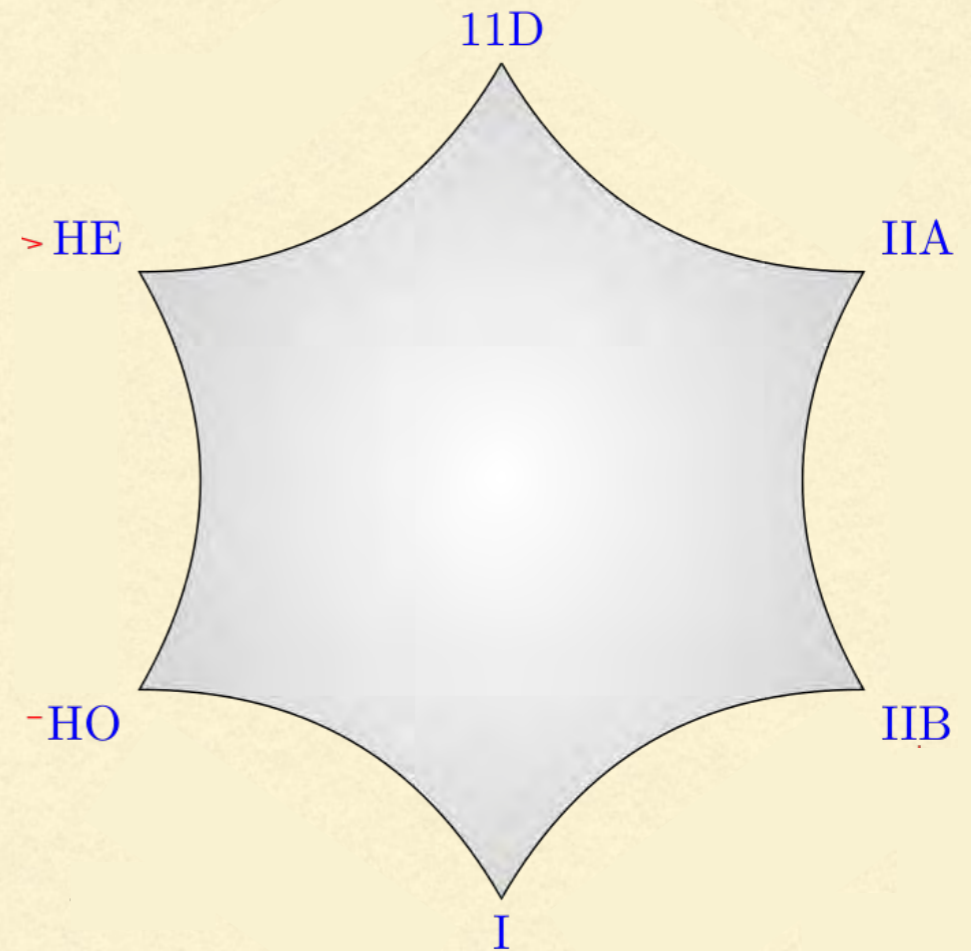
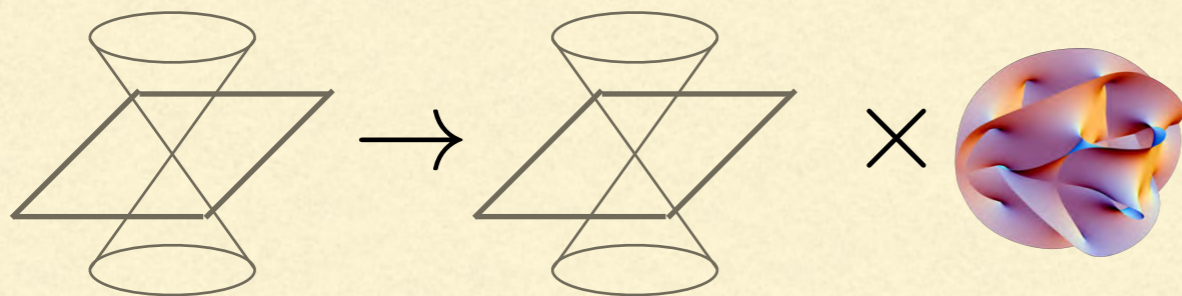


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$$\mathbb{R}^{9,1} \rightarrow \mathbb{R}^{9-d,1} \times \mathcal{M}_d$$



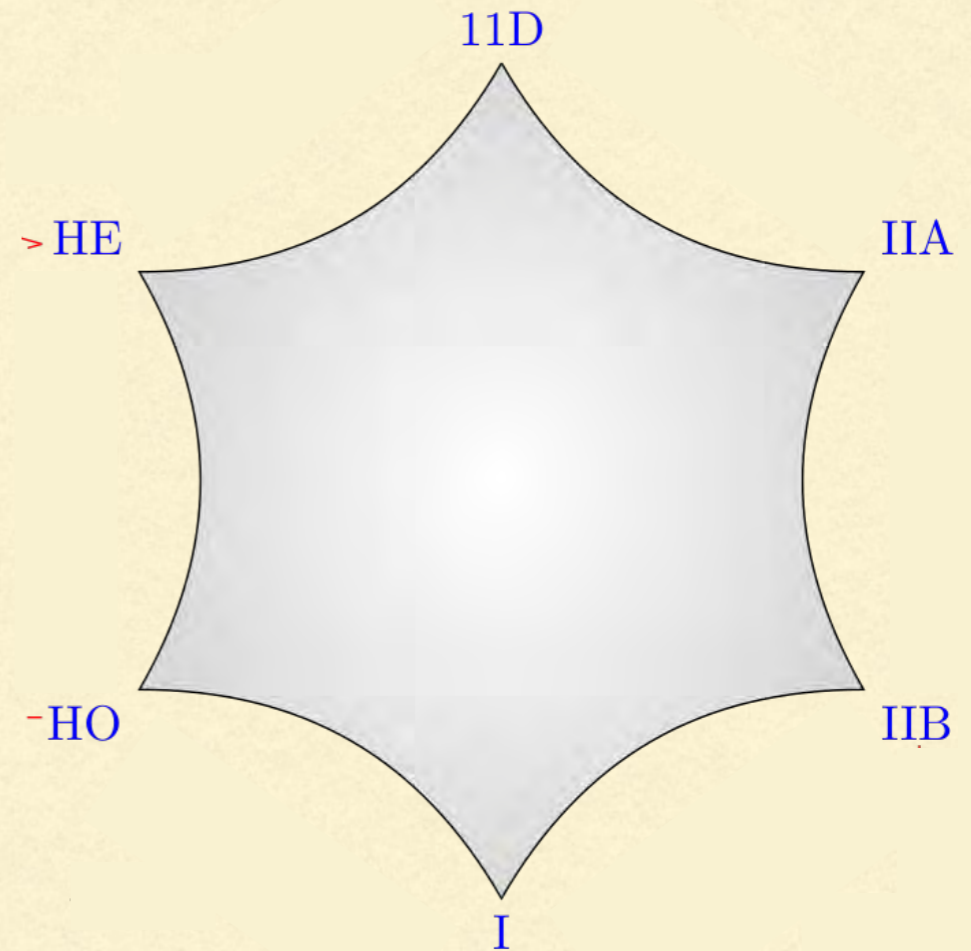
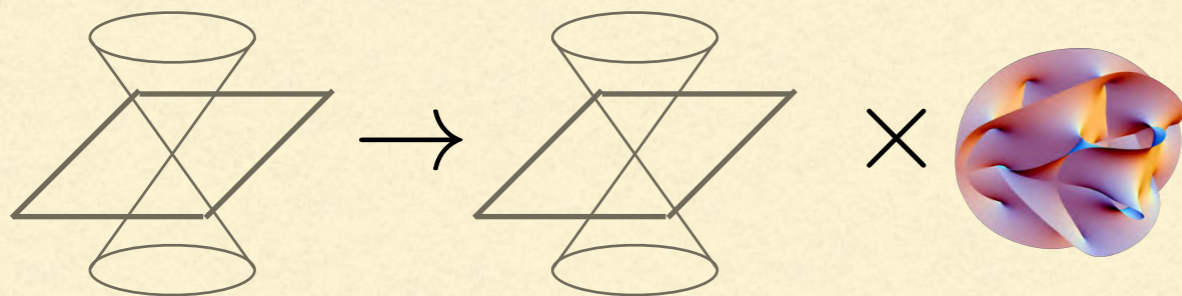
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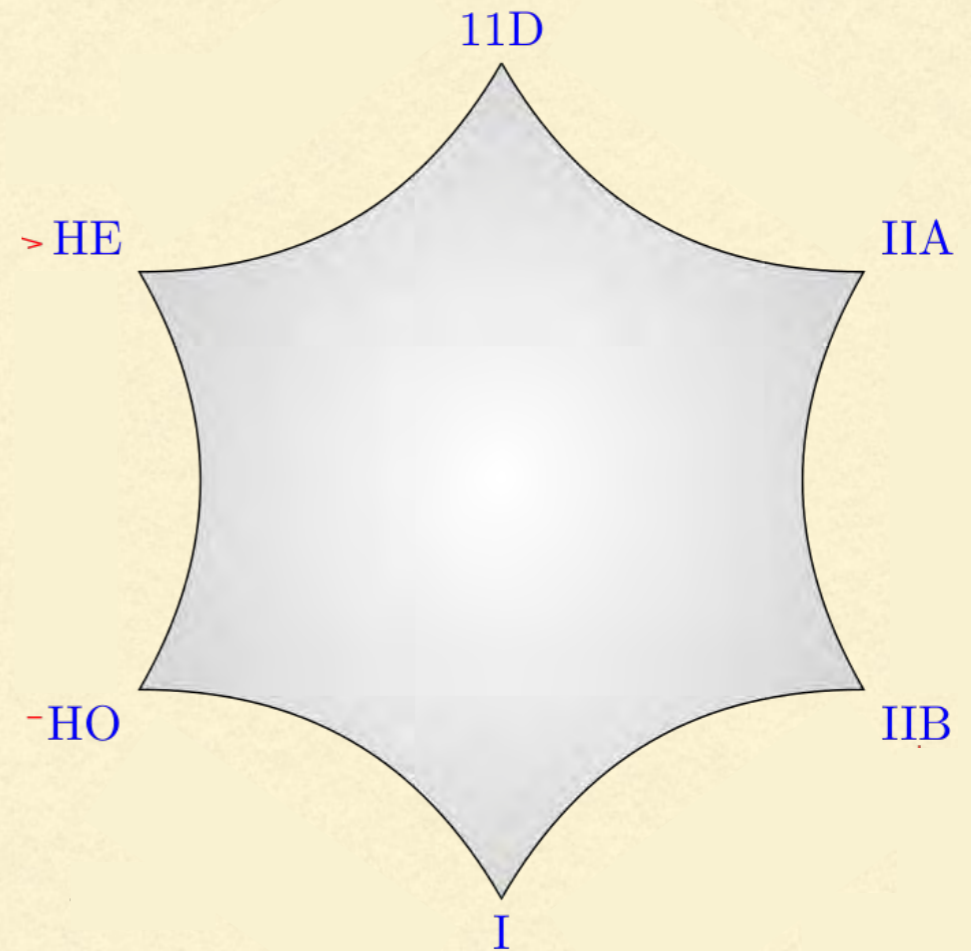
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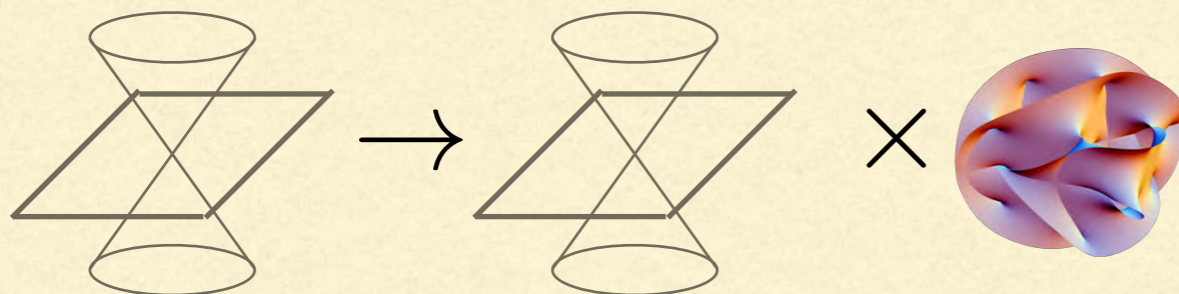
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**Compactification manifold**

Solves the ST equations of motion

Can be (geometric) or small (stringy)



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Why is this guy telling me  
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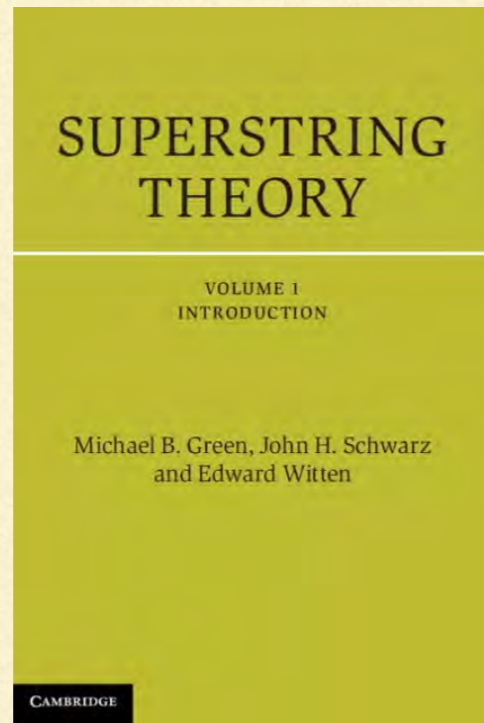




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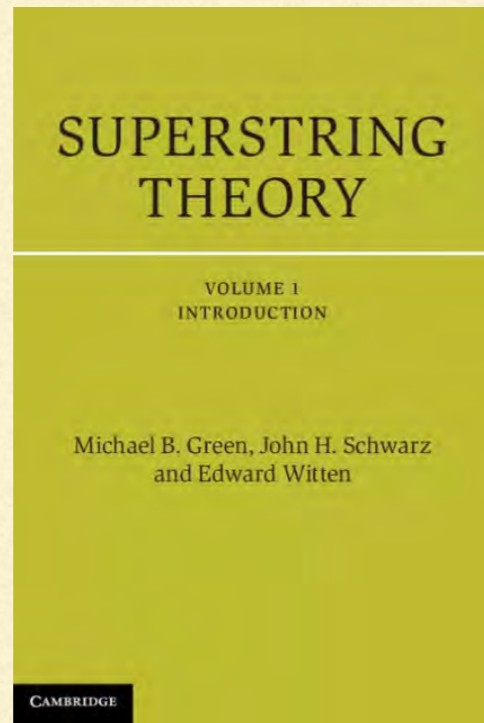


Published 1987

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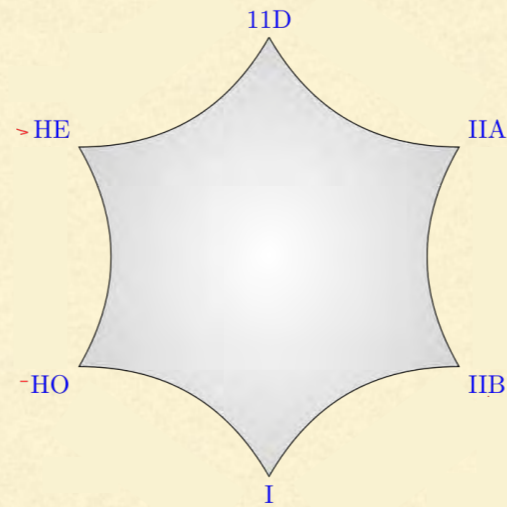
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Born 1989

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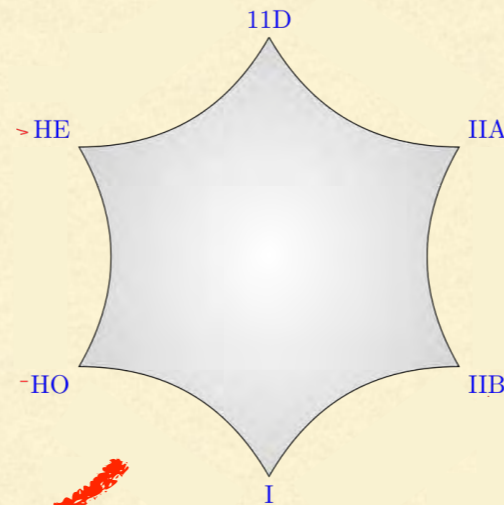
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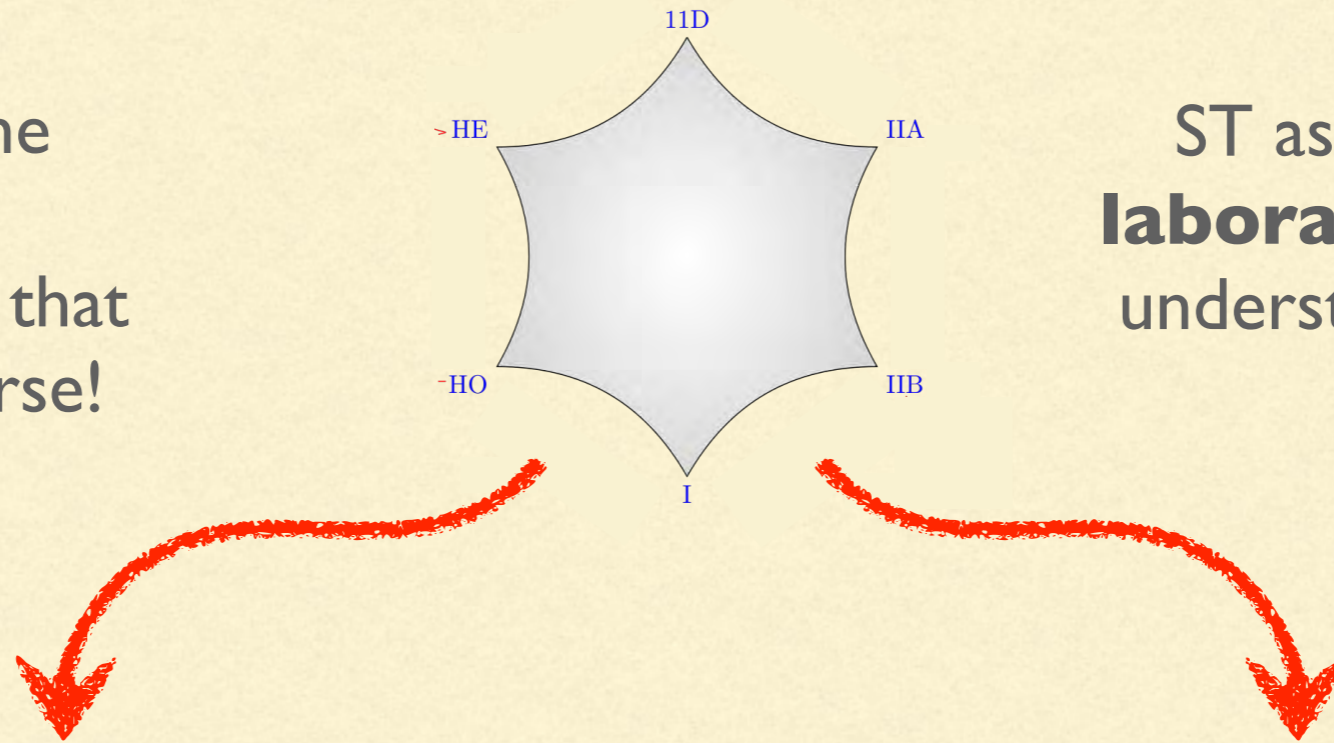
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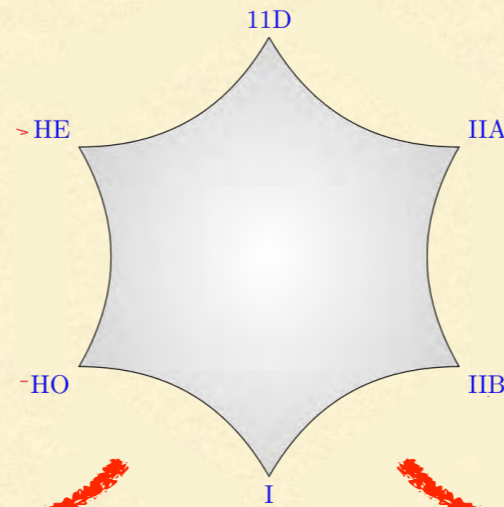
ST as a **theoretical laboratory**: We need to understand what it can & cannot do



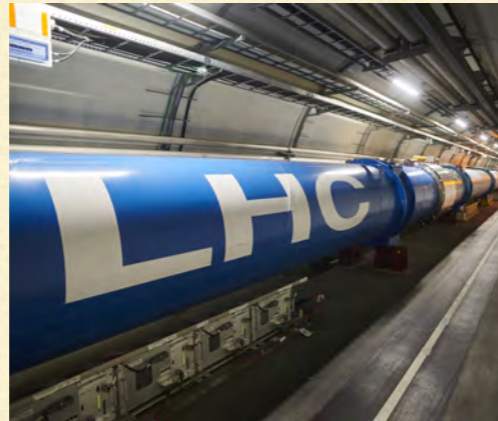
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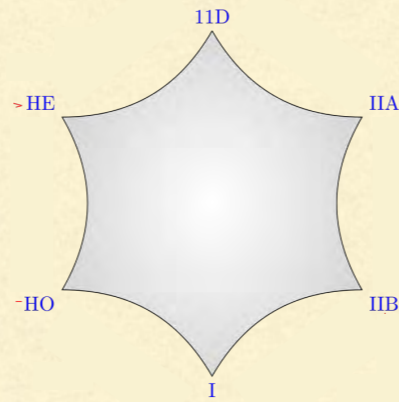


This is why people never stopped working on it.

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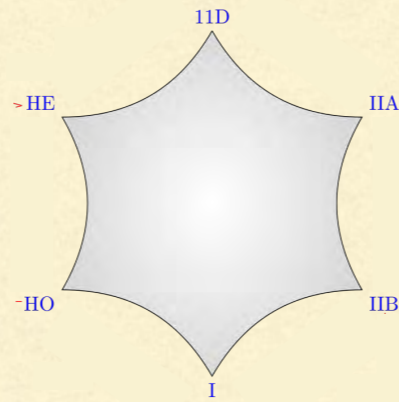
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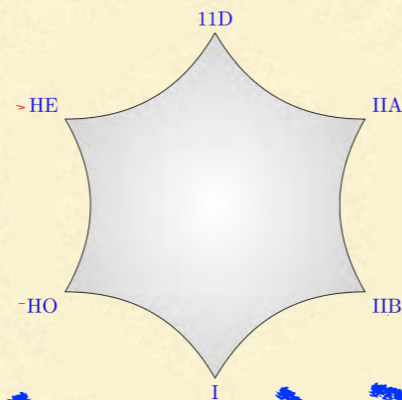
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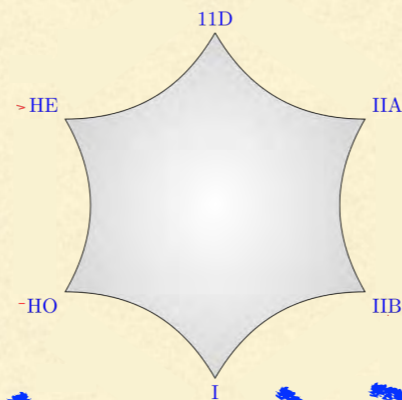
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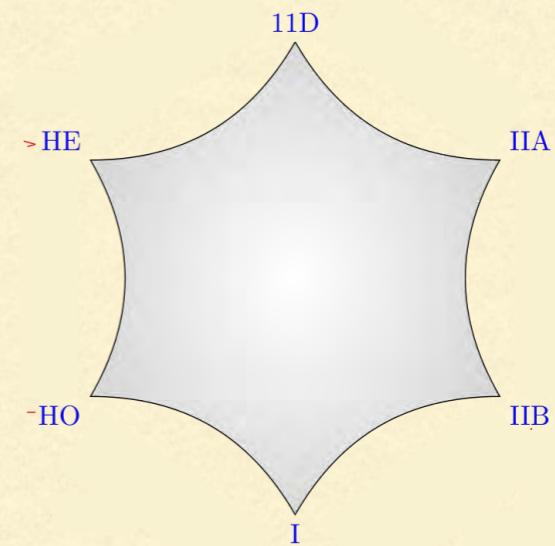


This is why there is still much we do not know,  
even after all these years.

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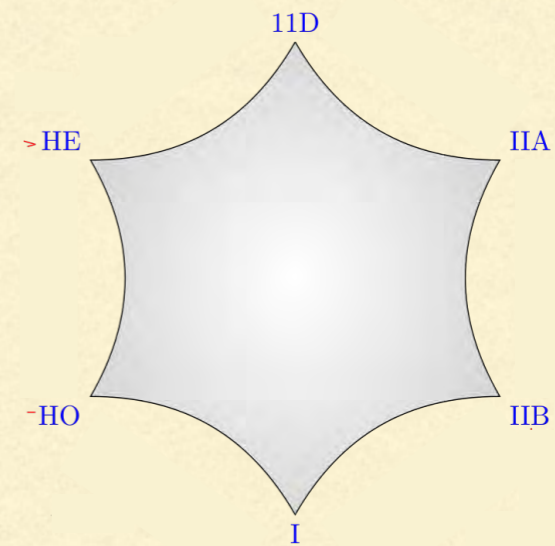
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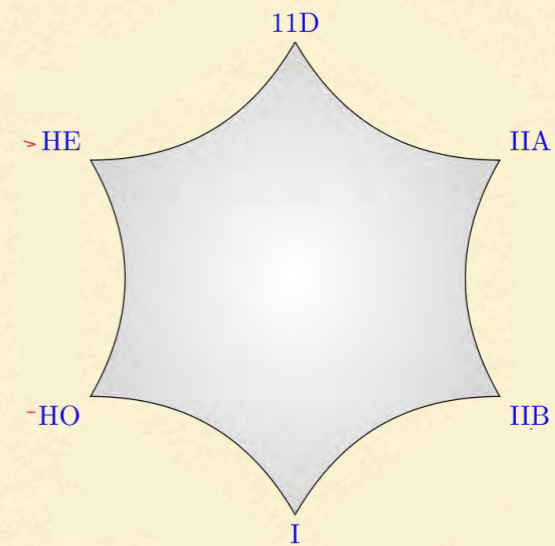
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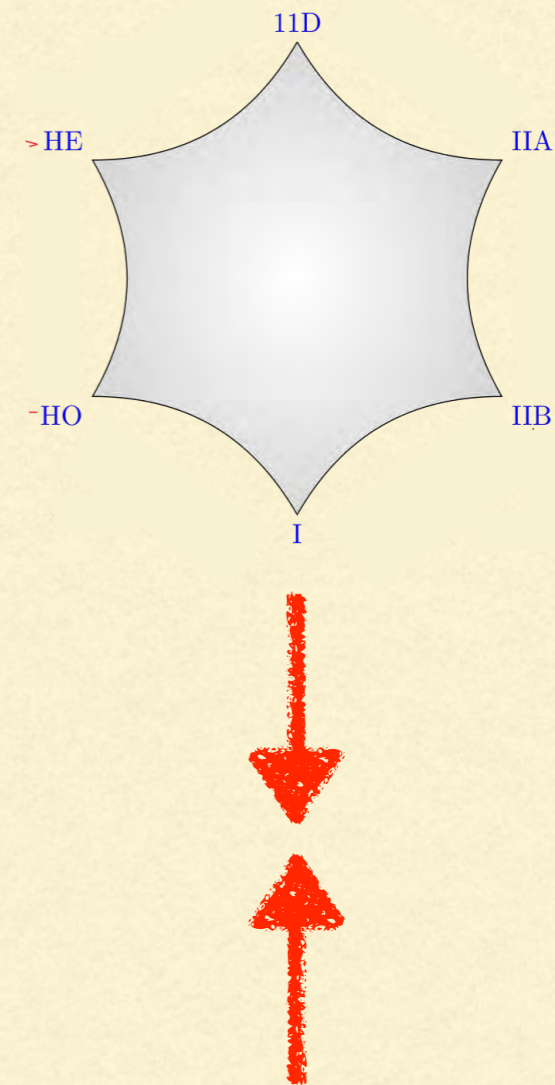
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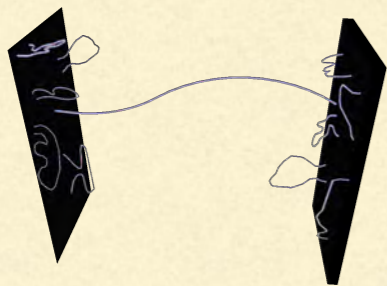
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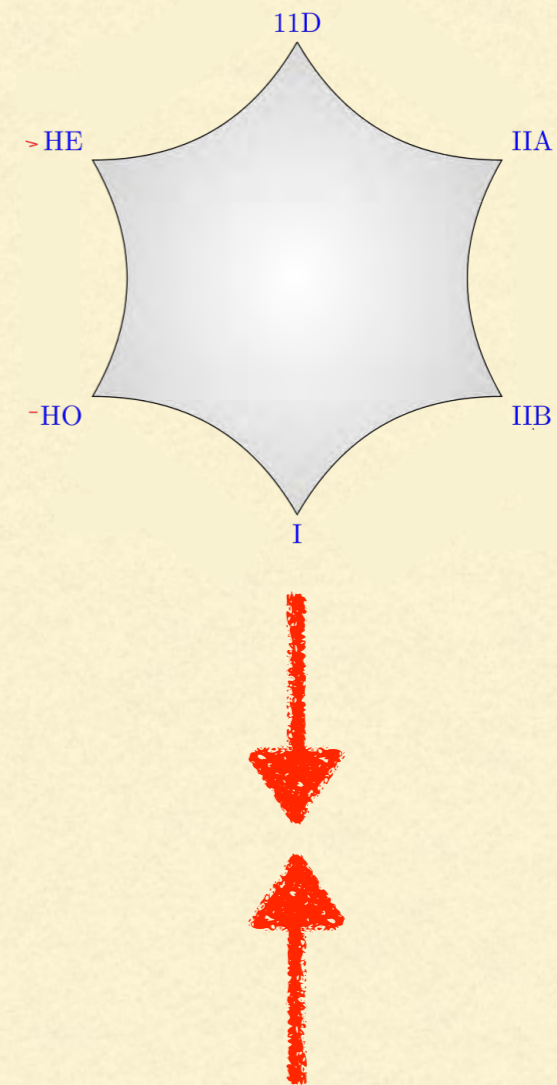
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New branes



New vacua



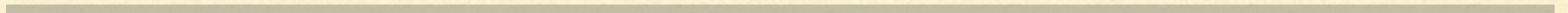
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we have achieved **String Universality**

[Adams De Wolfe Taylor '10]

(a.k.a. String Lamppost Principle)





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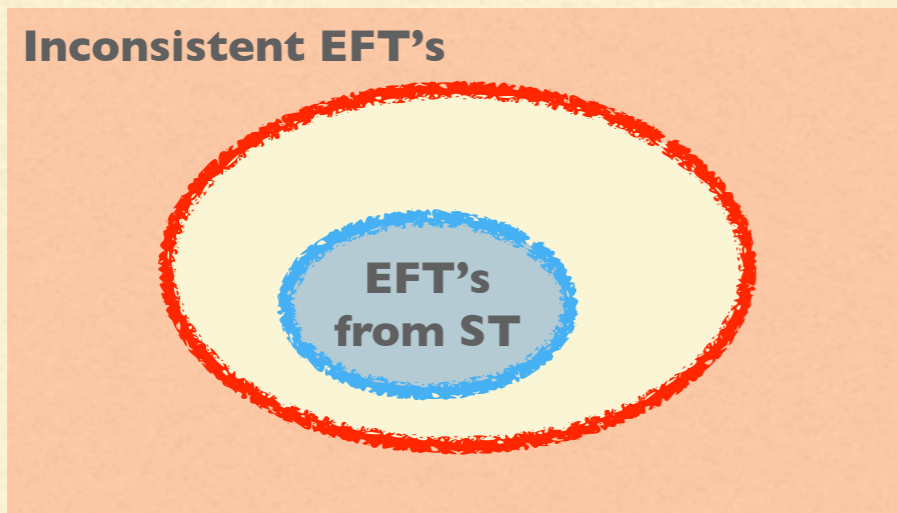
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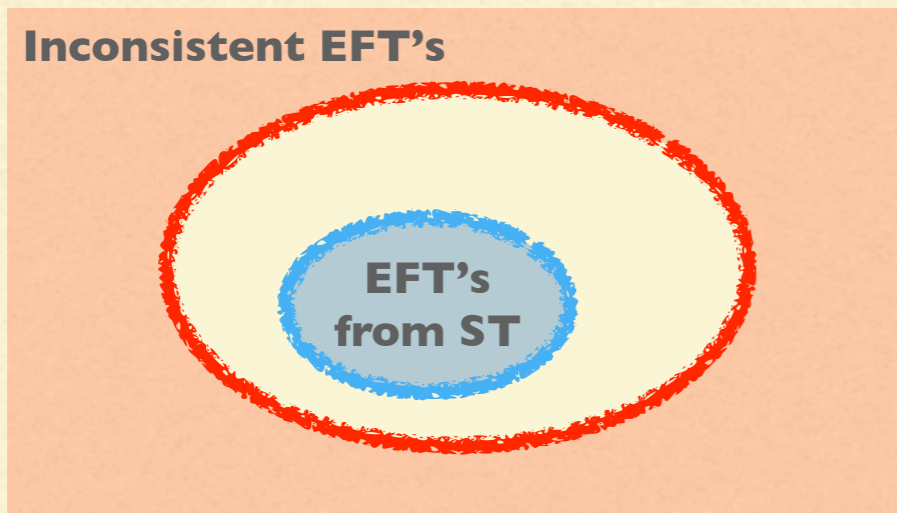
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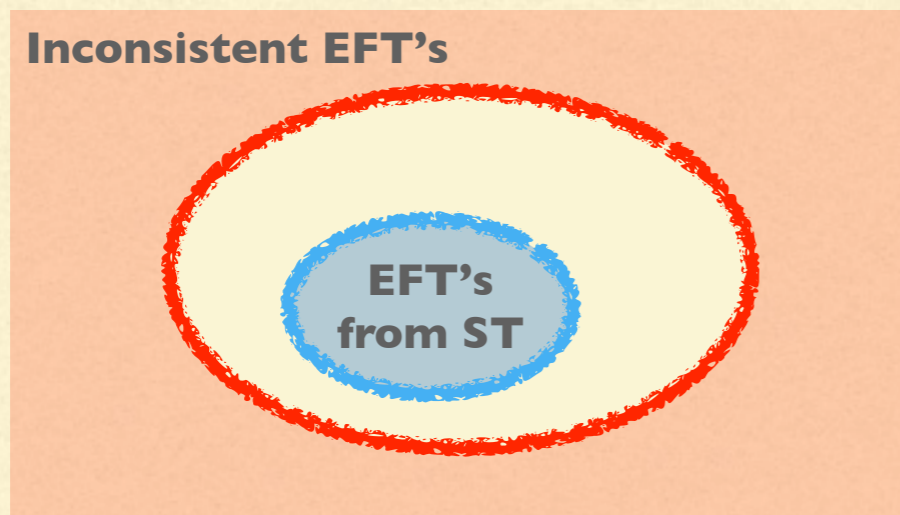
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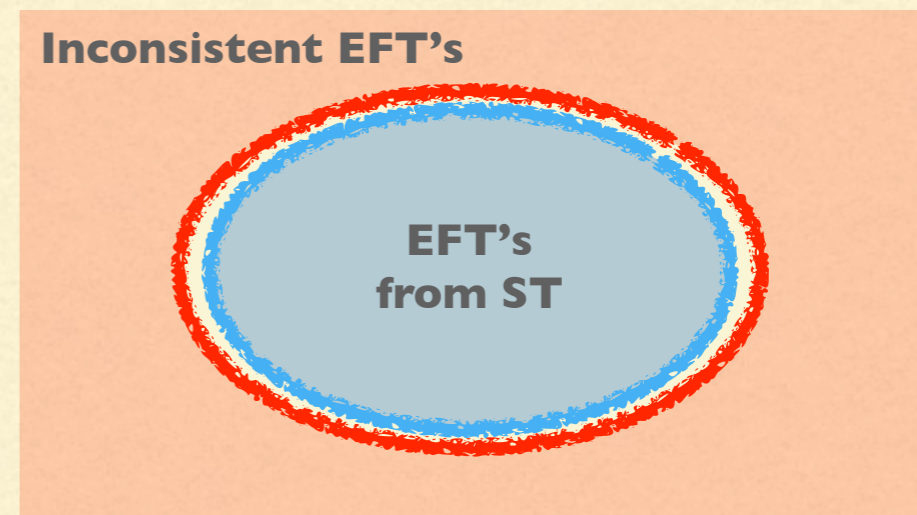
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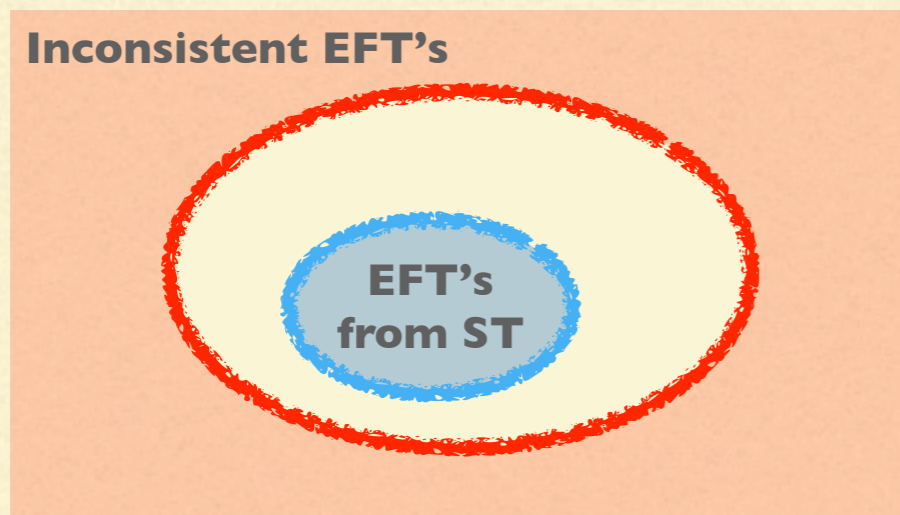
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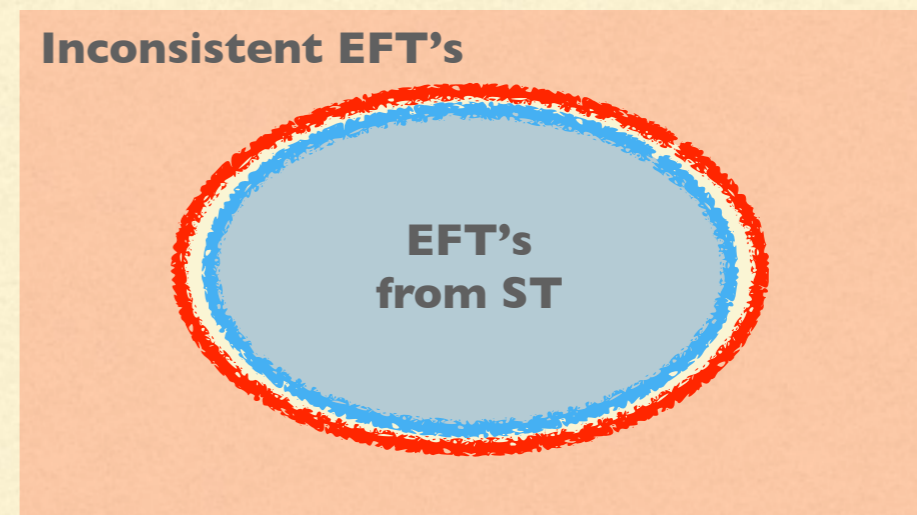
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“String theory is the only game in town”

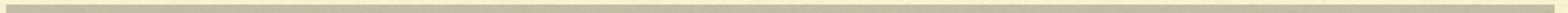


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**Plan** of the talk: Progress overview by # of supercharges

(32 = maximum number)

32 Q's



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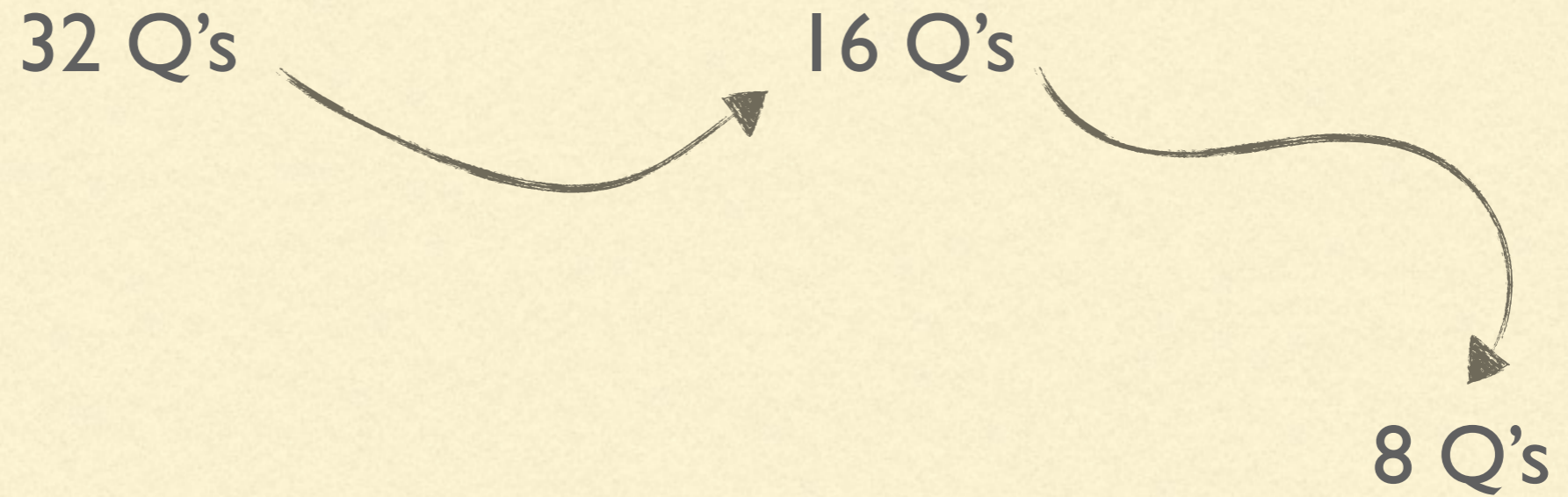
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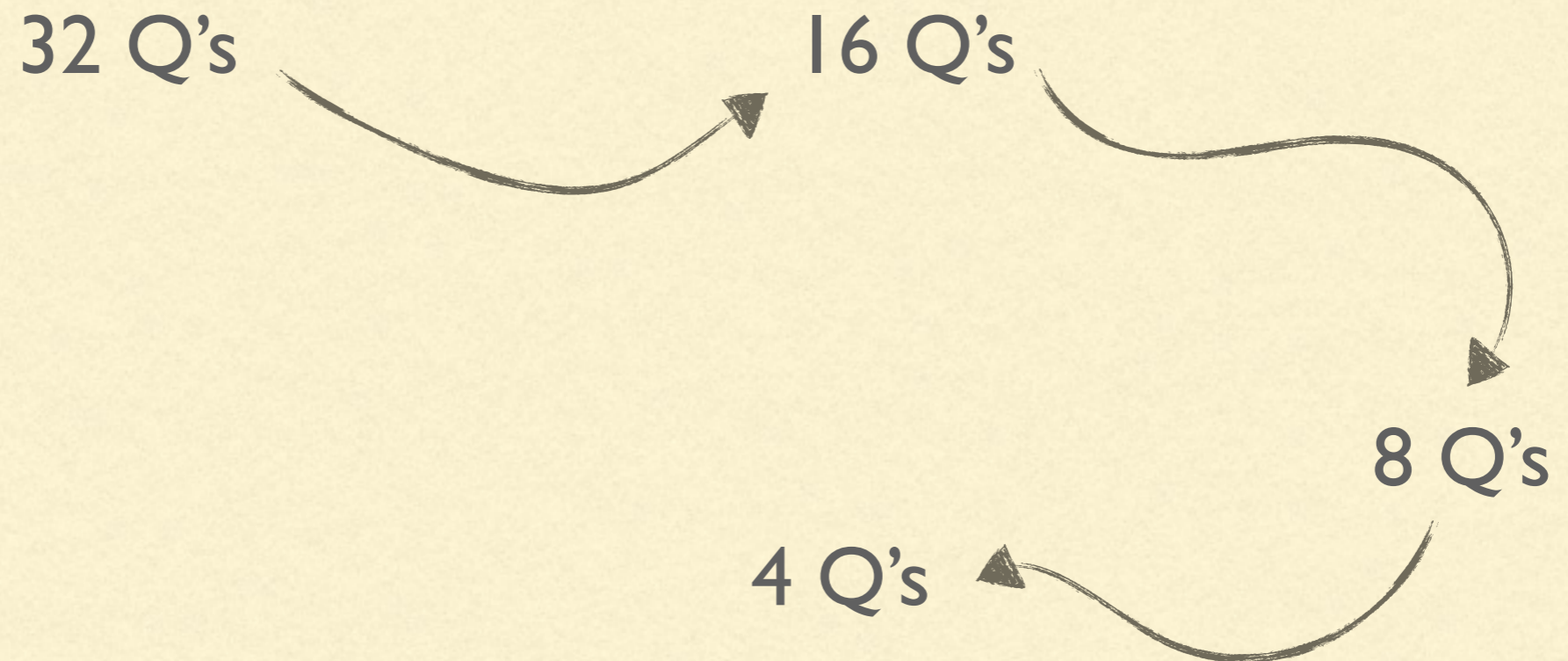
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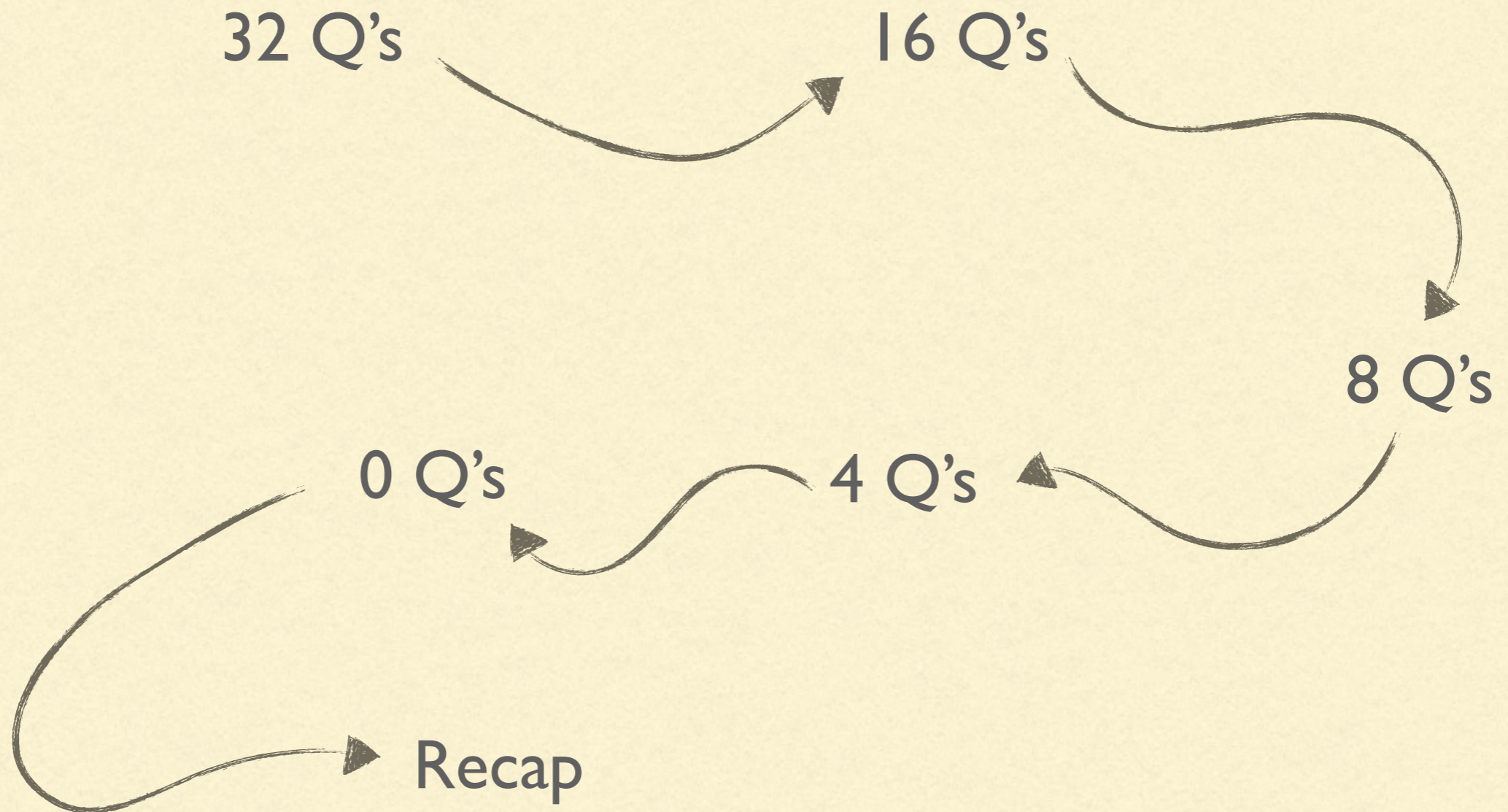




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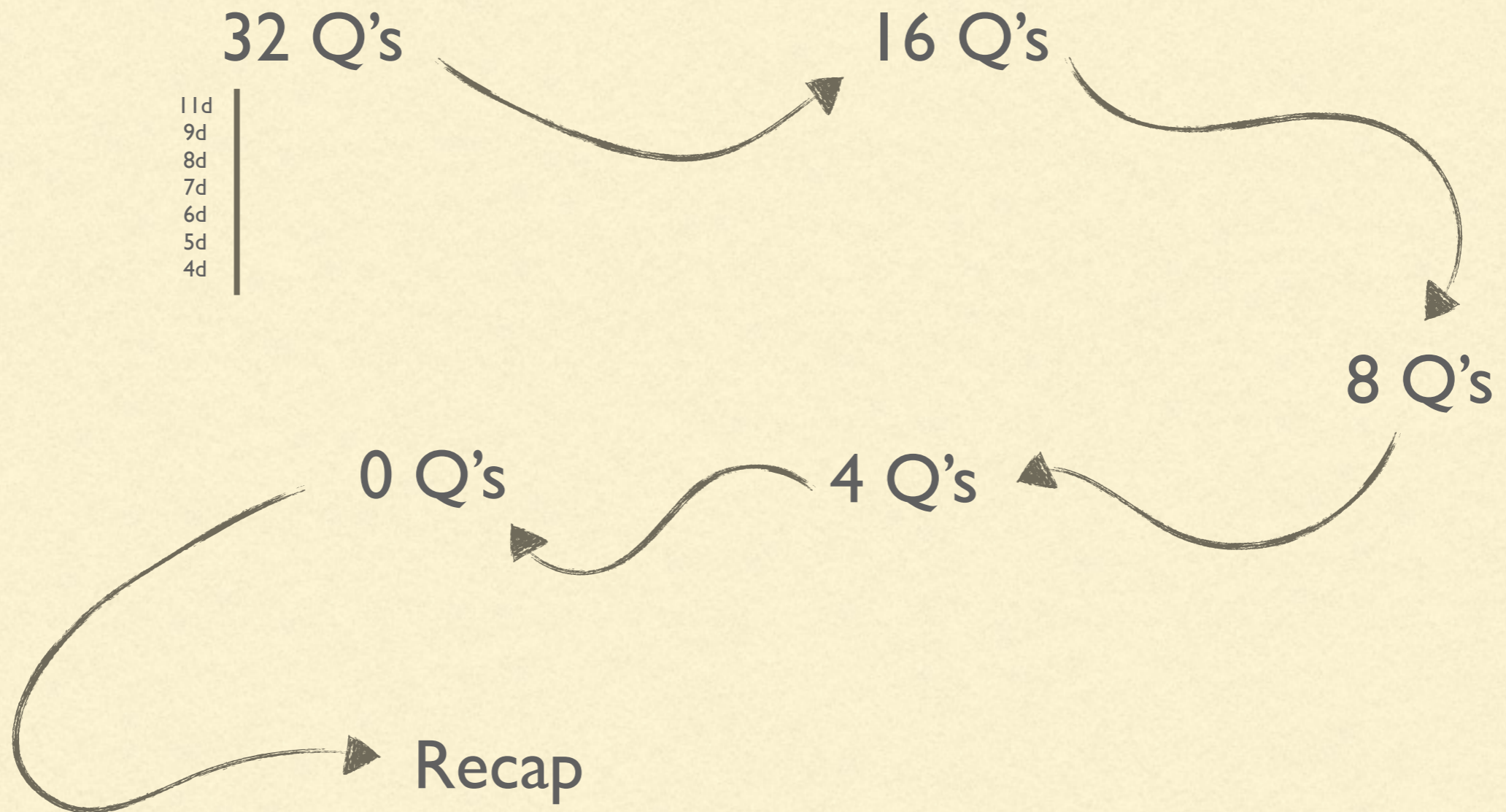
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Recap

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# Plan of the talk: Progress overview by # of supercharges

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Will also point out **open questions** along the way

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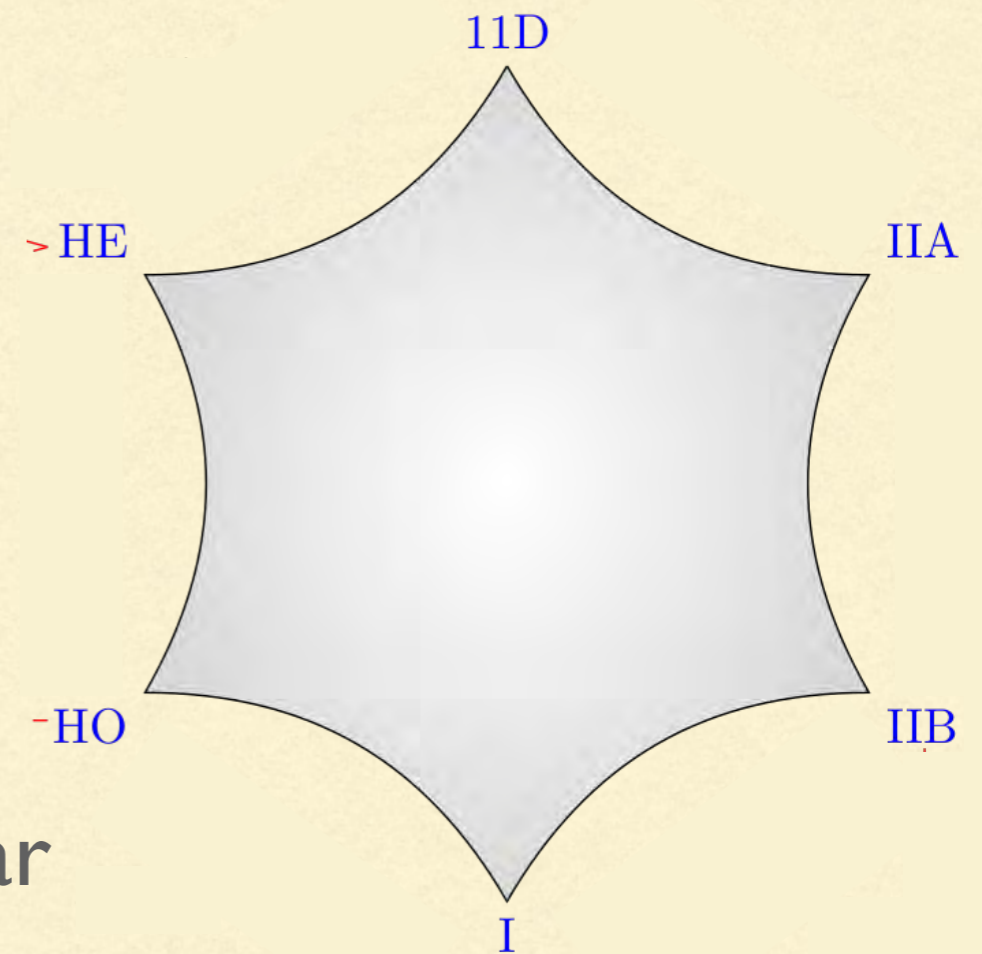
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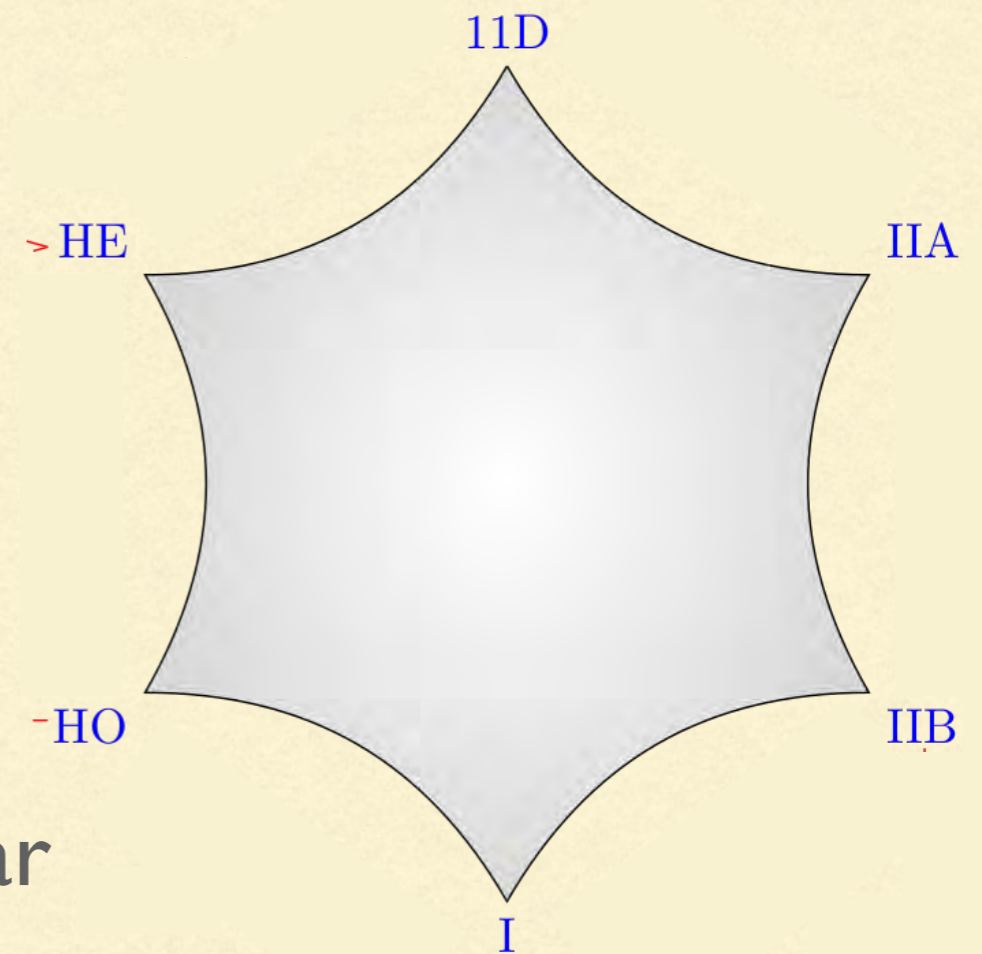


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$d < 10$ : Toroidal compactification of these

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(i.e. so the R-symmetry is partly gauged; they have AdS vacuum or running solutions)

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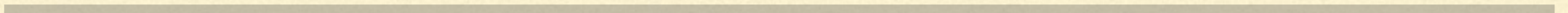


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See L. Zapata's poster.  
See C. LasHeras's poster.



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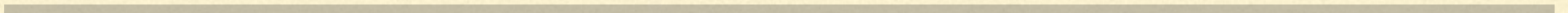
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11	$0.101 \pm 0.005$	0.102808

[Guerrerri-Murali-Penedones-Vieira '21, Guerrerri-Murali-Penedones-Vieira '23, Bossard-Loty '23]

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Looking forward to seeing how far this can be pushed!

**See Andrea's talk!**

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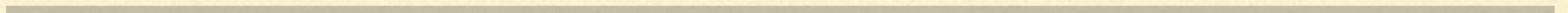
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Lagrangian fully fixed by SUSY

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String universality achieved!

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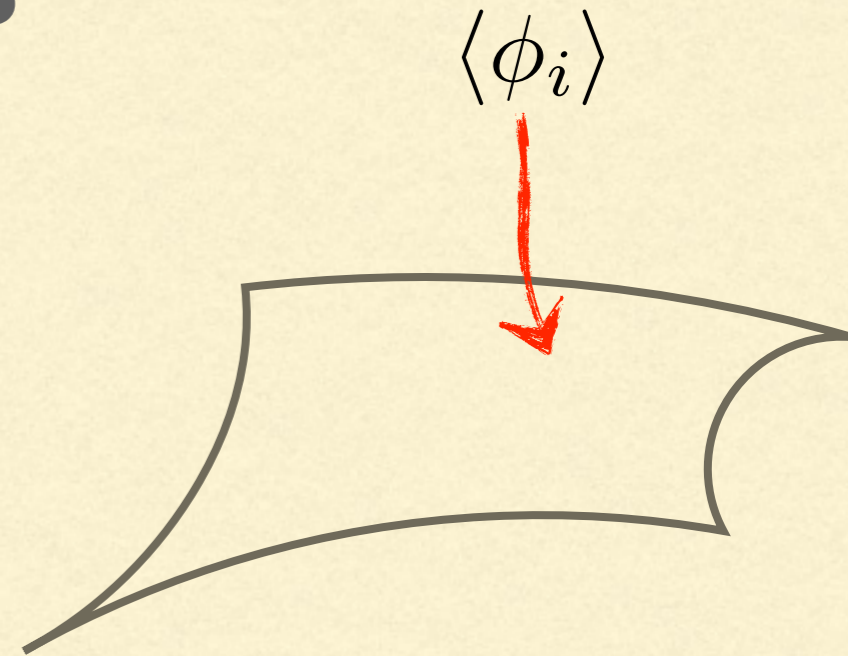
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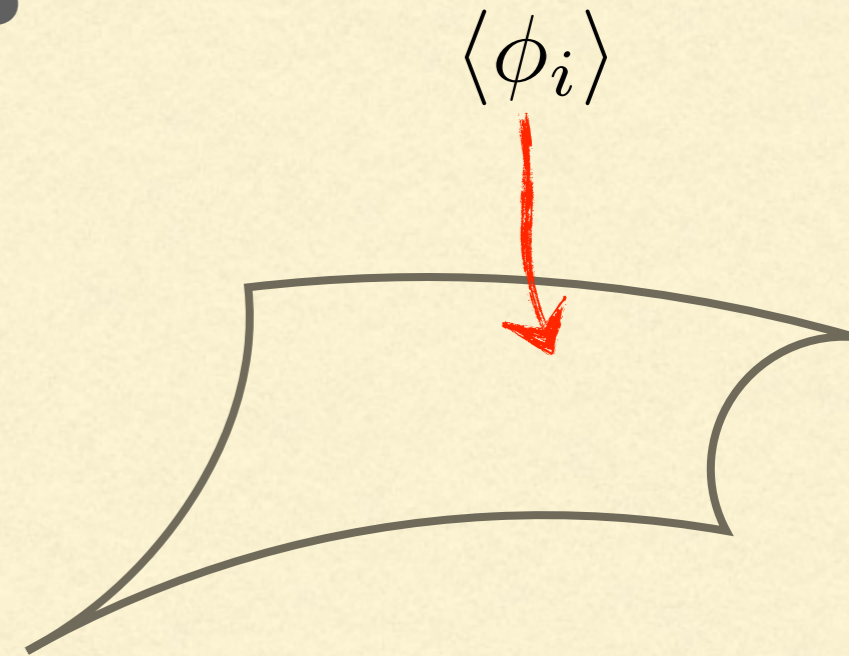


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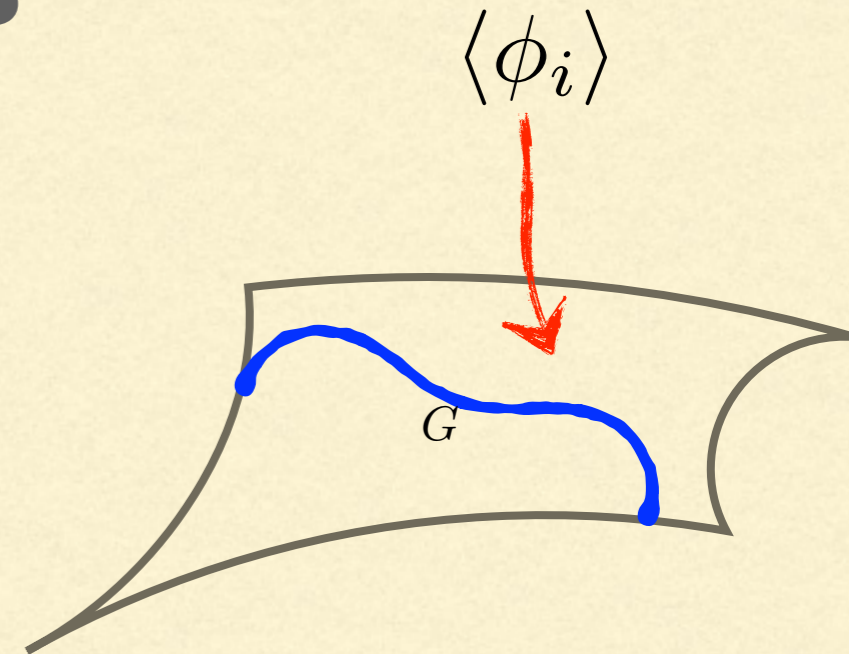
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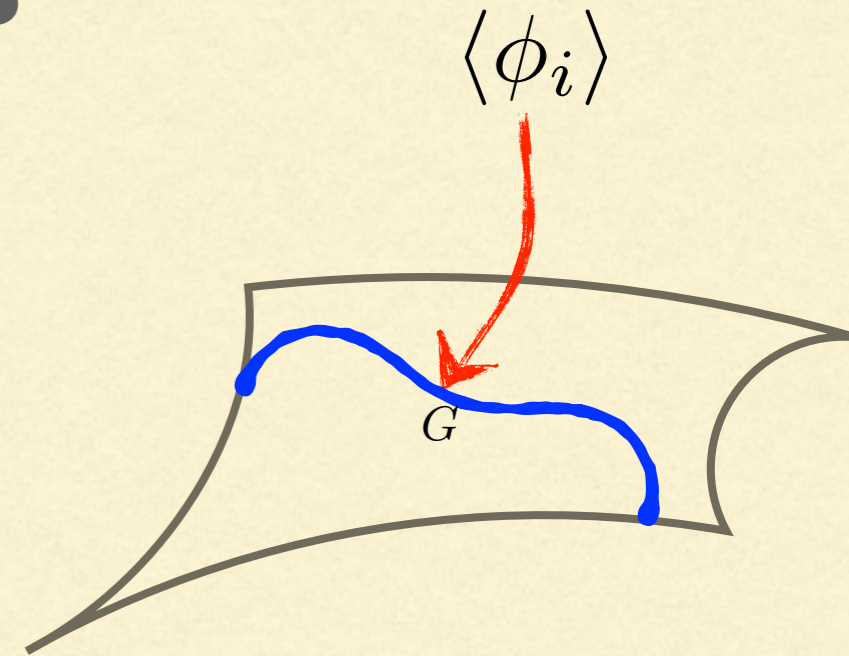




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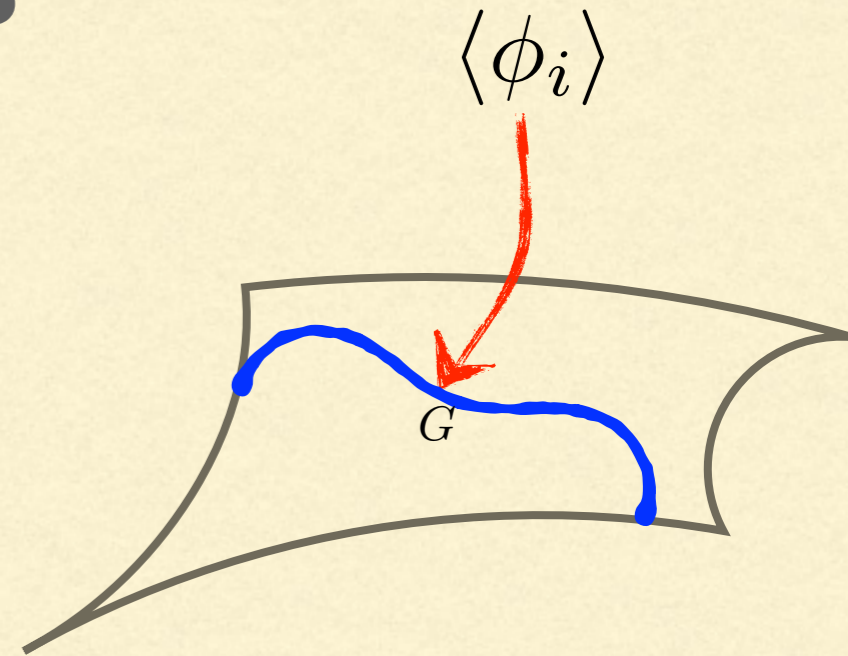


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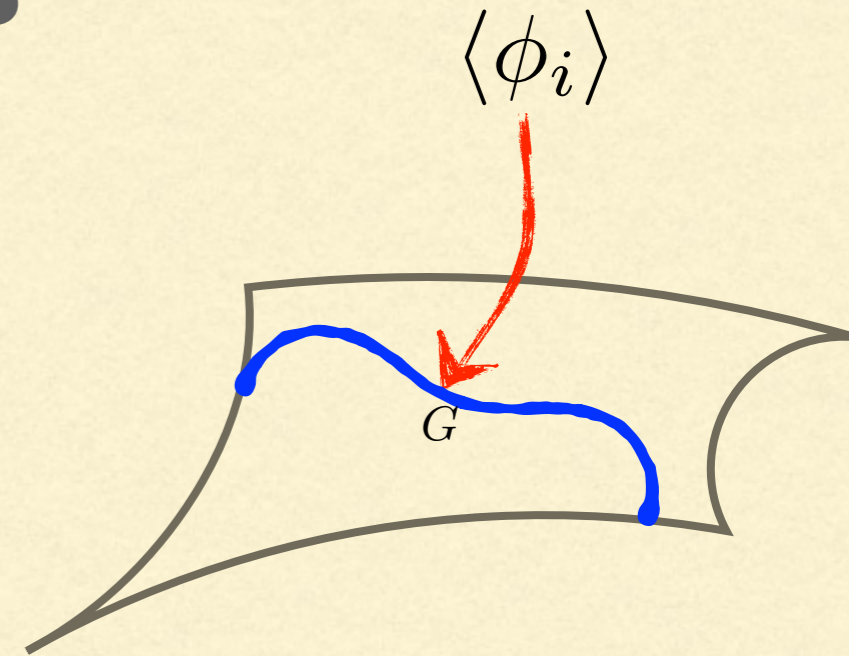
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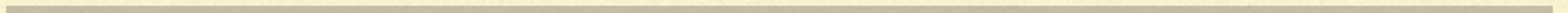


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Let us first discuss **rank**.

As an example, take  $d=9$

[Hellerman '05,Aharony-Komargodski-Patir '09]



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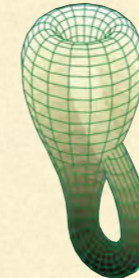
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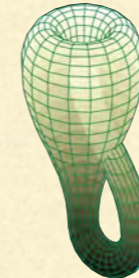
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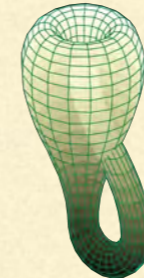
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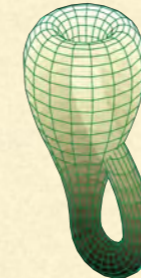
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- Upper bound  $r < 26-d$  from Swampland  
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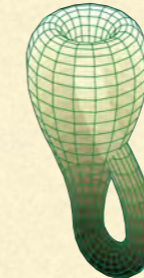
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**We have rank universality in 9d**

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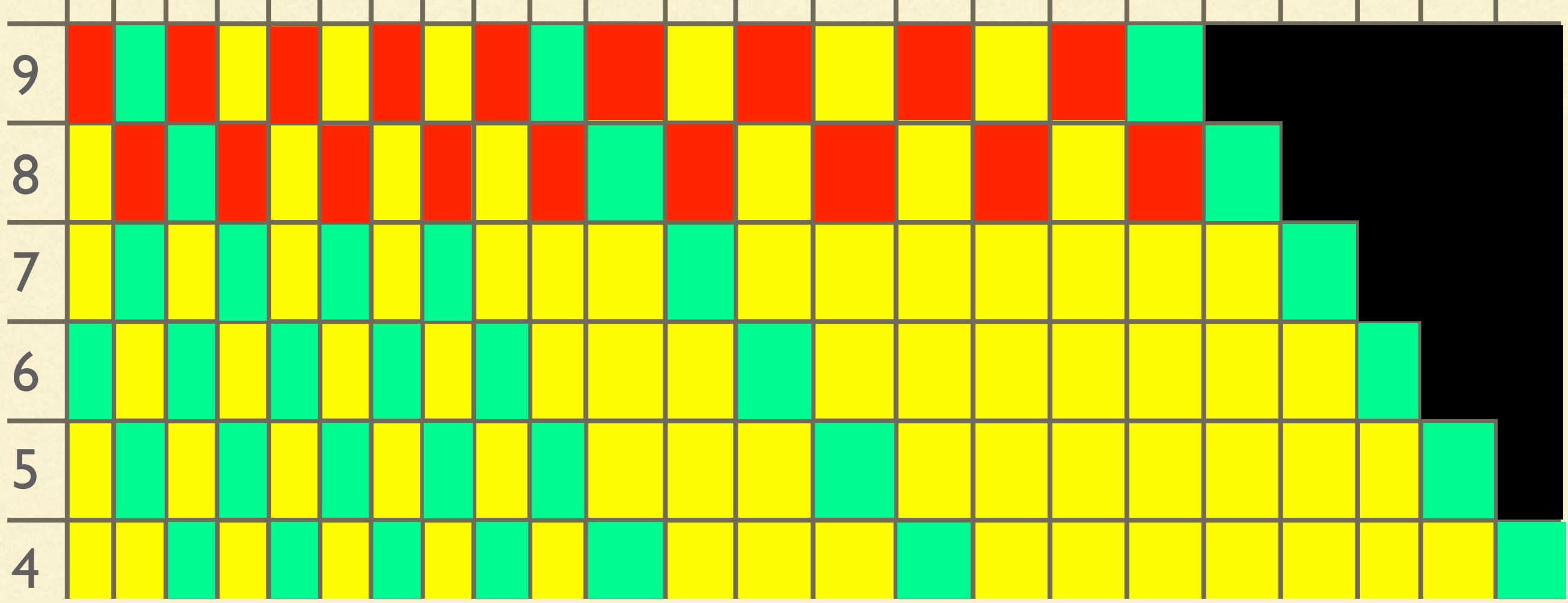
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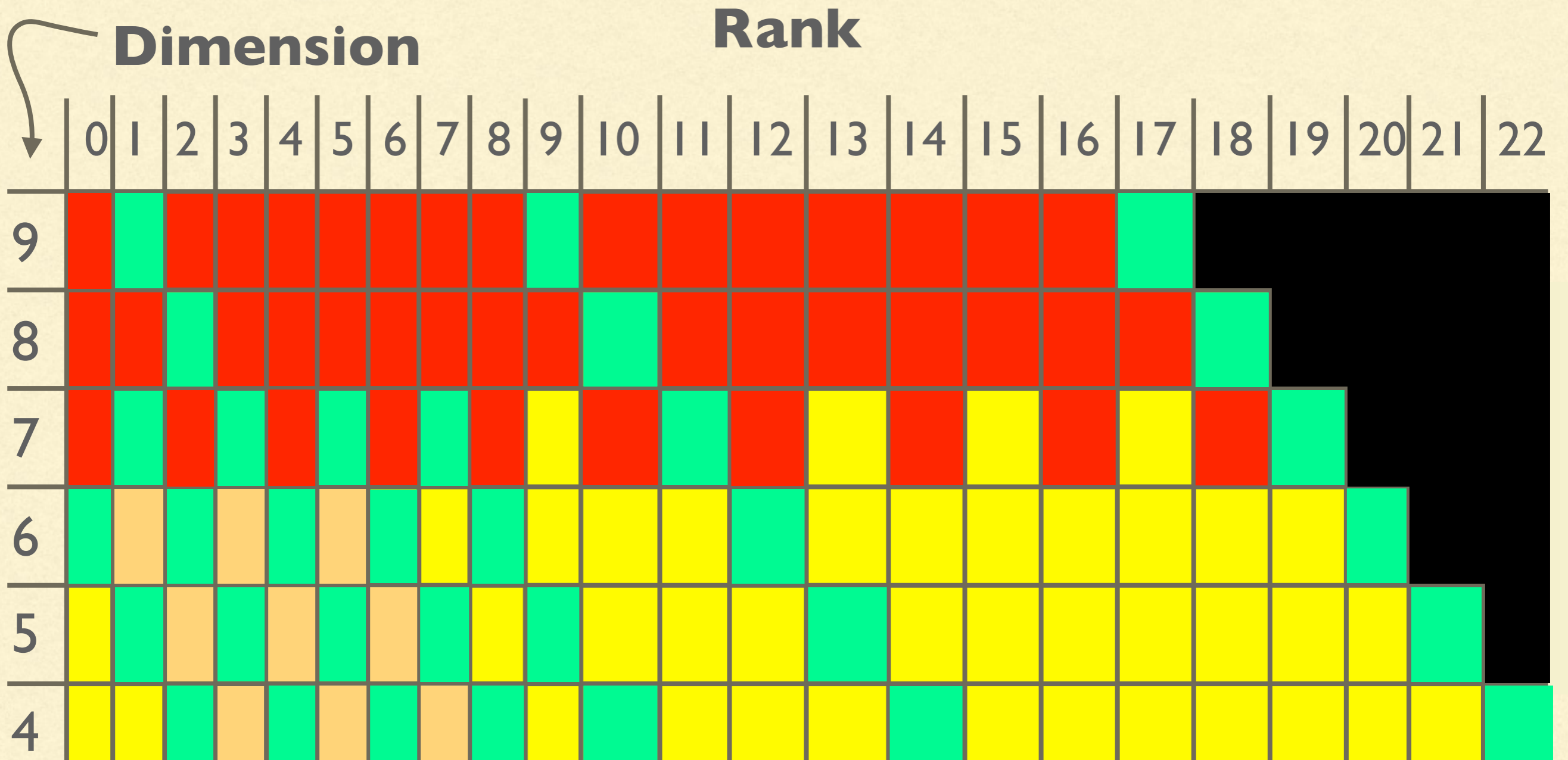
We don't know whether they have a stringy embedding

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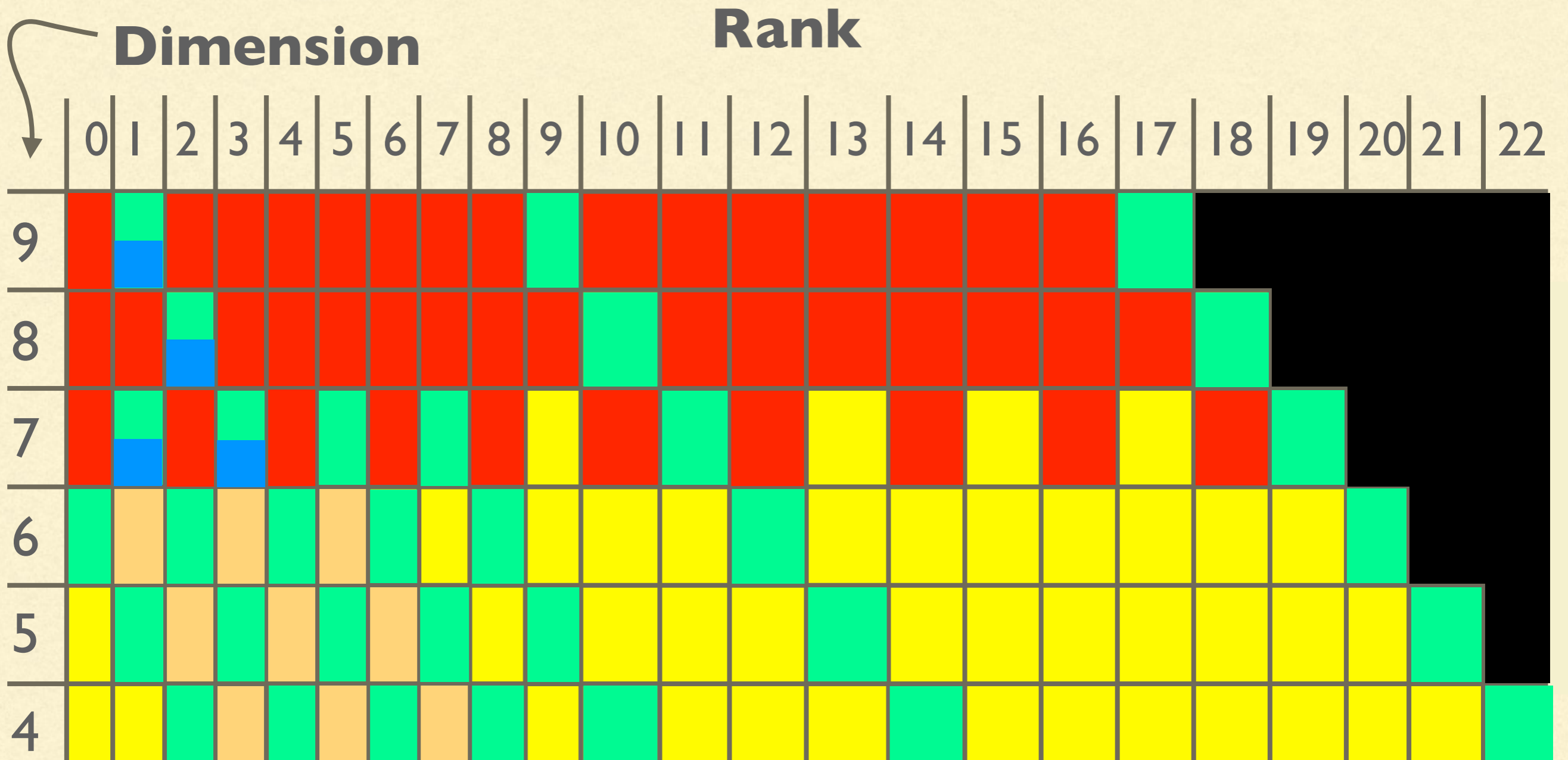
**Dimension** **Rank** (circa 2019)



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What about non-abelian groups?

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**Top-down:**



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Appeared before this

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**Q: Can we prove that 10d het. gauge group is  $Spin(32)/\mathbb{Z}_2$ ?**

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Lots of progress **beyond supergravity**: topological sector

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- Discrete topological couplings to cancel subtle anomalies

[Iñaki García-Etxebarria, Hirotaka Hayashi, Kantaro Ohmori, Yuji Tachikawa, Kazuya Yonekura '17]

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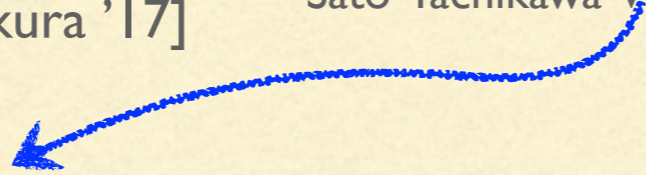
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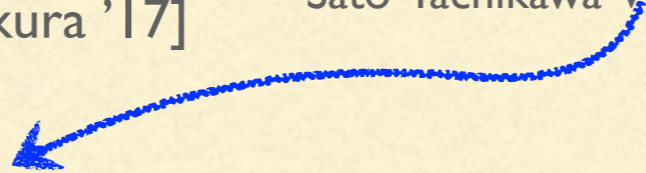
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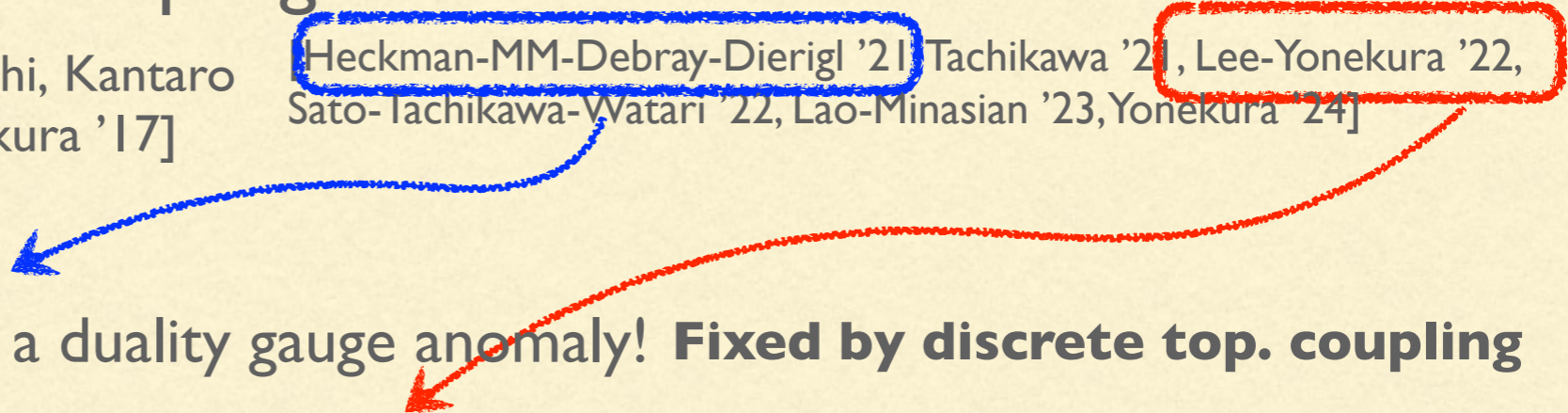
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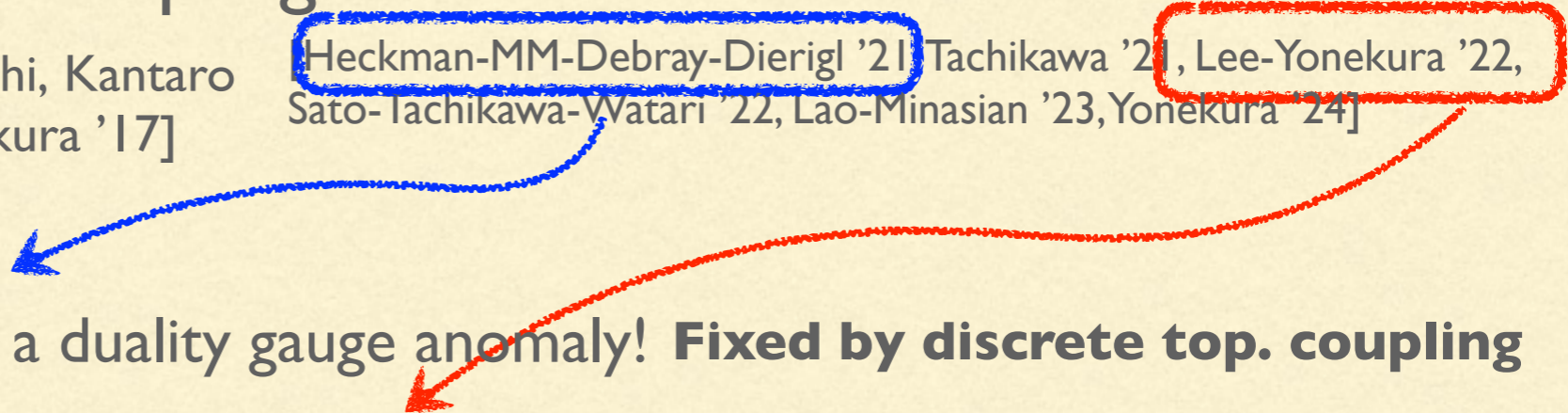
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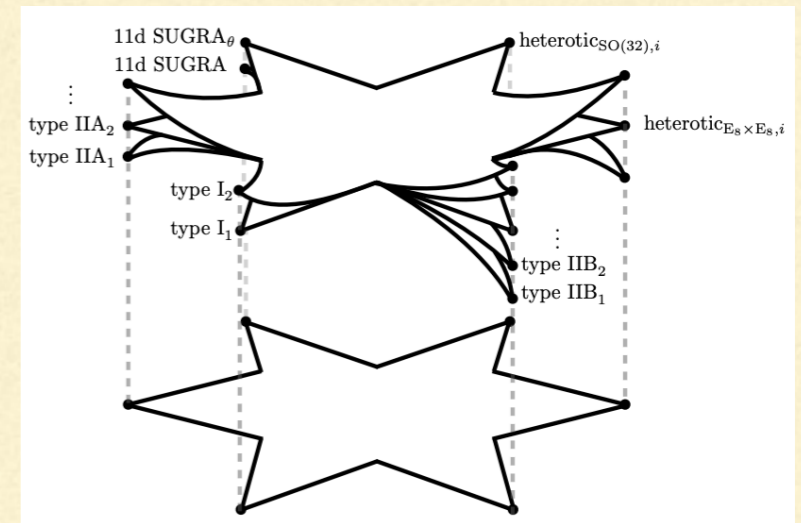
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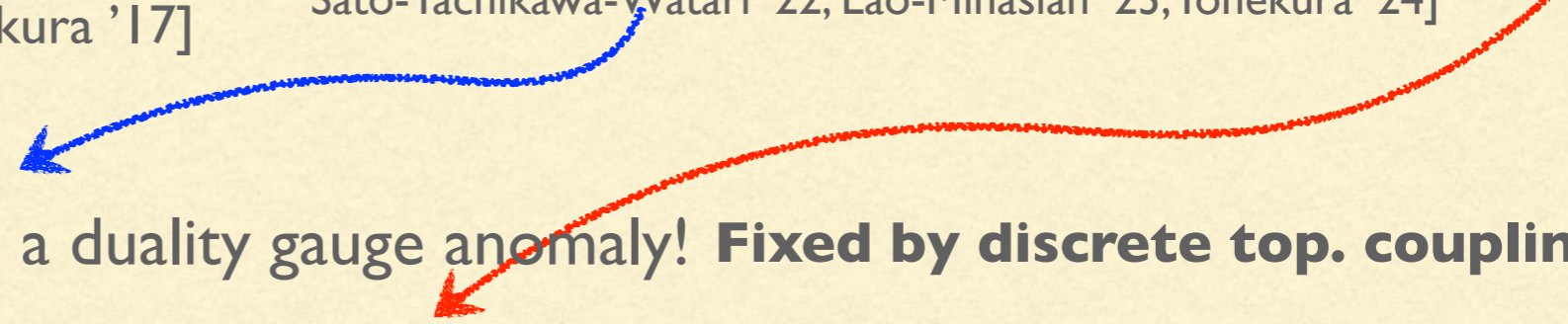


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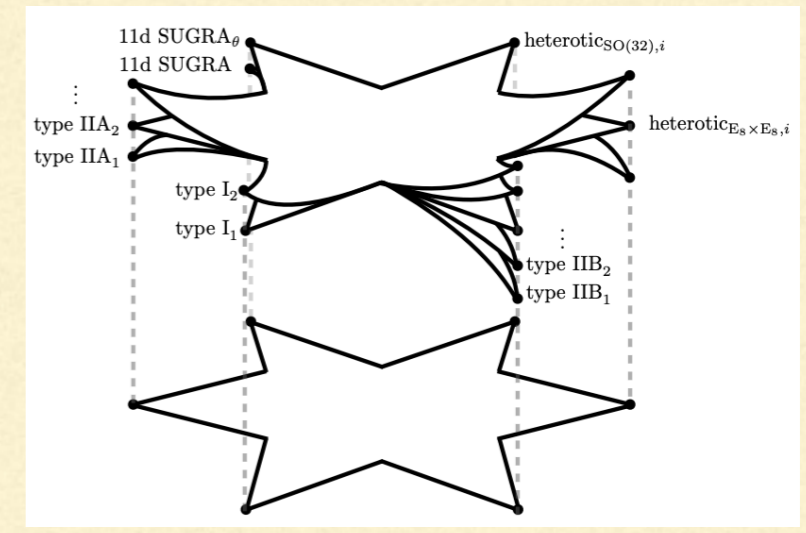
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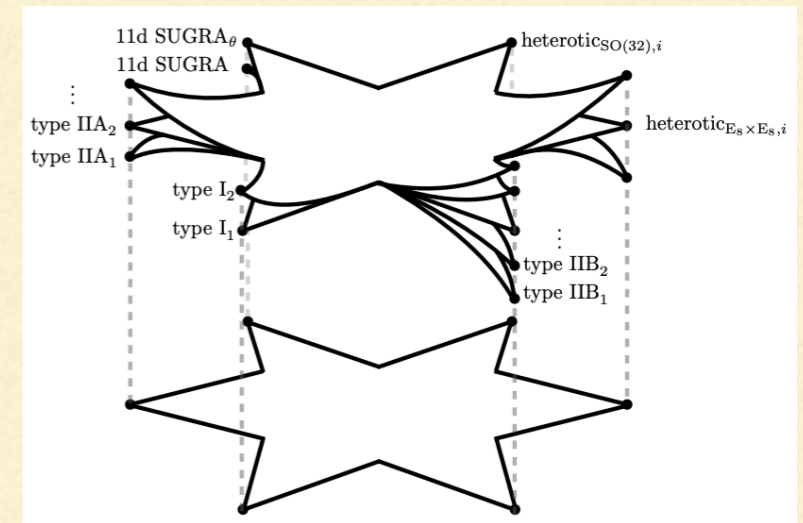
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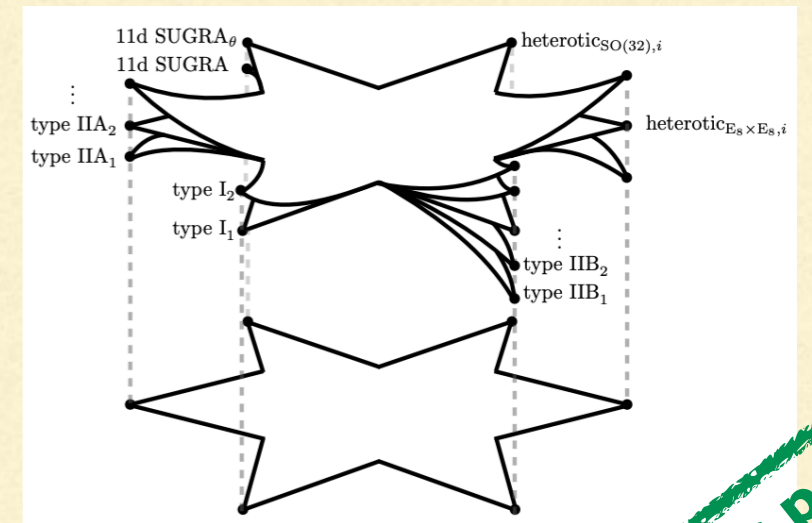
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- Systematic study of infinite distance limits

[Lee-Lerche-Weigand '21, Collazuol-Graña-Herraez '22, Cvetič-Dierigl-Ling-Zhang '22, Etheredge-Heidenreich-McNamara-Rudelius-Ruiz-Valenzuela '23, 24, Collazuol-Melnikov '24]

See V. Collazuol's poster!  
See I. Ruiz's poster!

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We've also discovered **new branes**

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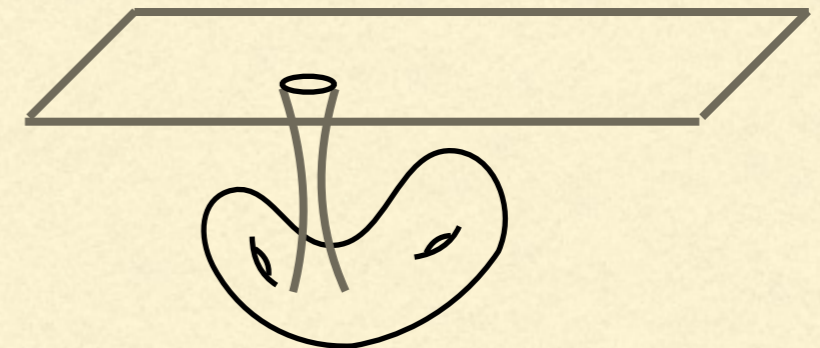
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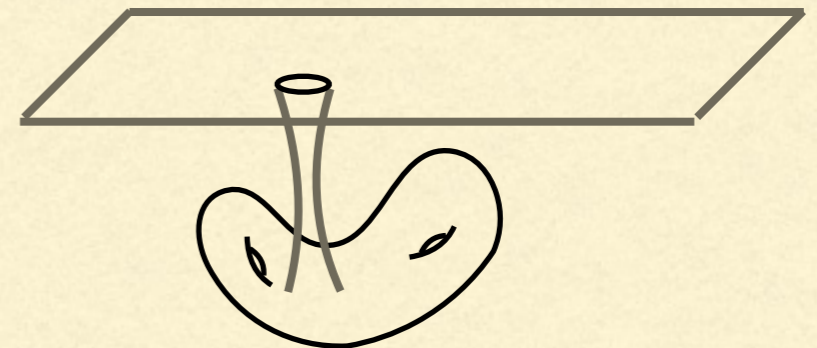
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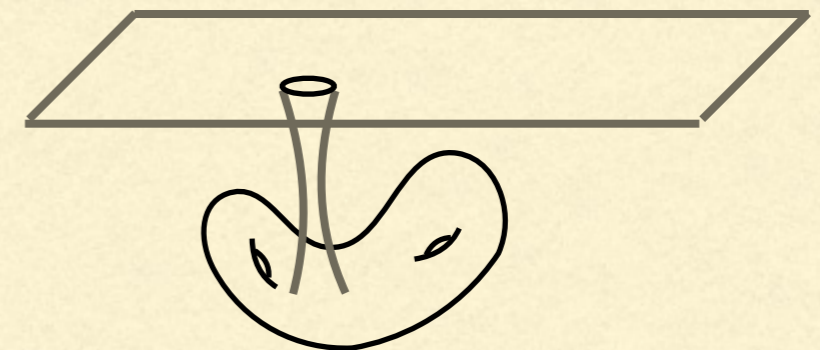
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Breaking the global charge  
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# 8 supercharges

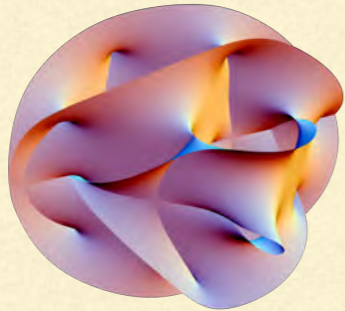
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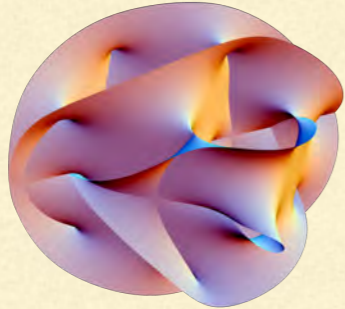


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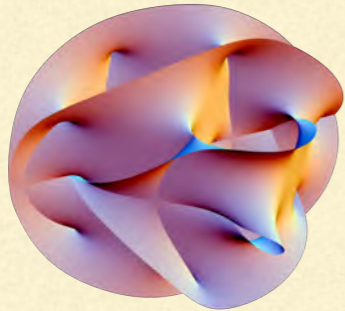
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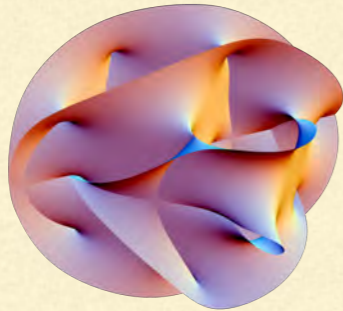
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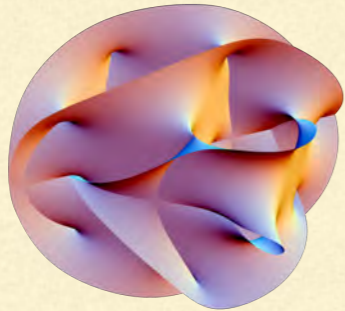
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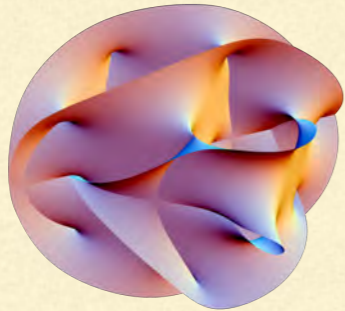
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But still, much to be said!

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**6d (1,0)**

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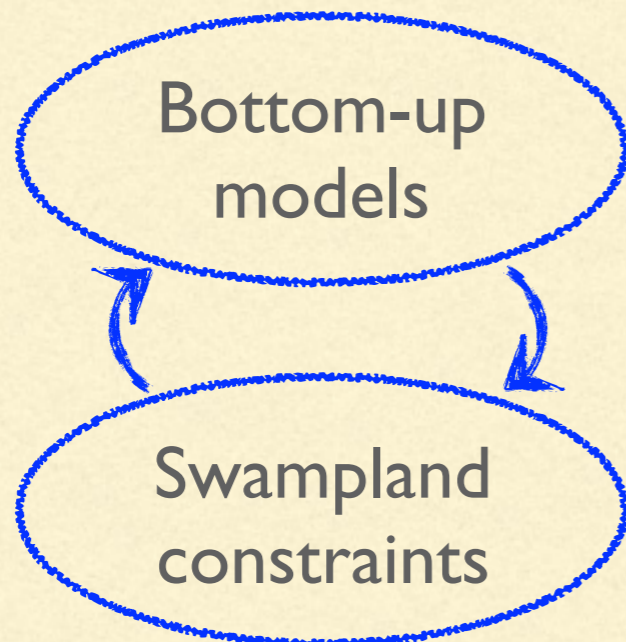
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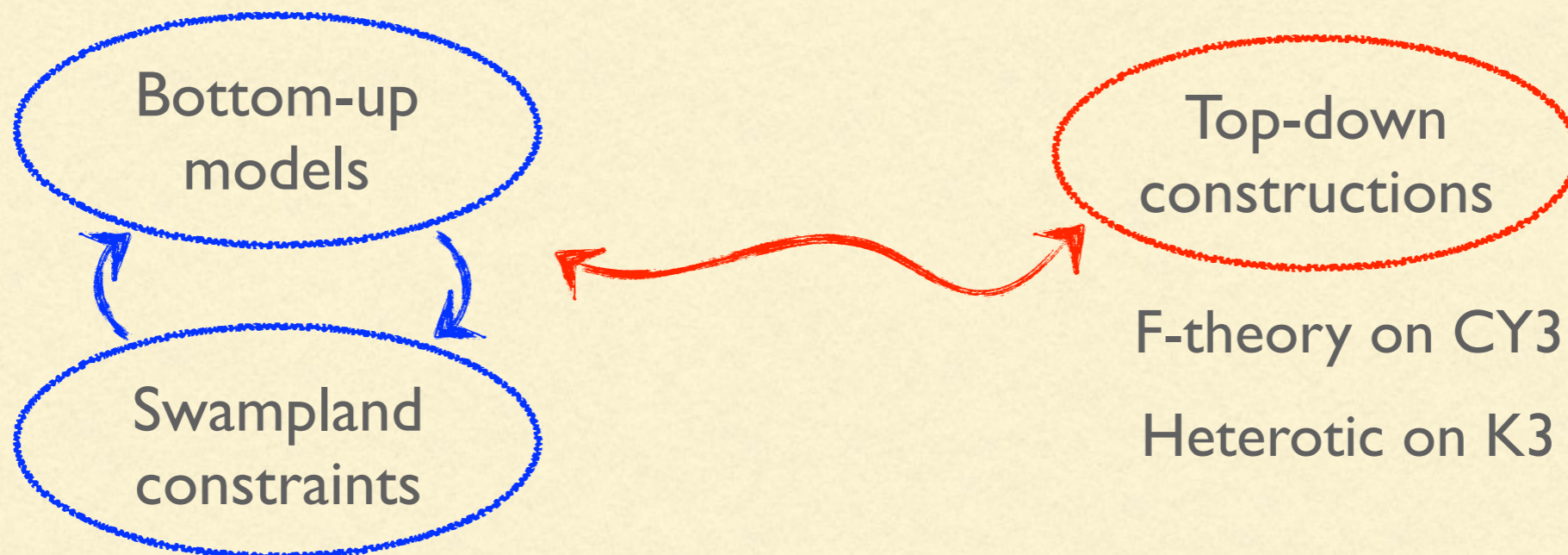
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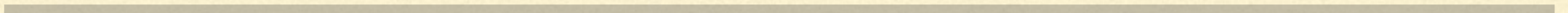


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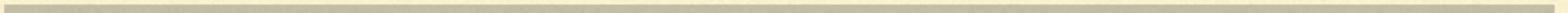
**5d N=1 & 4d N=2**

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Now we have numerical CY3 metrics!

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- Is 5d N=1 pure sugra (only gravity multiplet  $(g_{\mu\nu}, A_\mu, \Psi_\mu)$ ) in the Swampland?

[See Houri Tarazi gong show in Strings '22]

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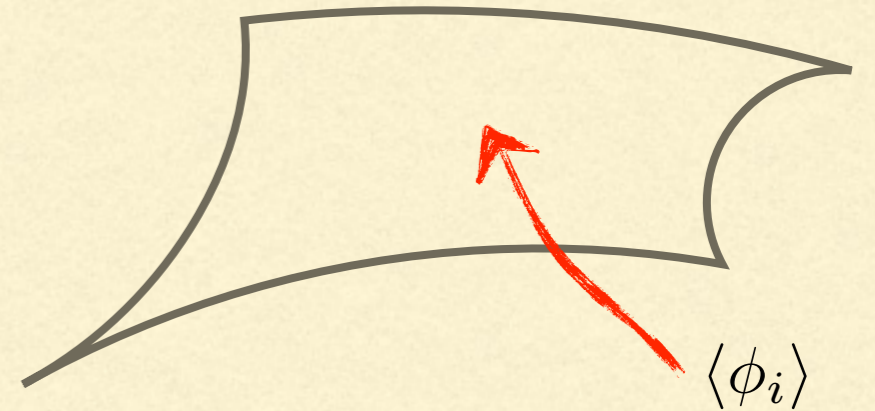
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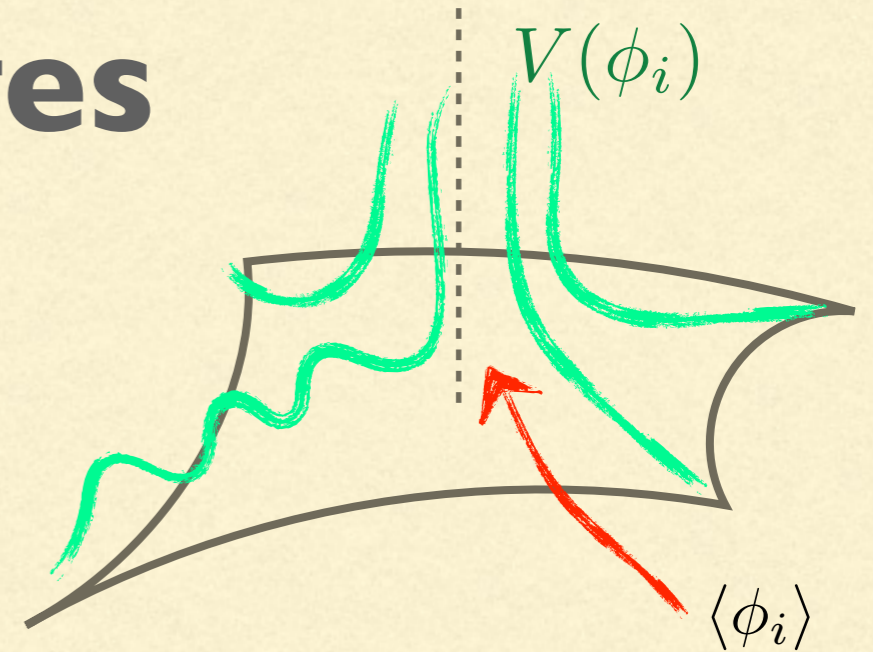
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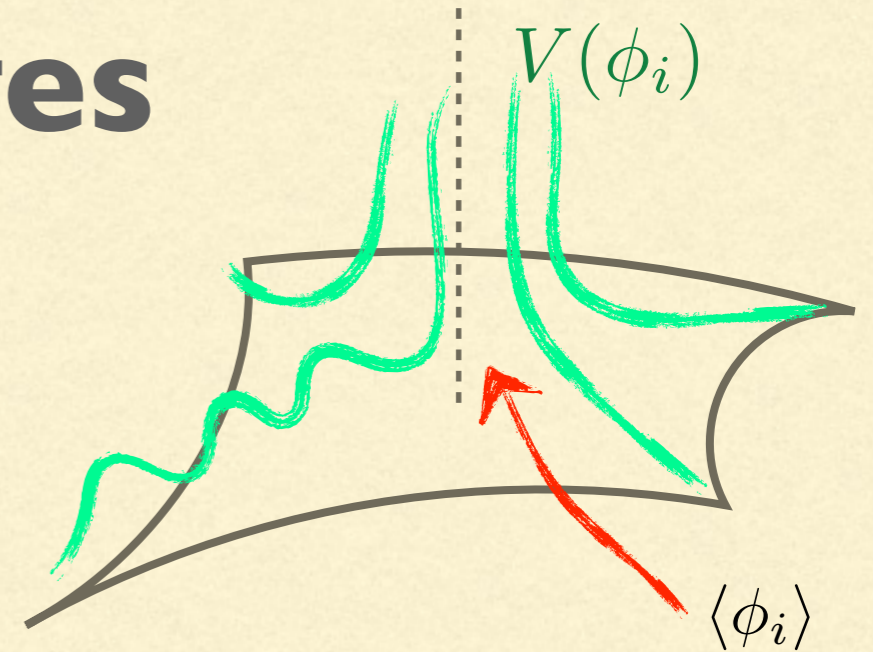
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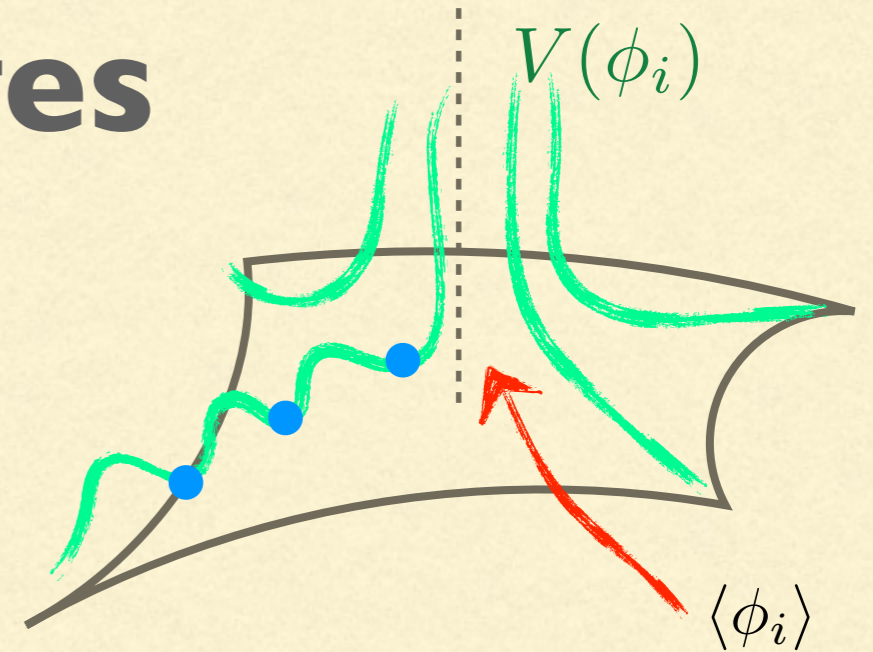
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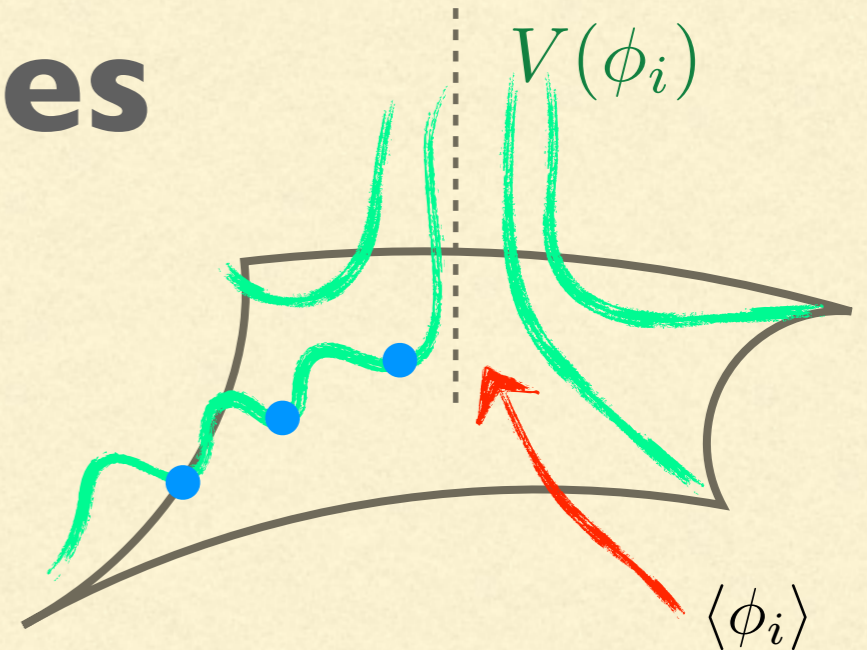
Natural Q: **How many flux vacua?** ●



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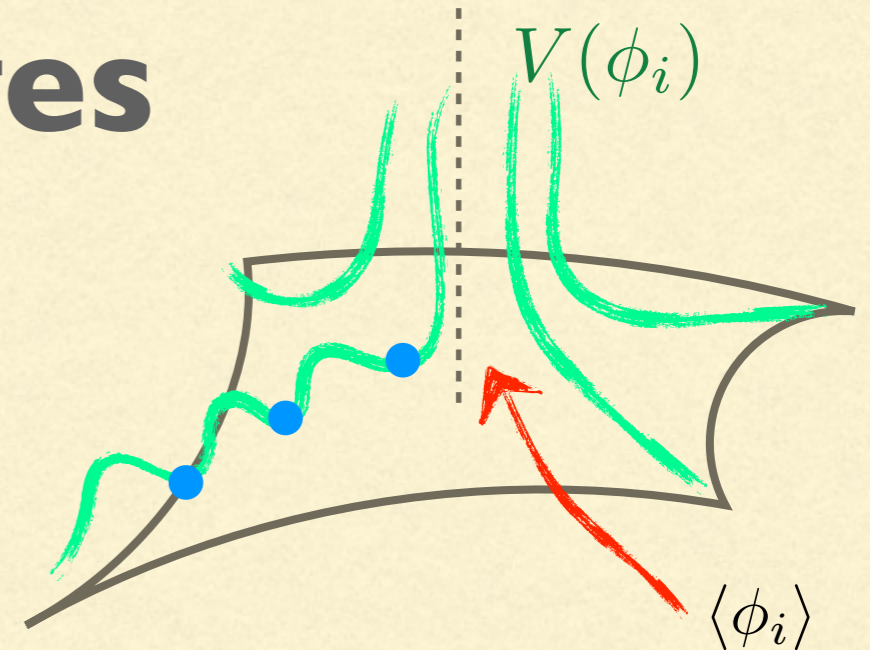
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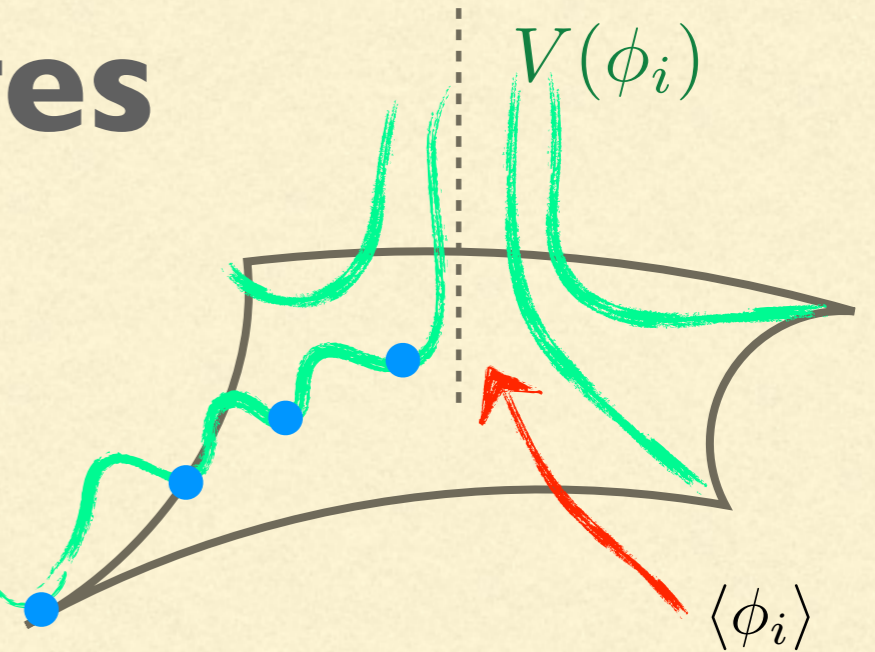
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- 4d and below
- Moduli space lifted by **potential**

$$V = V_{\text{Flux}} + V_{\text{correction}}$$



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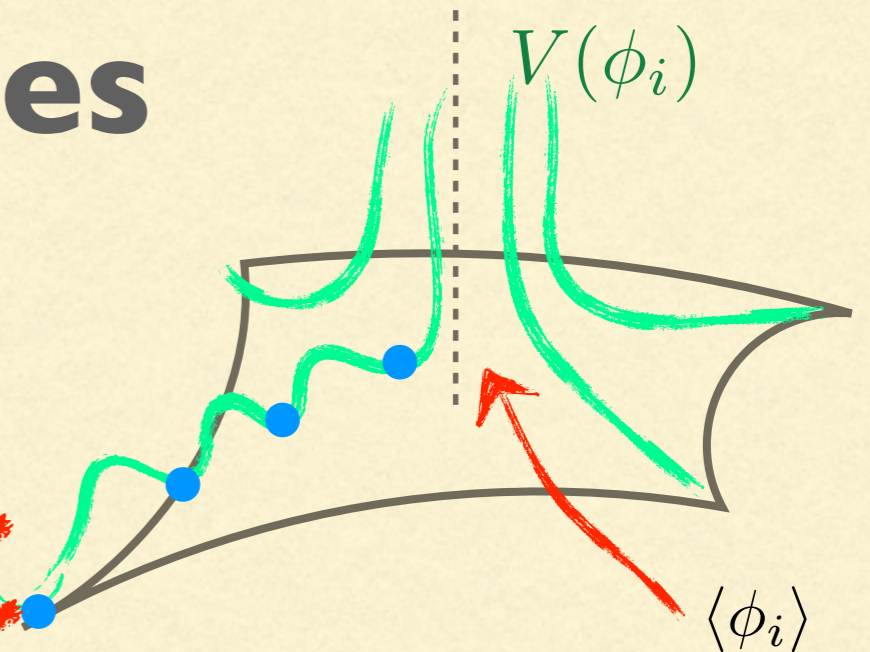
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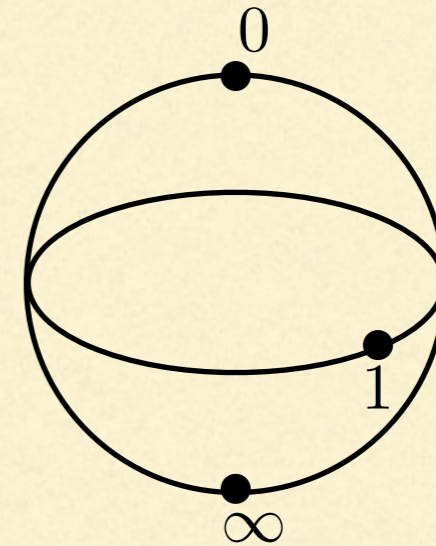
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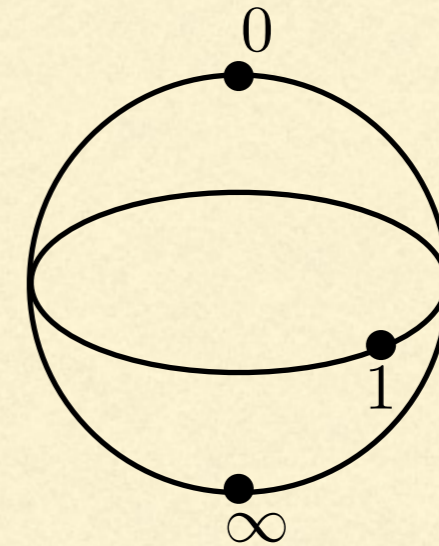


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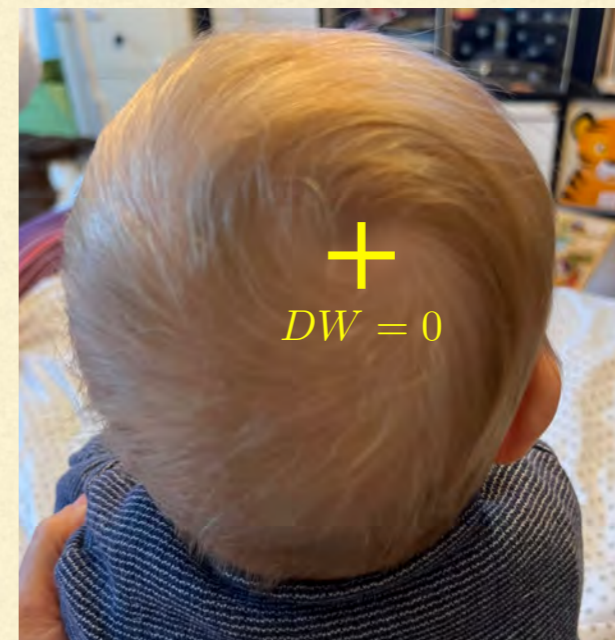
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- Index theorem for flux vacua

[S. Lüst '24]

Uses generalization of hairy ball theorem to find SUSY minima in complicated moduli spaces



(Hairy ball courtesy of Sam Dierigl)

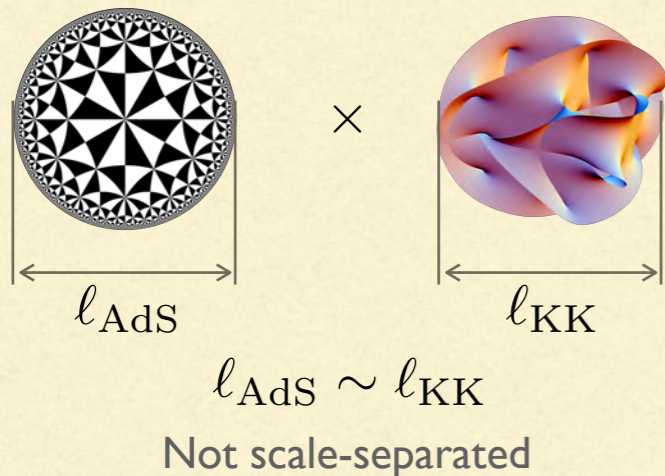
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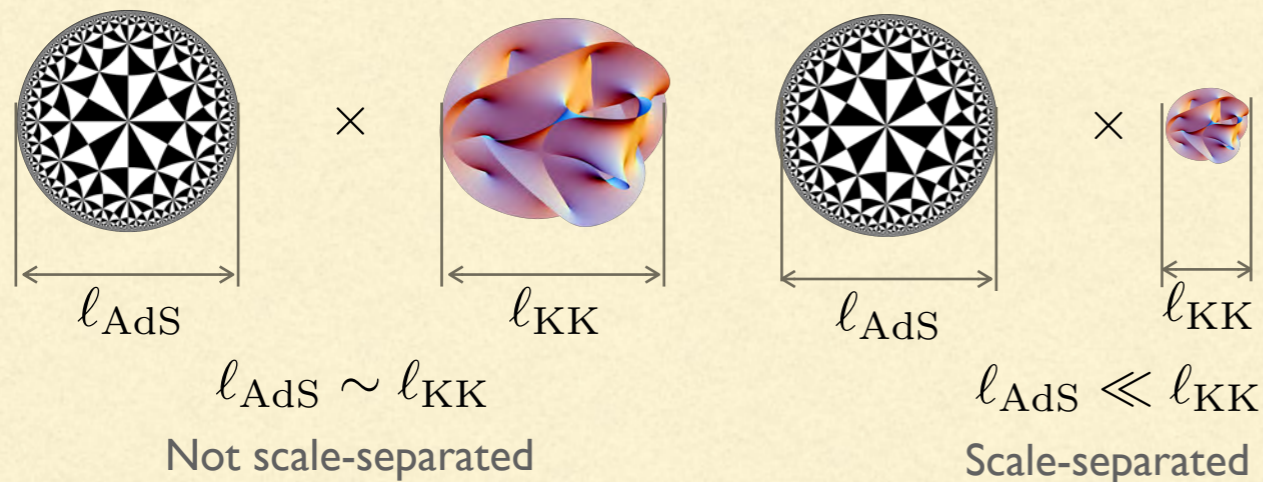
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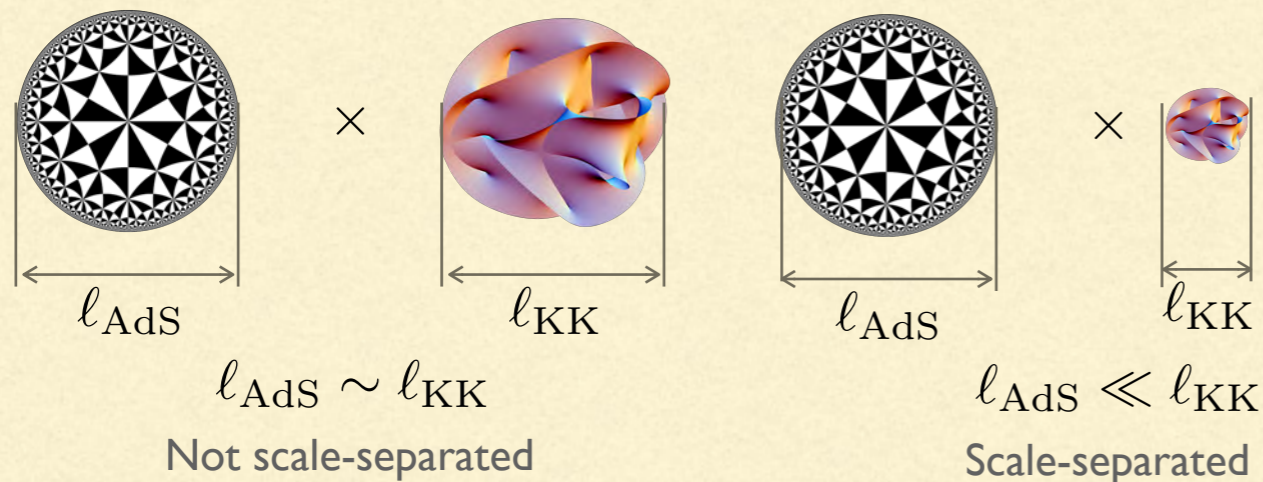


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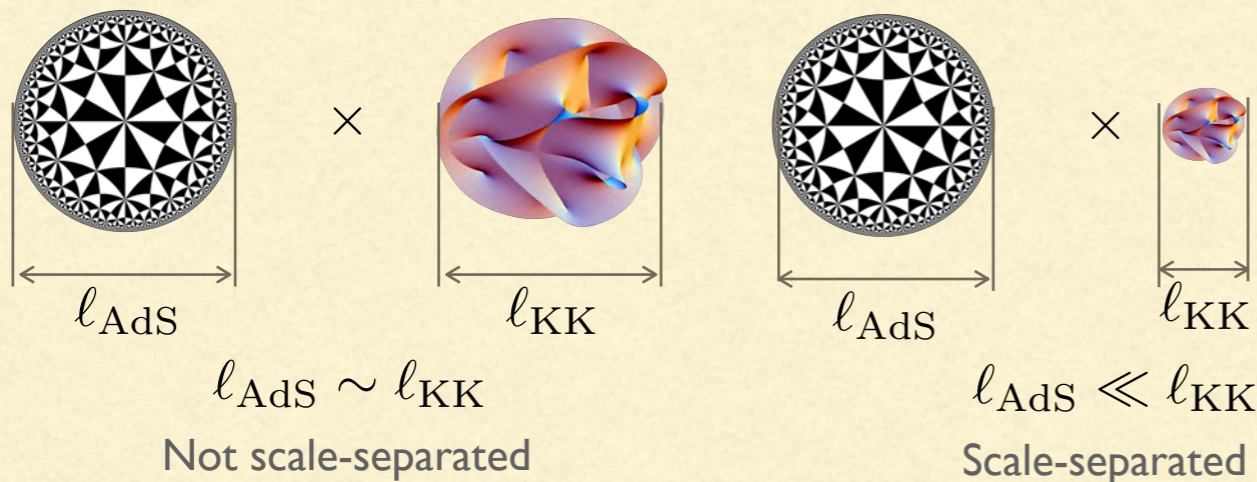
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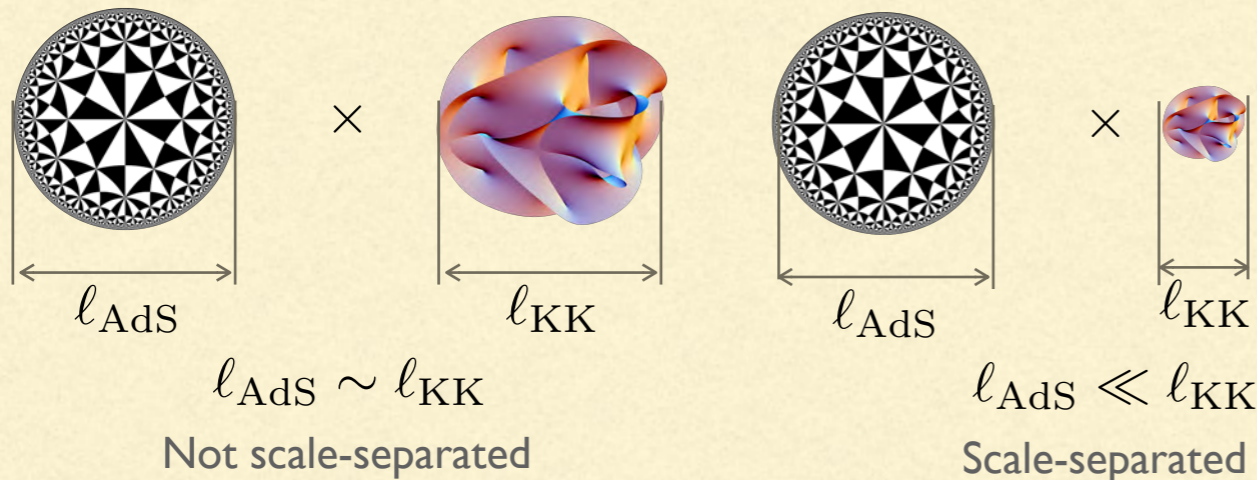
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- Progress towards KKLT-like 4d  $N=1$  vacua  
String field theory for computing  $W$

See Jakob's talk!  
See Minjae's talk!

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Most interesting case. A lot of **progress!**

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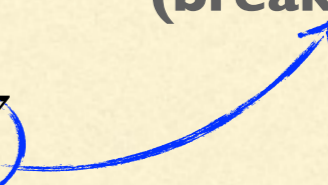
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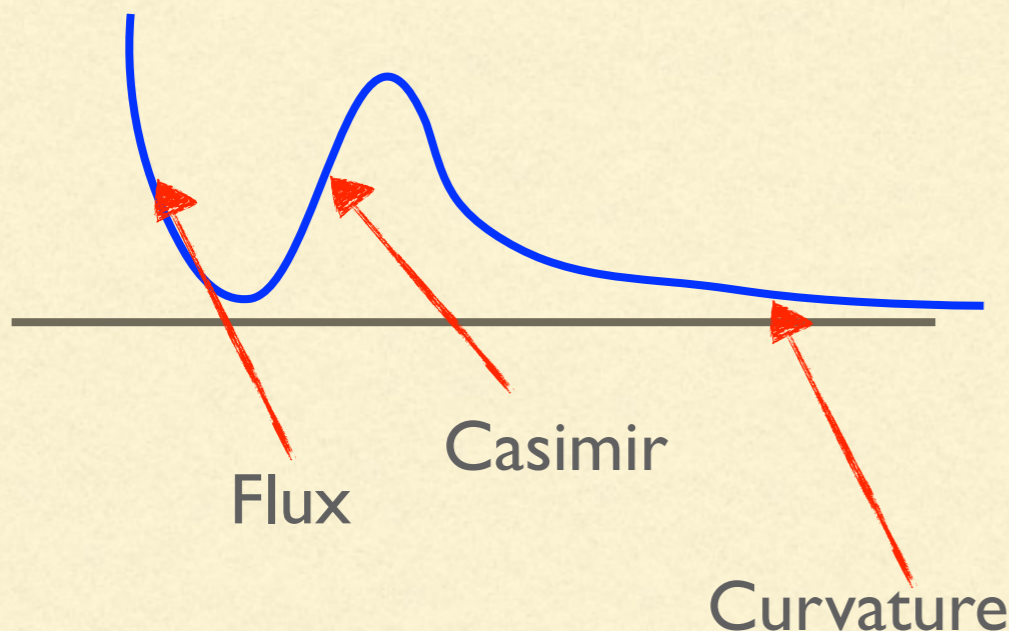
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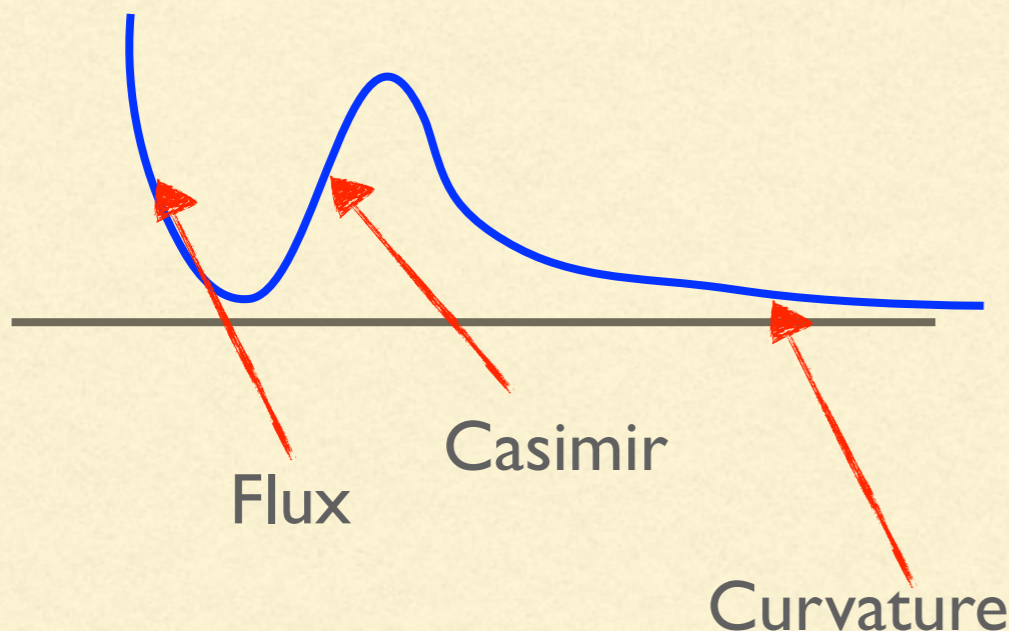
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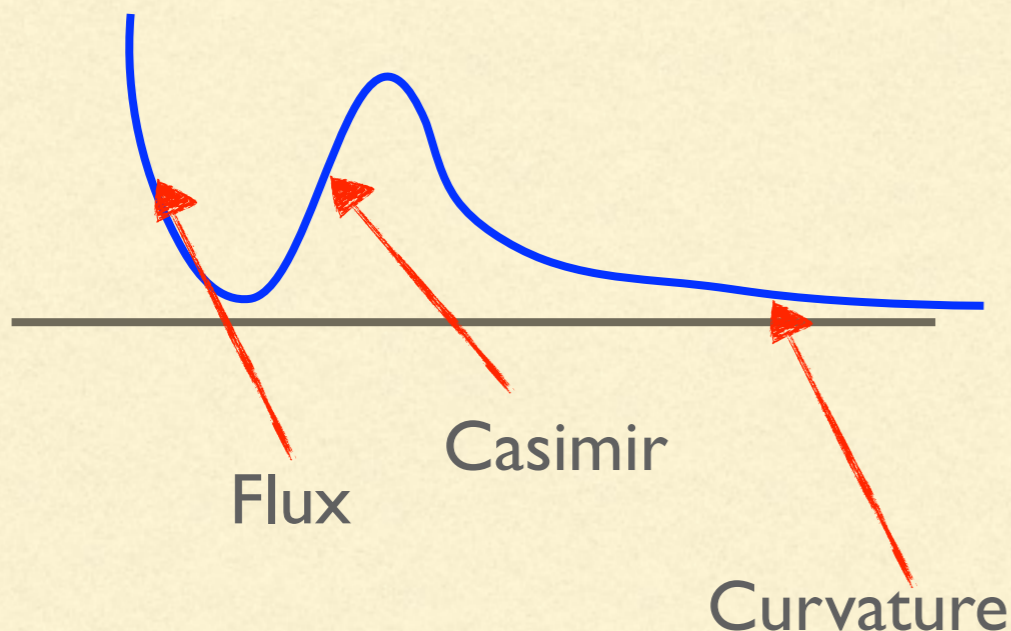
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**Doesn't have to be hyperbolic!** [MM, Bento, WIP]



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Also a lot of progress from **worldsheet** perspective

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Extended to 9d holomorphically factorized theories of rank 9 [Parra de Freitas '24]

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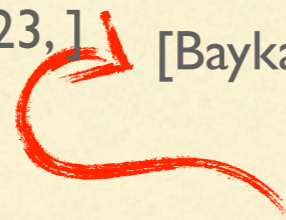
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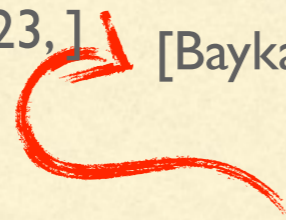


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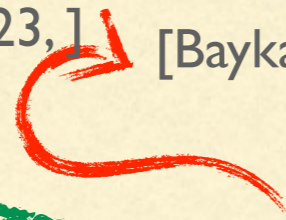


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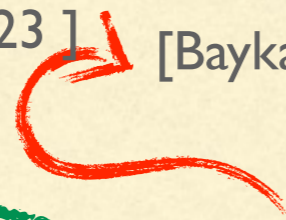


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One-loop vacuum energy positive in all three cases!

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**Can we find de Sitter in this corner of the Landscape?**

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Nilmanifolds + orientifolds: Classical dS?

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“The accelerated phase of expansion of our Universe today has only lasted around 0.5 e-folds”



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Also, models of **transient acceleration**

“The accelerated phase of expansion of our Universe today has only lasted around 0.5 e-folds”

...so lets build models that accelerate only for a while!

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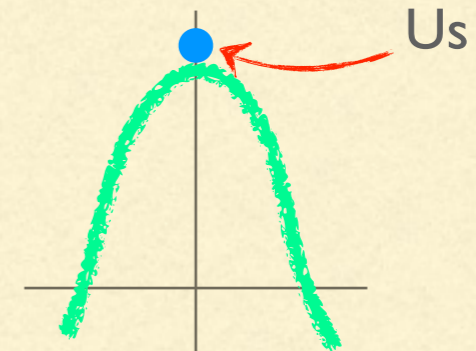
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...so lets build models that accelerate only for a while!

E.g. a de Sitter maximum [MM, Bento, WIP]  
(actually OK with cosmo constraints!) [Agrawal, Obied '18]



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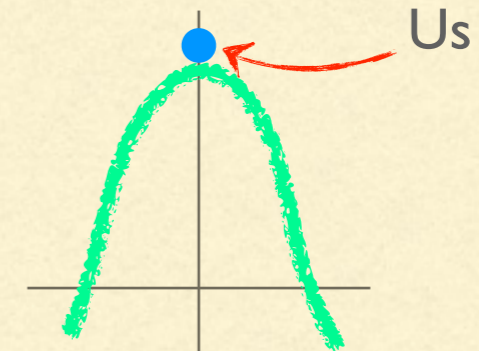
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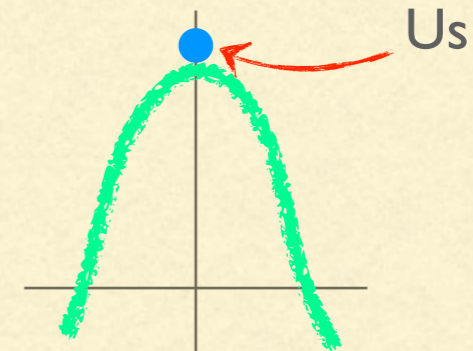
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See F. Apers poster!

See Susha's talk!

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And so, we reach the **end** of this short review.

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There is much more that I could not cover, just below the surface.

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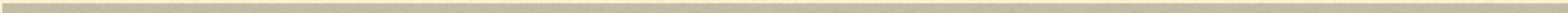
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There is much more that I could not cover, just below the surface.

But I hope one thing was clear...



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We are currently living in the

# Time of Exploration



There's constantly  
new stuff going on.

It's extremely  
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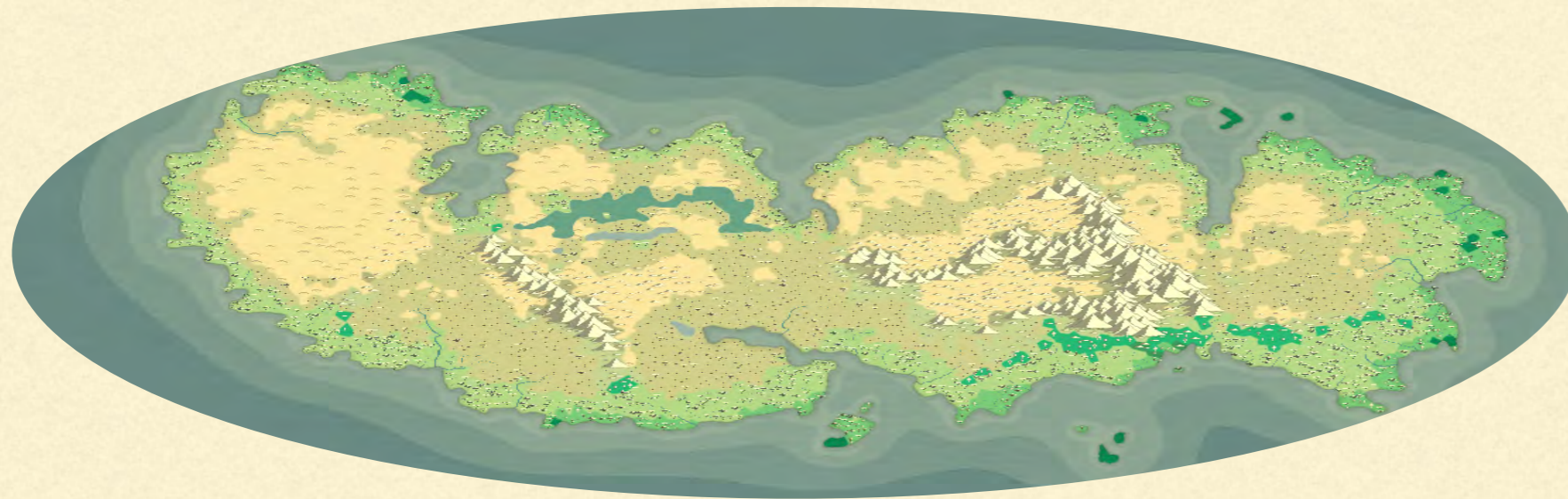
Exploring the String Landscape doesn't feel like "constructing" a model, or inventing a setup.

It feels like **discovering** something that was already in place.

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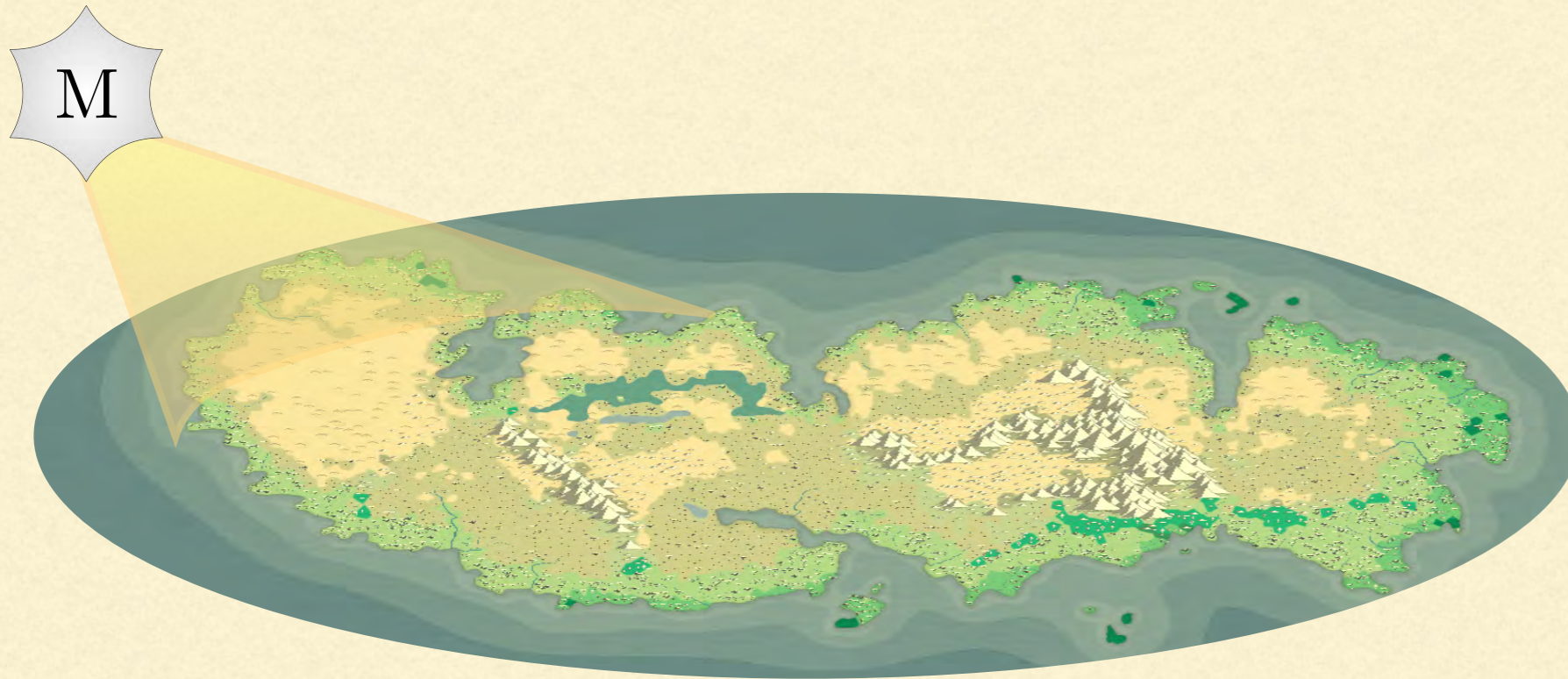
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By combining new and old ideas in top-down constructions



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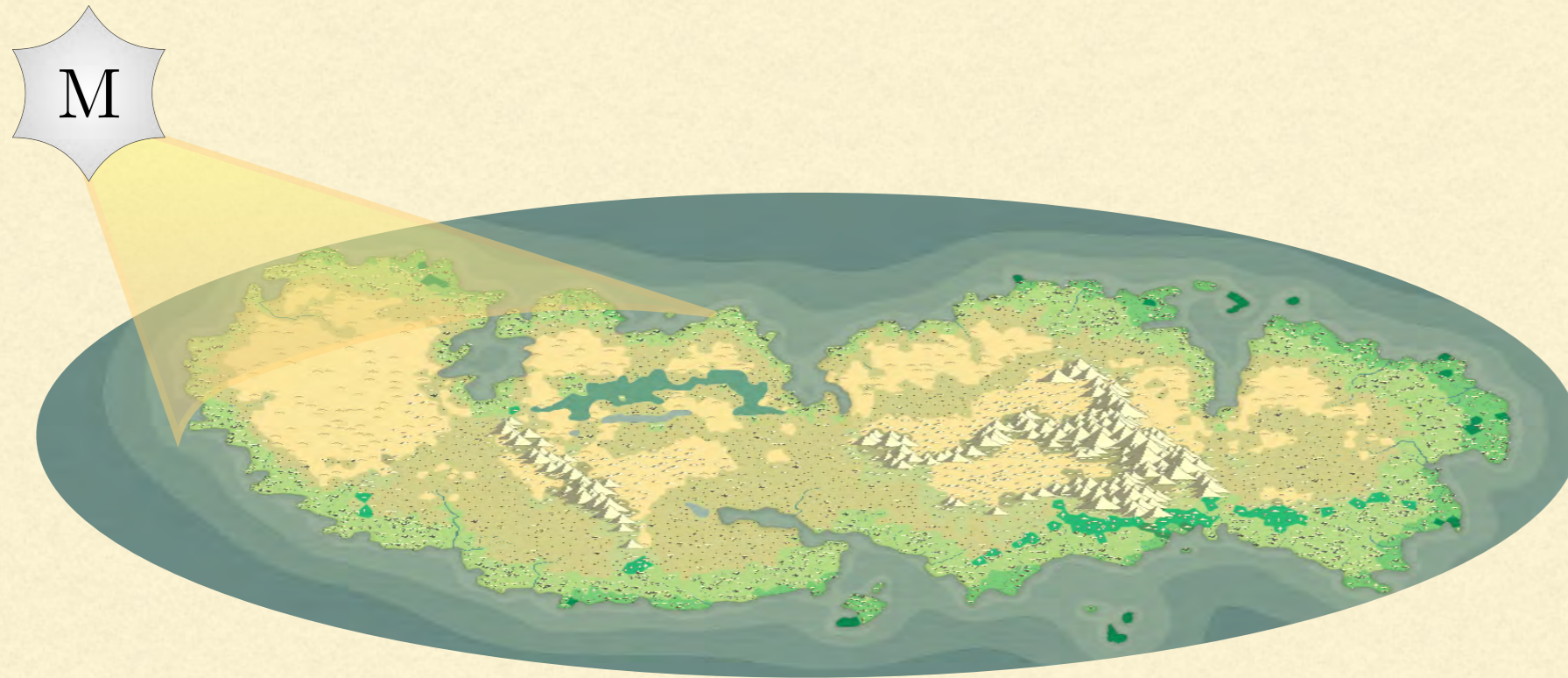
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M

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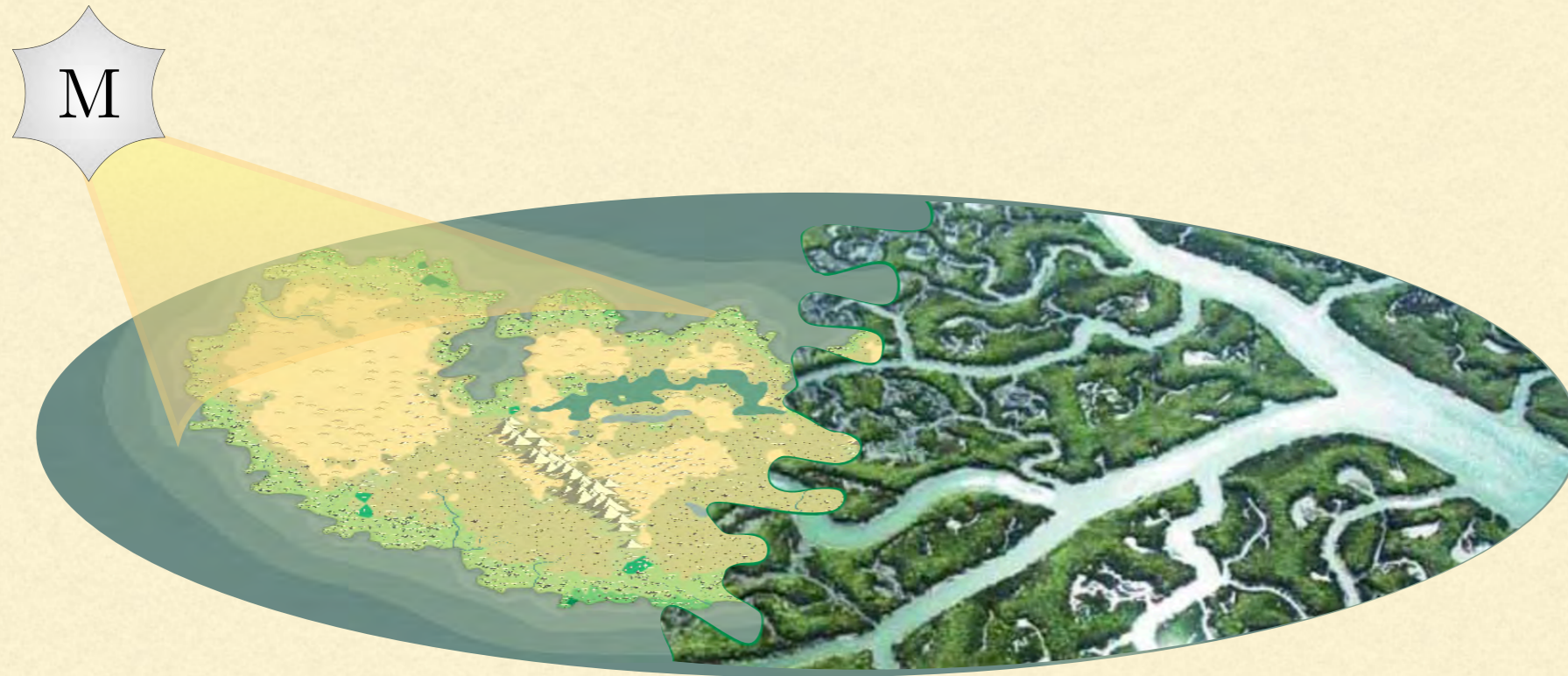
By combining new and old ideas in top-down constructions



with  
bottom-up  
Swampland  
constraints

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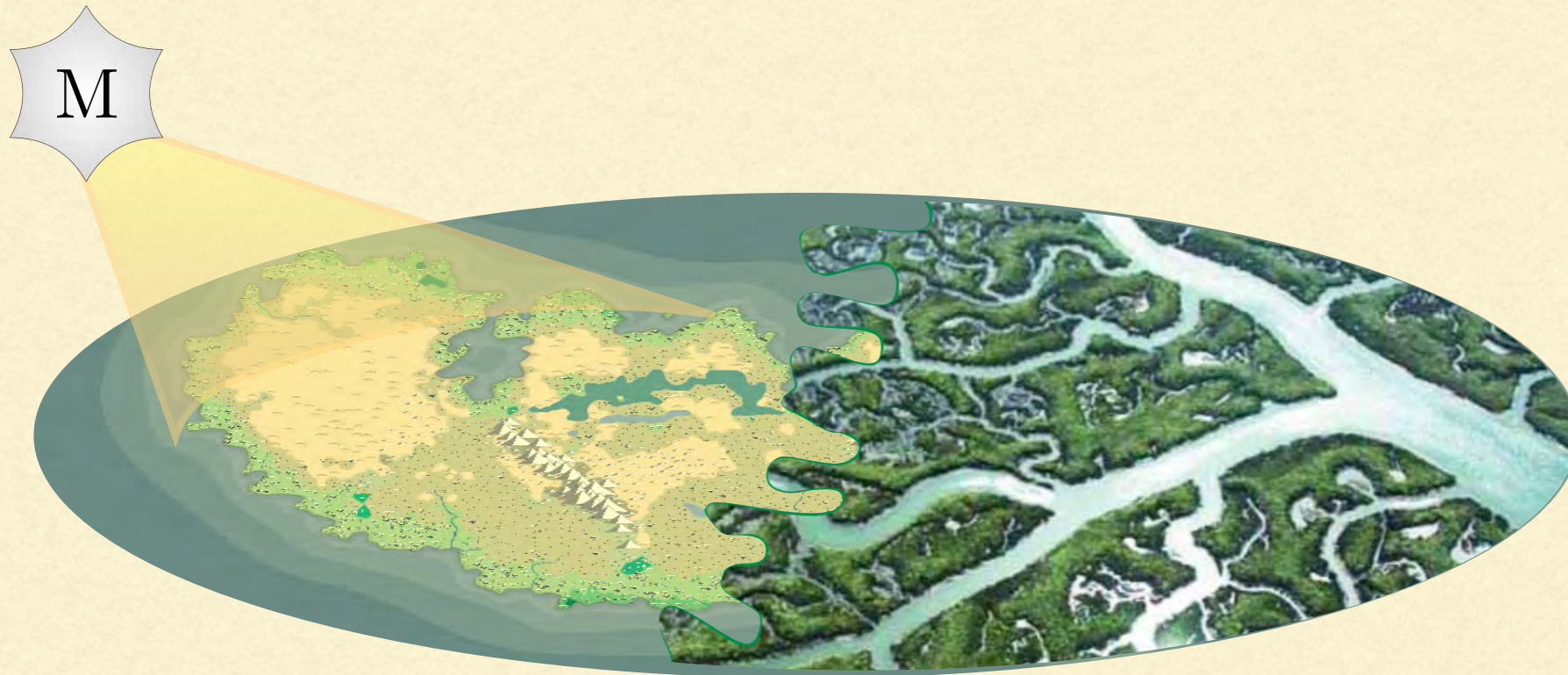


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By combining new and old ideas in top-down constructions



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we **can** chart the String Landscape

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we **can** chart the String Landscape and find where we are in it.

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But we need all the help we can get, so...

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we **can** chart the String Landscape and find where we are in it.

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**Join in the adventure!**

*Merci beaucoup — Thank you!*

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