The Swampland Distance Conjecture and towers of tensionless branes

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Based on: A. Font, A. H., L. E. Ibáñez [arXiv: 1904.05379 [hep-th]]

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June 6, 2019

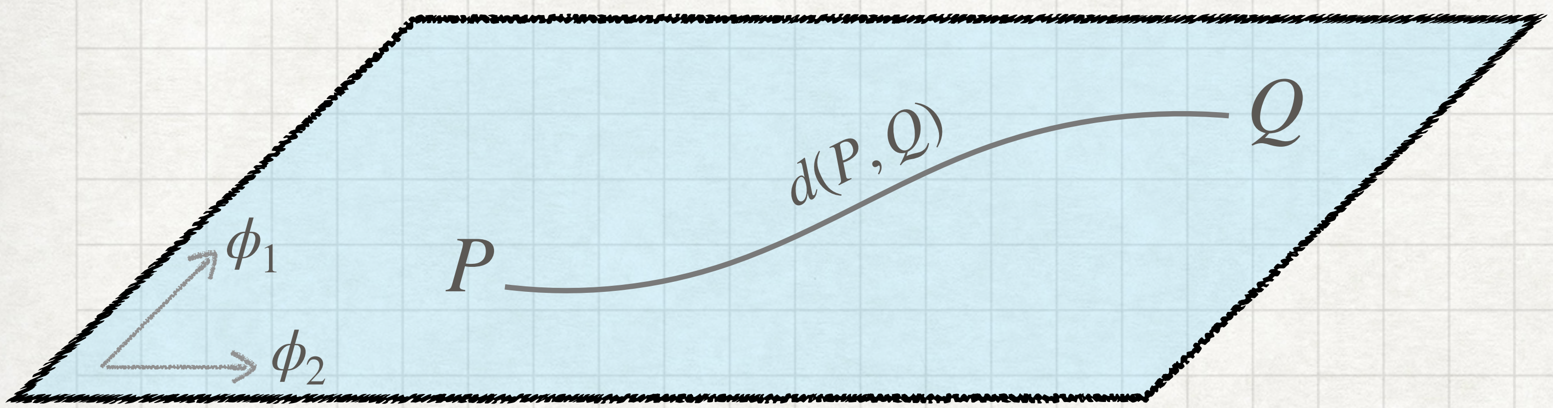
THE SWAMPLAND DISTANCE CONJECTURE

[Ooguri, Vafa '06]

Starting from a point P in moduli space, and moving to a point Q an infinite distance away, there appears a tower of states which becomes exponentially massless according to

$$M(Q) \;\sim\; M(P)\; e^{-\alpha d(P,Q)}$$

Scalar manifold with metric $g_{ij}(\phi_i)$ from kinetic terms



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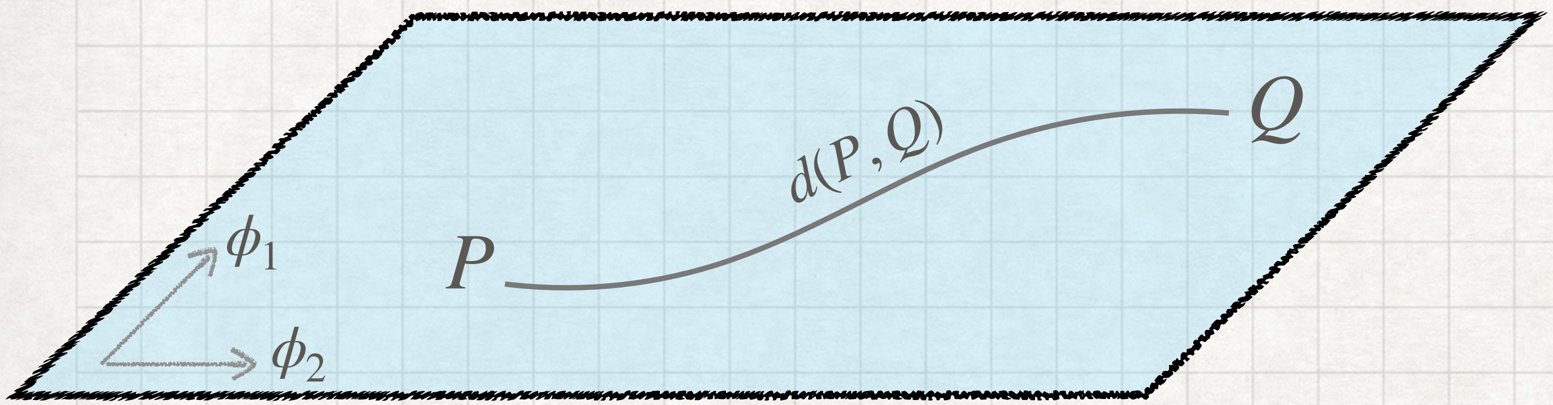
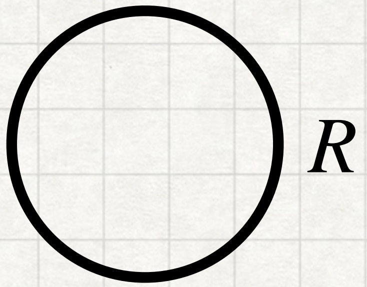


- Example: Compactification on a circle of radius



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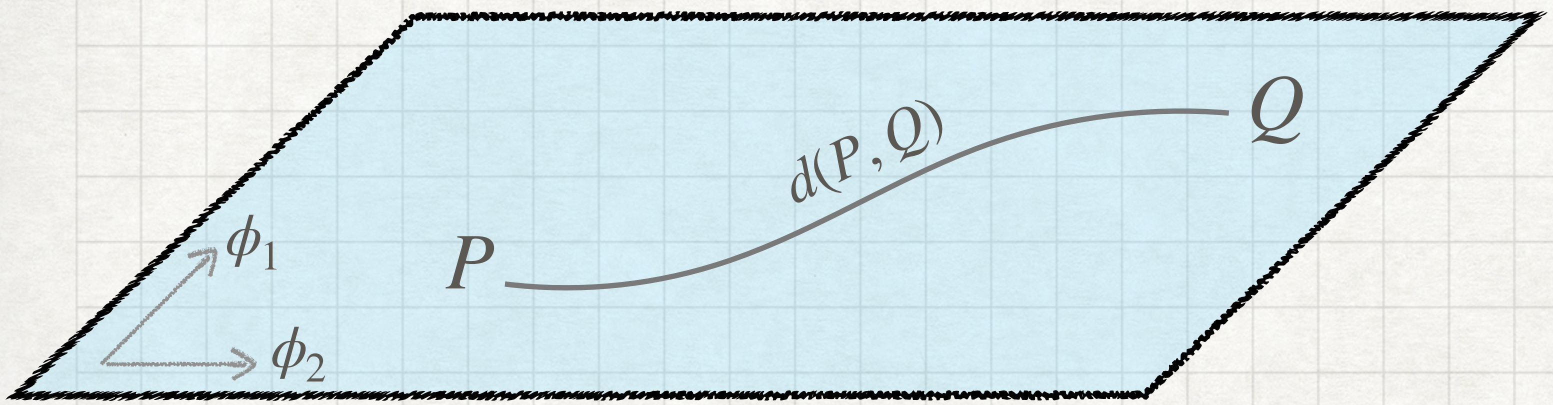

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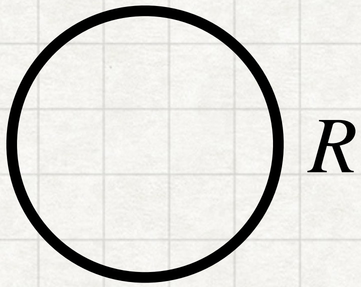

$R \to \infty$ Kaluza-Klein tower

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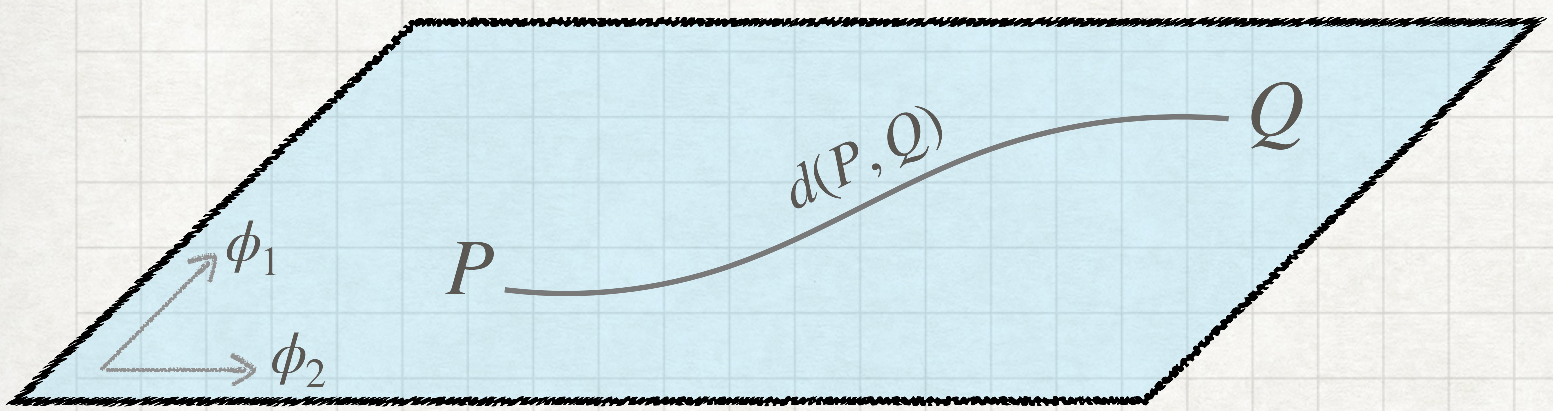

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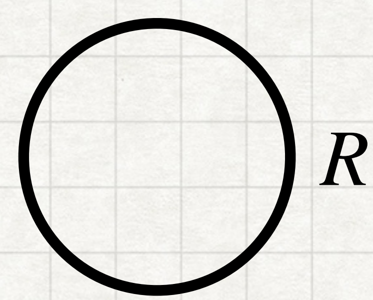

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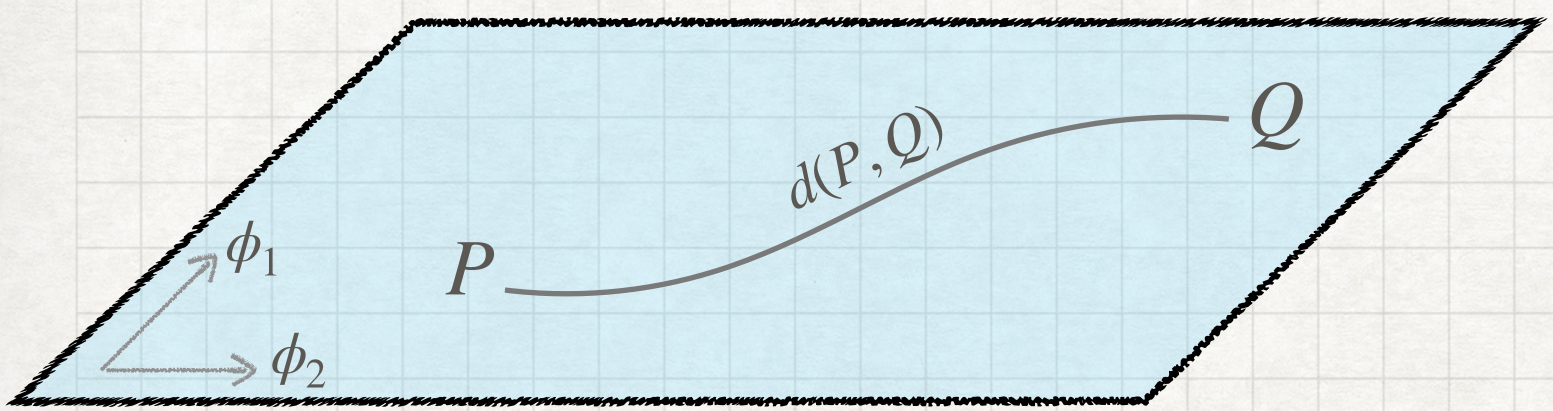

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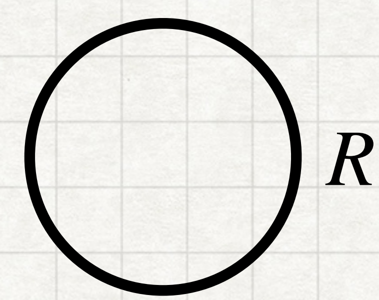

$R \to \infty$ Kaluza-Klein tower ✓

$R \to 0$? ? ? ? ? ? ?

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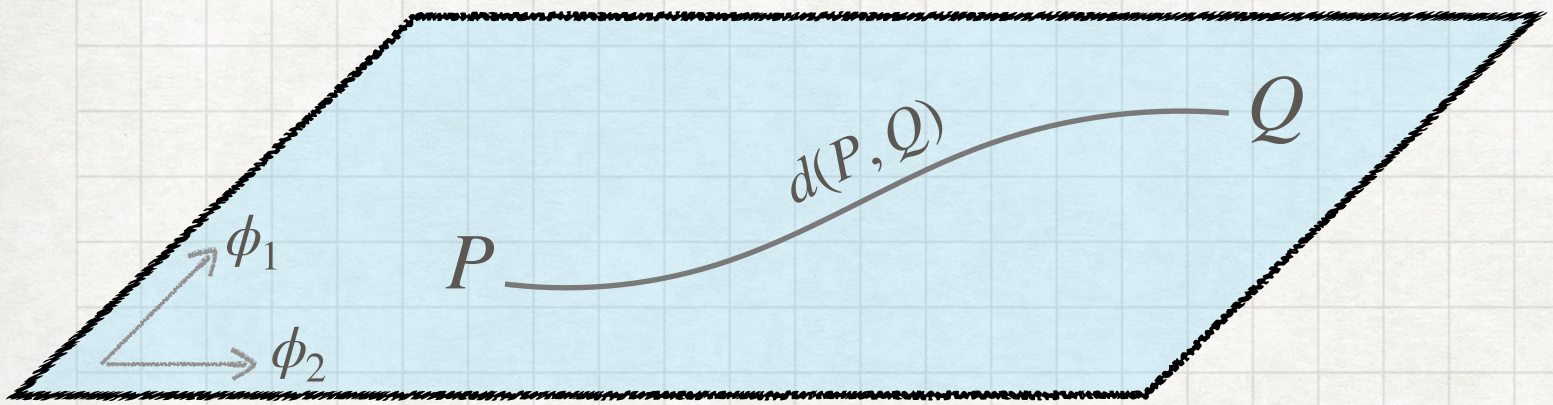

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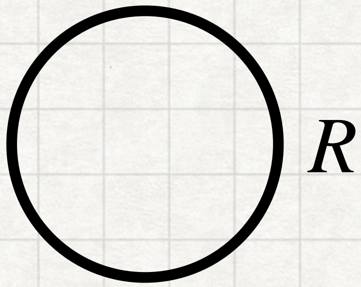

$R \to \infty$ Kaluza-Klein tower ✓

$R \to 0$ ✗

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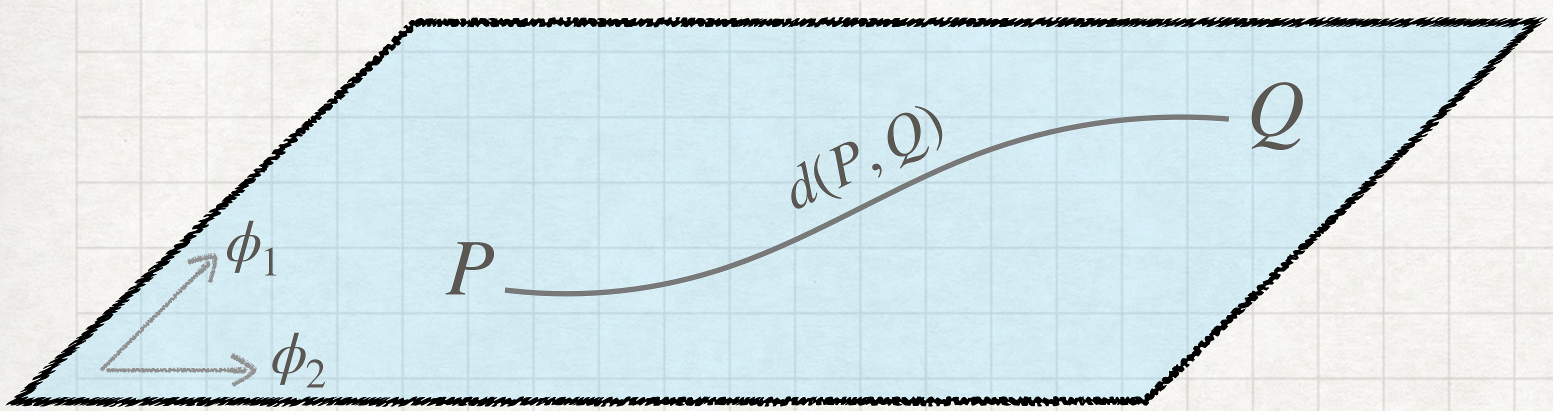

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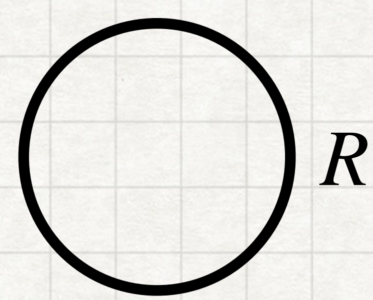

$R \to \infty$ Kaluza-Klein tower ✓

$R \to 0$ Winding tower ✓

THE SWAMPLAND DISTANCE CONJECTURE

[Ooguri, Vafa '06]

- Infinite towers of particles at infinite distance points in Complex Structure moduli space $\longrightarrow$ D3-branes wrapping 3-cyles in the internal CY

  [Grimm, Palti, Valenzuela '18]
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- Equivalent results for the mirror Kähler moduli space in type IIA $\longrightarrow$ Tower of particles from D0-D2 branes bound states [Corvilain, Grimm, Valenzuela '18]

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- BUT… What about extended objects? $\longrightarrow$ Infinite towers of **tensionless 4d strings and domain walls?**

TOWERS OF TENSIONLESS DOMAIN WALLS

-BUILDING THE TOWER-

Type IIA on CY (orientifolds) without fluxes $\longrightarrow$ Dp-branes wrapping (p-2)-cycles

1. Find a “basis of domain walls” and characterise what subset of the basis becomes tensionless at any infinite distance point

2. Use some monodromy to populate an infinite tower of DW states

TOWERS OF TENSIONLESS DOMAIN WALLS

-BUILDING THE TOWER-

1 Find a "basis of domain walls" and characterise what subset of the basis becomes tensionless at any infinite distance point

Brane	Cycle
D2	-
D4	P.D. $[\tilde{\omega}^a]$
D6	P.D. $[\omega_a]$
D8	$\mathcal{M}$
NS5	P.D. $[\beta^K]$

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Volume wrapped by the Dp-brane

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Volume wrapped by the Dp-brane

- Number of branes of each kind

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Volume wrapped by the Dp-brane

- Number of branes of each kind
- Combine them into a vector

$$\vec{q} = (e_0, e_a, q^a, m, h_K)$$

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$\vec{\Pi}(T^a) \longrightarrow$ Period vector

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BOUND STATES OF TENSIONLESS BRANES ARE TENSIONLESS

TOWERS OF TENSIONLESS DOMAIN WALLS

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- Subset of tensionless domain walls $\longrightarrow$ Constraints on the components of $\vec{q}$

TOWERS OF TENSIONLESS DOMAIN WALLS

-BUILDING THE TOWER-

Type IIA on CY (orientifolds) without fluxes $\longrightarrow$ Dp-branes wrapping (p-2)-cycles

1. Find a "basis of domain walls" and characterise what subset of the basis becomes tensionless at any infinite distance point ✓

2. Use some monodromy to populate an infinite tower of DW states

TOWERS OF TENSIONLESS DOMAIN WALLS

-BUILDING THE TOWER-

2 Use some monodromy to populate an infinite tower of DW states

$\vec{\Pi}(T^a) \longrightarrow$ Period vector

$$K = -\log\left(i\,\Pi \cdot \Upsilon \cdot \Pi\right)$$

Monodromy transformation

$$\boxed{\begin{gathered}\vec{\Pi}(T^a) \;\longrightarrow\; R_i\,\vec{\Pi}(T^a) \;=\; \vec{\Pi}(T^a, T^i + i) \\ K \;\longrightarrow\; K\end{gathered}}$$

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$$K \;\longrightarrow\; K$$

$$T \;=\; 2\,e^{K/2}\,\Pi\cdot q \;\longrightarrow\; T' \;=\; 2\,e^{K/2}\,\left[R_i\,\Pi\right]\cdot q \;=\; 2\,e^{K/2}\,\Pi\cdot\left[R_i^t\,q\right]$$

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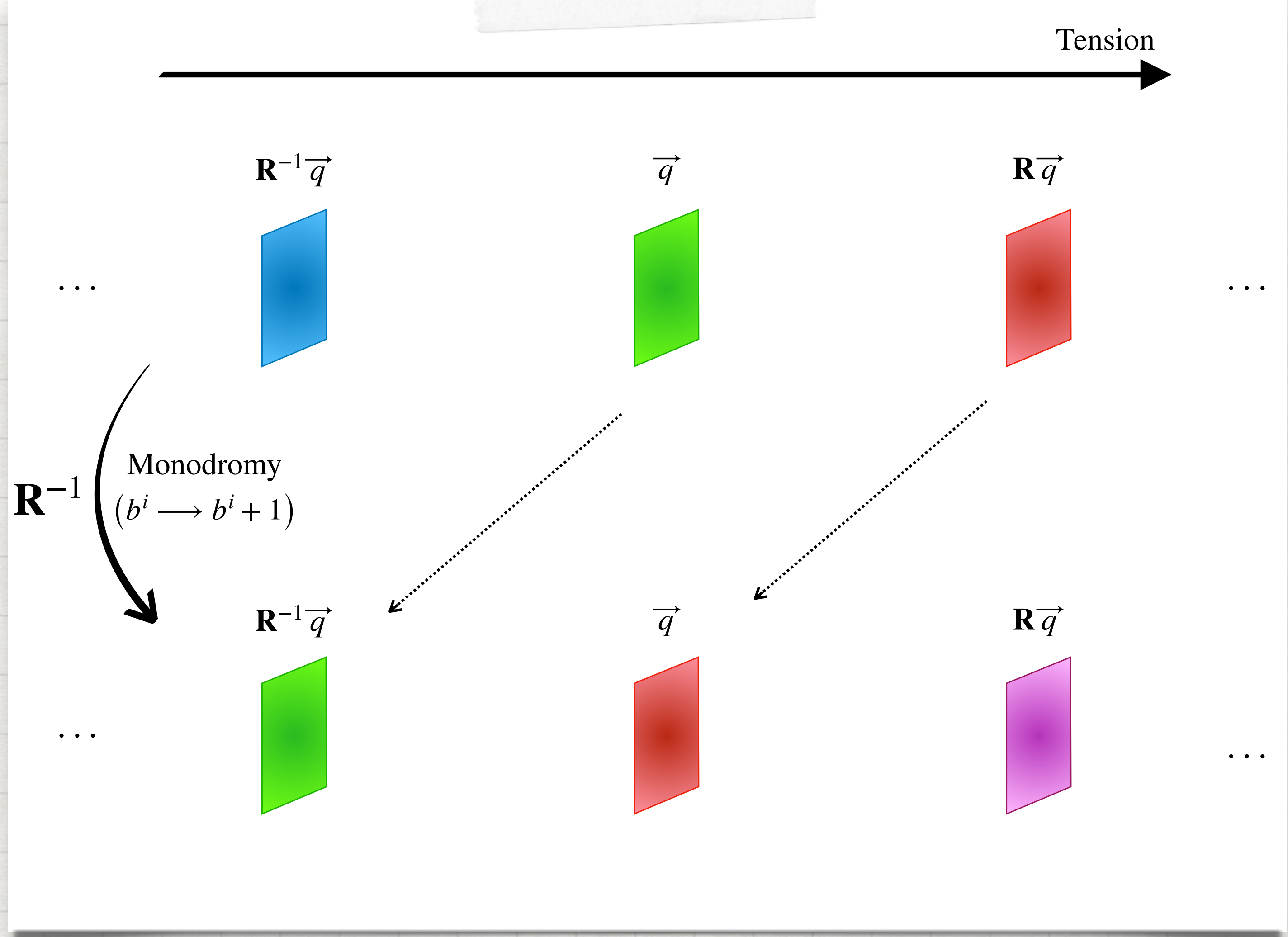

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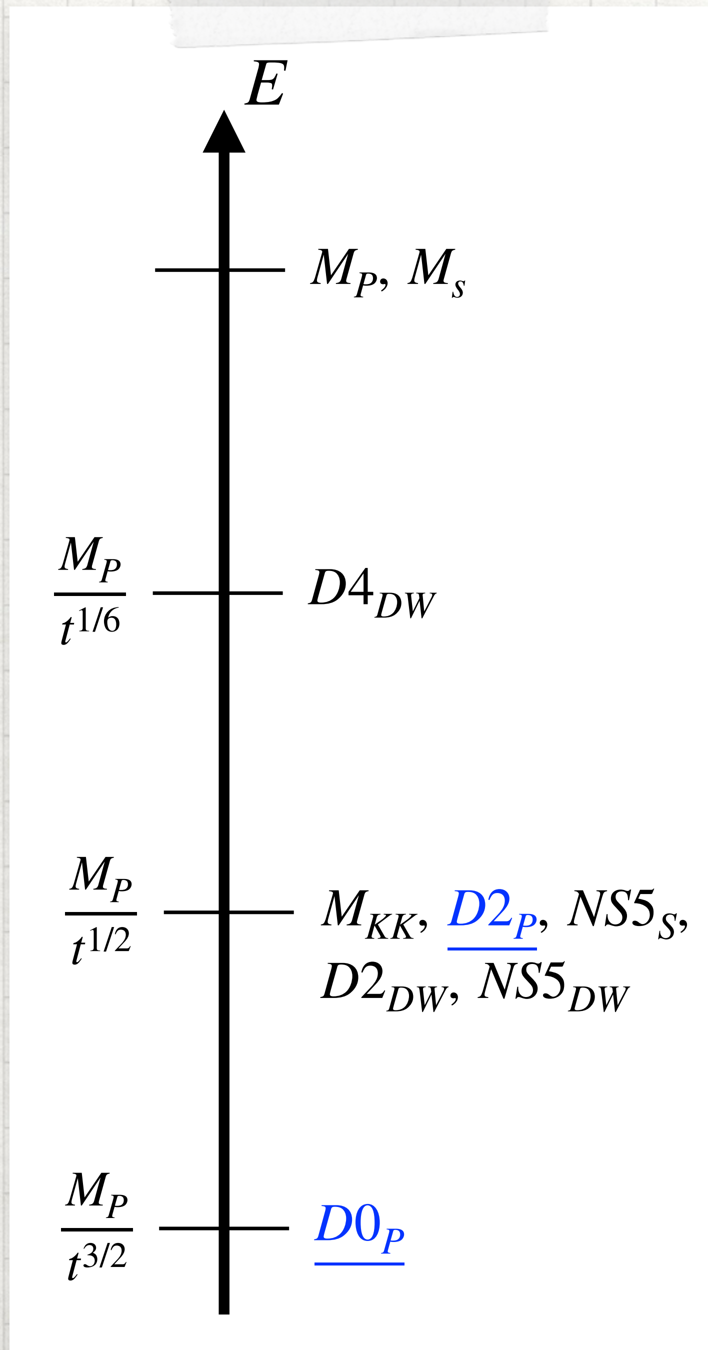
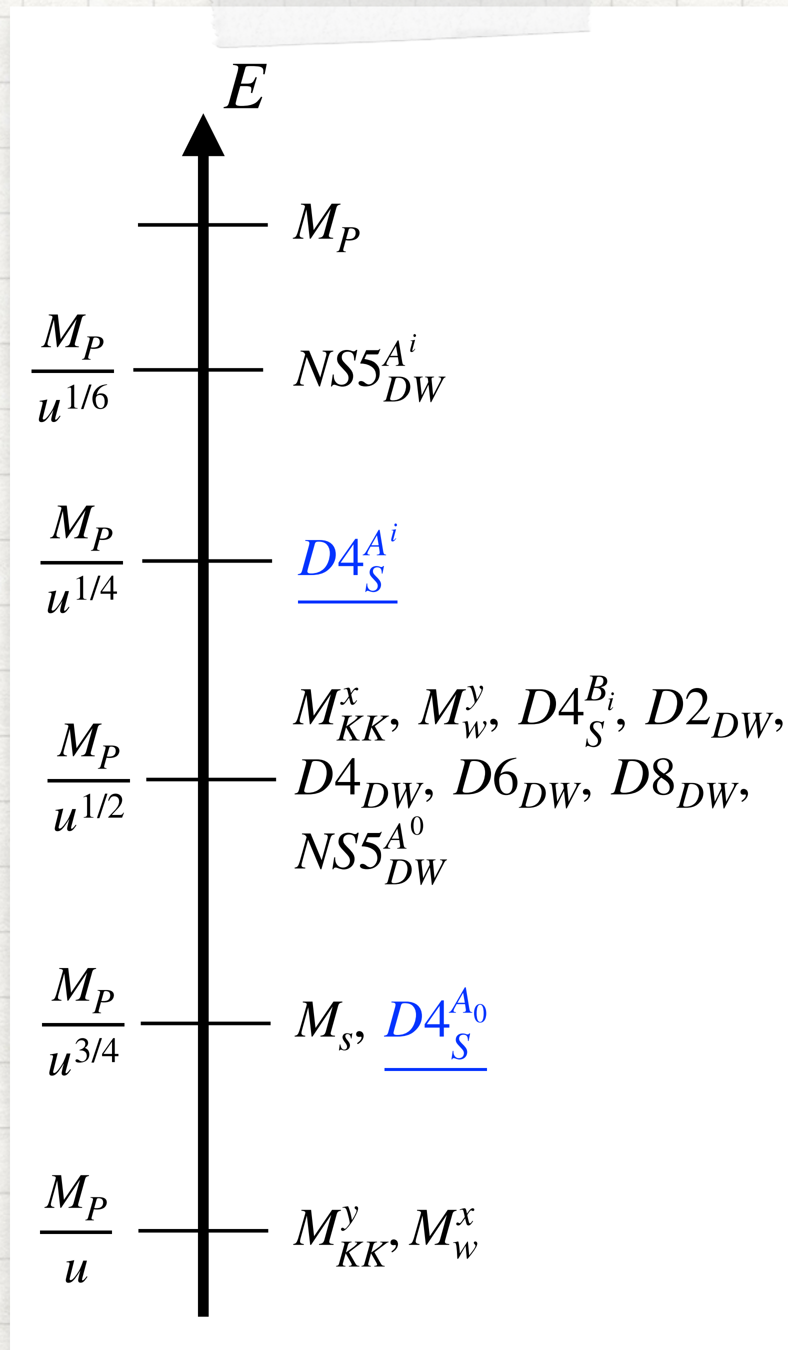
TOWERS OF TENSIONLESS DOMAIN WALLS

-ENERGY SCALES-

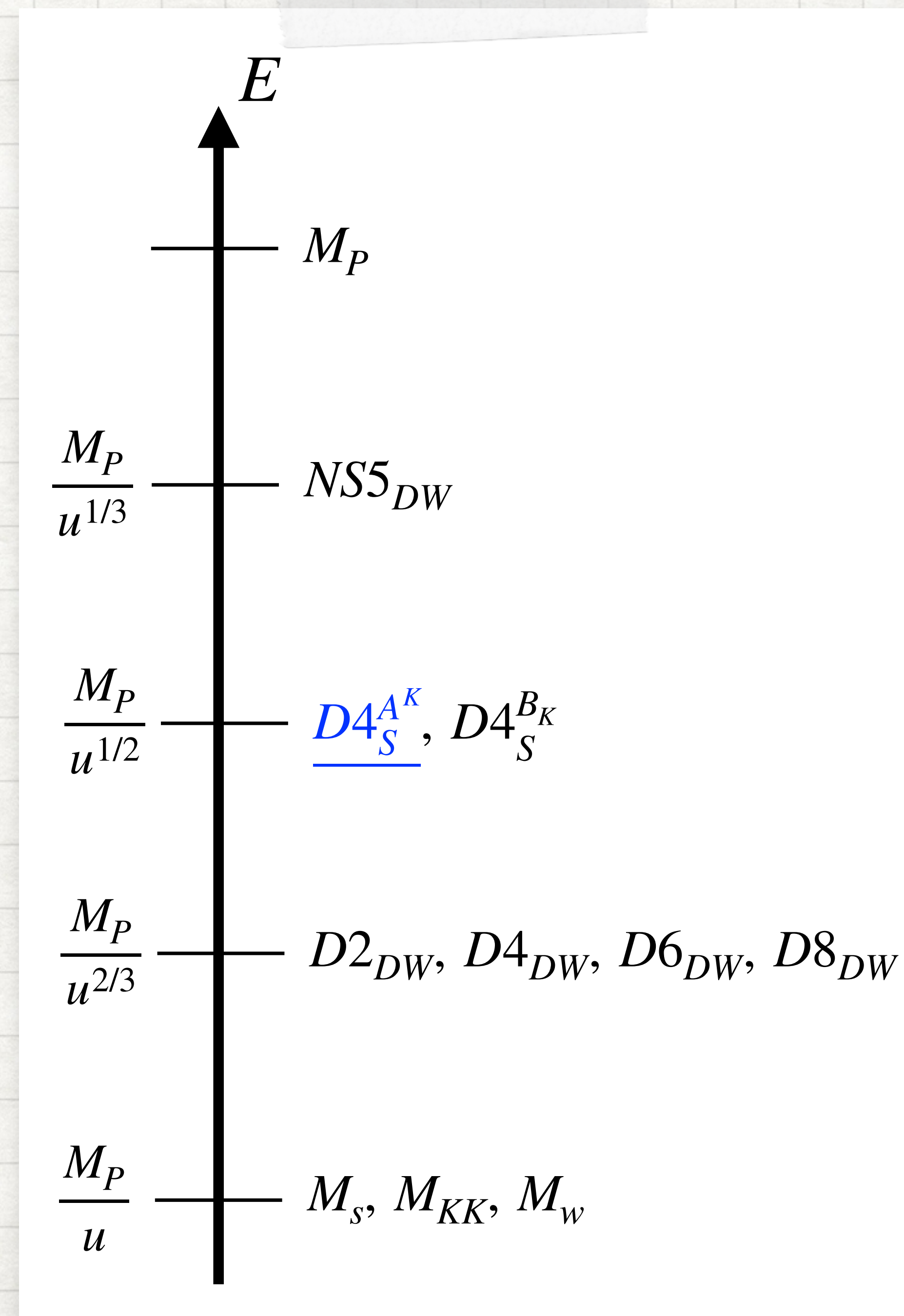
Type IIA isotropic toroidal (orientifold) $\longrightarrow$ $S,\ T,\ U$ moduli



$t \to \infty$



$u \to \infty$



$s \propto u \to \infty$

SOME IMPLICATIONS & CONCLUSIONS

- **SDC** ⟶ Infinite towers of tensionless 4d extended objects (strings and domain walls) at infinite distances for general CY_3
- Relation to **WGC** ⟶ Prevent **global symmetry** at infinite distance
- **Energy scales** of these towers are **<u>not heavier</u>** than that of particles (in general)
    - Implications for the **validity of the EFT**
    - Implications for the **emergence proposal** → Species bound → Emergent potentials
- Towers of **exotic domain walls**


That's all Folks!

BACK-UP SLIDES

TOWERS OF TENSIONLESS DOMAIN WALLS

-TOROIDAL CASE-

1 Find a "basis of domain walls" and characterise what subset of the basis becomes tensionless at any infinite distance point

Brane	Cycle	Tension (in units of $M_P^3/\sqrt{4\pi}$)
D2	-	$\frac{e_0}{(8\,n^0n^1n^2n^3t^1t^2t^3)^{1/2}}$
D4	i-th 2-torus	$\frac{\lvert e_iT^i\rvert}{(8\,n^0n^1n^2n^3t^1t^2t^3)^{1/2}}$
D6	i-th and j-th 2-tori	$\frac{\lvert q^iT^jT^k\rvert}{(8\,n^0n^1n^2n^3t^1t^2t^3)^{1/2}}$
D8	All tori	$\frac{\lvert mT^1T^2T^3\rvert}{(8\,n^0n^1n^2n^3t^1t^2t^3)^{1/2}}$
NS5	$y^1=y^2=y^3=0$	$\frac{\lvert h_0N^0\rvert}{(8\,n^0n^1n^2n^3t^1t^2t^3)^{1/2}}$
NS5	$y^i=x^j=x^k=0$	$\frac{\lvert h_iN^i\rvert}{(8\,n^0n^1n^2n^3t^1t^2t^3)^{1/2}}$

$$T_{\mathrm{D}p}(\gamma_{p-2}) = \frac{M_P^3}{\sqrt{4\pi}}\,4e^{K/2}\mathcal{V}_{p-2}$$

Volume wrapped by the Dp-brane

$$\vec{q} = (e_0, e_i, q^i, m, h_I)$$

- For general bound states

$$T = 2\,e^{K/2}\,\lvert W\rvert$$

$$\sum_i \lvert W_i\rvert \leq \left\lvert \sum_i W_i \right\rvert$$

TOWERS OF TENSIONLESS STRINGS

1. Find a "basis of strings" and characterise what subset of the basis becomes tensionless at any infinite distance point

General CY_3

Brane	Cycle	Tension (in units of M_P^2)
D4	P.D. $[\beta^K]$	$\frac{1}{2} e^{K_{CS}/2}\, e^{\phi_4}\, \lvert X^K \rvert$
D4	P.D. $[\alpha_K]$	$\frac{1}{2} e^{K_{CS}/2}\, e^{\phi_4}\, \lvert \mathcal{F}^K \rvert$
NS5	P.D. $[\omega_a]$	$8\, e^{K_K} \left\lvert \frac{1}{2} \sum_{b,c} \kappa_{abc}\, T^b\, T^c \right\rvert$

Toroidal orbifold

Brane	Cycle	Tension (in units of M_P^2)
D4	P.D. $[\beta^K]$	$\sqrt{\frac{n^K}{2n^I n^J n^L}}$
D4	P.D. $[\alpha_K]$	$\frac{1}{4n^K}$
NS5	P.D. $[\omega_a]$	$\frac{2}{t^i}$

$$T_{\mathrm{D4}}(\gamma_3) = \frac{M_P^2}{2} \frac{e^{\phi_4}}{\mathcal{V}^{1/2}} \mathcal{V}_3$$

$$T_{\mathrm{NS5}}(\gamma_4) = 8 M_P^2\, e^{K_K}\, \mathcal{V}_4 .$$

TOWERS OF TENSIONLESS DOMAIN WALLS

-BUILDING THE TOWER-

3 Check that (at least) one of the monodromies populates only tensionless states

- Subset of tensionless domain walls $\longrightarrow$ Constraints on the components of $\vec{q}$

Do monodromy transformations preserve these constraints? ✓

$$P_i^t \cdot q = \begin{pmatrix} 0 & \vec{\delta}_i^{\,t} & 0 & 0 & 0 \\ 0 & 0 & \kappa_{iab} & 0 & 0 \\ 0 & 0 & 0 & \vec{\delta}_i & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} e_0 \\ e_a \\ q^a \\ -m \\ h_K \end{pmatrix} = \begin{pmatrix} e_i \\ \kappa_{iab} q^b \\ -m\,\vec{\delta}_i \\ 0 \\ 0 \end{pmatrix} = q'$$

<u>Example:</u> Torus $t^1 \longrightarrow \infty$

Subset of tensionless domain walls

$$e_1 = q^2 = q^3 = m = 0 \xrightarrow{\text{Monodromy}} \vec{q}\,' \text{ with } e_1' = q^{2\prime} = q^{3\prime} = m' = 0$$

TOWERS OF TENSIONLESS DOMAIN WALLS

-ENERGY SCALES-

Type IIA isotropic toroidal (orientifold) $\longrightarrow S, T, U$ moduli