Scale-separated AdS_3 in Type IIB: From flux vacua to domain-walls

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Based on work with Álvaro Arboleya, Clara Roldán and Giuseppe Sudano

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On scale-separated AdS flux vacua

- Scale separation is often invoked to have a good lower-dimensional effective field theory arising from a string compactification

$$\boxed{L_{\rm AdS} \gg L_{\rm internal}}$$

[a proxy for KK modes decoupling]

- To date (and to my knowledge), **no example of scale-separated AdS/CFT pair**

- Scale separation in massive IIA: AdS_4 vacua of DGKT & AdS_3 vacua

[Calabi-Yau 3-fold]

[De Wolfe, Giryavets, Kachru, Taylor, '05]
[Cámara, Font, Ibáñez, '05]

[G_2-holonomy space]

[Farakos, Tringas, Van Riet, '20]

- Towards the branes behind mIIA flux vacua : ($F_{(4)}$, $F_{(0)}$) for both AdS_4 & AdS_3

[D4-branes probing a strongly-coupled singularity]

[Apers, Montero, Valenzuela, '25] [Apers, '26]

- Scale-separated type IIB AdS_3 flux vacua **expected not to exist …**

  [Emelin, Farakos, Tringas, '21]
  [Van Hemelryck, '22]
  [Apers, '22]

- Scale-separated type IIB AdS_3 flux vacua **expected not to exist … but they do!**

[Emelin, Farakos, Tringas, ’21]
[Van Hemelryck, ’22]
[Apers, ’22]

[Arboleya, AG, Morittu ’24]

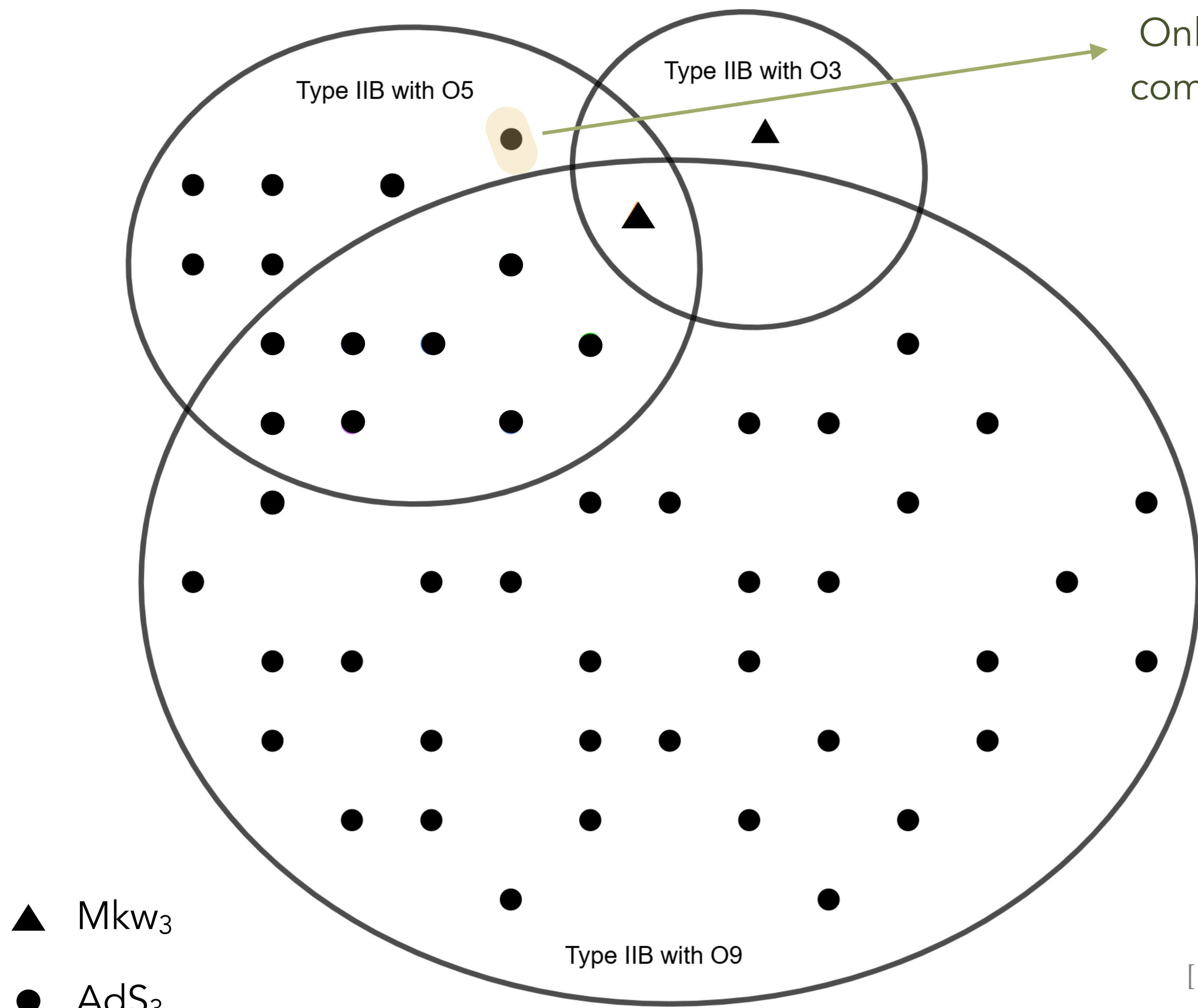
Type IIB with O5

One class of AdS_3 flux vacua
compatible **with scale separation!**

- Scale-separated type IIB AdS_3 flux vacua **expected not to exist … but they do!**

[Emelin, Farakos, Tringas, '21]
[Van Hemelryck, '22]
[Apers, '22]

[Arboleya, AG, Morittu '24]



Only **one class** of AdS_3 flux vacua compatible **with scale separation!**

[the needle in the haystack]

[Arboleya, Casagrande, AG, Morittu '25]

Goal:

To understand the branes behind this class of scale-separated AdS_3 flux vacua in type IIB

$\boxed{\text{10D domain-wall}}$

$R \to 0$ $\qquad\qquad$ $R \to \infty$

asymptotically flat spacetime

AdS_3 x M_7 flux vacuum

[Kounnas, Lüst, Petropoulos, Tsimpis, '07]

The flux compactification story

- Type IIB compactification on a specific 7D solvmanifold (with G_2-structure)

[Scherk, Schwarz, '79]

$$\boxed{ds_{10}^2 = \tau^{-2}\, ds_3^2 + \rho^2\, ds_7^2}$$

3D dilaton

internal volume

- Internal space:

[unit volume]

$$\boxed{ds_7^2 = \sum_{a=1,3,5} \ell_a^2\, (\eta^a)^2 + \sum_{i=2,4,6} \ell_i^2\, (\eta^i)^2 + \ell_7^2\, (\eta^7)^2}$$

Maurer-Cartan 1-forms

$$\begin{cases} d\eta^7 = 0 \\ d\eta^a = -\,\omega_a\, \eta^i \wedge \eta^7 \\ d\eta^i = \underbrace{\omega_i}_{\text{metric } \omega\text{-fluxes}}\, \eta^a \wedge \eta^7 \end{cases} \quad \text{with} \quad (a,i) = \{(1,2),(3,4),(5,6)\}$$

- **Constant** background fluxes

$$\begin{aligned} F_{(7)} &= f_7\, \eta^{1234567} \\ F_{(3)} &= f_{31}\, \eta^{127} + f_{32}\, \eta^{347} + f_{33}\, \eta^{567} - f_{34}\, \eta^{136} - f_{35}\, \eta^{235} - f_{36}\, \eta^{145} + f_{37}\, \eta^{246} \end{aligned}$$

$$\begin{aligned} dF_{(7)} &= 0 \\ dF_{(3)} &\neq 0 \end{aligned}$$

Notation: $\eta^{127} = \eta^1 \wedge \eta^2 \wedge \eta^7$, etc.

- Spacetime-filling **O5-plane/D5-brane** sources supporting AdS_3 flux vacua

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(1)}$	$\times$	$\times$	$\times$	$\times$	$\times$					$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(2)}$	$\times$	$\times$	$\times$			$\times$	$\times$			$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(3)}$	$\times$	$\times$	$\times$					$\times$	$\times$	$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(4)}$	$\times$	$\times$	$\times$	$\times$		$\times$			$\times$	
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(5)}$	$\times$	$\times$	$\times$		$\times$	$\times$		$\times$		
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(6)}$	$\times$	$\times$	$\times$	$\times$			$\times$	$\times$		
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(7)}$	$\times$	$\times$	$\times$		$\times$		$\times$		$\times$	

Spacetime-filling

[consistent with AdS_3]

Terminology: ``source branes"

- Spacetime-filling **O5-plane/D5-brane** sources supporting AdS_3 flux vacua

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(1)}$	$\times$	$\times$	$\times$	$\times$	$\times$					$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(2)}$	$\times$	$\times$	$\times$			$\times$	$\times$			$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(3)}$	$\times$	$\times$	$\times$					$\times$	$\times$	$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(4)}$	$\times$	$\times$	$\times$	$\times$		$\times$			$\times$	
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(5)}$	$\times$	$\times$	$\times$		$\times$	$\times$		$\times$		
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(6)}$	$\times$	$\times$	$\times$	$\times$			$\times$	$\times$		
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(7)}$	$\times$	$\times$	$\times$		$\times$		$\times$		$\times$	

$$dF_{(3)} = \tilde{j}^{\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}}$$

Flux-induced tadpole

for $\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(4,5,6,7)}$ sources

restricted f_{34} , f_{35} , f_{36} , f_{37}

- Spacetime-filling **O5-plane/D5-brane** sources supporting AdS$_3$ flux vacua

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(1)}$	$\times$	$\times$	$\times$	$\times$	$\times$					$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(2)}$	$\times$	$\times$	$\times$			$\times$	$\times$			$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(3)}$	$\times$	$\times$	$\times$					$\times$	$\times$	$\times$
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(4)}$	$\times$	$\times$	$\times$	$\times$		$\times$			$\times$	
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(5)}$	$\times$	$\times$	$\times$		$\times$	$\times$		$\times$		
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(6)}$	$\times$	$\times$	$\times$	$\times$			$\times$	$\times$		
$\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(7)}$	$\times$	$\times$	$\times$		$\times$		$\times$		$\times$	

$$dF_{(3)} = 0$$

$$dF_{(3)} = \tilde{j}^{\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}}$$

Flux-induced tadpole

for $\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(4,5,6,7)}$ sources

No flux-induced tadpole

for $\widetilde{\mathrm{O5}}/\widetilde{\mathrm{D5}}^{(1,2,3)}$ sources

restricted f_{34} , f_{35} , f_{36} , f_{37}

unrestricted f_{31} , f_{32} , f_{33} (and f_7)

Type IIB + DBI dimensional reduction $\Rightarrow$ $\mathcal{N}=1$ supergravity in D=3

- Supegravity model with 8 scalars $\phi^A = \{\tau,\, \rho,\, \ell_1,\, \ell_2,\, \ell_3,\, \ell_4,\, \ell_5\,,\ell_6\}$

$$L_{\text{kin}} = -K_{AB}(\partial\phi^A)(\partial\phi^B) = -\frac{(\partial\tau)^2}{\tau^2} - 7\,\frac{(\partial\rho)^2}{\rho^2} - \sum_{m,n=1}^{6}(1+\delta_{mn})\,\frac{(\partial\ell_m)(\partial\ell_n)}{\ell_m\,\ell_n}$$

$$\begin{aligned} W \;=\;& \frac{f_7}{\tau^{\frac{3}{2}}\,\rho^{\frac{7}{2}}} + \frac{\rho^{\frac{1}{2}}}{\tau^{\frac{3}{2}}}\left(f_{31}\,\ell_{3456} + f_{32}\,\ell_{1256} + f_{33}\,\ell_{1234} + \frac{f_{34}}{\ell_{136}} + \frac{f_{35}}{\ell_{352}} + \frac{f_{36}}{\ell_{514}} + \frac{f_{37}}{\ell_{246}}\right) \\ +\;& \frac{1}{\tau\,\rho}\Big[\left(\omega_1\,\ell_1^2 + \omega_2\,\ell_2^2\right)\ell_{3456} + \left(\omega_3\,\ell_3^2 + \omega_4\,\ell_4^2\right)\ell_{1256} + \left(\omega_5\,\ell_5^2 + \omega_6\,\ell_6^2\right)\ell_{1234}\Big] \end{aligned}$$

from which $\quad V = K^{AB}\left(\frac{\partial W}{\partial\phi^A}\right)\left(\frac{\partial W}{\partial\phi^B}\right) - 2\,W^2$

- All supersymmetric AdS$_3$ solutions are obtained by solving $\dfrac{\partial W}{\partial \phi^A} = 0$

- Playing with **unrestricted fluxes**: weak-coupling & hierarchy of scales

$$g_s^2 \sim \left(\frac{f_7}{f_{31}\, f_{32}\, f_{33}} \right) \quad , \quad L_3 \sim (f_7\, f_{31}\, f_{32}\, f_{33})^{\frac{1}{4}} \quad , \quad L_7 \equiv (\mathrm{vol}_7)^{\frac{1}{7}} \sim \left(\frac{f_7^7}{f_{31}\, f_{32}\, f_{33}} \right)^{\frac{1}{28}}$$

Example: $|f_{31}| \sim N^{a_1}$, $|f_{32}| \sim N^{a_2}$, $|f_{33}| \sim N^{a_3}$ and $|f_7| \sim N^b$

with $N \in \mathbb{N}^+$ being a scaling parameter gives $(a \equiv a_1 + a_2 + a_3)$

$$g_s^2 \sim N^{b-a} \quad , \quad L_7 \sim N^{\frac{7b-a}{28}} \quad , \quad \frac{L_7}{L_3} \sim N^{-\frac{2a}{7}}$$

$$\Rightarrow \quad \frac{a}{7} < b < a \quad , \quad N \gg 1 \quad \Rightarrow \quad \boxed{g_s^2 \ll 1} \quad \text{and} \quad \boxed{L_3 \gg L_7 \gg 1}$$

weak coupling

scale separation

The 10D domain-wall (DW) story

$R \to 0$

$R \to \infty$

asymptotically

flat spacetime

AdS$_3$ x M_7 flux vacuum

- Consider **O-planes/D-branes** & **KK monopoles** responsible for the fluxes

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7	Flux
O1/D1	$\times$	$\times$									f_7
O5/D5$^{(1)}$	$\times$	$\times$				$\times$	$\times$	$\times$	$\times$		f_{31}
O5/D5$^{(2)}$	$\times$	$\times$		$\times$	$\times$			$\times$	$\times$		f_{32}
O5/D5$^{(3)}$	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$				f_{33}
O5/D5$^{(4)}$	$\times$	$\times$			$\times$		$\times$	$\times$		$\times$	f_{34}
O5/D5$^{(5)}$	$\times$	$\times$		$\times$			$\times$		$\times$	$\times$	f_{35}
O5/D5$^{(6)}$	$\times$	$\times$			$\times$	$\times$			$\times$	$\times$	f_{36}
O5/D5$^{(7)}$	$\times$	$\times$		$\times$		$\times$		$\times$		$\times$	f_{37}
KK5$^{(1,a)}$	$\times$	$\times$		$\bullet$		$\times$	$\times$	$\times$	$\times$		ω_1
	$\times$	$\times$		$\times$	$\times$	$\bullet$		$\times$	$\times$		ω_3
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$	$\bullet$			ω_5
KK5$^{(2,i)}$	$\times$	$\times$			$\bullet$	$\times$	$\times$	$\times$	$\times$		ω_2
	$\times$	$\times$		$\times$	$\times$		$\bullet$	$\times$	$\times$		ω_4
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$		$\bullet$		ω_6

One common transverse direction R

[codimension-1 brane intersection]

Terminology: ``DW branes''

• Consider **O-planes/D-branes** & **KK monopoles** responsible for the fluxes

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7	Flux
O1/D1	$\times$	$\times$									f_7
O5/D5$^{(1)}$	$\times$	$\times$				$\times$	$\times$	$\times$	$\times$		f_{31}
O5/D5$^{(2)}$	$\times$	$\times$		$\times$	$\times$			$\times$	$\times$		f_{32}
O5/D5$^{(3)}$	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$				f_{33}
O5/D5$^{(4)}$	$\times$	$\times$			$\times$		$\times$	$\times$		$\times$	f_{34}
O5/D5$^{(5)}$	$\times$	$\times$		$\times$			$\times$		$\times$	$\times$	f_{35}
O5/D5$^{(6)}$	$\times$	$\times$			$\times$	$\times$			$\times$	$\times$	f_{36}
O5/D5$^{(7)}$	$\times$	$\times$		$\times$		$\times$		$\times$		$\times$	f_{37}
KK5$^{(1,a)}$	$\times$	$\times$		$\bullet$		$\times$	$\times$	$\times$	$\times$		ω_1
	$\times$	$\times$		$\times$	$\times$	$\bullet$		$\times$	$\times$		ω_3
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$	$\bullet$			ω_5
KK5$^{(2,i)}$	$\times$	$\times$			$\bullet$	$\times$	$\times$	$\times$	$\times$		ω_2
	$\times$	$\times$		$\times$	$\times$		$\bullet$	$\times$	$\times$		ω_4
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$		$\bullet$		ω_6

***H*-functions** (color branes)

$$H_1 \; , \; H_5^{(1)} \; , \; H_5^{(2)} \; , \; H_5^{(3)}$$

One common transverse direction *R*

[codimension-1 brane intersection]

• Consider **O-planes/D-branes** & **KK monopoles** responsible for the fluxes

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7	Flux
O1/D1	$\times$	$\times$									f_7
O5/D5$^{(1)}$	$\times$	$\times$				$\times$	$\times$	$\times$	$\times$		f_{31}
O5/D5$^{(2)}$	$\times$	$\times$		$\times$	$\times$			$\times$	$\times$		f_{32}
O5/D5$^{(3)}$	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$				f_{33}
O5/D5$^{(4)}$	$\times$	$\times$			$\times$		$\times$	$\times$		$\times$	f_{34}
O5/D5$^{(5)}$	$\times$	$\times$		$\times$			$\times$		$\times$	$\times$	f_{35}
O5/D5$^{(6)}$	$\times$	$\times$			$\times$	$\times$			$\times$	$\times$	f_{36}
O5/D5$^{(7)}$	$\times$	$\times$		$\times$		$\times$		$\times$		$\times$	f_{37}
KK5$^{(1,a)}$	$\times$	$\times$		$\bullet$		$\times$	$\times$	$\times$	$\times$		ω_1
	$\times$	$\times$		$\times$	$\times$	$\bullet$		$\times$	$\times$		ω_3
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$	$\bullet$			ω_5
KK5$^{(2,i)}$	$\times$	$\times$			$\bullet$	$\times$	$\times$	$\times$	$\times$		ω_2
	$\times$	$\times$		$\times$	$\times$		$\bullet$	$\times$	$\times$		ω_4
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$		$\bullet$		ω_6

***H*-functions** (color branes)

$H_1\ ,\ H_5^{(1)}\ ,\ H_5^{(2)}\ ,\ H_5^{(3)}$

***H*-functions** (background branes)

$H_5^{(4)}\ ,\ H_5^{(5)}\ ,\ H_5^{(6)}\ ,\ H_5^{(7)}$

One common transverse direction *R*

[codimension-1 brane intersection]

- Consider **O-planes/D-branes** & **KK monopoles** responsible for the fluxes

	dt	dx	dR	η^1	η^2	η^3	η^4	η^5	η^6	η^7	Flux
O1/D1	$\times$	$\times$									f_7
O5/D5$^{(1)}$	$\times$	$\times$				$\times$	$\times$	$\times$	$\times$		f_{31}
O5/D5$^{(2)}$	$\times$	$\times$		$\times$	$\times$			$\times$	$\times$		f_{32}
O5/D5$^{(3)}$	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$				f_{33}
O5/D5$^{(4)}$	$\times$	$\times$			$\times$		$\times$	$\times$		$\times$	f_{34}
O5/D5$^{(5)}$	$\times$	$\times$		$\times$			$\times$		$\times$	$\times$	f_{35}
O5/D5$^{(6)}$	$\times$	$\times$			$\times$	$\times$			$\times$	$\times$	f_{36}
O5/D5$^{(7)}$	$\times$	$\times$		$\times$		$\times$		$\times$		$\times$	f_{37}
KK5$^{(1,a)}$	$\times$	$\times$		$\bullet$		$\times$	$\times$	$\times$	$\times$		ω_1
	$\times$	$\times$		$\times$	$\times$	$\bullet$		$\times$	$\times$		ω_3
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$	$\bullet$			ω_5
KK5$^{(2,i)}$	$\times$	$\times$			$\bullet$	$\times$	$\times$	$\times$	$\times$		ω_2
	$\times$	$\times$		$\times$	$\times$		$\bullet$	$\times$	$\times$		ω_4
	$\times$	$\times$		$\times$	$\times$	$\times$	$\times$		$\bullet$		ω_6

***H*-functions** (color branes)

$H_1 \ , \ H_5^{(1)} \ , \ H_5^{(2)} \ , \ H_5^{(3)}$

***H*-functions** (background branes)

$H_5^{(4)} \ , \ H_5^{(5)} \ , \ H_5^{(6)} \ , \ H_5^{(7)}$

KK-monopole *H*-functions

$H_{\mathrm{KK}}^{(a)} \ , \ H_{\mathrm{KK}}^{(i)}$

One common transverse direction *R*

[codimension-1 brane intersection]

- 10D geometry

$$
\begin{aligned}
ds^2_{10} \;=\;& \left(H_1\, H_5^{(1)}\, H_5^{(2)}\, H_5^{(3)}\right)^{-\frac{1}{2}} \left(H_5^{(4)}\, H_5^{(5)}\, H_5^{(6)}\, H_5^{(7)}\right)^{-\frac{1}{2}} ds_2^2 \\
&+ \left(H_1\, H_5^{(1)}\, H_5^{(2)}\, H_5^{(3)}\right)^{\frac{1}{2}} \left(H_5^{(4)}\, H_5^{(5)}\, H_5^{(6)}\, H_5^{(7)}\right)^{\frac{1}{2}} \left(\prod_a H_{\mathrm{KK}}^{(a)}\right) \left(\prod_i H_{\mathrm{KK}}^{(i)}\right) dR^2 \\
&+ \left(H_1\, H_5^{(1)}\, H_5^{(2)}\, H_5^{(3)}\right)^{\frac{1}{2}} \left(H_5^{(4)}\, H_5^{(5)}\, H_5^{(6)}\, H_5^{(7)}\right)^{-\frac{1}{2}} \left(\prod_a H_{\mathrm{KK}}^{(a)}\right) \left(\prod_i H_{\mathrm{KK}}^{(i)}\right) \left(\eta^7\right)^2 \\
&+ \left(\frac{H_1\, H_5^{(1)}}{H_5^{(2)}\, H_5^{(3)}}\right)^{\frac{1}{2}} \left[\left(\frac{H_5^{(4)}\, H_5^{(6)}}{H_5^{(5)}\, H_5^{(7)}}\right)^{\frac{1}{2}} \left(\frac{H_{\mathrm{KK}}^{(2)}}{H_{\mathrm{KK}}^{(1)}}\right) \left(\eta^1\right)^2 + \left(\frac{H_5^{(5)}\, H_5^{(7)}}{H_5^{(4)}\, H_5^{(6)}}\right)^{\frac{1}{2}} \left(\frac{H_{\mathrm{KK}}^{(1)}}{H_{\mathrm{KK}}^{(2)}}\right) \left(\eta^2\right)^2\right] \\
&+ \left(\frac{H_1\, H_5^{(2)}}{H_5^{(3)}\, H_5^{(1)}}\right)^{\frac{1}{2}} \left[\left(\frac{H_5^{(4)}\, H_5^{(5)}}{H_5^{(6)}\, H_5^{(7)}}\right)^{\frac{1}{2}} \left(\frac{H_{\mathrm{KK}}^{(4)}}{H_{\mathrm{KK}}^{(3)}}\right) \left(\eta^3\right)^2 + \left(\frac{H_5^{(6)}\, H_5^{(7)}}{H_5^{(4)}\, H_5^{(5)}}\right)^{\frac{1}{2}} \left(\frac{H_{\mathrm{KK}}^{(3)}}{H_{\mathrm{KK}}^{(4)}}\right) \left(\eta^4\right)^2\right] \\
&+ \left(\frac{H_1\, H_5^{(3)}}{H_5^{(1)}\, H_5^{(2)}}\right)^{\frac{1}{2}} \left[\left(\frac{H_5^{(5)}\, H_5^{(6)}}{H_5^{(4)}\, H_5^{(7)}}\right)^{\frac{1}{2}} \left(\frac{H_{\mathrm{KK}}^{(6)}}{H_{\mathrm{KK}}^{(5)}}\right) \left(\eta^5\right)^2 + \left(\frac{H_5^{(4)}\, H_5^{(7)}}{H_5^{(5)}\, H_5^{(6)}}\right)^{\frac{1}{2}} \left(\frac{H_{\mathrm{KK}}^{(5)}}{H_{\mathrm{KK}}^{(6)}}\right) \left(\eta^6\right)^2\right]
\end{aligned}
$$

[harmonic superposition]

[Tseytlin, '96]

- 10D dilaton

$$\boxed{e^{2\Phi} = \left(\frac{H_1}{H_5^{(1)}\, H_5^{(2)}\, H_5^{(3)}}\right) \left(H_5^{(4)}\, H_5^{(5)}\, H_5^{(6)}\, H_5^{(7)}\right)^{-1}}$$

- 10D gauge flux

$$F_{(3)} = F_{(3)}^{(ele)} + F_{(3)}^{(mag)}$$

with

Note: $F_{(7)} = -\star F_{(3)}^{(ele)}$

$$\begin{aligned}
F_{(3)}^{(ele)} &= d\left(H_1{}^{-1}\right) \wedge dt \wedge dx \\
F_{(3)}^{(mag)} &= -\left(H_5^{(1)}\right)' \eta^{127} - \left(H_5^{(2)}\right)' \eta^{347} - \left(H_5^{(3)}\right)' \eta^{567} \\
&\quad + \frac{\left(H_5^{(4)}\right)'}{H_{\mathrm{KK}}^{(1)}\, H_{\mathrm{KK}}^{(3)}\, H_{\mathrm{KK}}^{(6)}} \eta^{136} + \frac{\left(H_5^{(5)}\right)'}{H_{\mathrm{KK}}^{(2)}\, H_{\mathrm{KK}}^{(3)}\, H_{\mathrm{KK}}^{(5)}} \eta^{235} + \frac{\left(H_5^{(6)}\right)'}{H_{\mathrm{KK}}^{(1)}\, H_{\mathrm{KK}}^{(4)}\, H_{\mathrm{KK}}^{(5)}} \eta^{145} \\
&\quad - \frac{\left(H_5^{(7)}\right)'}{H_{\mathrm{KK}}^{(2)}\, H_{\mathrm{KK}}^{(4)}\, H_{\mathrm{KK}}^{(6)}} \eta^{246}
\end{aligned}$$

- Type IIB EOM's with both source and DW branes **automatically solved!**

- *H*-functions

$R \to 0$ $\longrightarrow$ $R \to \infty$

asymp. flat spacetime **AdS_3 x M_7 flux vacuum**

- *H*-functions

$R \to 0$ $\quad\longmapsto\quad$ $R \to \infty$

asymp. flat spacetime **AdS$_3$ x M_7 flux vacuum**

Harmonic functions

$$H_1 = 1 + |f_7|\, R \quad , \quad H_5^{(1)} = 1 + |f_{31}|\, R \quad , \quad H_5^{(2)} = 1 + |f_{32}|\, R \quad , \quad H_5^{(3)} = 1 + |f_{33}|\, R$$

- H-functions

$R \to 0$ $\longmapsto$ $R \to \infty$

asymp. flat spacetime **AdS$_3$ x M_7 flux vacuum**

Harmonic functions

$$H_1 = 1 + |f_7|\, R \quad , \quad H_5^{(1)} = 1 + |f_{31}|\, R \quad , \quad H_5^{(2)} = 1 + |f_{32}|\, R \quad , \quad H_5^{(3)} = 1 + |f_{33}|\, R$$

Non-harmonic functions (chosen to recover AdS$_3$)

$$H_5^{(4)} \; , \; H_5^{(5)} \; , \; H_5^{(6)} \; , \; H_5^{(7)}$$

- H-functions

$R \to 0$ $\qquad$ $R \to \infty$

asymp. flat spacetime $\longrightarrow$ AdS$_3$ x M_7 flux vacuum

Harmonic functions

$$H_1 = 1 + |f_7|\, R \quad , \quad H_5^{(1)} = 1 + |f_{31}|\, R \quad , \quad H_5^{(2)} = 1 + |f_{32}|\, R \quad , \quad H_5^{(3)} = 1 + |f_{33}|\, R$$

Non-harmonic functions (chosen to recover AdS$_3$)

$$H_5^{(4)} \ , \ H_5^{(5)} \ , \ H_5^{(6)} \ , \ H_5^{(7)}$$

KK-monopole functions (not independent)

$$\omega_1 = -\frac{\left(H_{\text{KK}}^{(1)}\right)'}{H_{\text{KK}}^{(2)}\, H_5^{(4)}\, H_5^{(6)}} \quad , \quad \omega_3 = -\frac{\left(H_{\text{KK}}^{(3)}\right)'}{H_{\text{KK}}^{(4)}\, H_5^{(4)}\, H_5^{(5)}} \quad , \quad \omega_5 = -\frac{\left(H_{\text{KK}}^{(5)}\right)'}{H_{\text{KK}}^{(6)}\, H_5^{(5)}\, H_5^{(6)}}$$

$$\omega_2 = -\frac{\left(H_{\text{KK}}^{(2)}\right)'}{H_{\text{KK}}^{(1)}\, H_5^{(5)}\, H_5^{(7)}} \quad , \quad \omega_4 = -\frac{\left(H_{\text{KK}}^{(4)}\right)'}{H_{\text{KK}}^{(3)}\, H_5^{(6)}\, H_5^{(7)}} \quad , \quad \omega_6 = -\frac{\left(H_{\text{KK}}^{(6)}\right)'}{H_{\text{KK}}^{(5)}\, H_5^{(4)}\, H_5^{(7)}}$$

An example :

$$\omega_a = \omega_i \equiv \omega \qquad \text{and} \qquad f_{34} = f_{35} = f_{36} = f_{37} \equiv \tilde{f}$$

Harmonic functions

$$H_1 = 1 + |f_7|\, R \quad , \quad H_5^{(1)} = 1 + |f_{31}|\, R \quad , \quad H_5^{(2)} = 1 + |f_{32}|\, R \quad , \quad H_5^{(3)} = 1 + |f_{33}|\, R$$

Non-harmonic functions (a choice)

$$H_5^{(4)} = 2\, c_1\, c_3\, c_6\, R^{-\frac{3}{2}} \left(1 + \tilde{f}\, R\right) \quad , \quad H_5^{(5)} = 2\, c_2\, c_3\, c_5\, R^{-\frac{3}{2}} \left(1 + \tilde{f}\, R\right)$$

$$H_5^{(6)} = 2\, c_1\, c_4\, c_5\, R^{-\frac{3}{2}} \left(1 + \tilde{f}\, R\right) \quad , \quad H_5^{(7)} = 2\, c_2\, c_4\, c_6\, R^{-\frac{3}{2}} \left(1 + \tilde{f}\, R\right)$$

KK-monopole functions (not independent)

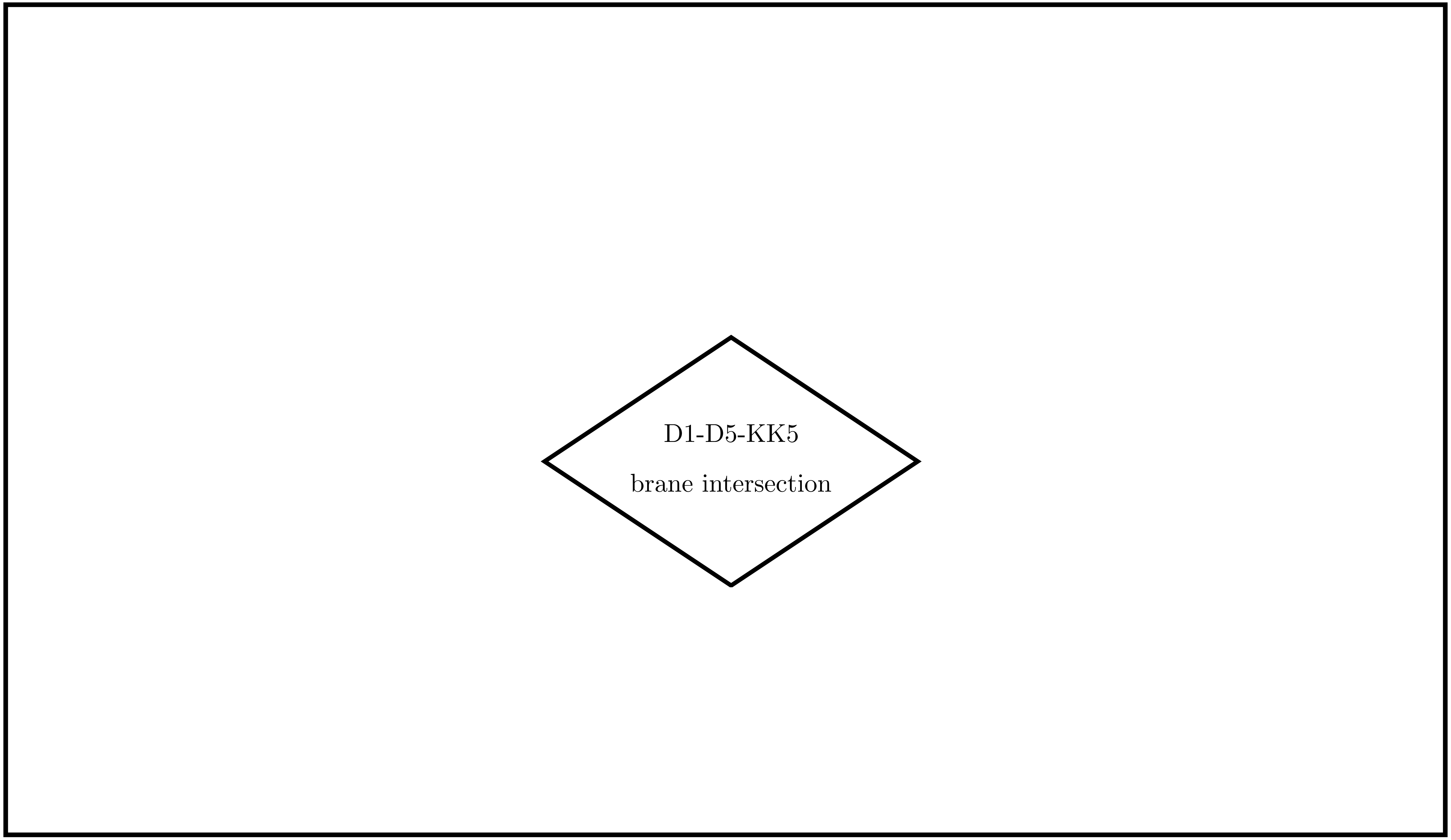
$$H_{\mathrm{KK}}^{(a)} = c_a\, R^{-\frac{1}{2}}\, e^{\frac{1+4\,\tilde{f}\,R}{4\,\tilde{f}^2\,R^2}} \quad , \quad H_{\mathrm{KK}}^{(i)} = c_i\, R^{-\frac{1}{2}}\, e^{\frac{1+4\,\tilde{f}\,R}{4\,\tilde{f}^2\,R^2}}$$

Note: AdS_3 recovered if $c_1 \cdots c_6 = \dfrac{1}{8\,\omega\,\tilde{f}^2}$

Summary

$R \to 0$ $\longmapsto$ $R \to \infty$

asymp. flat spacetime **AdS_3 x M_7 flux vacuum**



Summary

$R \to 0$ $\longrightarrow$ $R \to \infty$

asymp. flat spacetime | **AdS$_3$ x *M*$_7$ flux vacuum**

D1-D5-KK5

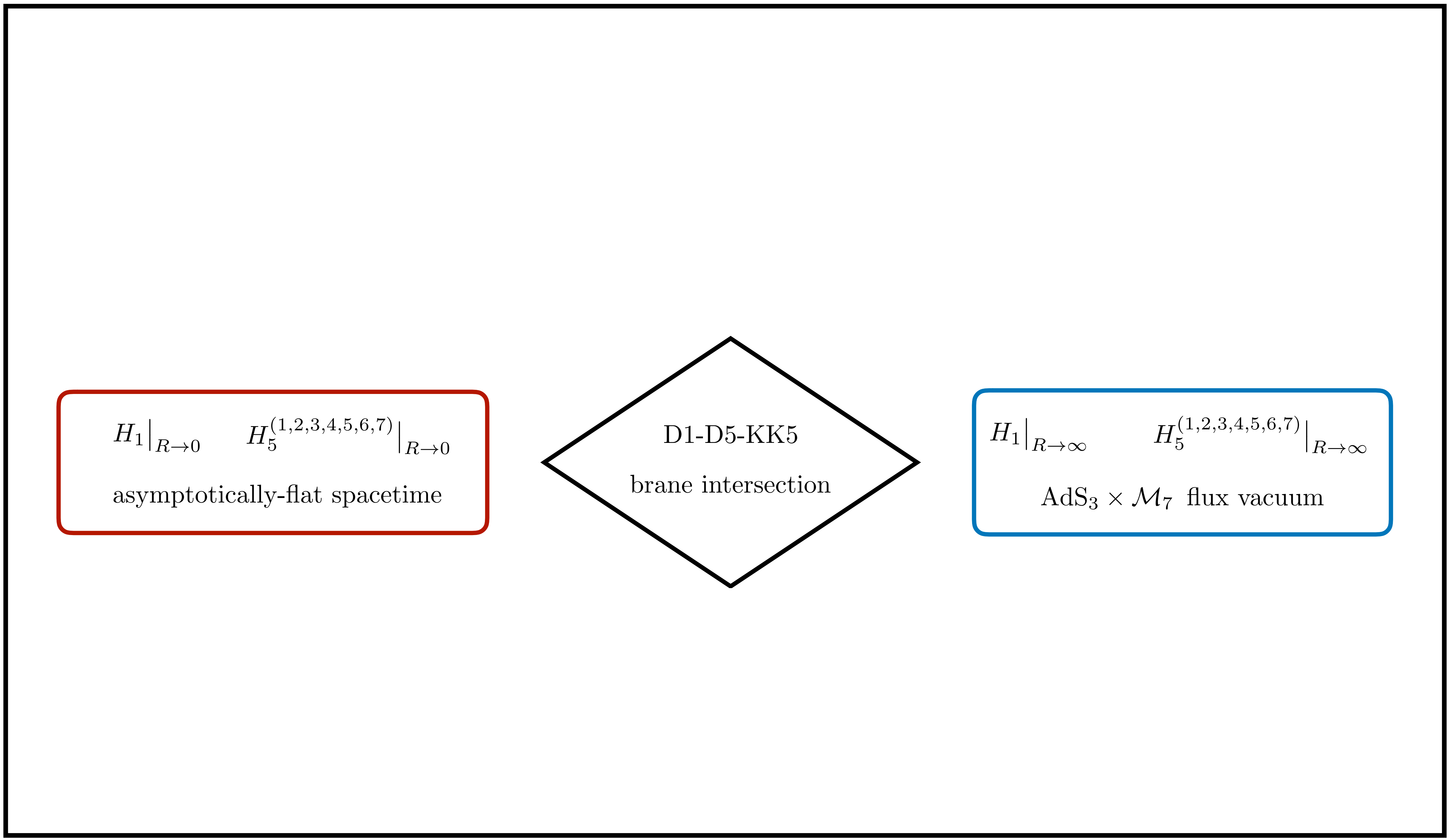
brane intersection

$H_1\big|_{R\to\infty}$ $\quad$ $H_5^{(1,2,3,4,5,6,7)}\big|_{R\to\infty}$

AdS$_3 \times \mathcal{M}_7$ flux vacuum

Summary

$R \to 0$
$R \to \infty$
asymp. flat spacetime
AdS_3 x M_7 flux vacuum



$H_1\big|_{R\to 0}$ $H_5^{(1,2,3,4,5,6,7)}\big|_{R\to 0}$
asymptotically-flat spacetime
D1-D5-KK5
brane intersection
$H_1\big|_{R\to \infty}$ $H_5^{(1,2,3,4,5,6,7)}\big|_{R\to \infty}$
$\mathrm{AdS}_3 \times \mathcal{M}_7$ flux vacuum

Summary

$R \to 0$ $\longrightarrow$ $R \to \infty$

asymp. flat spacetime → **AdS$_3$ x M_7 flux vacuum**

$$H_1\big|_{R\to 0} = H_5^{(1,2,3)}\Big|_{R\to 0} = 1$$

$$H_5^{(4,5,6,7)}\Big|_{R\to\infty}$$

background solution

D1-D5-KK5

brane intersection

$$H_1\big|_{R\to\infty} \qquad H_5^{(1,2,3,4,5,6,7)}\Big|_{R\to\infty}$$

AdS$_3 \times \mathcal{M}_7$ flux vacuum

[strongly-coupled singularity]

Summary

$R \to 0$ $\qquad\qquad$ $R \to \infty$

asymp. flat spacetime $\qquad$ **AdS$_3$ x *M*$_7$ flux vacuum**

$H_5^{(4,5,6,7)}\Big|_{R\to\infty}$

interpolating solution

$H_1\big|_{R\to 0} = H_5^{(1,2,3)}\Big|_{R\to 0} = 1$

$H_5^{(4,5,6,7)}\Big|_{R\to\infty}$

background solution

D1-D5-KK5

brane intersection

$H_1\big|_{R\to\infty}$ $\qquad$ $H_5^{(1,2,3,4,5,6,7)}\Big|_{R\to\infty}$

$\mathrm{AdS}_3 \times \mathcal{M}_7$ flux vacuum

[strongly-coupled singularity]

Message to take home

- We have made progress in understanding/characterising scale-separated AdS_3 flux vacua in type IIB and their 10D domain-wall (and brane) description

Things to look at…

- KK-modes decoupling ? [Van Hemelryck, '25]

- D1-D5 branes decoupling from the bulk ? [Apers, '26]

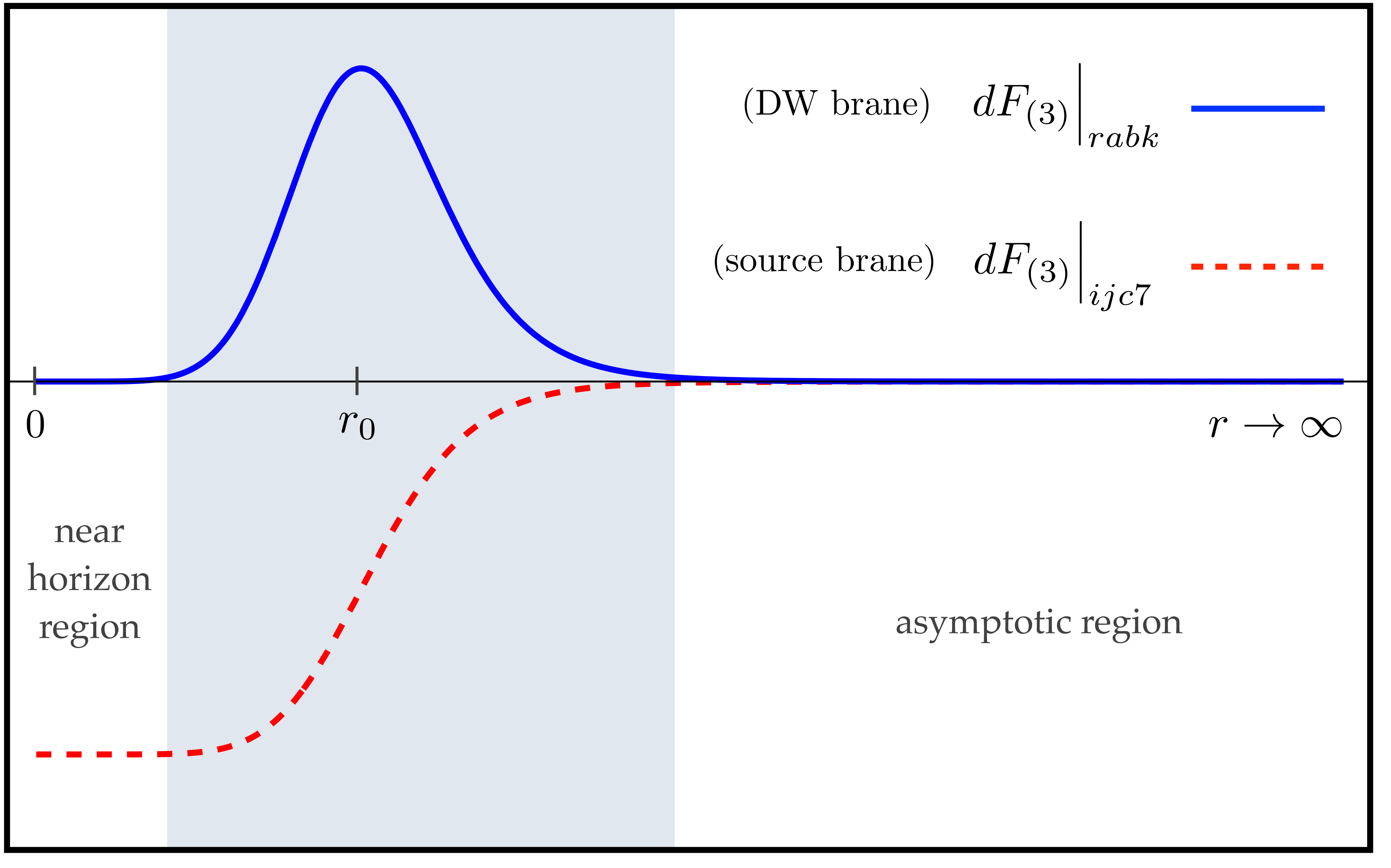
- Holographic AdS_3 / CFT_2 constraints ? [Bobev, Paul, Revello, '26]

ευχαριστώ !

thanks !

Extra slides

Flux/brane correspondence



Note: New transverse coordinate $r = R^{-\frac{1}{4}}$

Type IIB EOM's with both source and DW branes

$$\boxed{2\kappa^2 S_{\rm IIB} = \int \mathrm{d}^{10}X\,\sqrt{-G}\left[e^{-2\Phi}\left(R^{(10)} + 4(\partial\Phi)^2\right) - \frac{1}{4}\sum_{p=1,3}\frac{|F_{(2p+1)}|^2}{(2p+1)!}\right] + \sum_{k=4}^{7}\tilde{S}^{(k)}_{\rm loc} + \sum_{k=1}^{7} S^{(k)}_{\rm loc} + S^{\rm O1/D1}_{\rm loc}}$$

- Gauge potential equations

$$dF_{(3)} = \sum_{k=4}^{7}\tilde{J}^{\widetilde{\rm O5}/\widetilde{\rm D5}}_{(k)} + \sum_{k=1}^{7} J^{\rm O5/D5}_{(k)} \quad , \quad dF_{(7)} = J^{\rm O1/D1}$$

- Dilaton equation

$$2e^{-\Phi}\sqrt{-G}\left(R^{(10)} + 4\,\Box\Phi - 4\,(\partial\Phi)^2\right) - \sum_{k=4}^{7}\tilde{j}_{5(k)}\sqrt{-G^{(6\rm D)}_{(k)}} - \sum_{k=1}^{7} j_{5(k)}\sqrt{-G^{(6\rm D)}_{(k)}} - j_1\sqrt{-G^{(2\rm D)}} = 0$$

- Einstein equation

$$
\begin{aligned}
&\sqrt{-G}\ \Big[e^{-2\Phi}\left(R_{MN}+2\,\nabla_M\nabla_N\Phi\right) \\
&-\frac{1}{2}(F^2_{(1)})_{MN}-\frac{1}{2\cdot 2!}(F^2_{(3)})_{MN}+\frac{1}{4}G_{MN}\left(|F_{(1)}|^2+\tfrac{1}{3!}|F_{(3)}|^2\right)\Big] \\
&+j_1\,e^{-\Phi}\sqrt{-G^{(2\mathrm{D})}}\left(\frac{1}{2}\,G^{(2\mathrm{D})}_{MN}-\frac{1}{4}G_{MN}\right) \\
&+\sum_{j=1}^{7} j_{5(k)}\,e^{-\Phi}\sqrt{-G^{(6\mathrm{D})}_{(k)}}\left(\frac{1}{2}\,G^{(6\mathrm{D})}_{(k)\,MN}-\frac{1}{4}G_{MN}\right) \\
&+\sum_{j=4}^{7} \tilde{j}_{5(k)}\,e^{-\Phi}\sqrt{-G^{(6\mathrm{D})}_{(k)}}\left(\frac{1}{2}\,G^{(6\mathrm{D})}_{(k)\,MN}-\frac{1}{4}G_{MN}\right) \quad = \quad 0
\end{aligned}
$$

7D Solvmanifold: the one-form basis

$$
\begin{aligned}
\eta^a &= \cos\left[\sqrt{\omega_a\,\omega_i}\,x^7\right]\,dx^a + \sqrt{\frac{\omega_a}{\omega_i}}\sin\left[\sqrt{\omega_a\,\omega_i}\,x^7\right]\,dx^i \\
\eta^i &= -\sqrt{\frac{\omega_i}{\omega_a}}\sin\left[\sqrt{\omega_a\,\omega_i}\,x^7\right]\,dx^a + \cos\left[\sqrt{\omega_a\,\omega_i}\,x^7\right]\,dx^i \\
\eta^7 &= dx^7
\end{aligned}
$$

- Nilpotent limit $\omega_a \to 0 \quad \text{or} \quad \omega_i \to 0$