

AdS scale separation and the distance conjecture

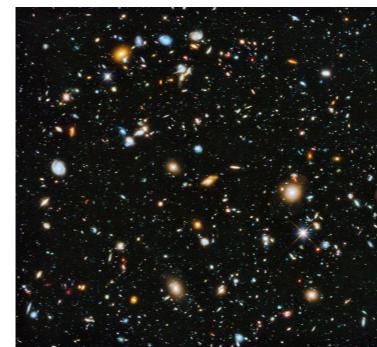
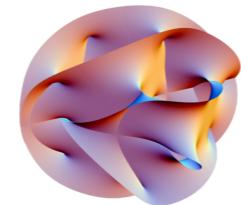
2212.06169 with Gary Shiu, Flavio Tonioni and Thomas Van Riet

SUSY 2023, Southampton



Scale separation

$$L_{KK} \ll L_{AdS}$$



AdS distance conjecture

AdS distance conjecture:

$$m_{tw} = m_0 |\Lambda|^\alpha \text{ for } \Lambda \rightarrow 0$$

Inspired from the swampland distance conjecture

Strong version for **SUSY** AdS: $\alpha = \frac{1}{2}$

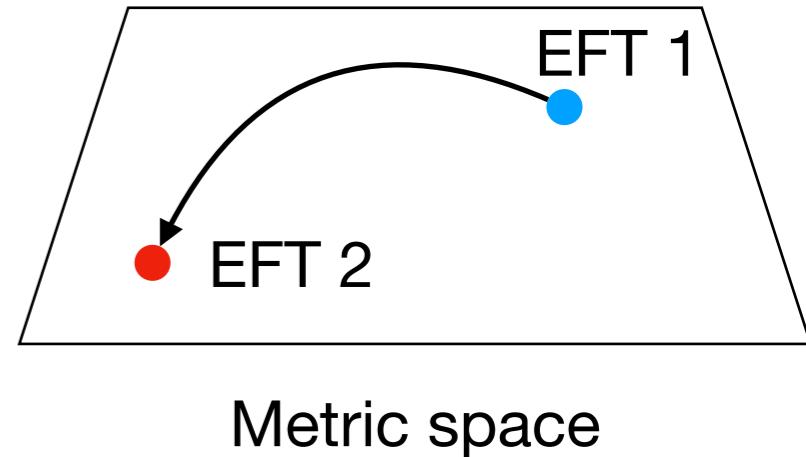
→ Forbids scale separation with KK tower

$$m_{tw} \propto 1/L_{KK}, \quad \Lambda \propto L_{\text{AdS}}^{-2}, \quad \Rightarrow \quad L_{KK} \sim L_{\text{AdS}}$$

Remarks:

1. Λ is determined by quantised fluxes, not a continuous quantity
2. Counterexamples to strong ADC are known: DGKT

[Lüst, Palti, Vafa, 2019]



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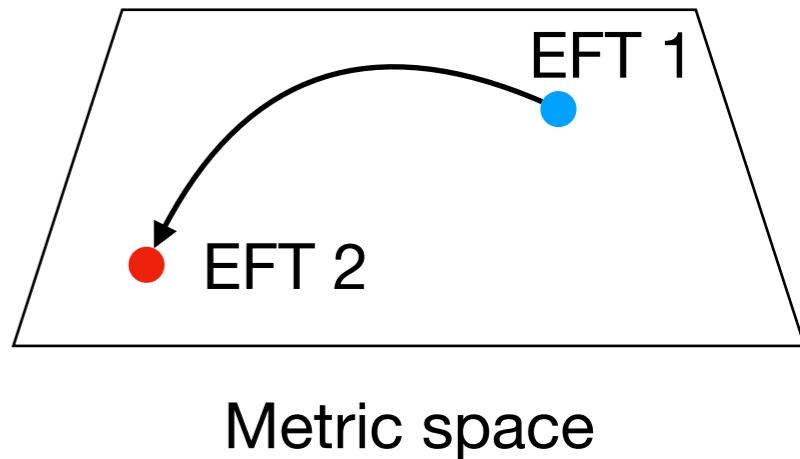
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Metric space

Can we go beyond the notion of AdS distance and use the ordinary distance conjecture instead?

Scale-separated vacua in mIIA

On orbifolded $\mathbb{T}^6/\text{Calabi-Yau}$

[DeWolfe, Kachru, Giryavets, Taylor, 2005]

[Lüst, Tsimpis, 2004]

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[Caviezel, Koerber, Körs, Lüst, Tsimpis, Zagermann, 2008]

...

$$H_3 = 2m \operatorname{Re}\Omega$$

$$dJ = 0$$

$$g_s F_0 = 5m$$

$$d\operatorname{Im}\Omega = 0$$

$$g_s F_2 = 0$$

$$dF_2 = H \wedge F_0 + j_{O6}$$

$$g_s F_4 = \frac{3}{2} m J \wedge J$$

$$g_s F_6 = 0$$

$$L_{AdS}^{-2} = m^2$$

Scale-separated vacua in mIIB

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$$F_0 \sim n^0$$

$$F_4 \sim n$$

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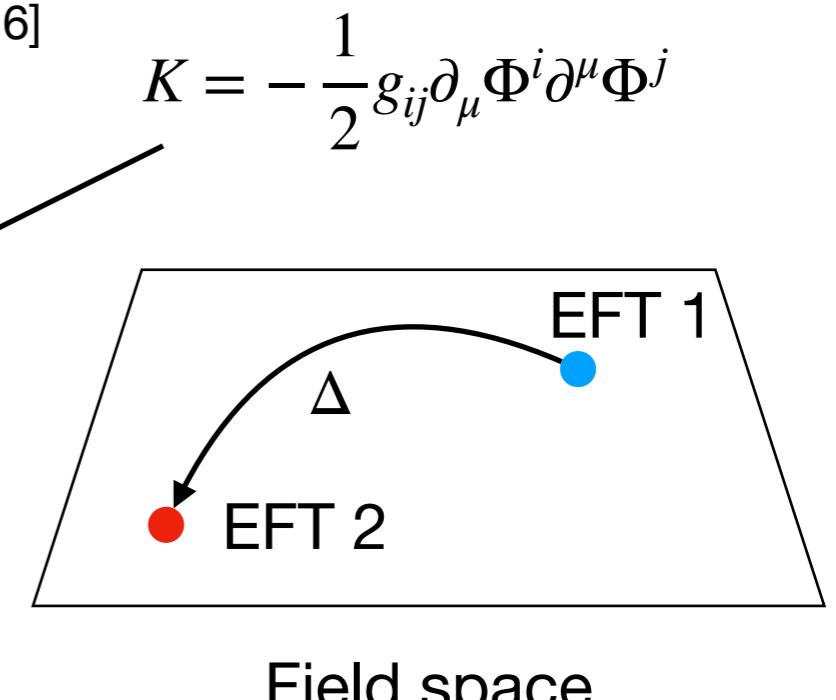
n is the F_4 flux quantum and labels the flux vacua

(Refined) Swampland distance conjecture

[Ooguri, Vafa, 2006], [Kläwer, Palti, 2016]

$$m_{tw} = m_0 e^{-\beta \Delta} \text{ for } \Delta \rightarrow \infty$$

$$\Delta = \int ds \frac{1}{M_{Pl}} \sqrt{g_{ij} \frac{d\Phi^i}{ds} \frac{d\Phi^j}{ds}}$$



Refined version: from moduli to all fields

For DGKT:

Flux vacua are labeled by flux quantum n

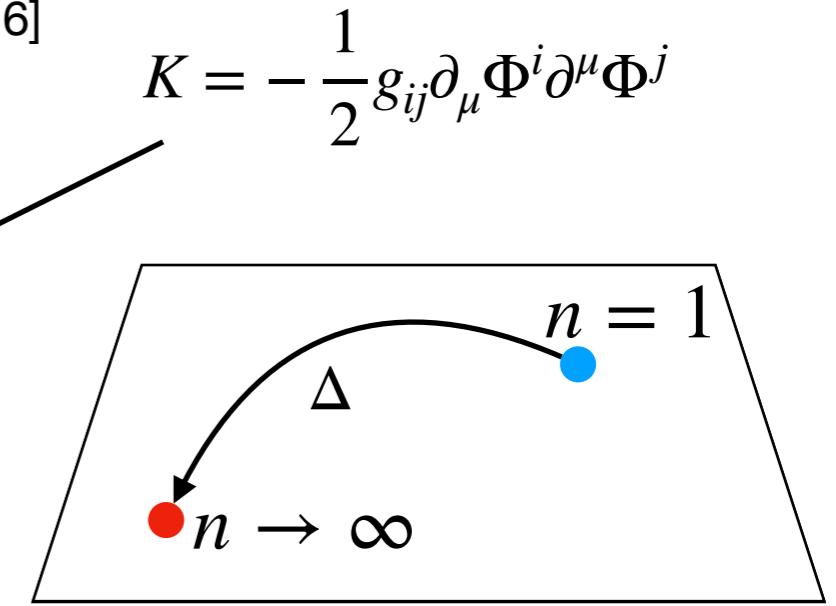
→ Invent a field that interpolates between different flux vacua

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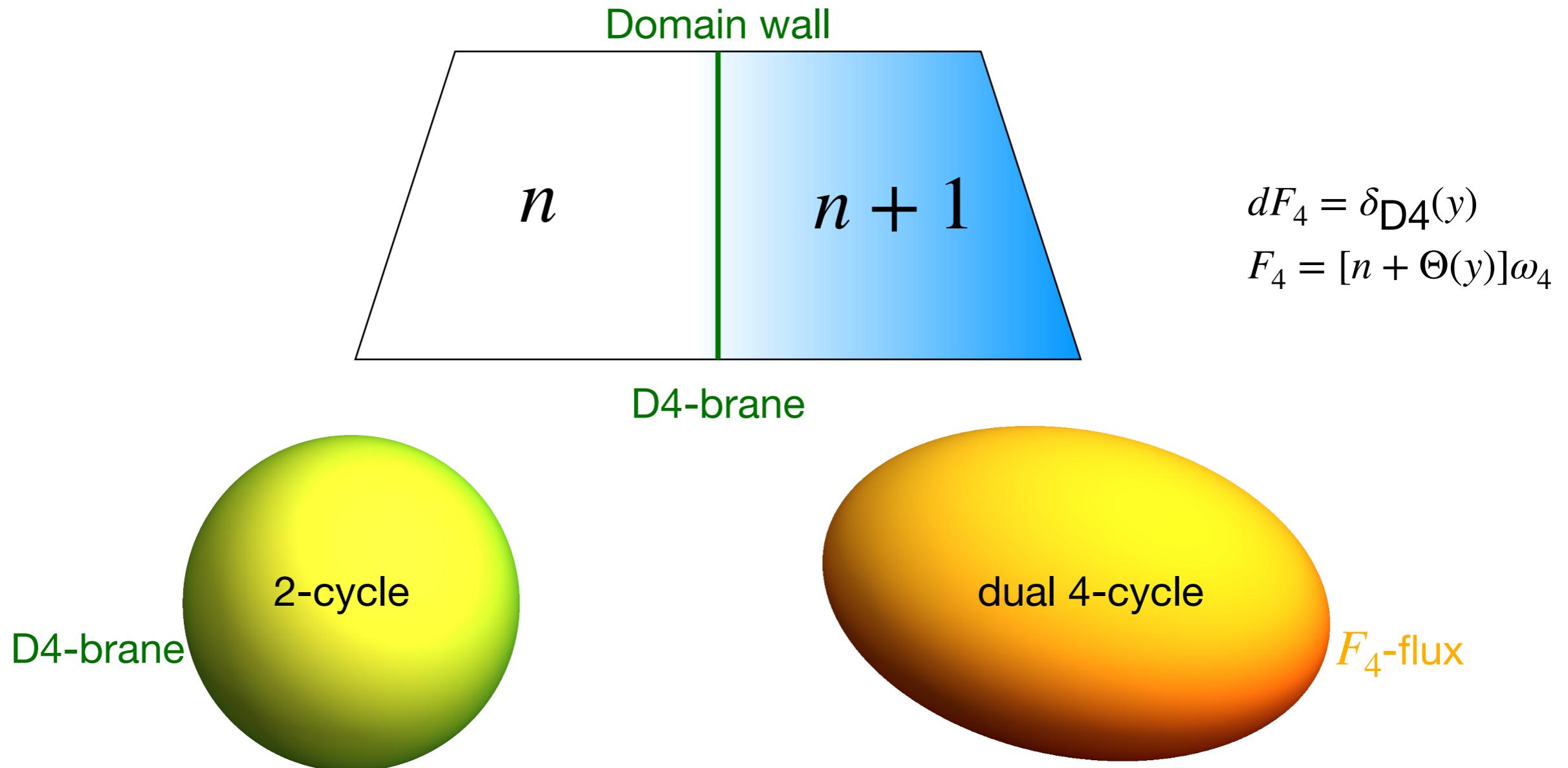
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D4 domain wall

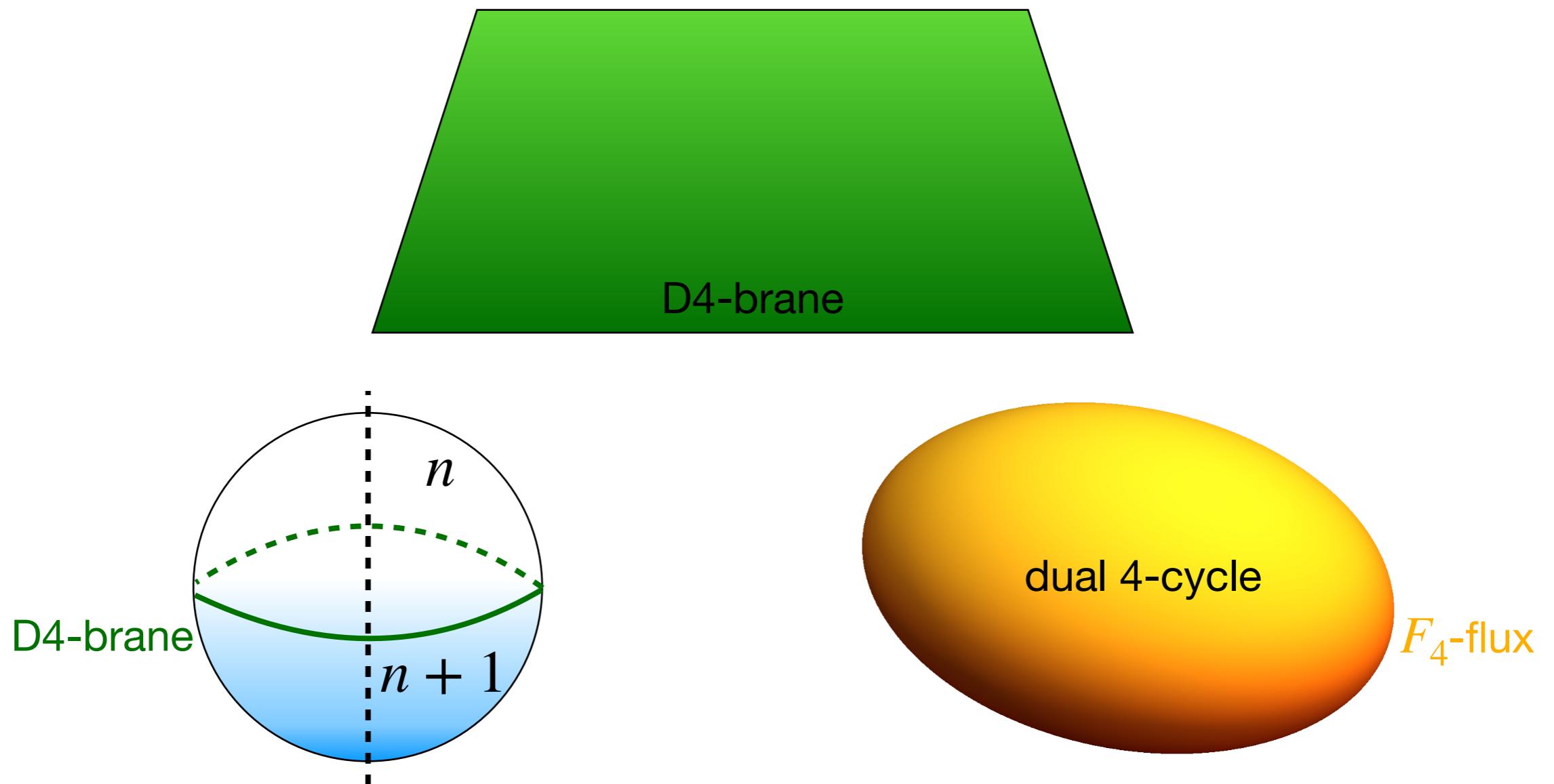
[Aharony, Antebi, Berkooz, 2008]



Put the domain wall in the compact dimensions

D4-brane on contractible cycle

[Shiu, Tonioni, VVH, Van Riet, 2022]

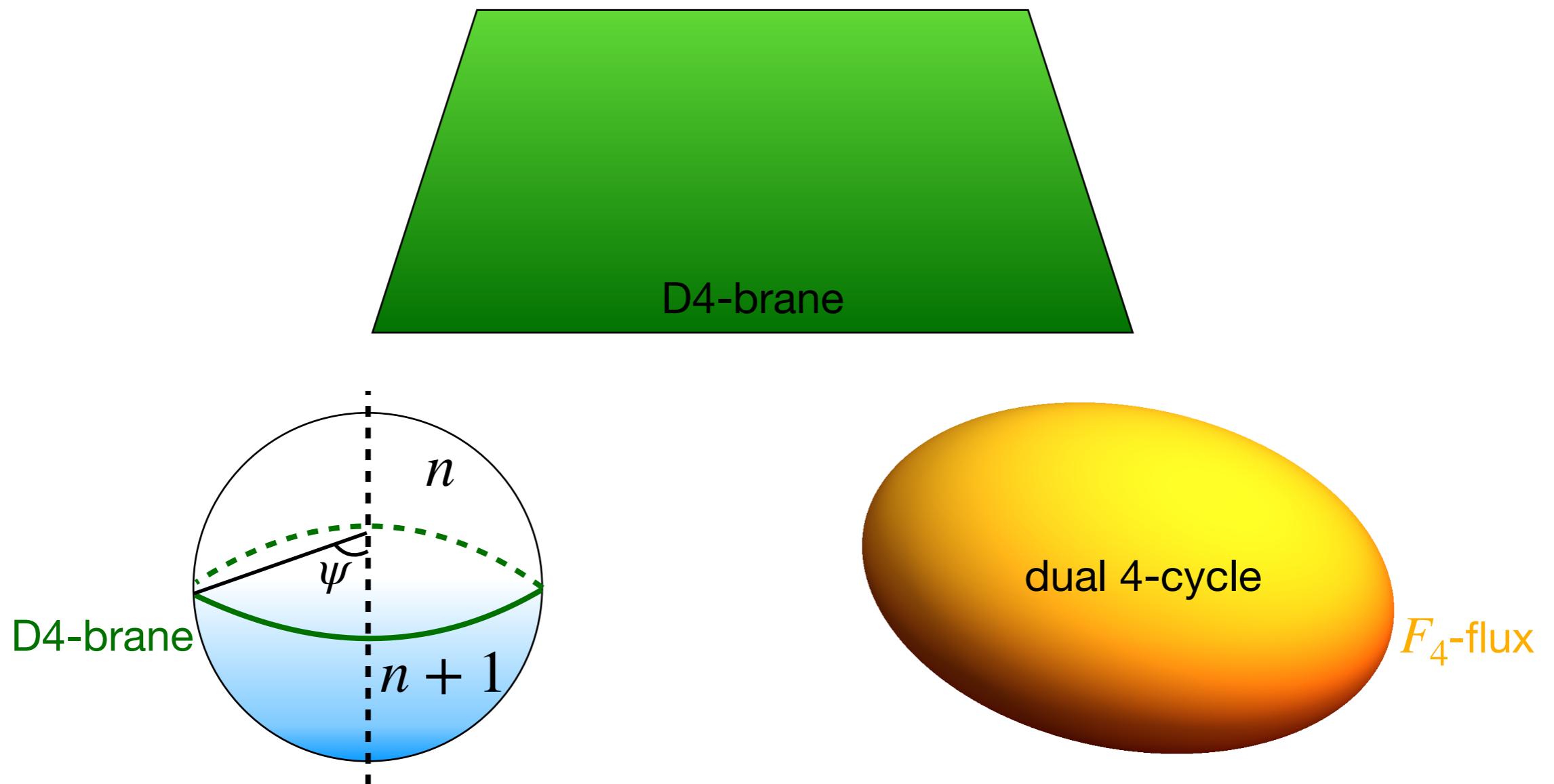


Position modulus ψ controls the flux:
at $\psi = 0, \pi, 2\pi, \dots$ different vacua with flux $n, n + 1, n + 2, \dots$

‘KPV’ in type IIA

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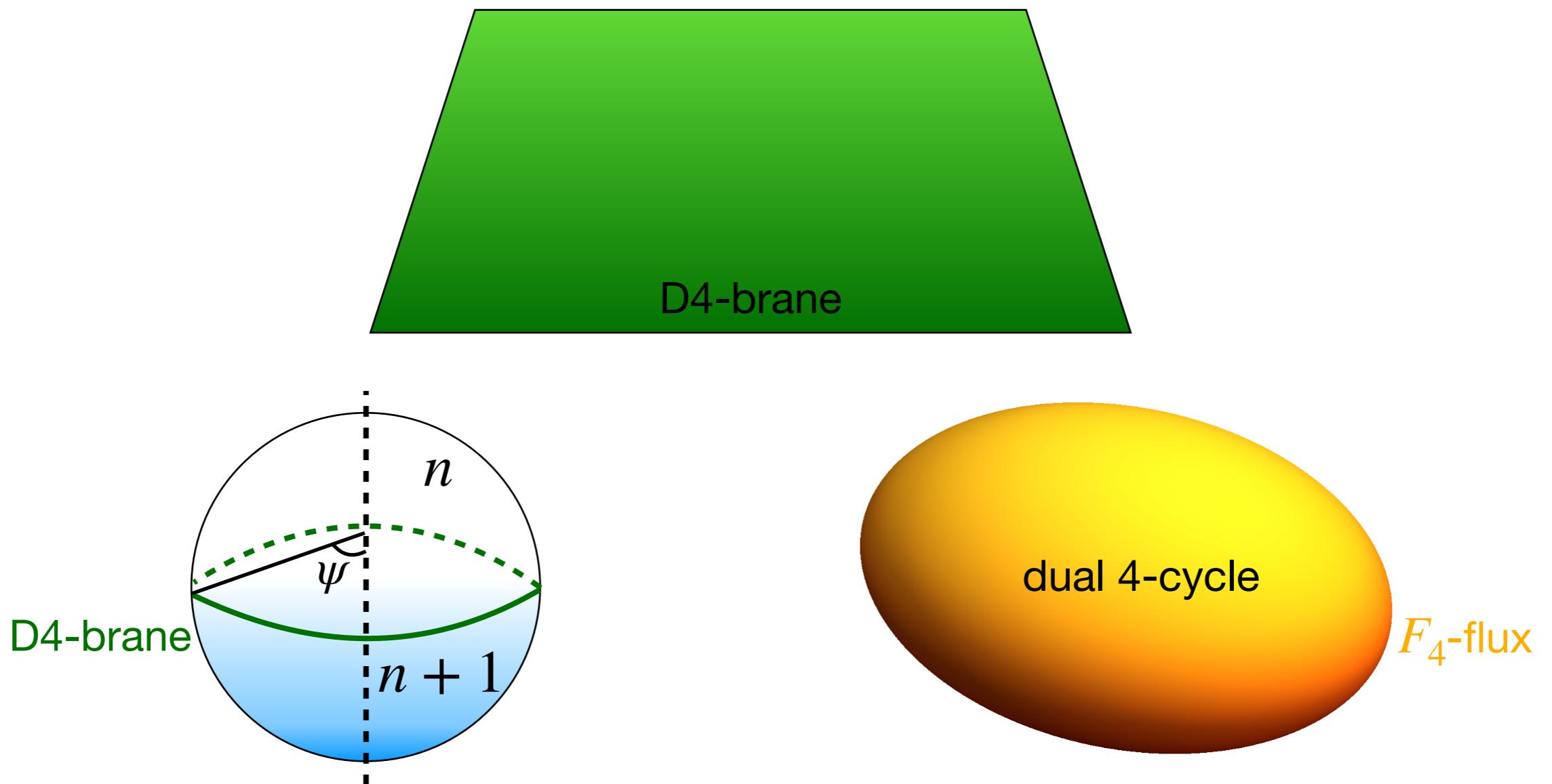


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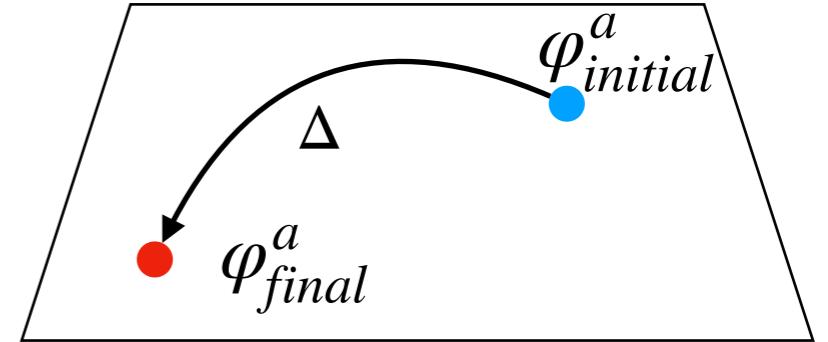
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Disclaimer: no dynamical process!

Distance with multiple fields

$$\Delta = \int ds \sqrt{g_{ab} \frac{d\varphi^a}{ds} \frac{d\varphi^b}{ds}}$$



3 F_4 -fluxes, 3 volumes

Fields $\varphi^a = \phi, L_1, L_2, L_3, \psi_1, \psi_2, \psi_3$

Metric g_{ab} known for dilaton and volumes, to be computed for the ψ s

Permutation symmetry leads to

$$L \equiv L_1 = L_2 = L_3, \quad \psi \equiv \psi_1 = \psi_2 = \psi_3$$

Multi-field problem → **look for geodesic in this field space**

Field space metric of ψ

Start from local metric

$$ds_{10}^2 = g_{\mu\nu}dx^\mu dx^\nu + L^2[d\psi^2 + f^2(\psi)d\varphi^2] + ds_{\Sigma_4}^2$$



Metric pulled-back on D4 worldvolume:

$$ds^2|_{D4} = (g_{\mu\nu} + L^2\partial_\mu\psi\partial_\nu\psi)dx^\mu dx^\nu + L^2f^2(\psi)d\varphi^2$$

Field metric from DBI: $\frac{g_{\psi\psi}}{M_{Pl}^2} = \gamma e^\phi L^3 |f(\psi)|$

Put in DBI-action
and expand

Field distance

After taking into account permutation symmetry and field redefinitions

$$\begin{aligned}\Delta &= \int ds \sqrt{g_{ab} \frac{d\varphi^a}{ds} \frac{d\varphi^b}{ds}} \\ &= \int ds \sqrt{\frac{8}{z^2} \left[\left(\frac{dx}{ds} \right)^2 + \left(\frac{dz}{ds} \right)^2 \right] + 6 \left(\frac{d\sigma}{ds} \right)^2}\end{aligned}$$

$$\frac{dx}{d\psi} = \sqrt{3\gamma |f(\psi)|/8}, \quad z = \exp(-D/2) = \exp(-\phi/2)L^{3/2}, \quad \sigma = \log L$$

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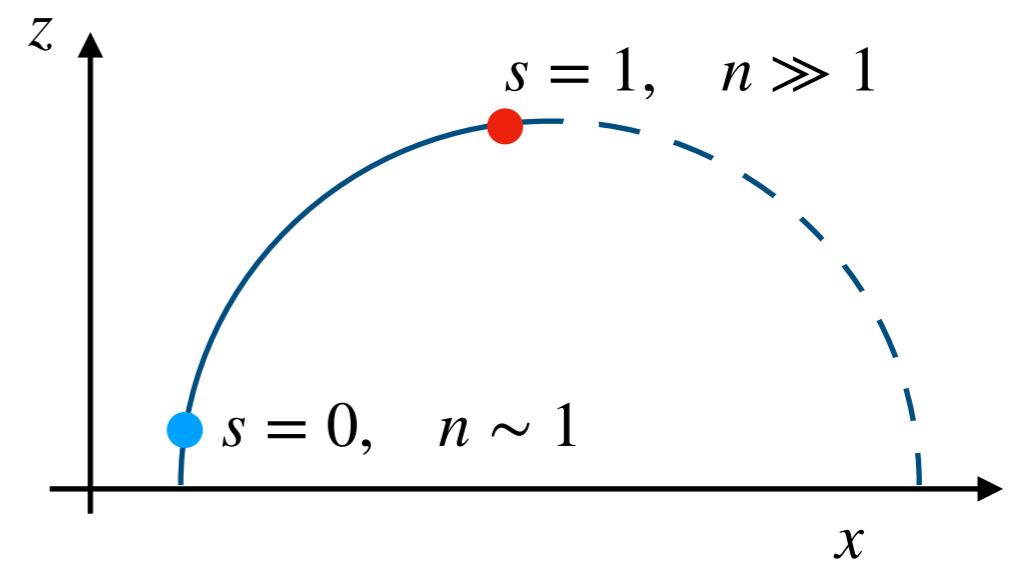
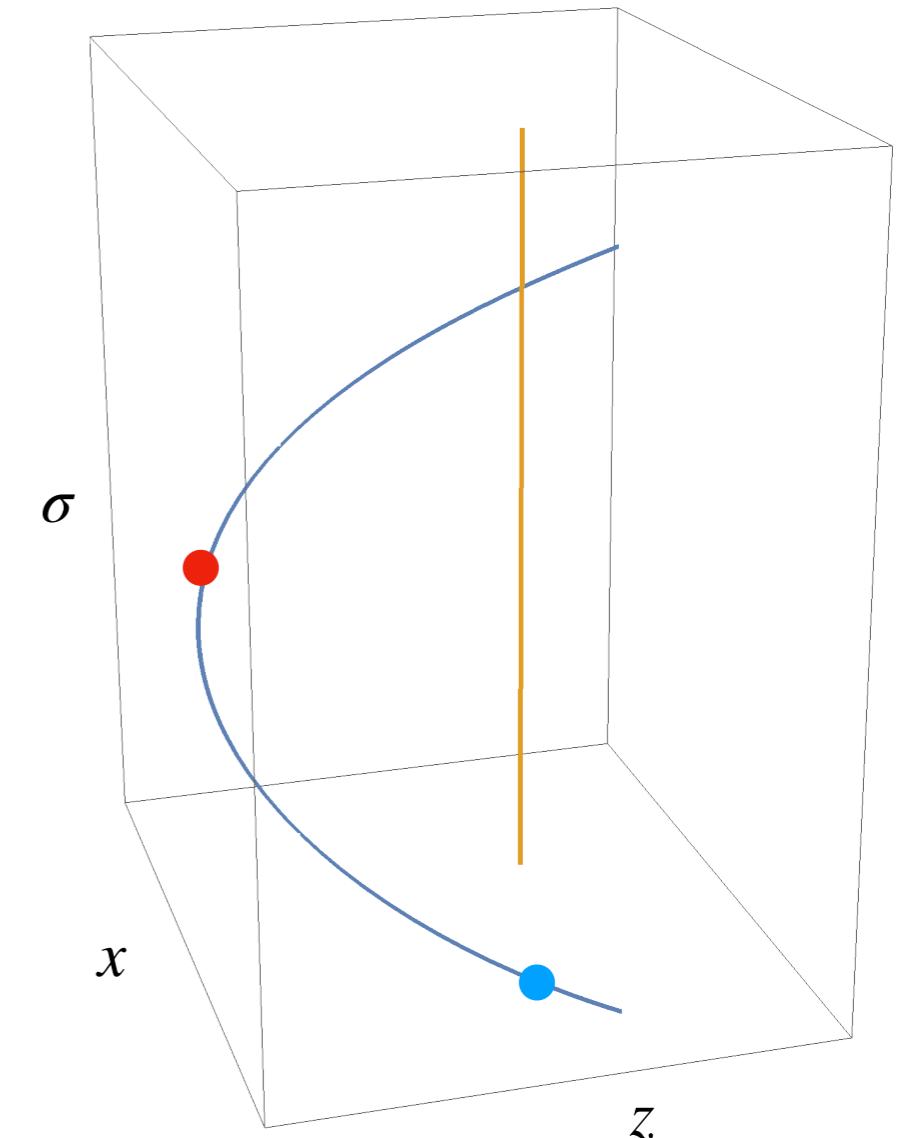
Helices!

Geodesics on $\mathbb{H}^2 \times \mathbb{R}$ are simple:
helices

3 fields, 6 integration constants to
be fixed by boundary conditions

Only 2 matter for the distance:

$$\Delta = \sqrt{8d_1^2 + 6d_3^2}$$



The distance conjecture is satisfied!

Distance logarithmic in n !

$$\Delta = \sqrt{\frac{103}{8}} \log n$$

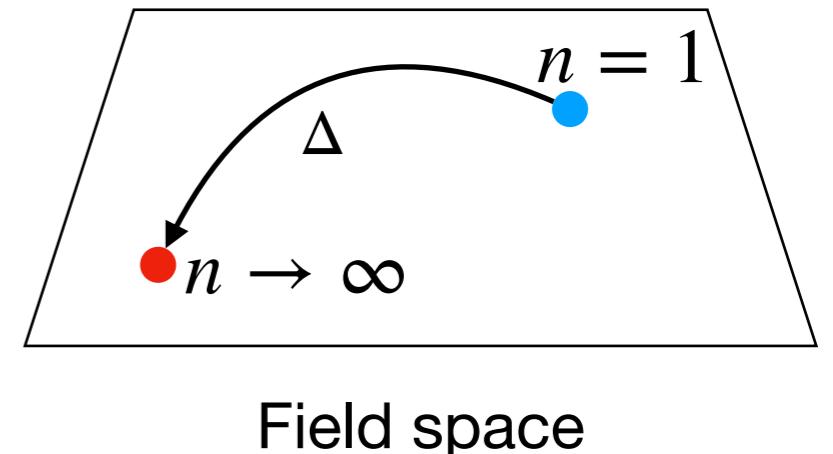
→ mass of tower polynomial in n

For KK-tower:

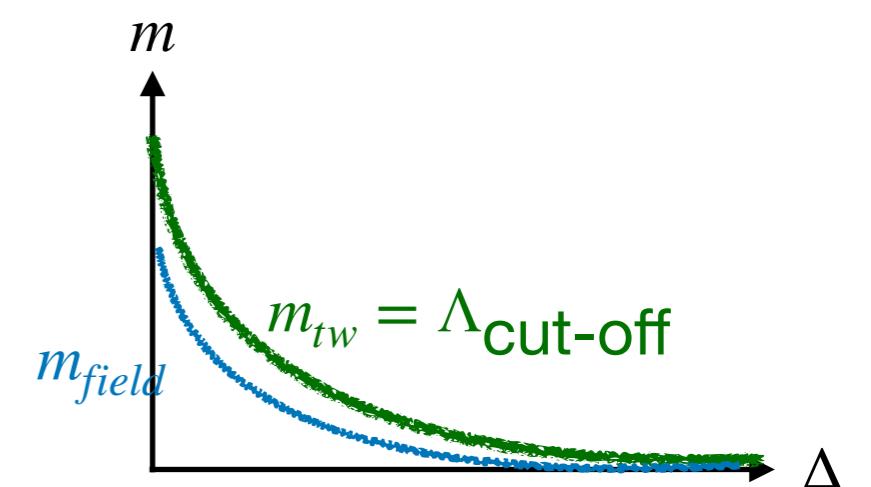
$$\frac{m_{KK}}{m_0} \sim n^{-1/4} \sim e^{-\beta\Delta} \implies \beta = 1/\sqrt{206}$$

Invalidating the EFT at $n \rightarrow \infty$?

No, scale separation! $m_{field}/m_{KK} \sim n^{-1/2}$



Field space



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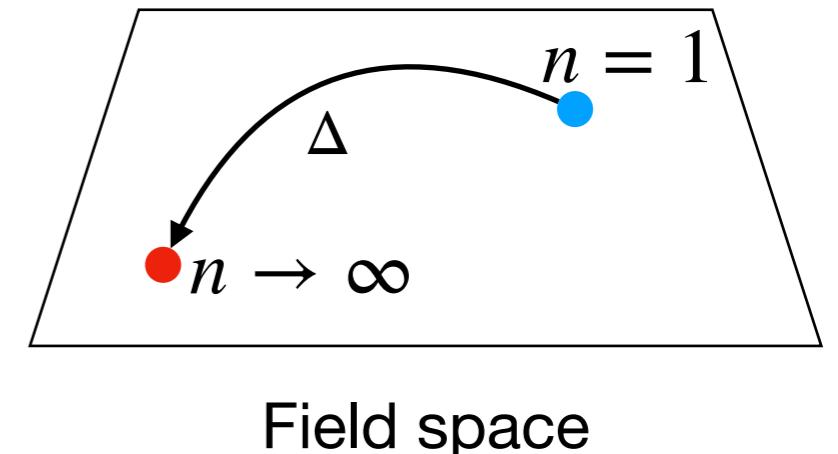
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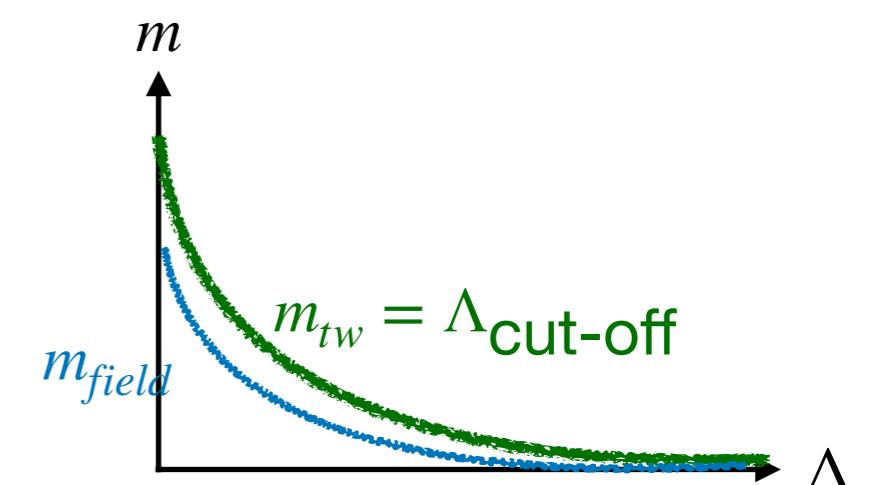
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Field space



The swampland distance conjecture does not invalidate the EFT!

Summary

1. Interpolating between DGKT flux vacua with D4-brane moduli
2. Field space becomes simple: $\mathbb{H}^2 \times \mathbb{R}$
3. DGKT vacua pass the test of the distance conjecture

KK-modes of D4s would make distance even smaller

Similar for scale-separated AdS_3 vacua on G_2 -manifolds

[Farakos, Tringas, Van Riet 2020]

[Farakos, Morittu, Tringas, 2023]

Go beyond DGKT: Extend to other flux vacua: massless type IIA

[Cribiori, Junghans, VH, Van Riet, Wräse, 2021]

See how it relates with other proposals for AdS distances

[Li, Palti, Petri, 2023]

Thank you!

Field space metric

From DBI-action of the D4-brane

10d metric near D4-brane:

$$ds_{10}^2 = g_{\mu\nu} dx^\mu dx^\nu + \ell_s^2 L^2 (d\psi^2 + f^2(\psi) d\varphi^2) + ds_{\Sigma_4}^2$$

DBI expanded:

$$S_{D4} = - \int d^4x \sqrt{-g_4} 2\pi \ell_s \mu_4 L e^{-\phi} |f(\psi)| \sqrt{1 + \ell_s^2 L^2 (\partial\psi)^2}$$

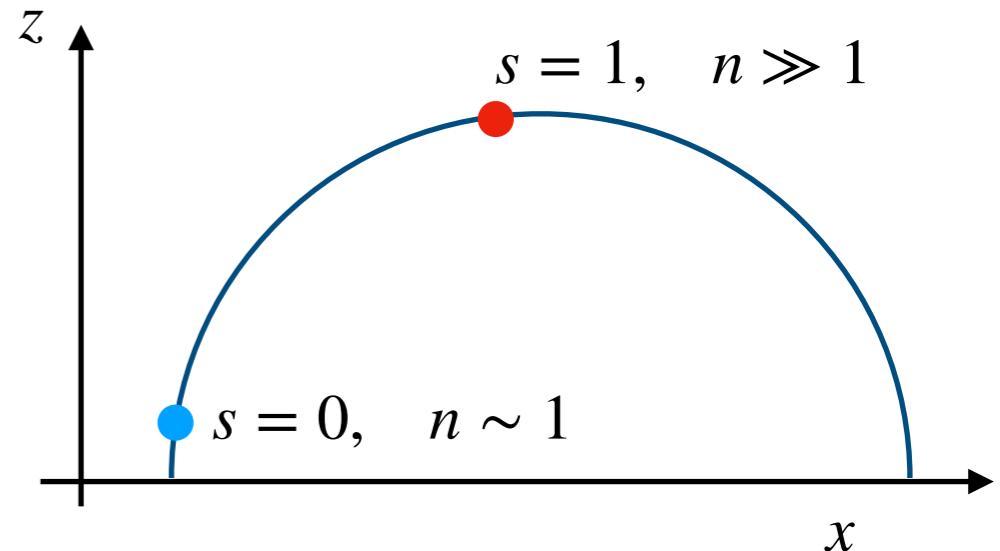
Metric: $\frac{g_{\psi\psi}}{M_{Pl}^2} = \gamma e^\phi L^3 |f(\psi)|$

Geodesic distance

$$x(s) = l \cos[h(s)] + x_0, \quad z = l \sin[h(s)], \quad \sigma(s) = d_3 s + d_4 s$$

$$h[s] = 2 \arctan \left[\tanh \left(\frac{d_1 s + d_2}{2} \right) \right]$$

$$\Delta = \sqrt{8d_1^2 + 6d_3^2}$$



Integration constants determined by boundary conditions

Comments on energy scales

- Effective mass of D4: $g^{\psi\psi} \partial_\psi^2 V(\psi) \sim m_{KK}$
- But $V(\psi)/V_{\text{flux}} \sim n^{-1/2}$: D4-brane energy density becomes parametrically smaller
- KK-modes would shorten distance even further
- Flux unwinding with D4-branes is not a dynamical process
- 3 four-cycles \Rightarrow 3 F_4 -fluxes \Rightarrow 3 D4-branes necessary