

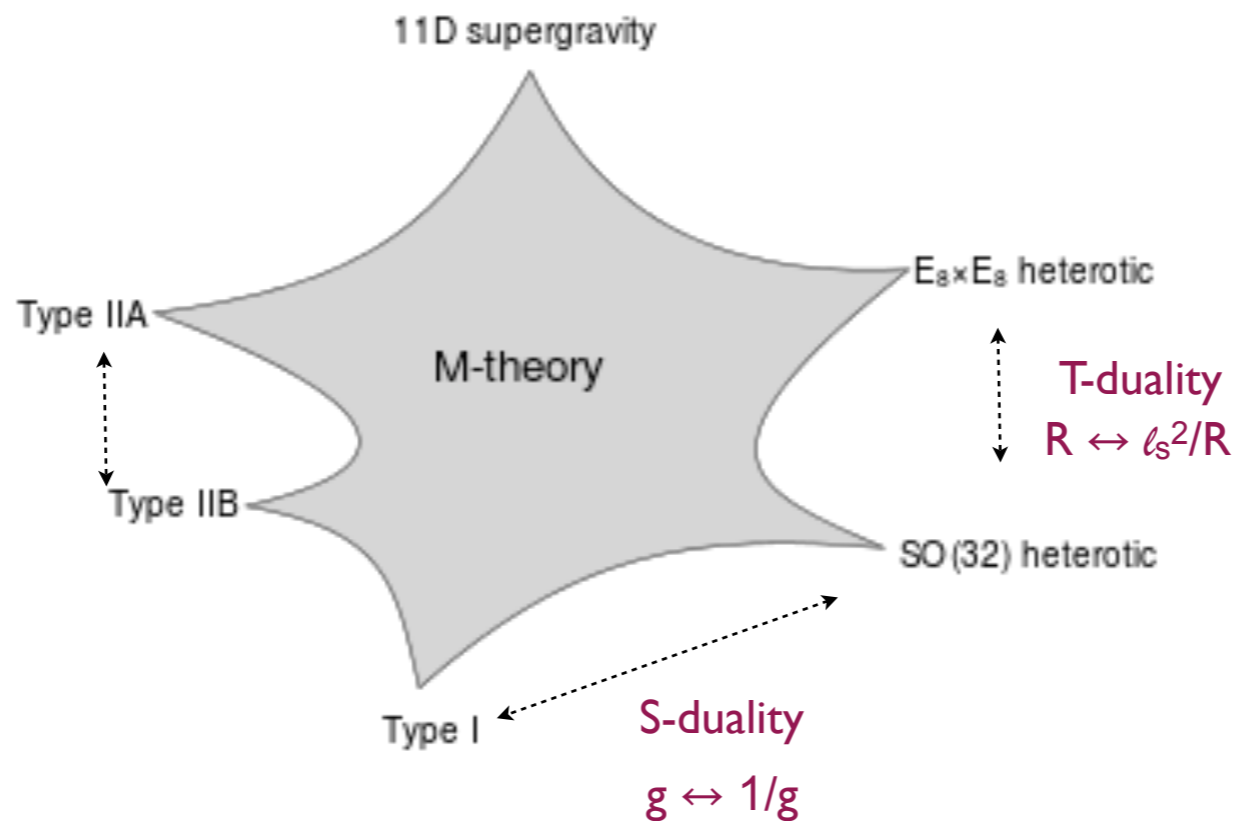
# String theory, from the landscape to the swampland

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CEA / Université Paris-Saclay  
France

IPhT@60, Saclay, November 2023

# String theory

- A remarkable theory of **quantum gravity**, calculable
- Second superstring revolution ('95): **unique theory!**

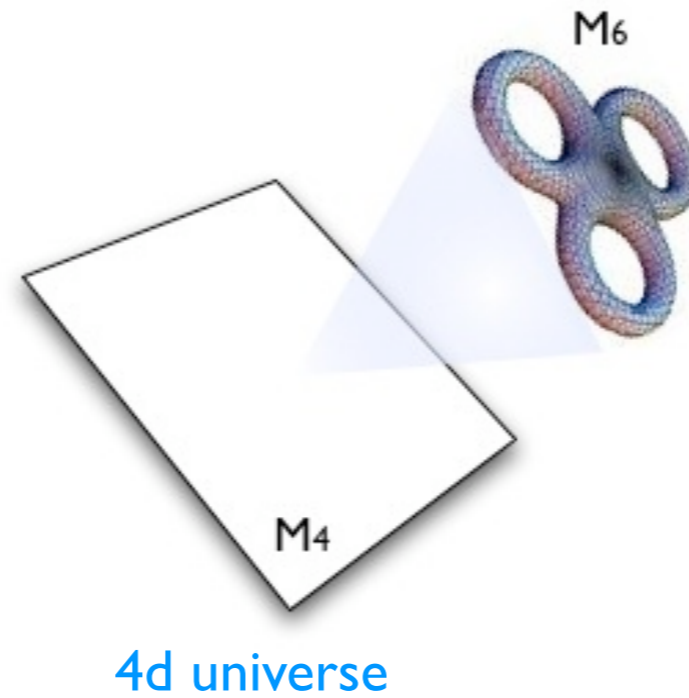


But

# Unique theory 10d

6d compact space

$$M_{10} = M_4 \times M_6$$



Geometry of  $M_6$   
determines physics  
in 4d

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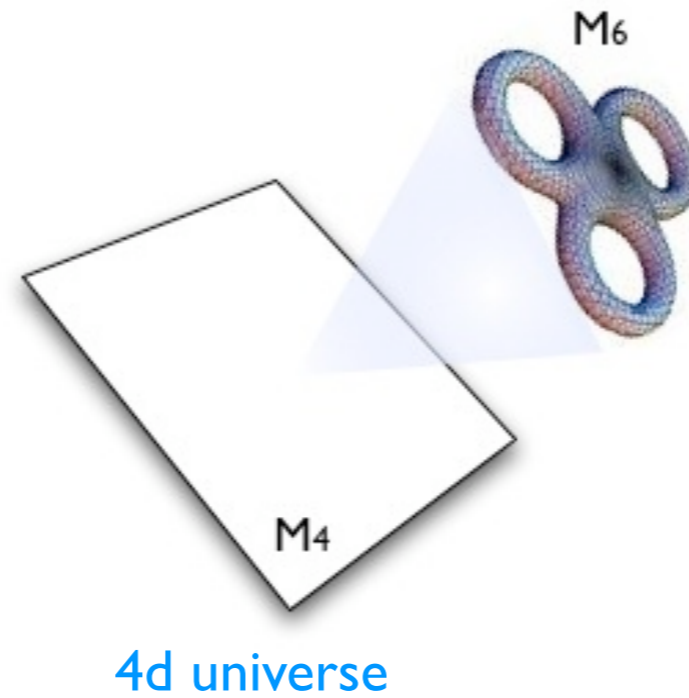
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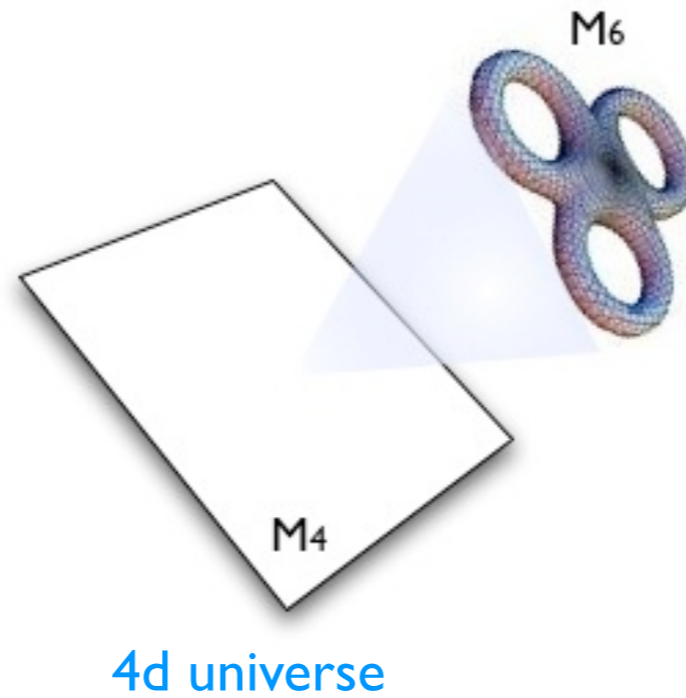
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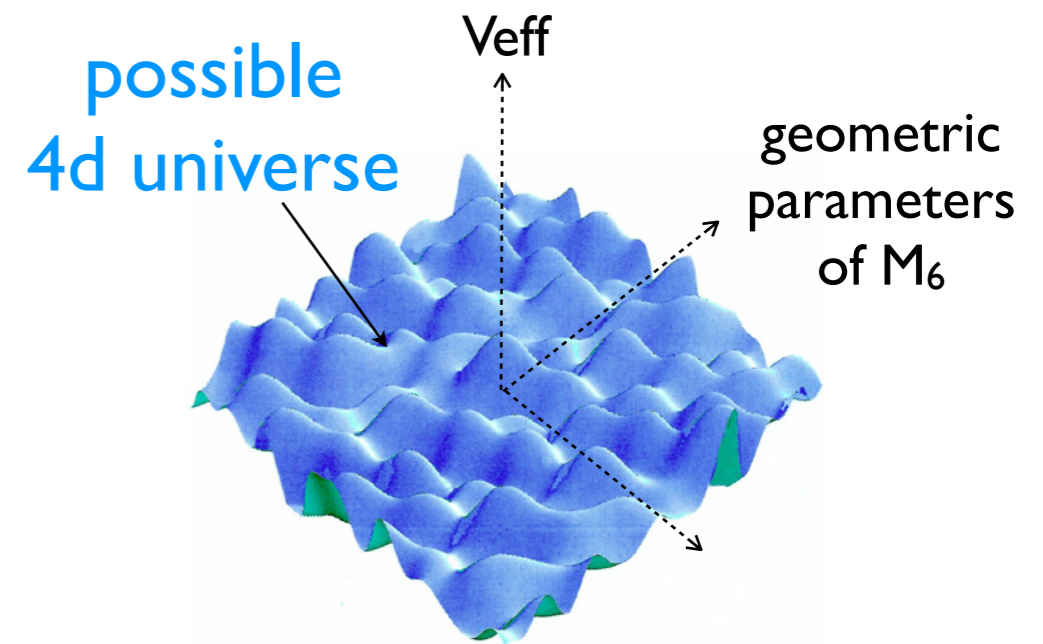
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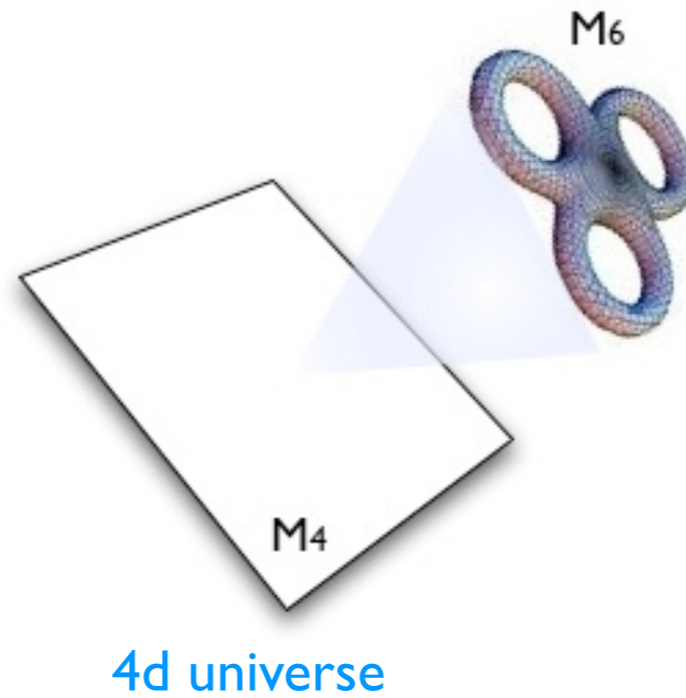
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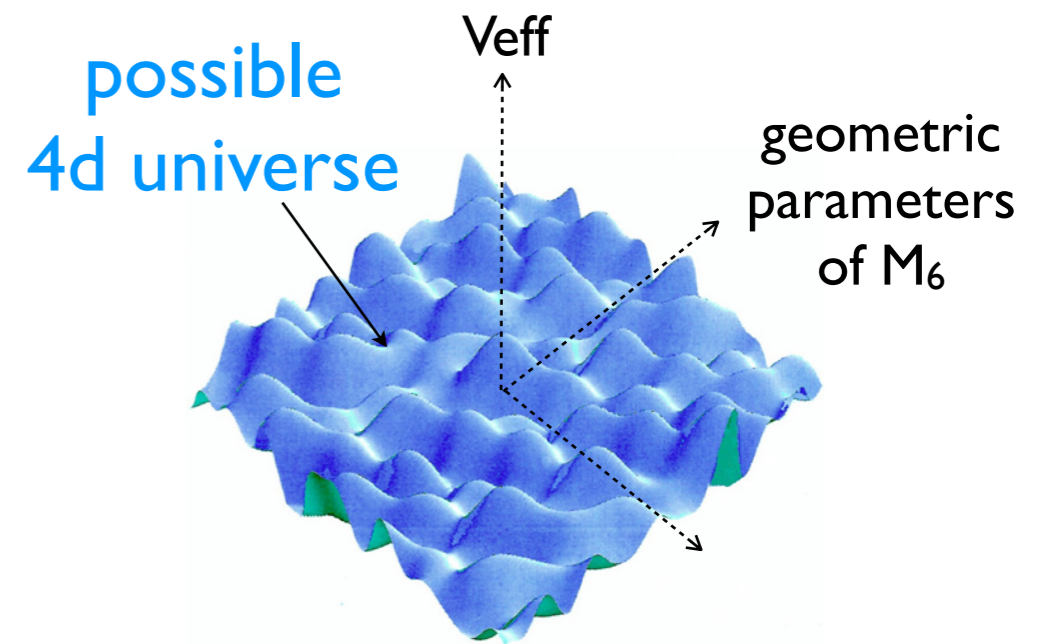
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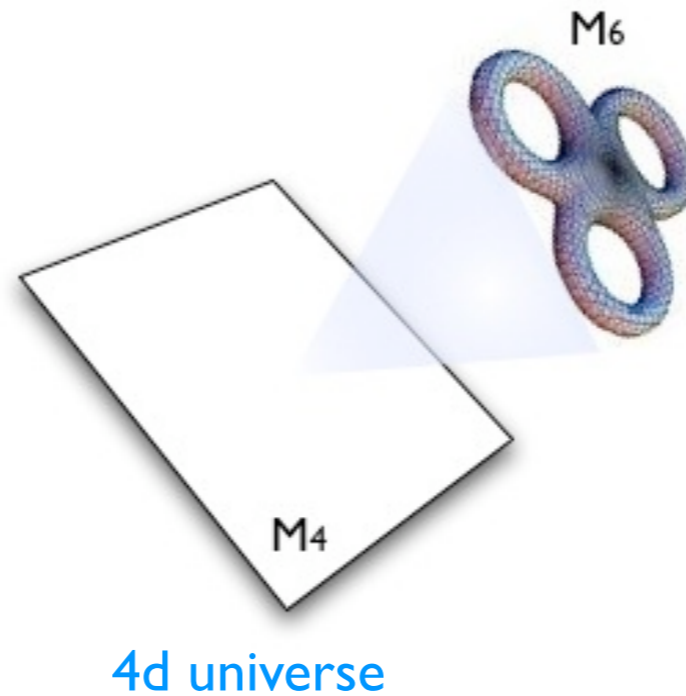
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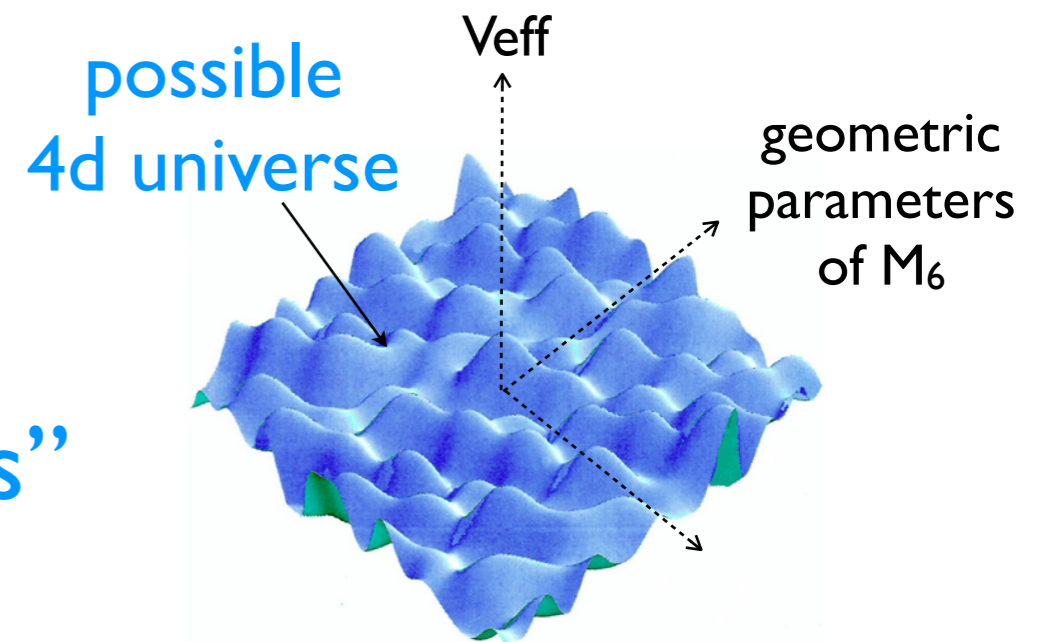
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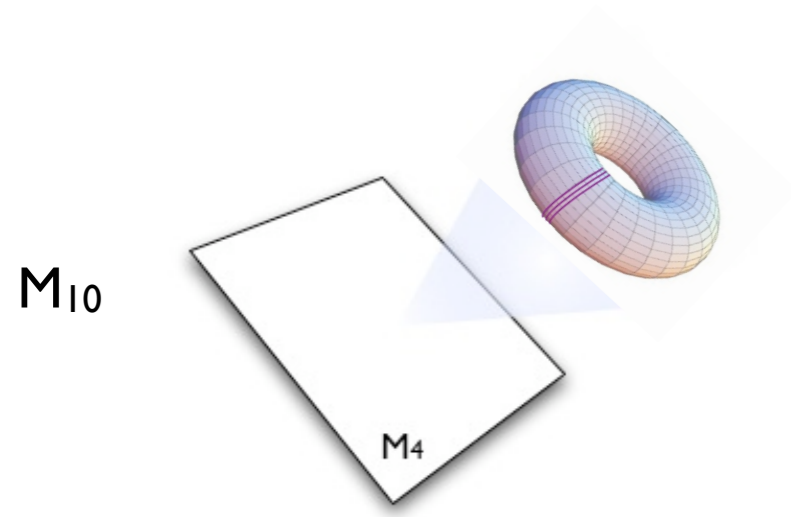
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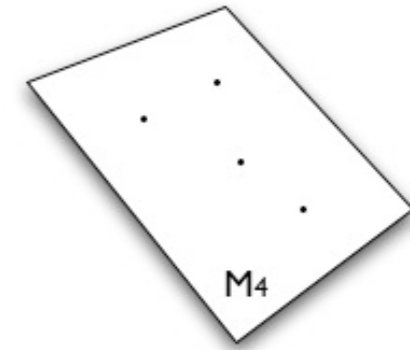
**Landscape of possible 4d “universes”**



# Simplest exemple



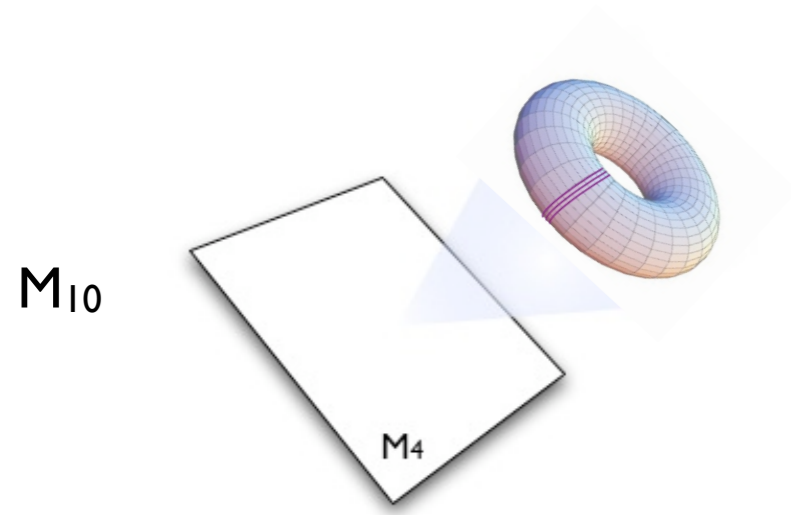
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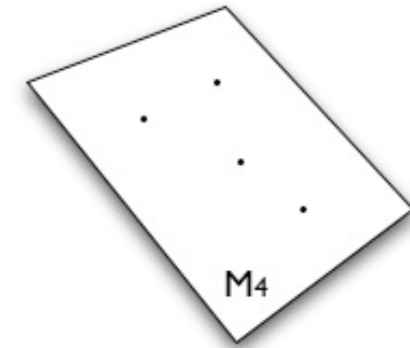
Observable world



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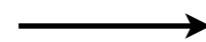


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Observable world

Supersymmetric



supersymmetric spectrum

**BUT**

4D space = Minkowski



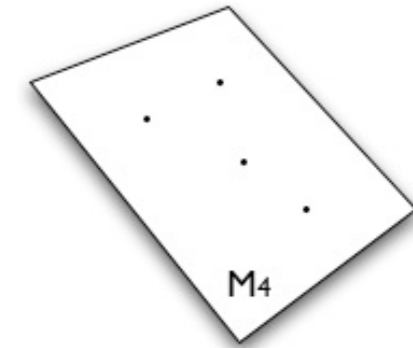
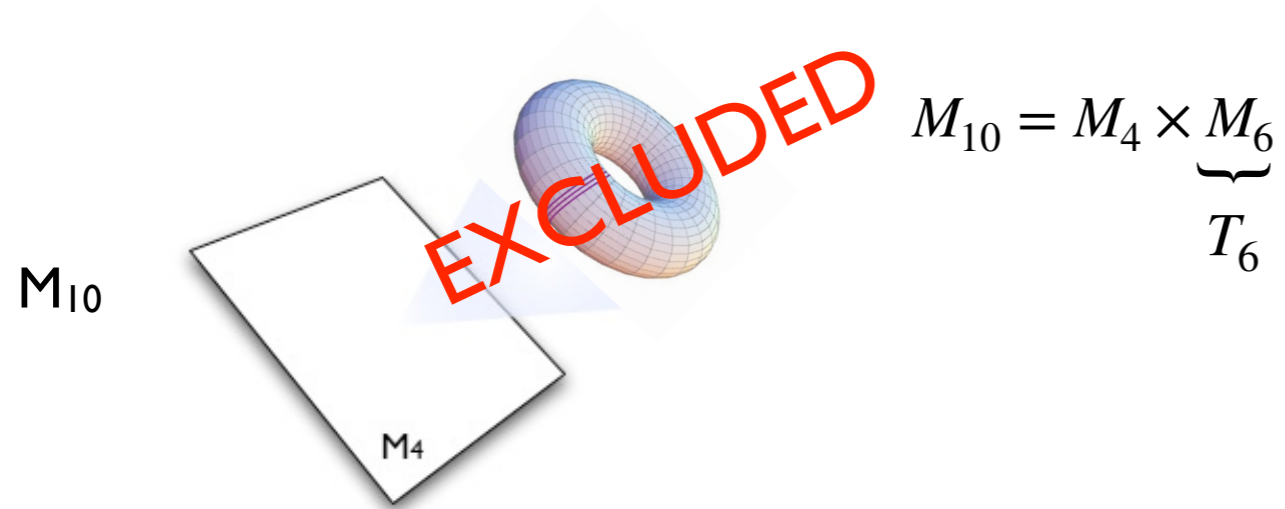
no cosmological constant

Radii of circles not fixed



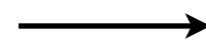
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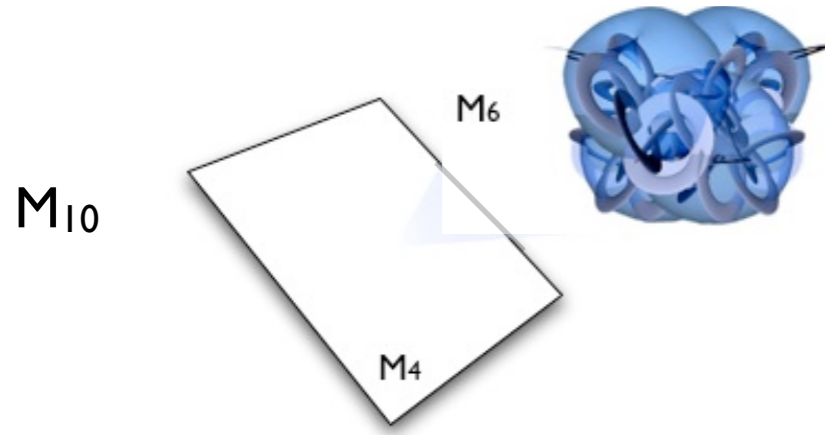
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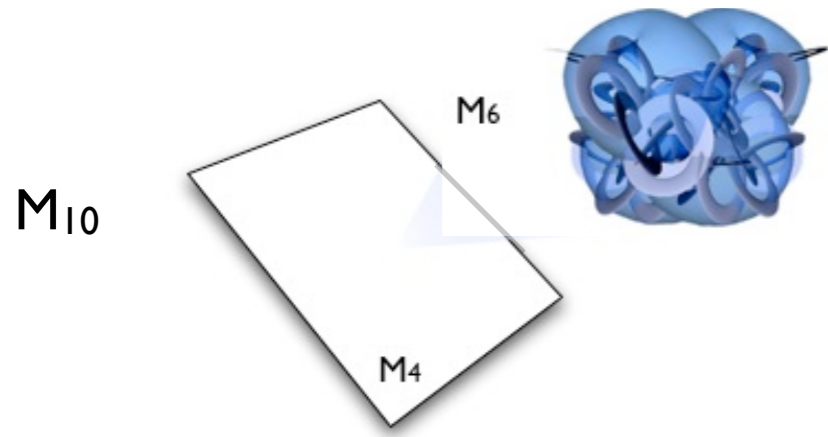
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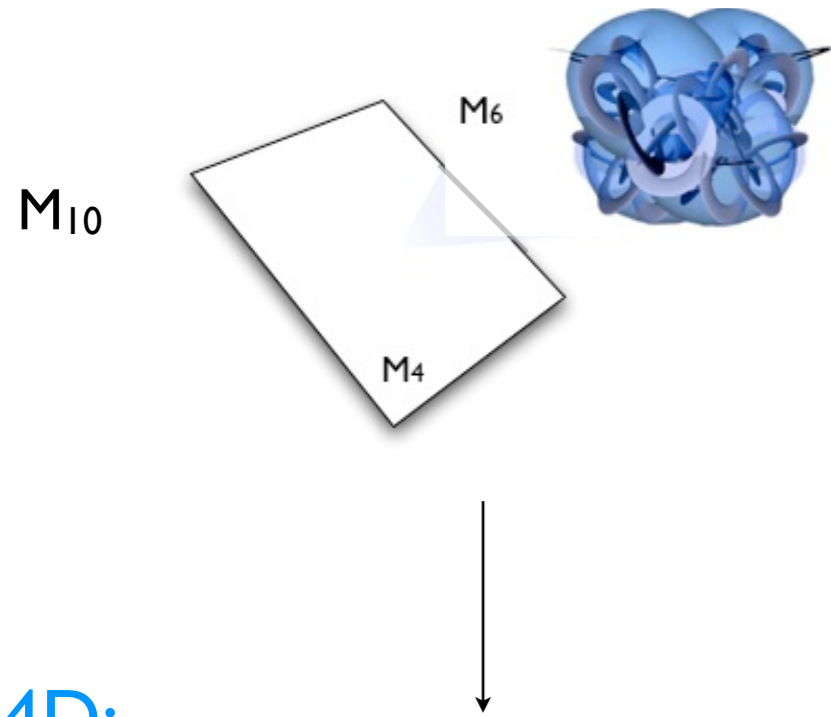
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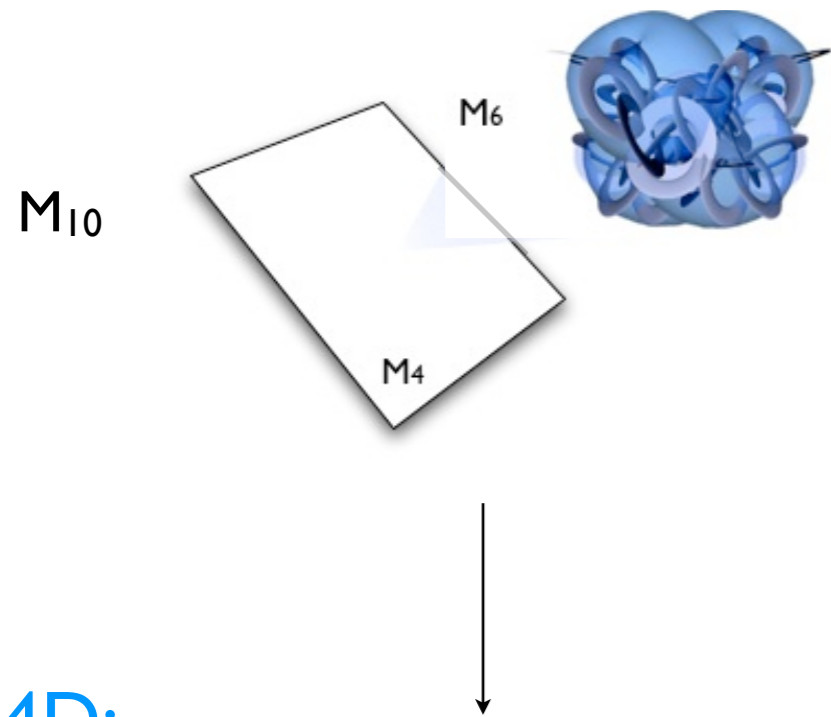
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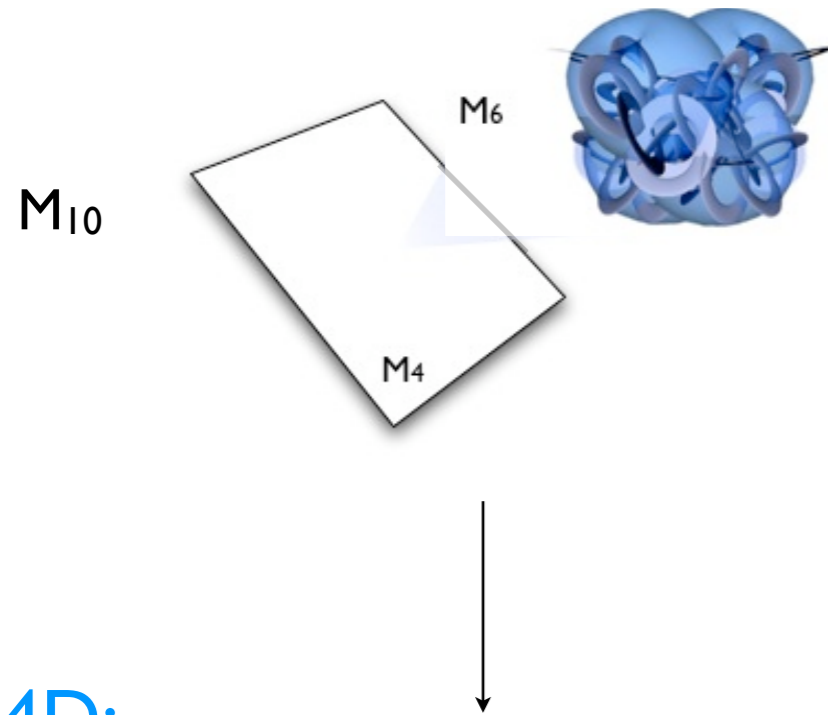
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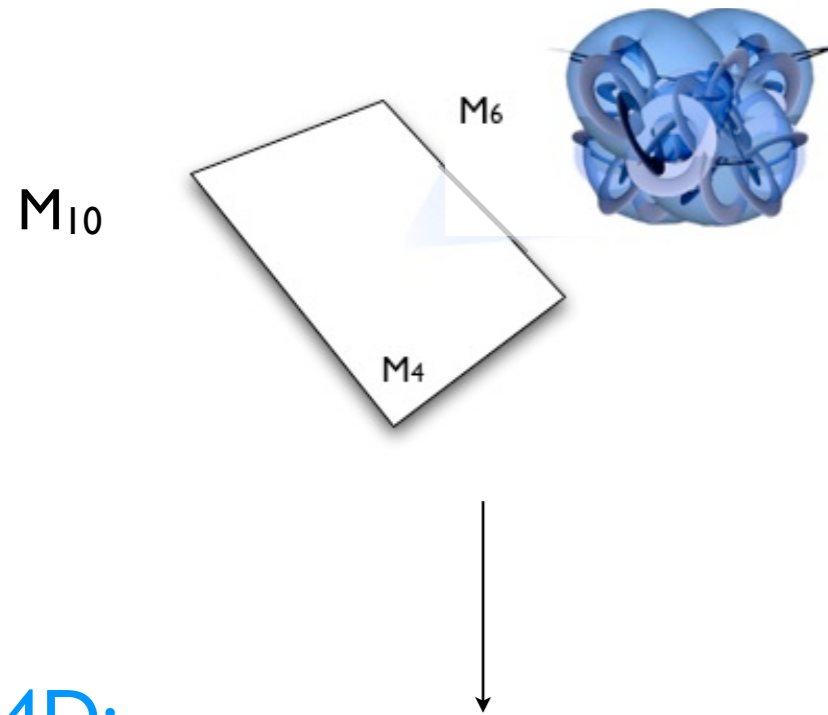
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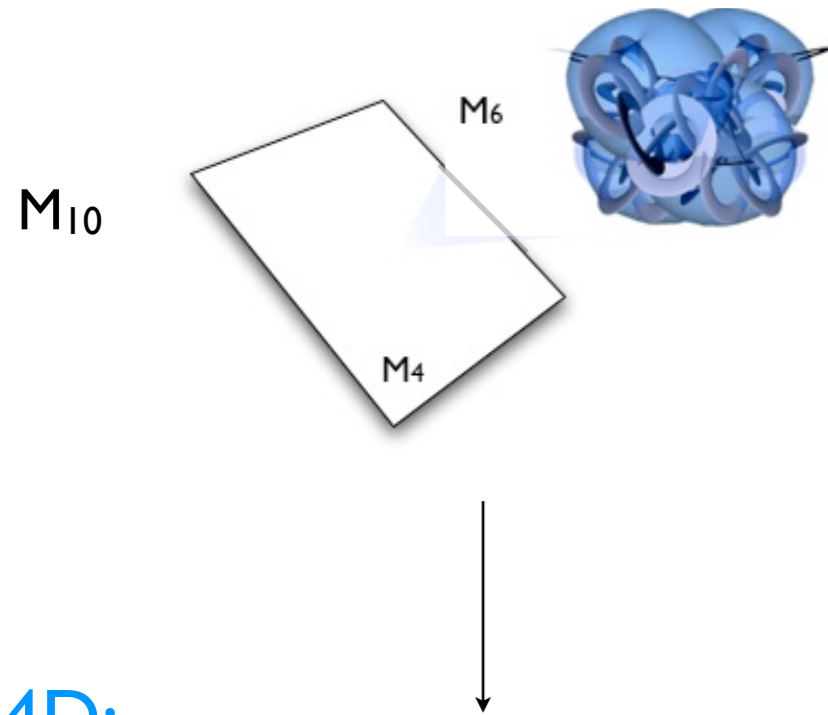
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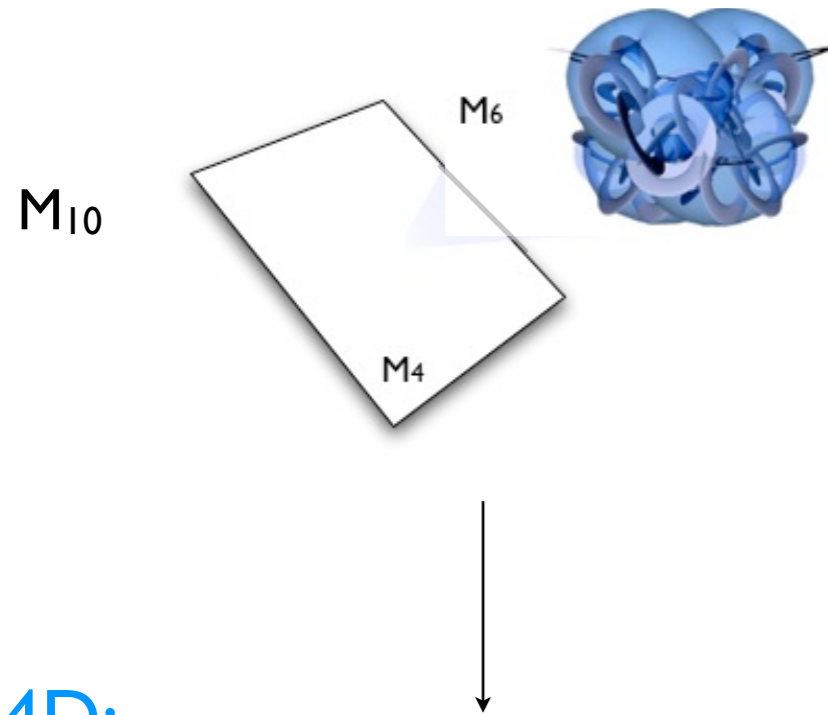
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**Landscape of possible 4d universes**

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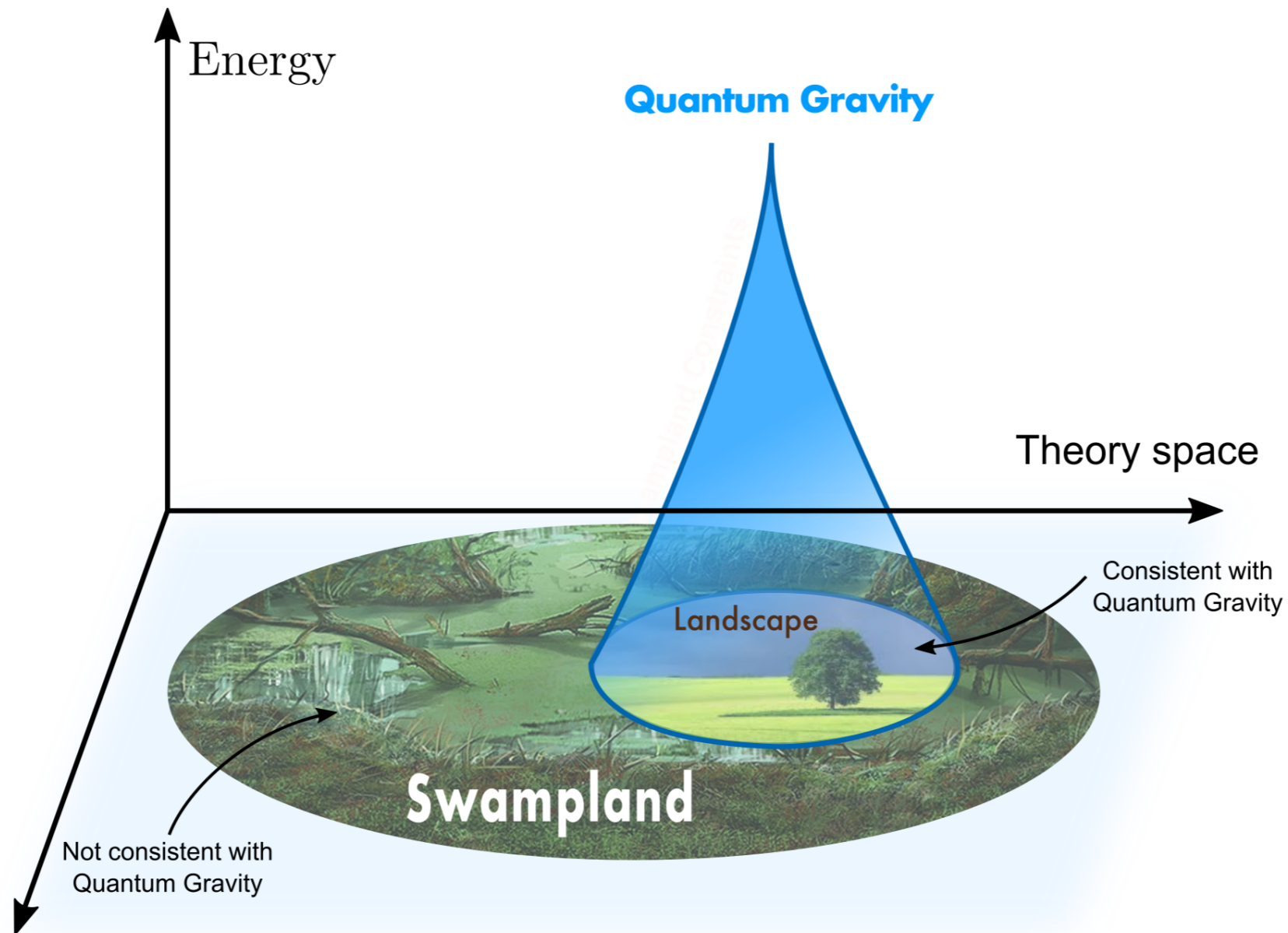
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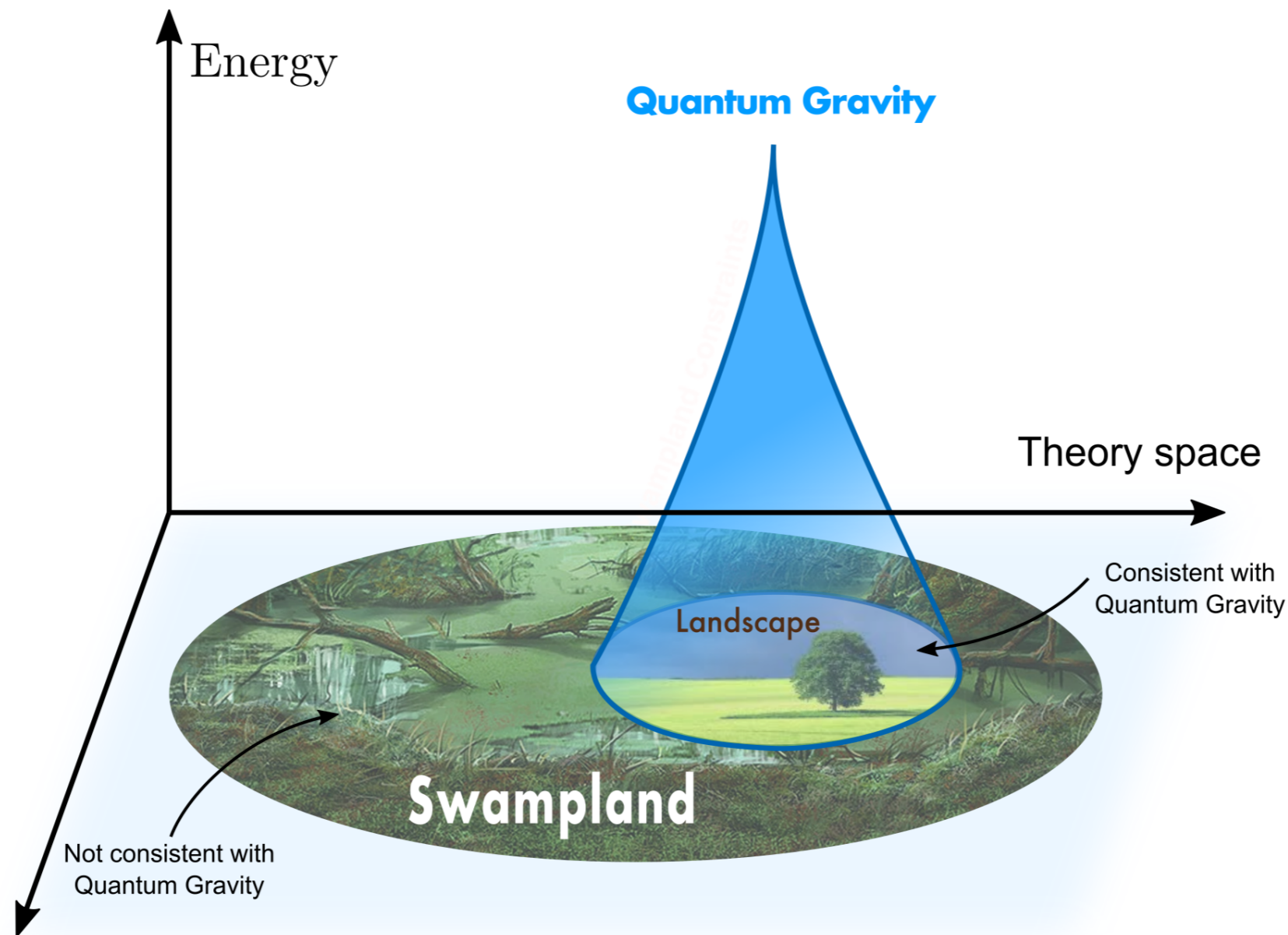
Or did we fall into the swampland ?

# The landscape and the swampland



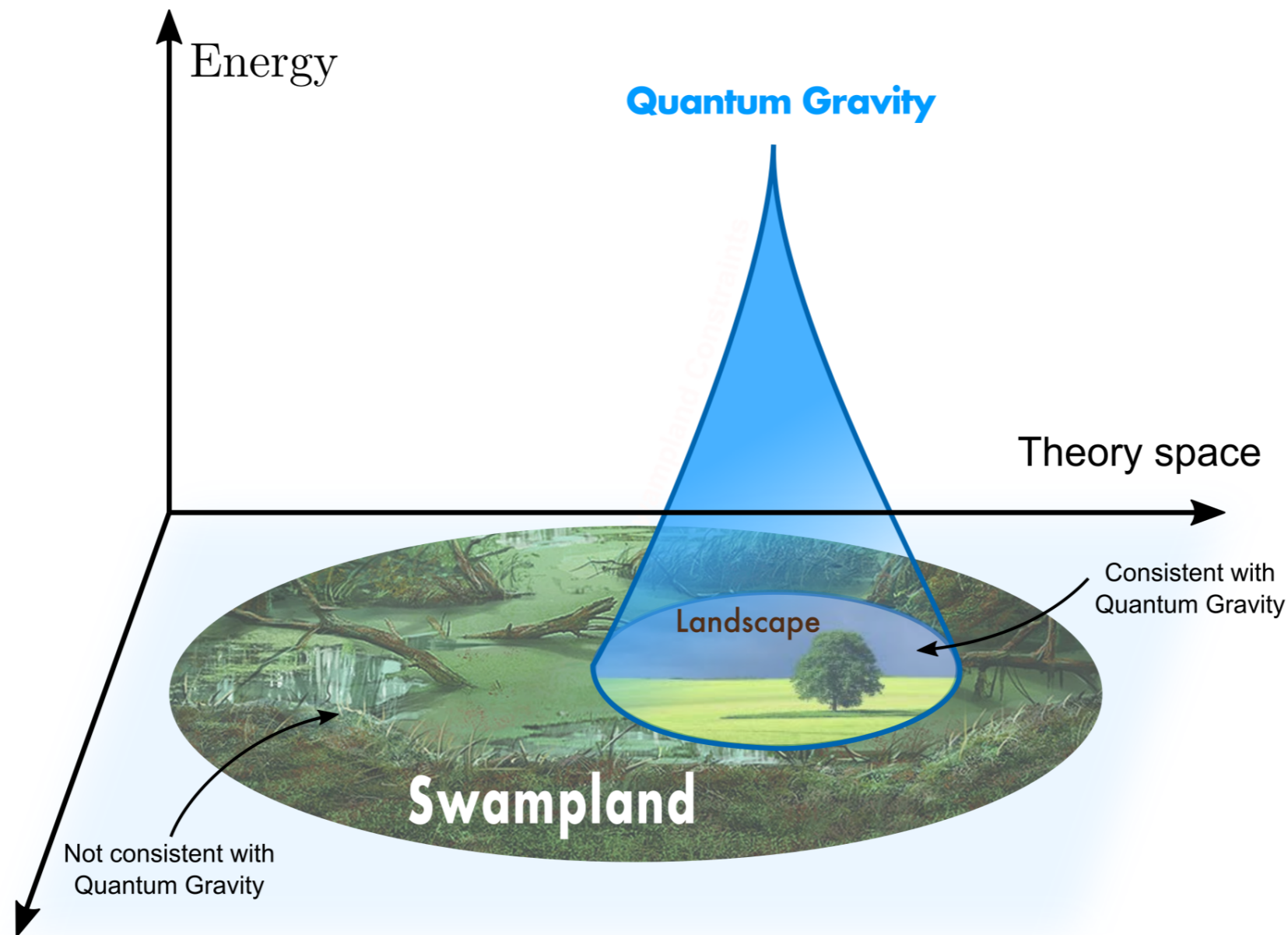


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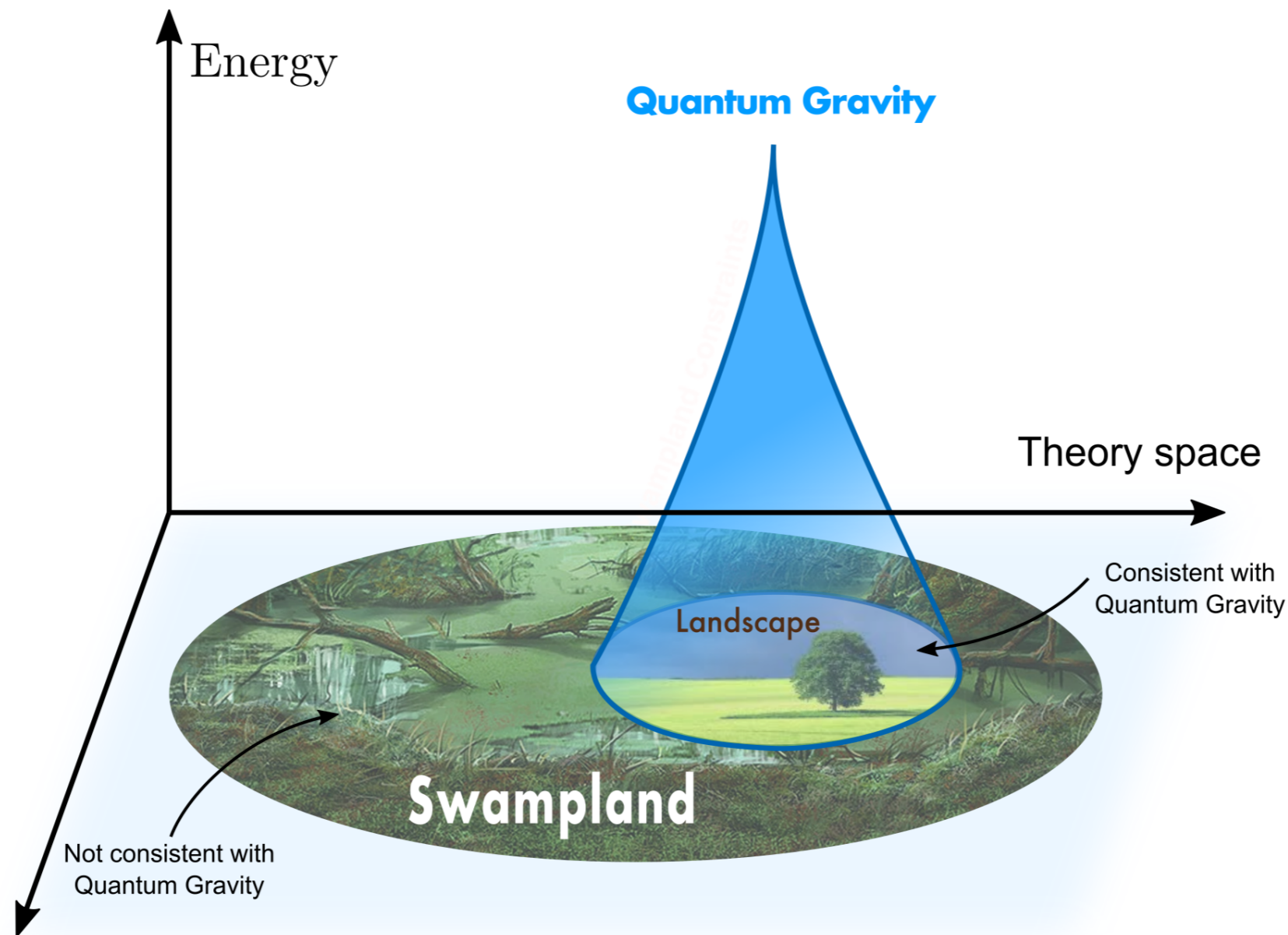
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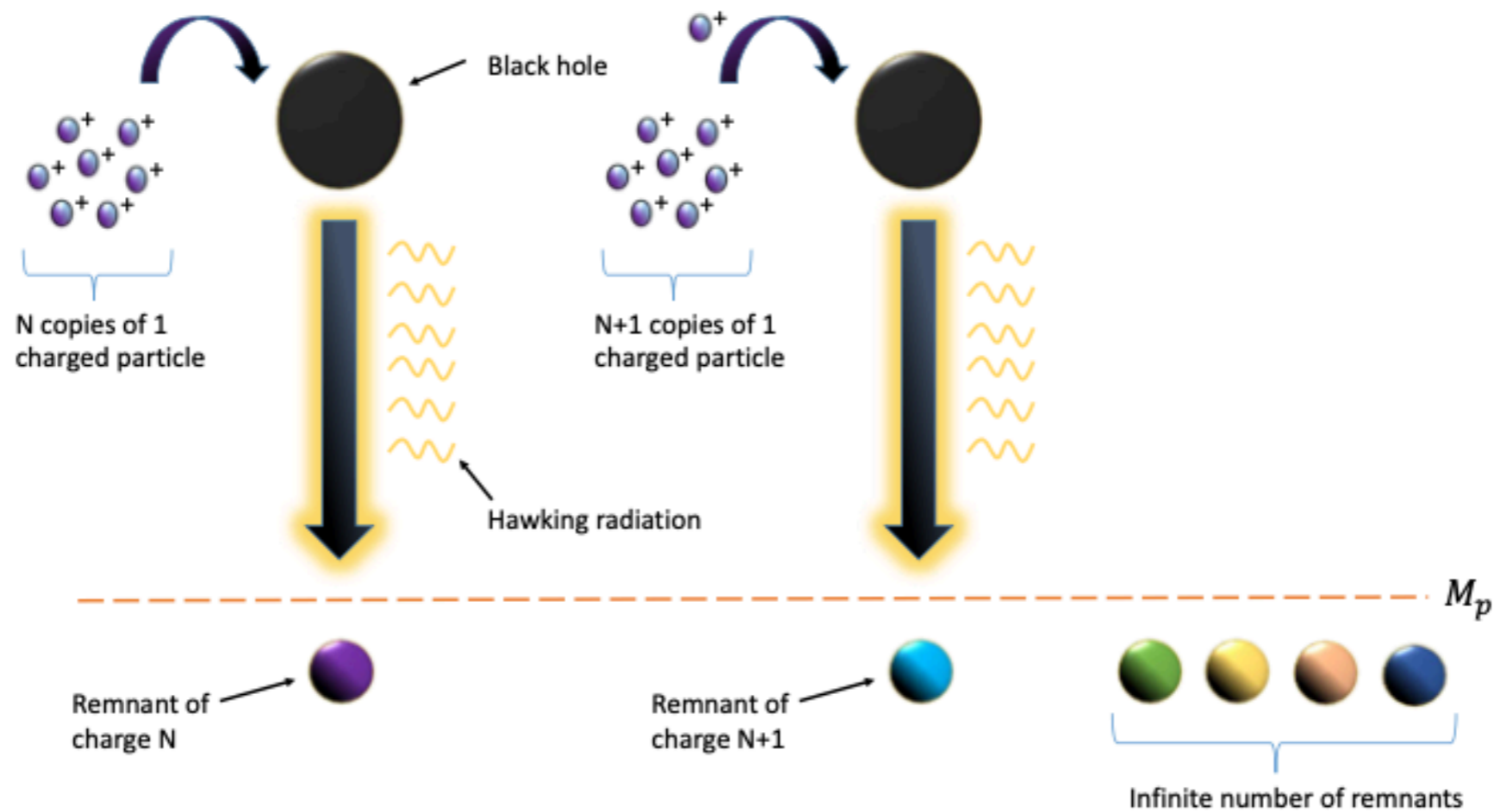
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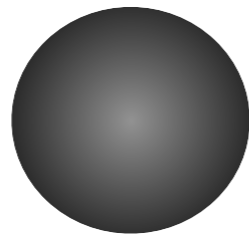
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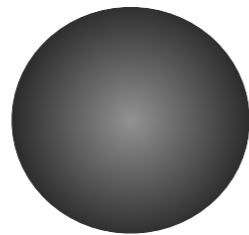
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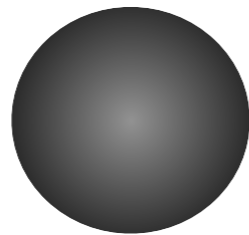
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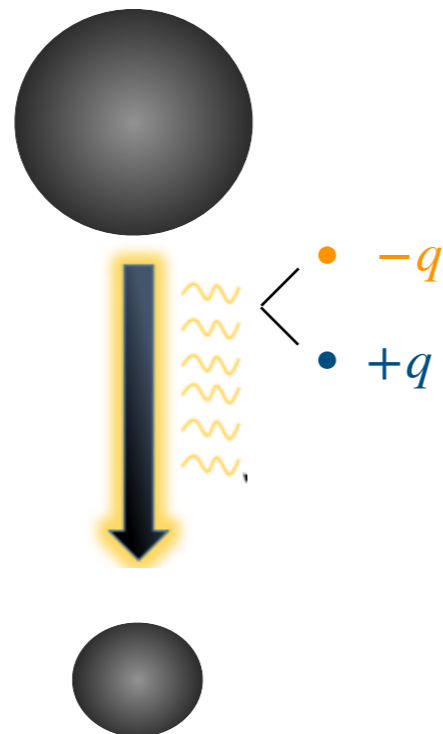
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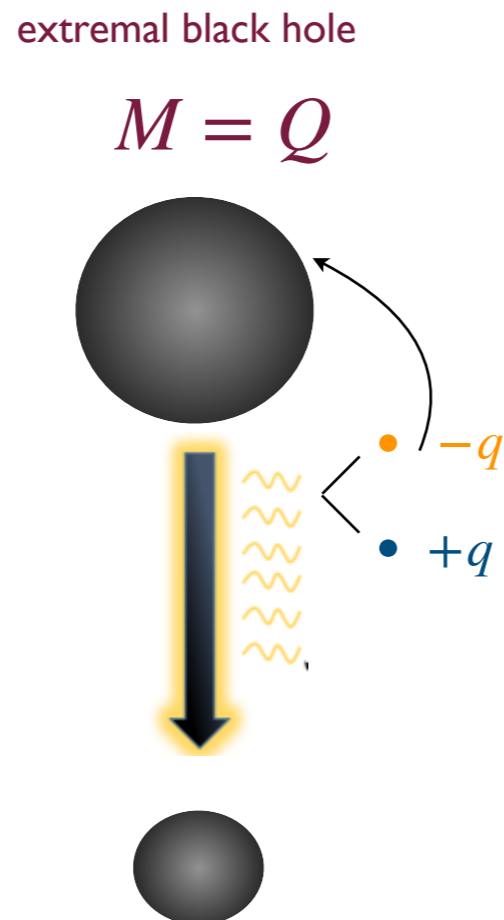
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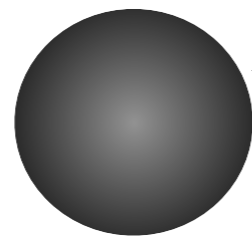
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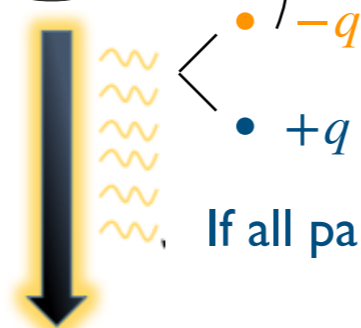
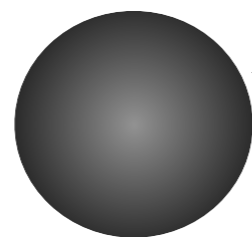
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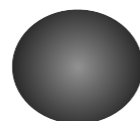
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superextremal black hole:  
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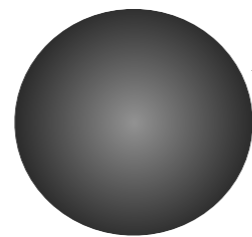
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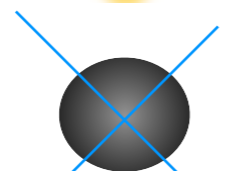
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$\Rightarrow$  extremal black holes  
cannot decay: remnants

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- The most speculative one: de Sitter swampland conjecture

# Swampland

- Conjectures based on physics of black holes and/or inspired by string theory
- Some on very firm footing (like no global symmetries and weak gravity)
- Some more speculative
- The most speculative one: de Sitter swampland conjecture

**de Sitter space is in the swampland!!**

- de Sitter swampland conjecture

Obied, Ooguri, Spodyneiko, Vafa 18  
(OOSV)

(inspired largely by our work)

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In an EFT

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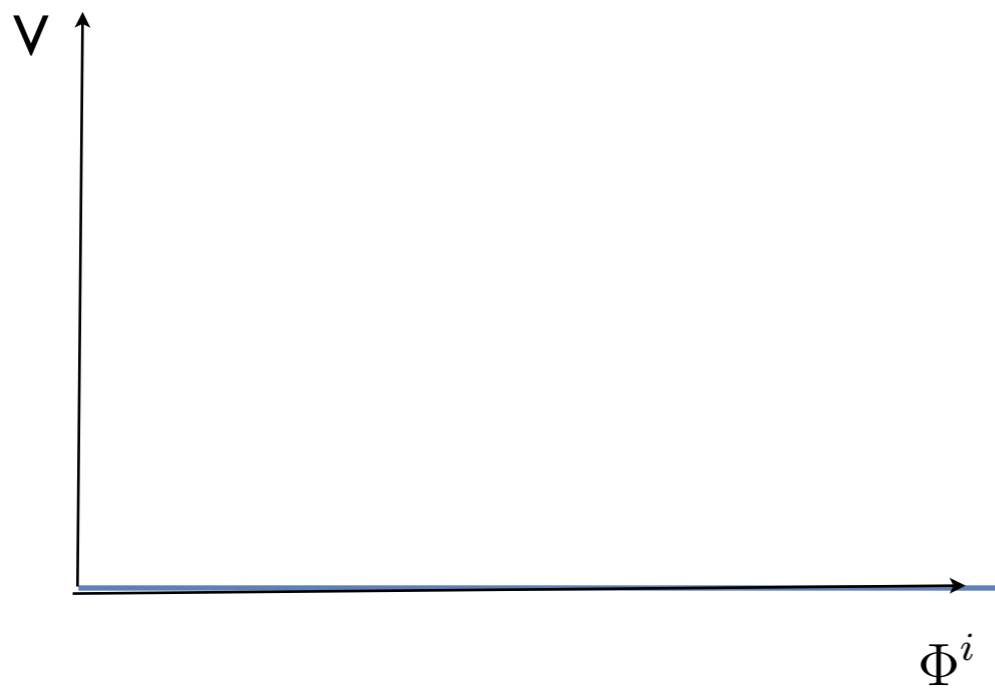
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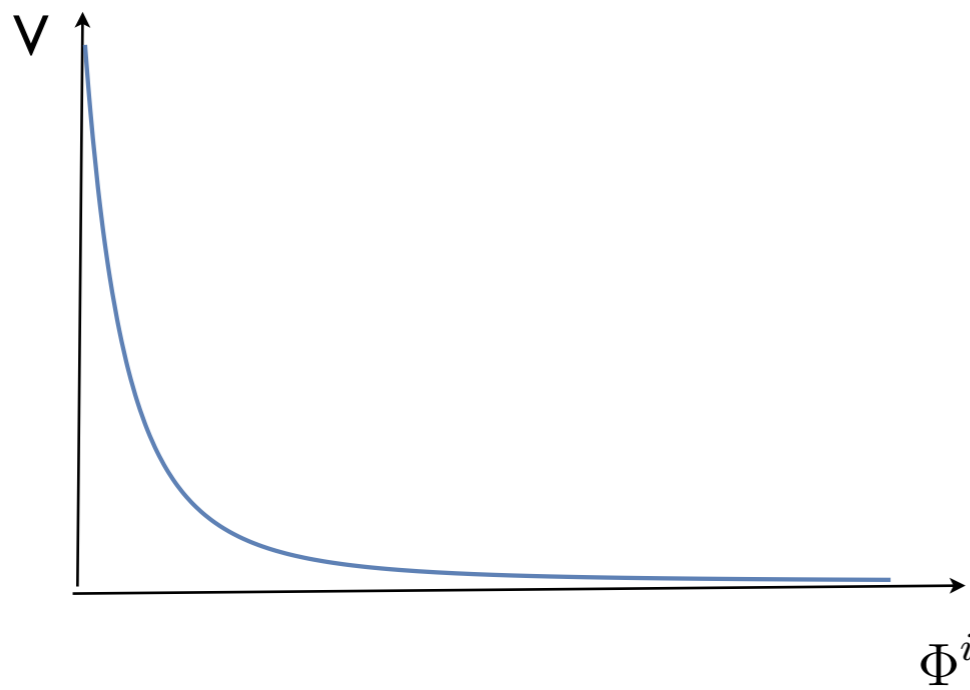
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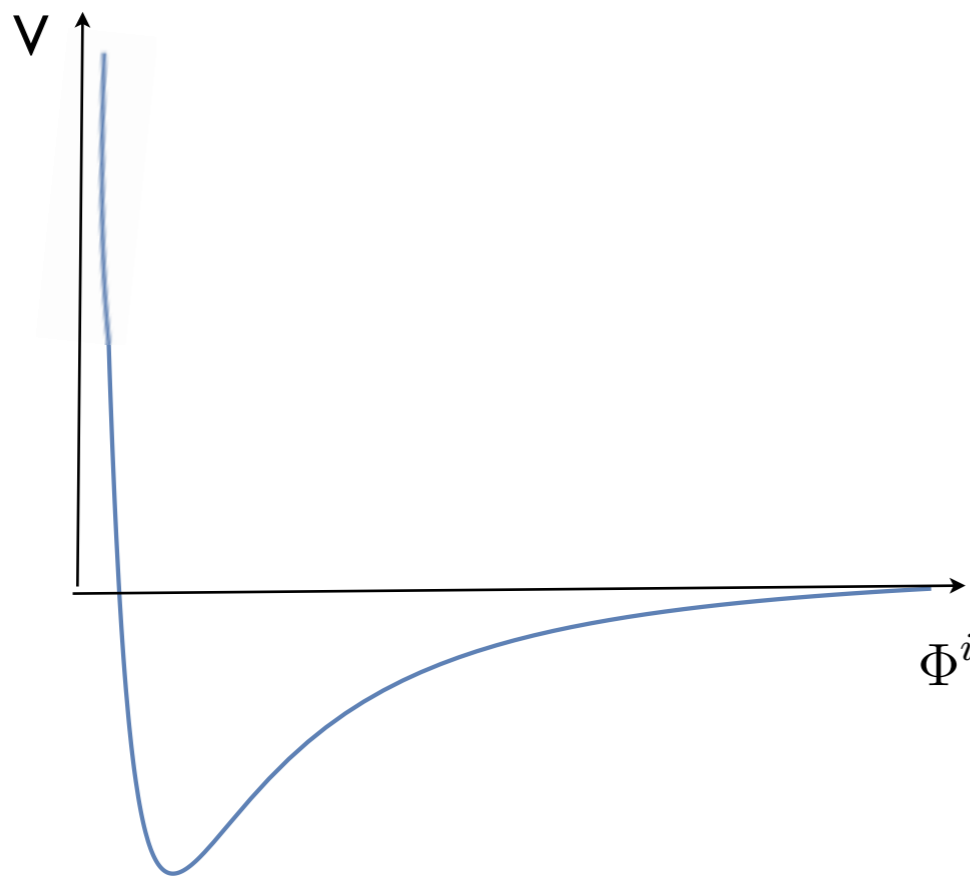
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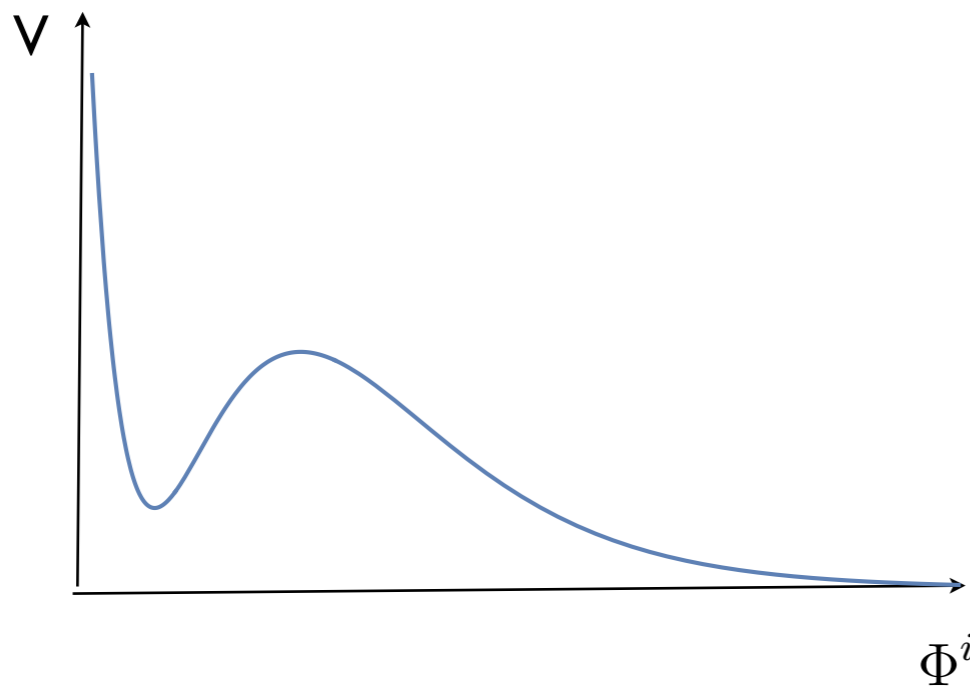
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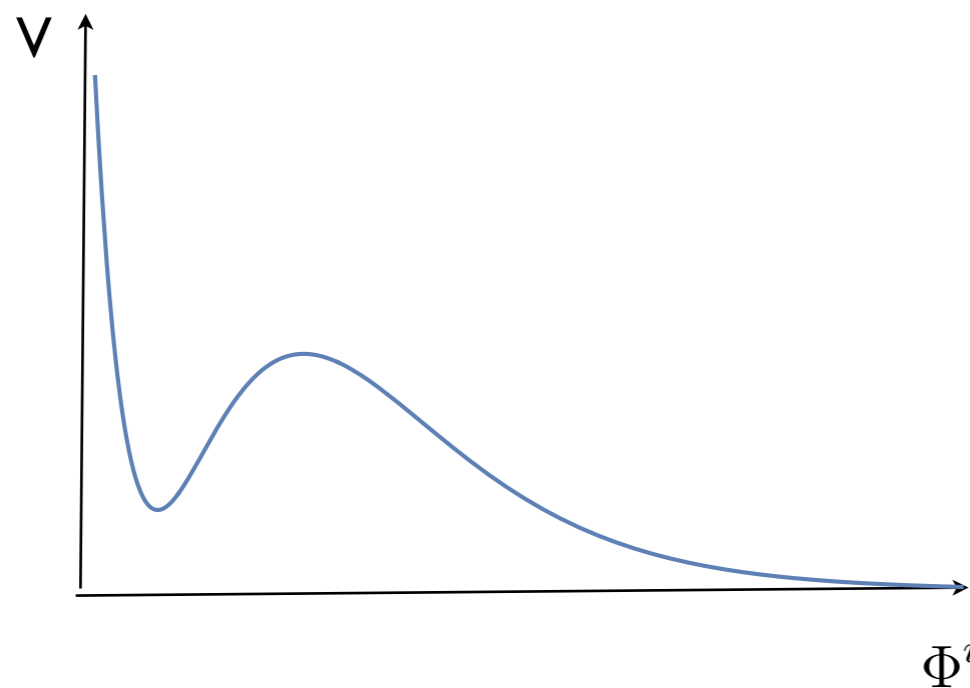
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The potential satisfies  $|\nabla V| \geq cV$

or

with  $c, c' > 0$  ( $\mathcal{O}(1)$  in Planck units)

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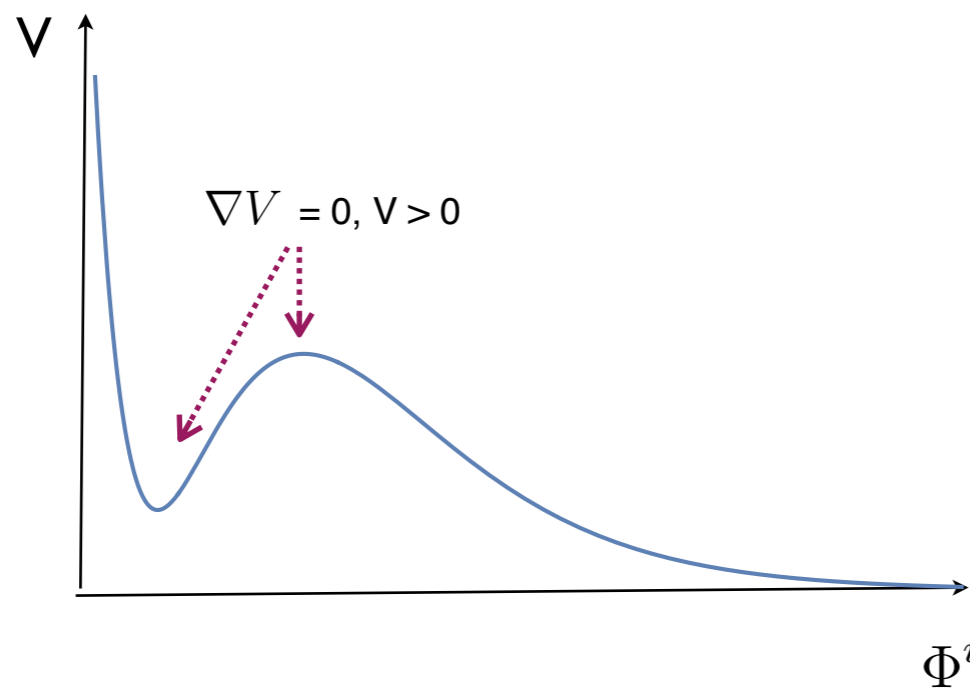
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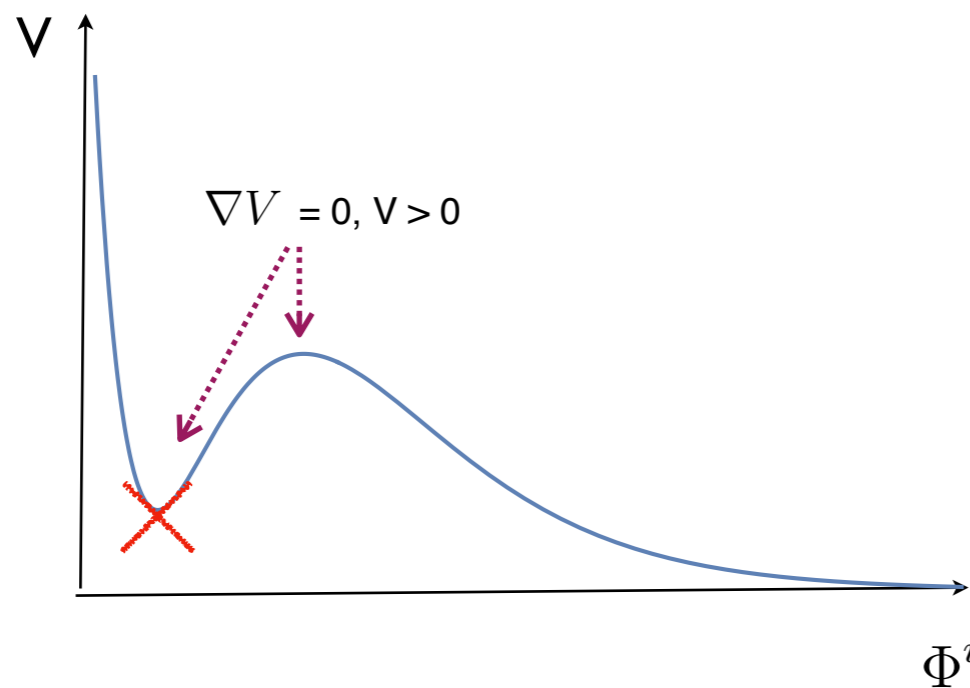
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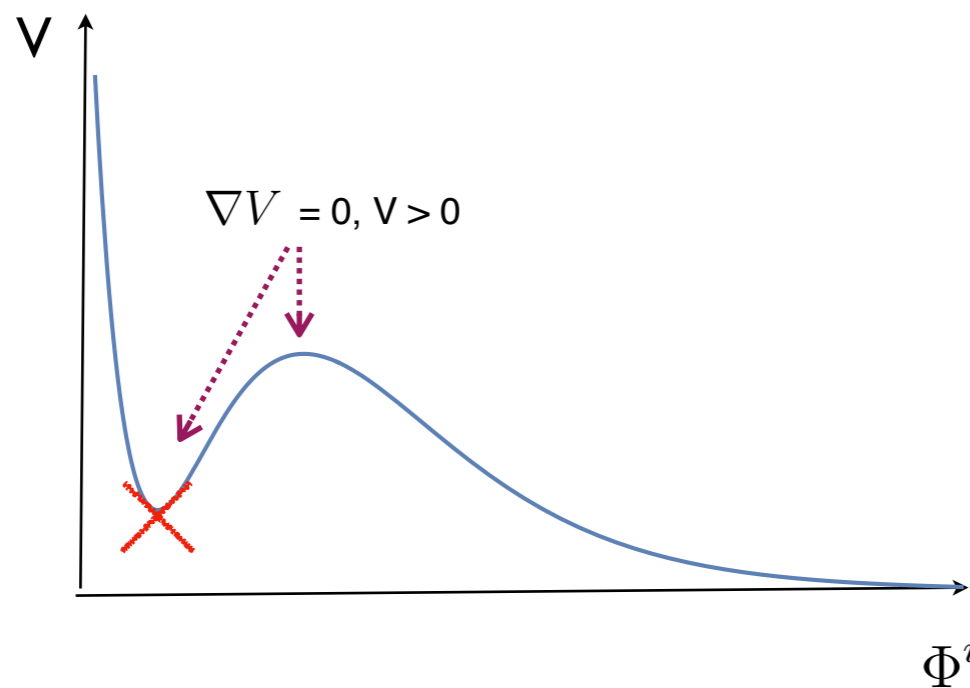
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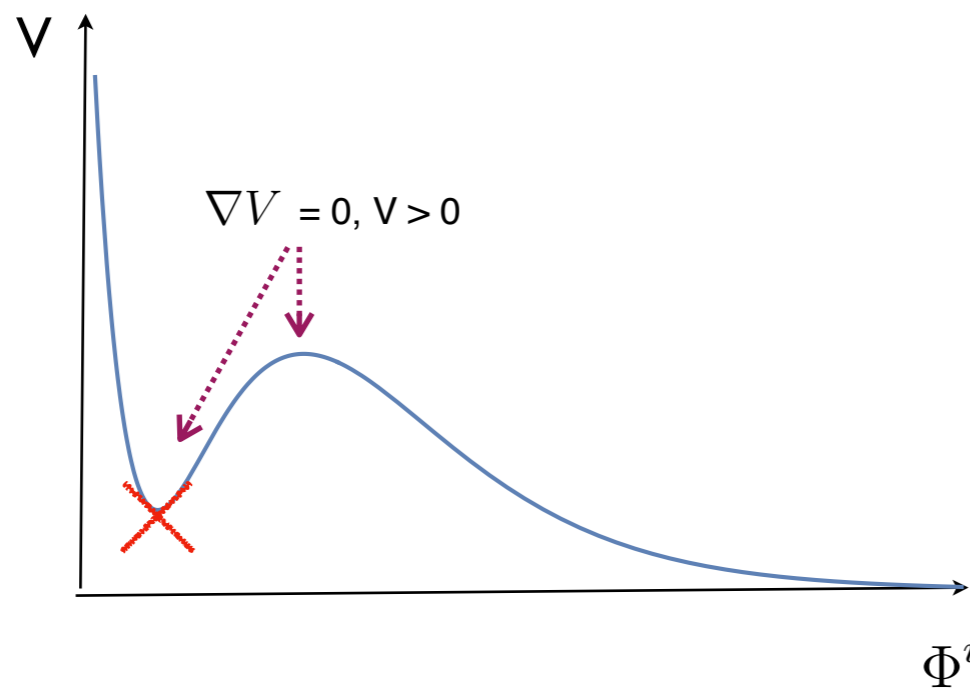
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If so, dark energy comes from quintessence field(s)

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KKLT 03

$10^{500}$   
dS vacua

OOSV 18

No dS vacua

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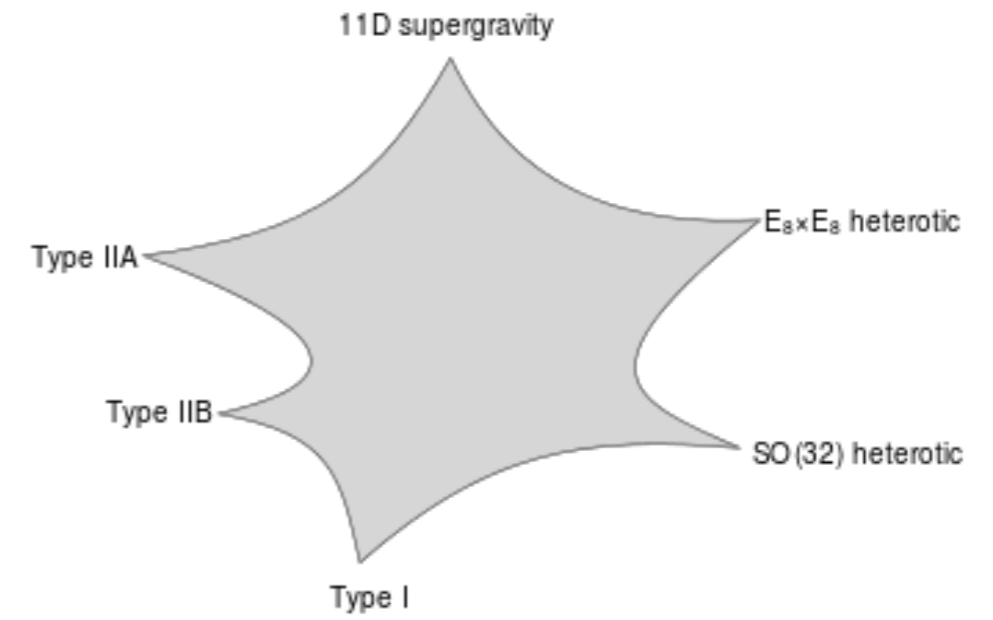
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Happy 60th birthday IPhT !!  
For many more to come

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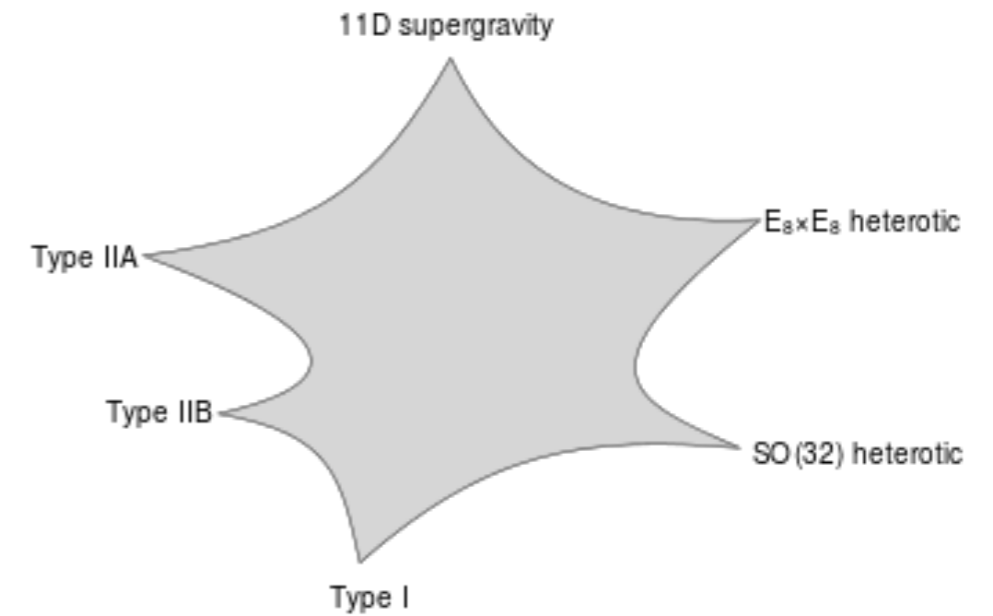
String theory is a remarkable and unique theory of quantum gravity



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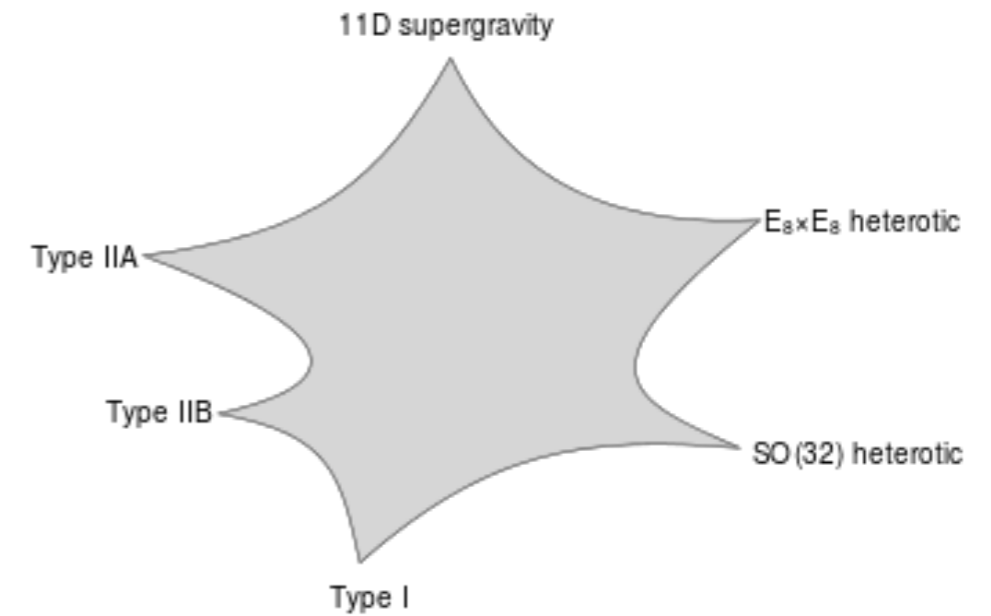




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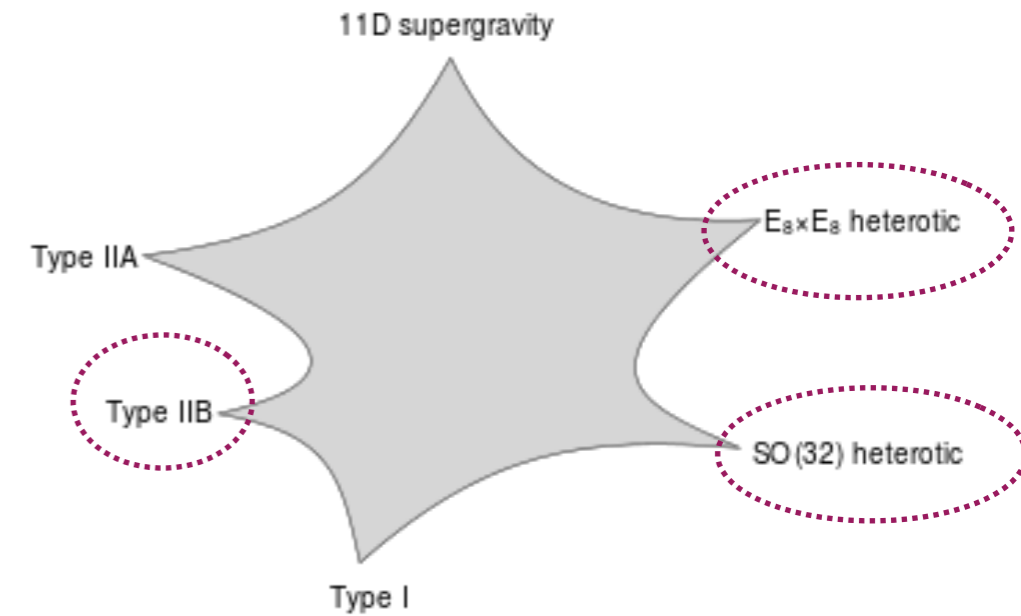
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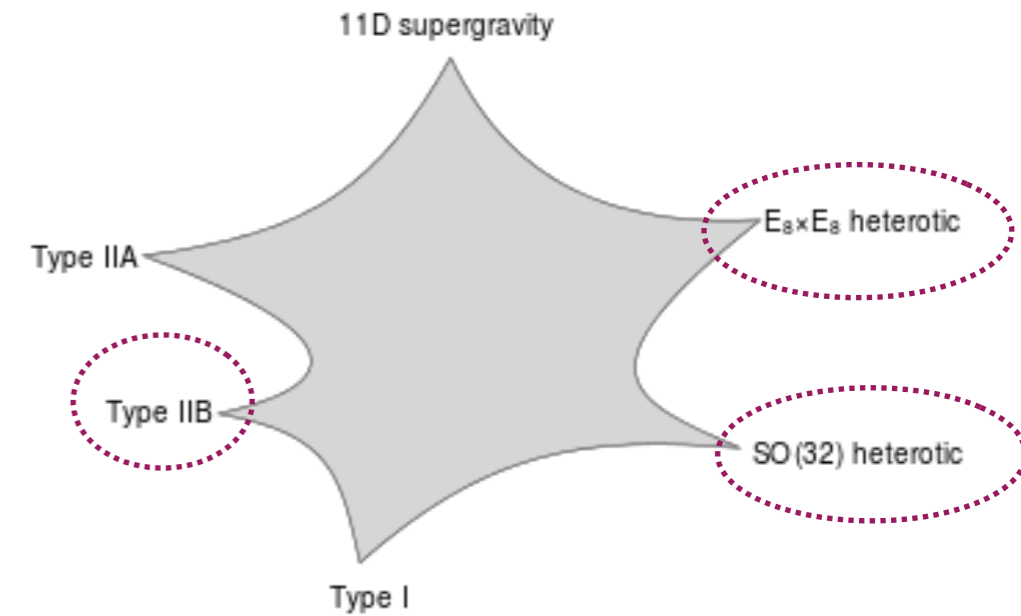
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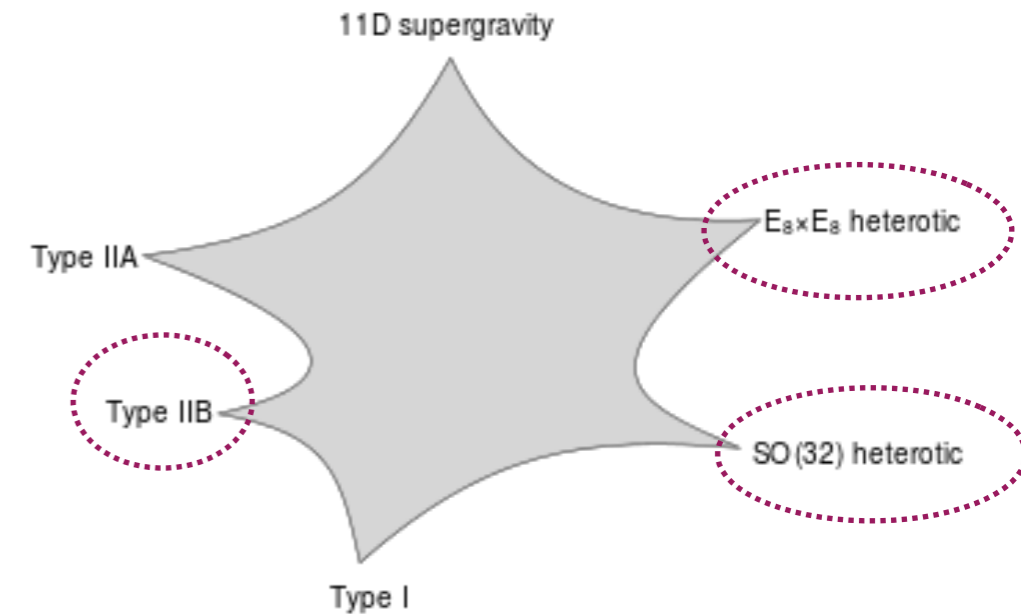
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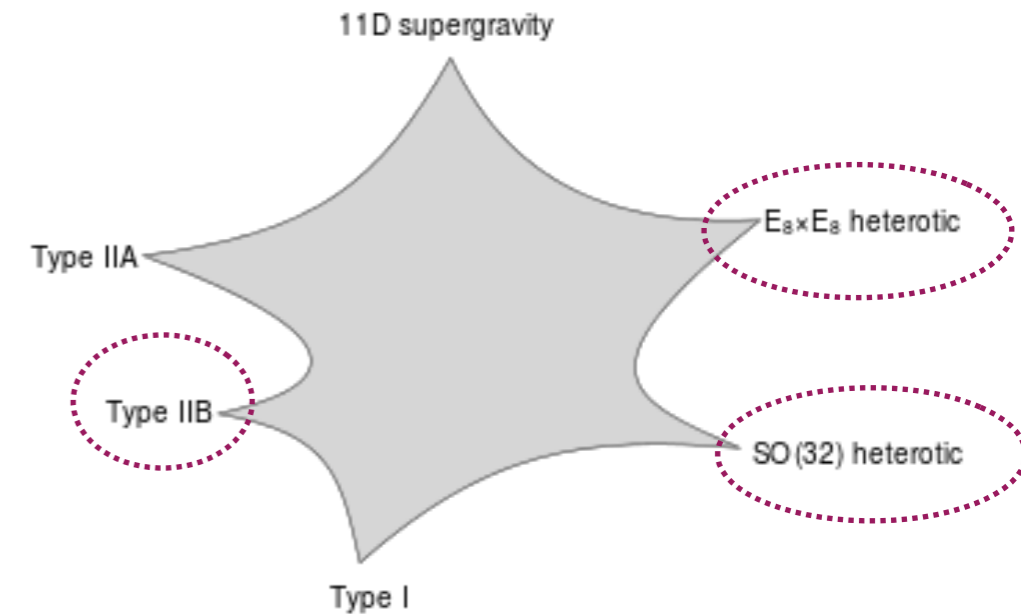
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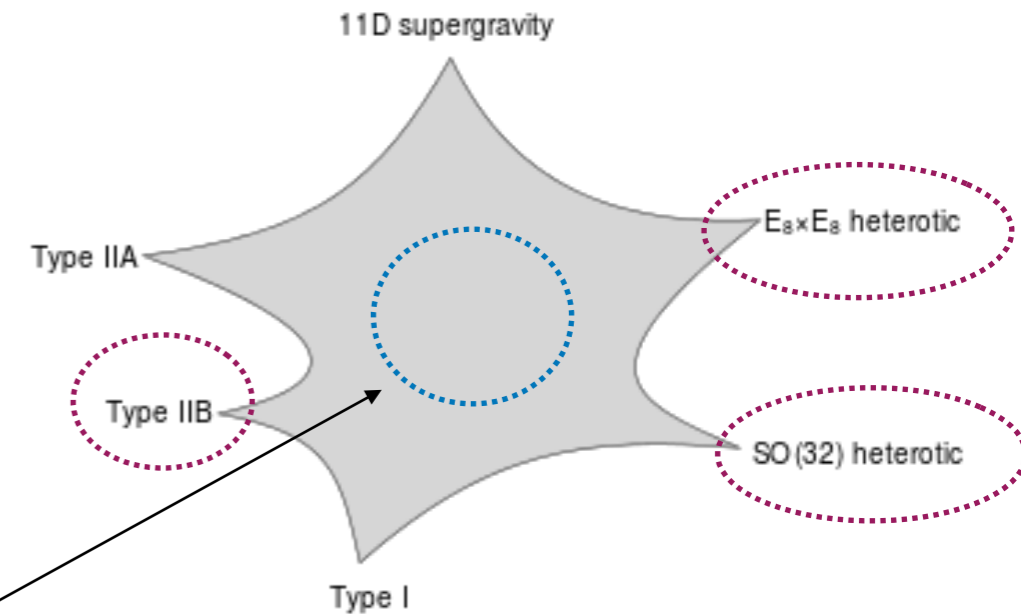


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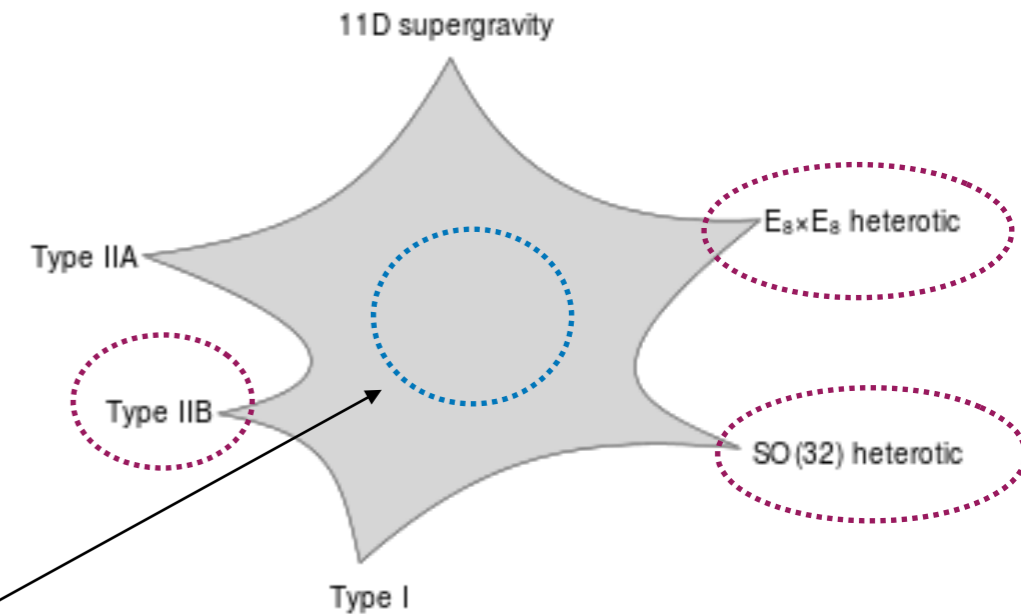
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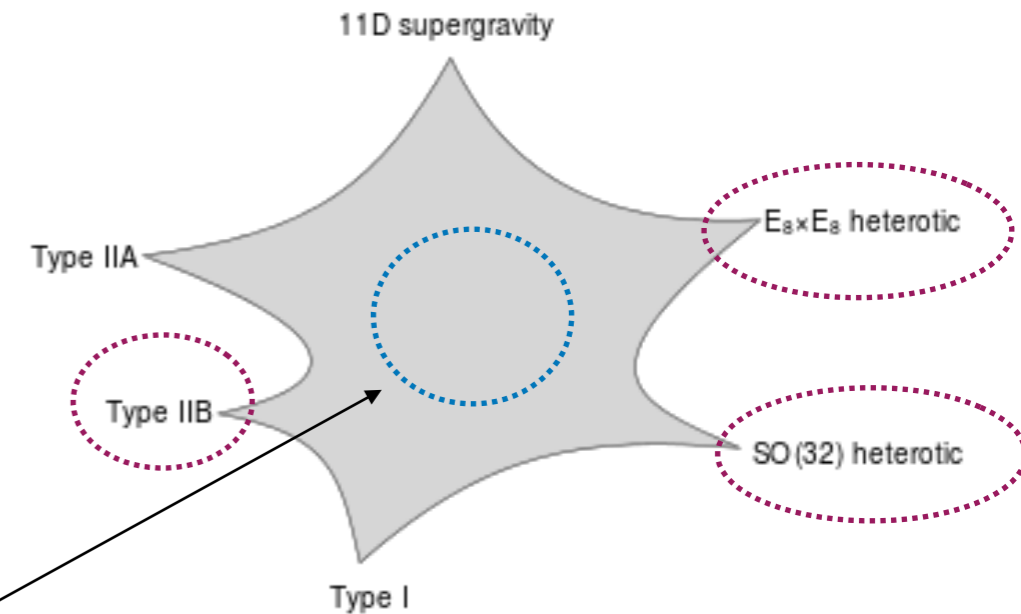
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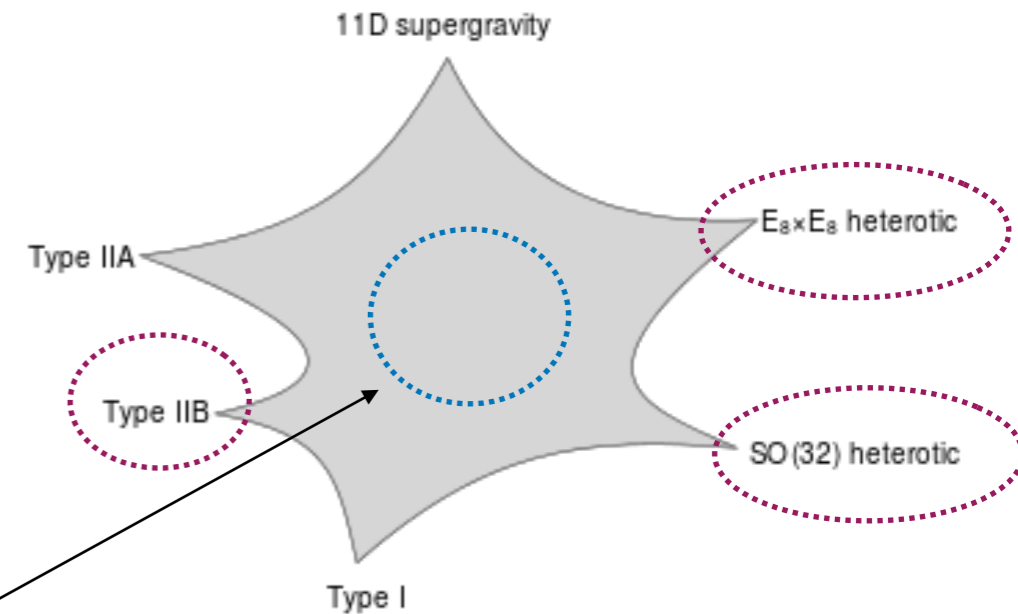
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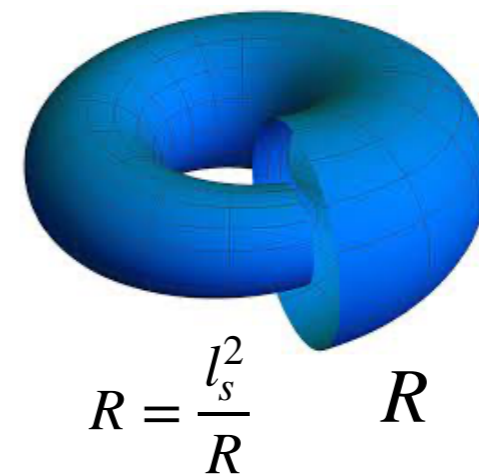
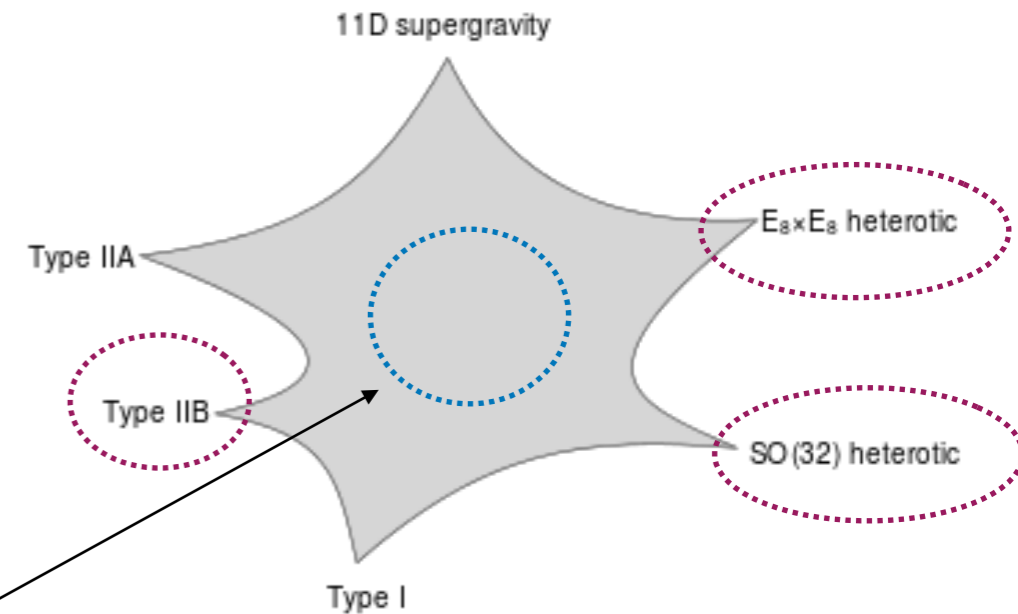
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T-folds

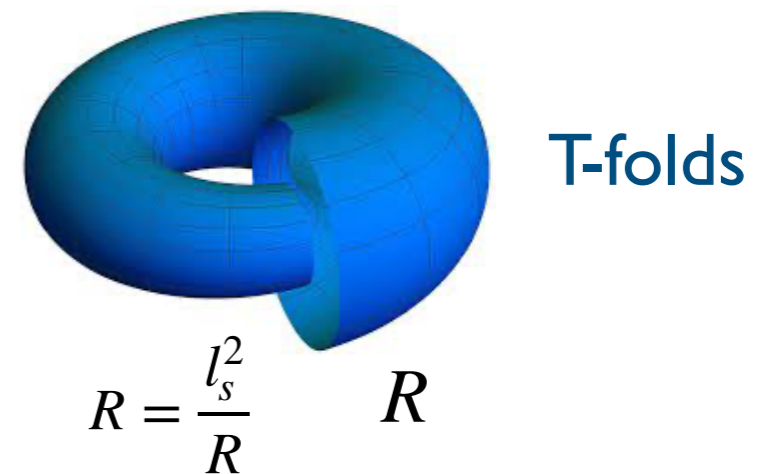
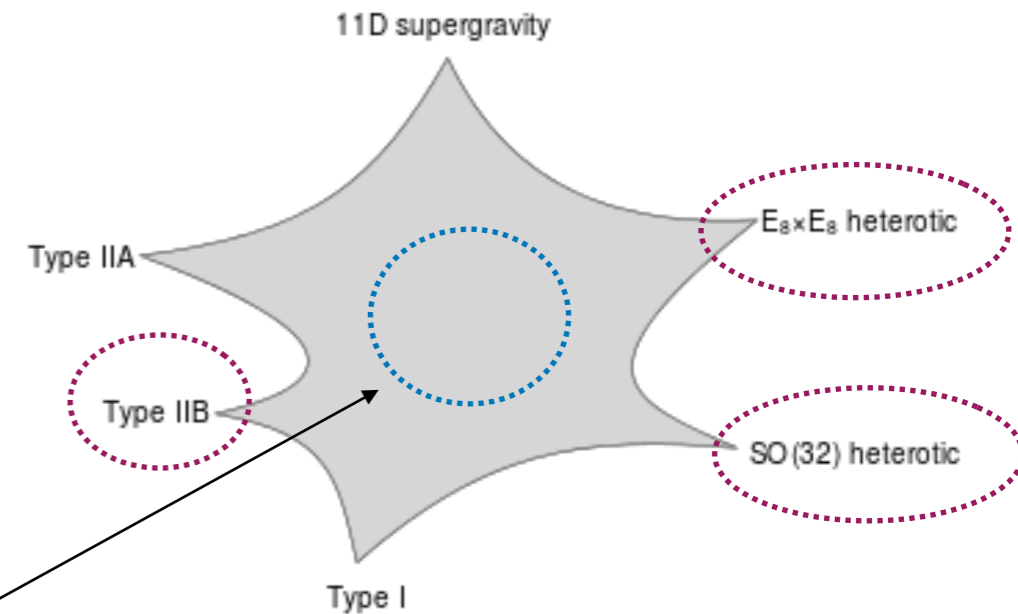
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Beautiful and still largely unexplored landscape

# Transplanckian Censorship Conjecture

Bedroya, Vafa 2019

- Sub-Planckian quantum fluctuations should remain quantum (cannot become larger than Hubble radius)

Or equivalently: The expansion of the universe must slow down before all sub-Planckian modes are stretched beyond the Hubble size

Two implications:

- no dS close to boundaries of moduli space, where

$$\frac{|\nabla V|}{V} \geq \frac{2}{\sqrt{(d-1)(d-2)}}$$

- dS can exist inside the bulk, if short lived

$$\tau \leq \frac{1}{H} \log \frac{M_P}{H}$$