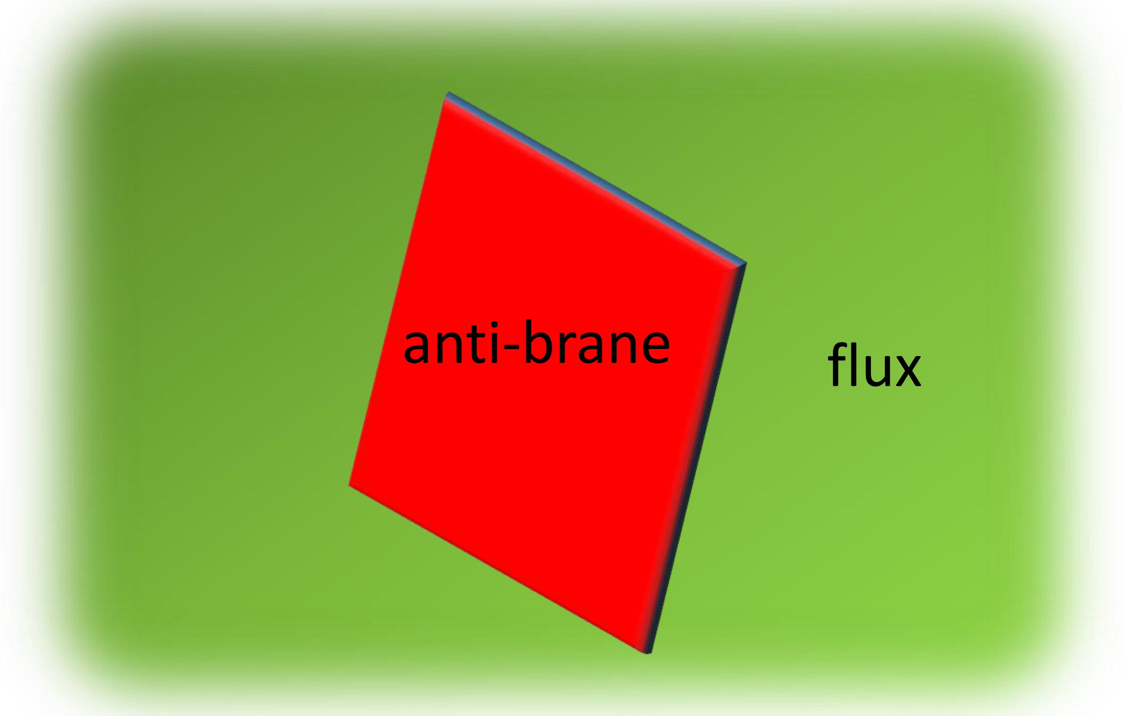
Brane-flux annihilation: a supergravity perspective

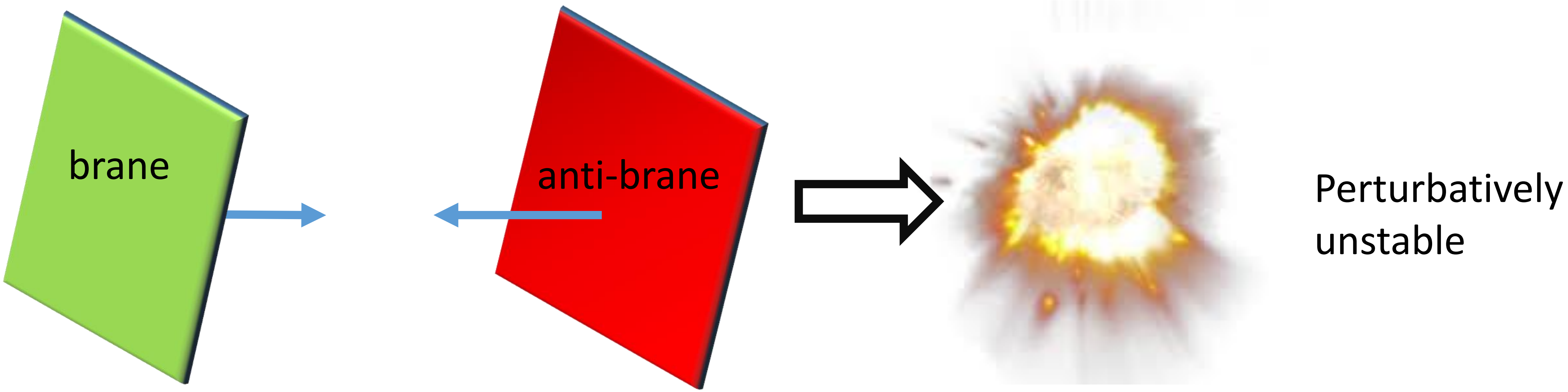
Thomas Van Riet – K.U.Leuven

With Danielsson, Gautason (2016) &
Cohen-Maldonado, Diaz, Vercnocke (2015)



Supergravity at 40, GGI, Florence, 2016

1. Motivation: susy-breaking in 10d



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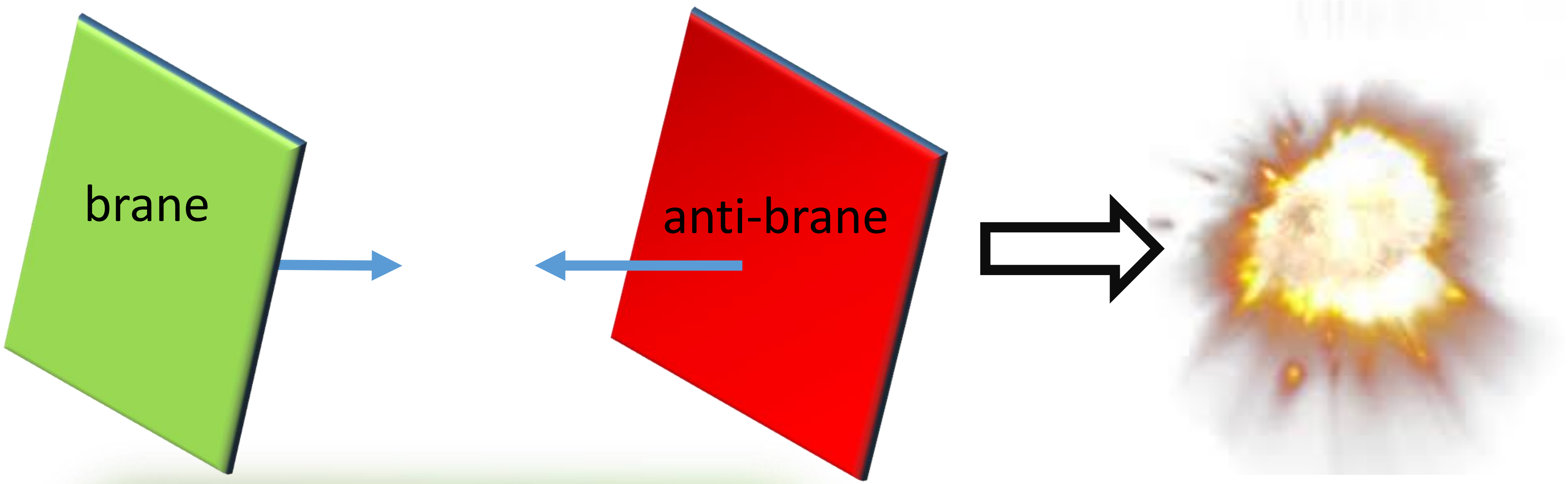
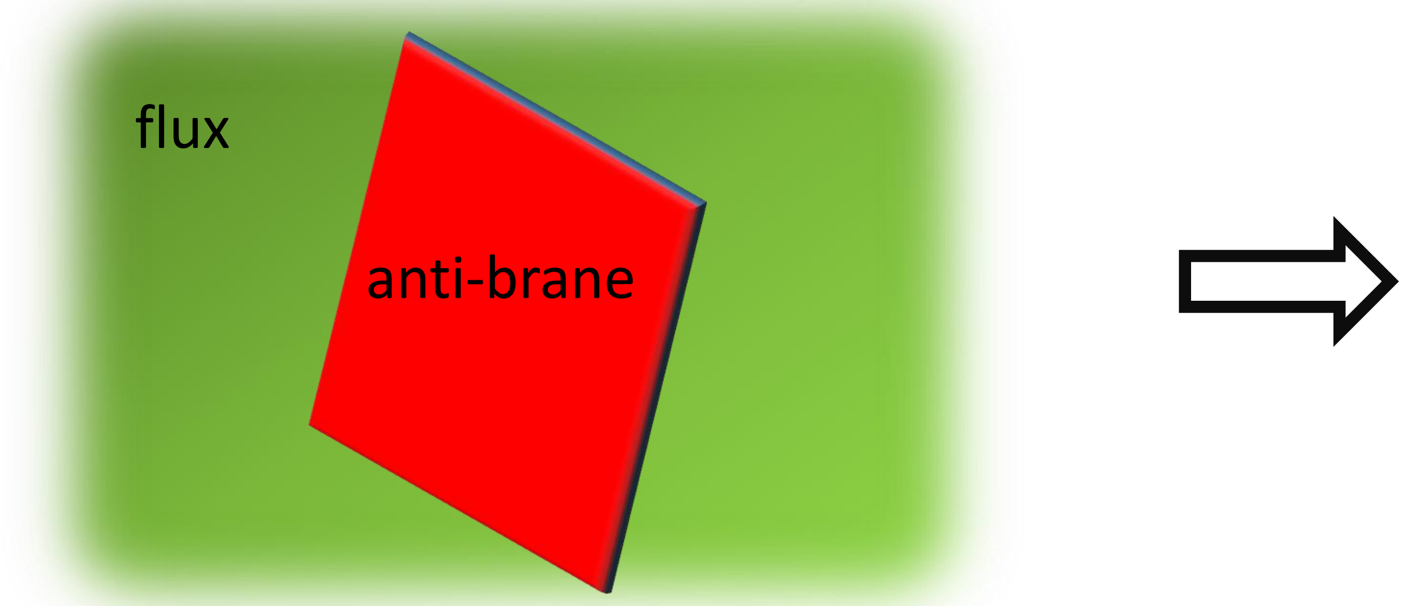
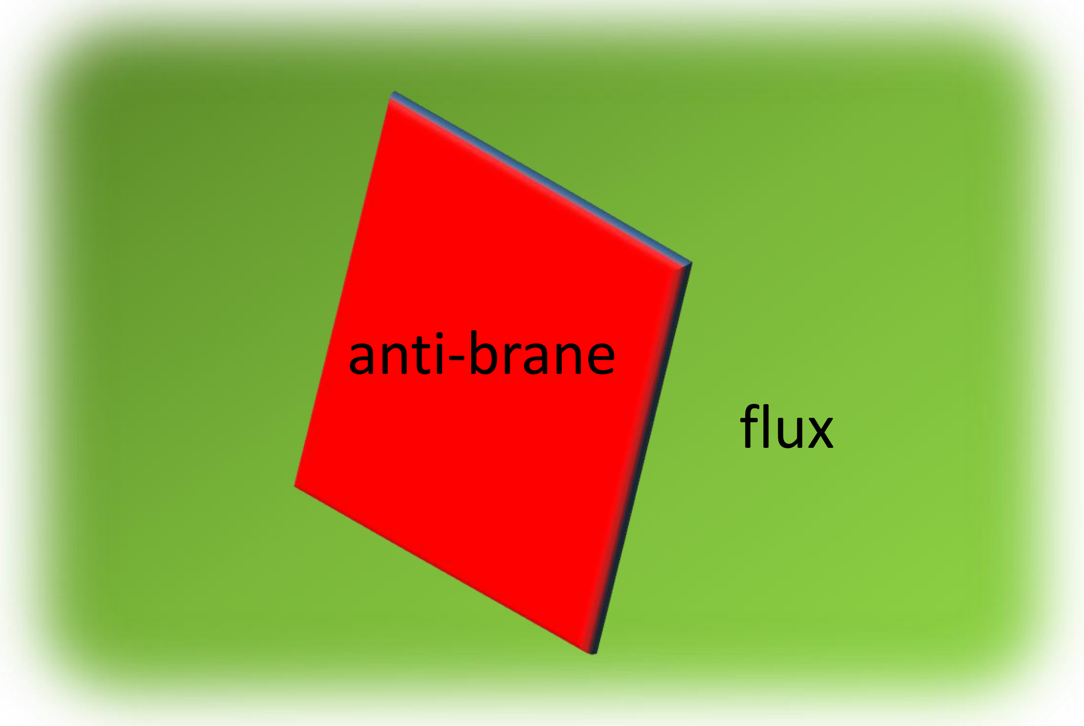


Perturbatively unstable



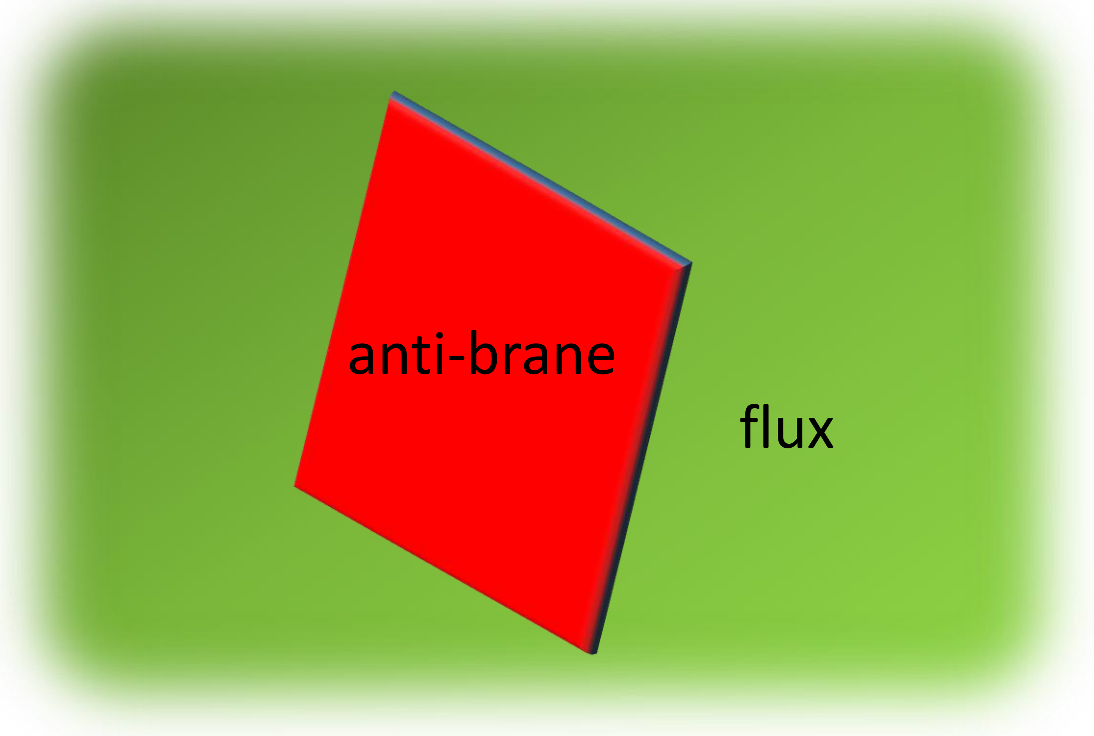
Perturbatively stable?

Yes! [Kachru&Pearson&Verlinde (KPV) 2002]



$$\mathrm{d}F_{8-p} = \underbrace{H \wedge F_{6-p}} + \underbrace{Q_p \delta}$$

Opposite orientation



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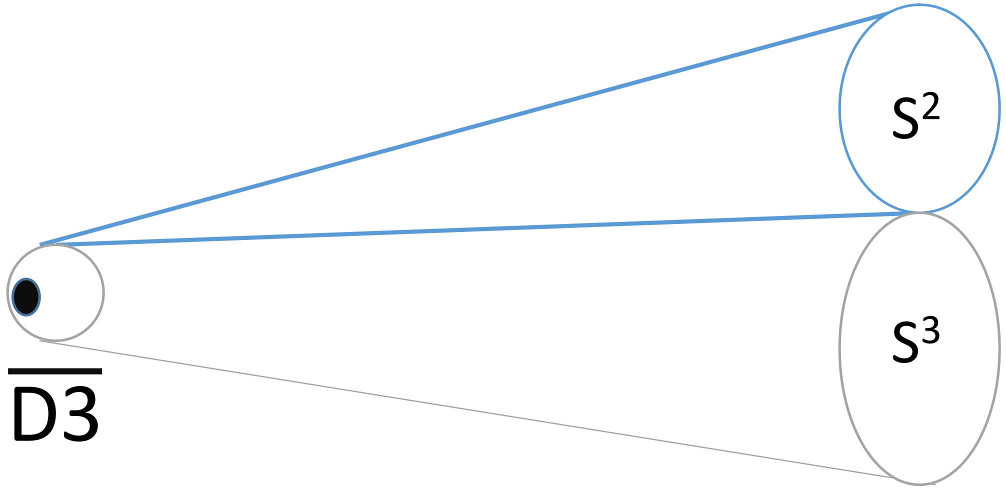
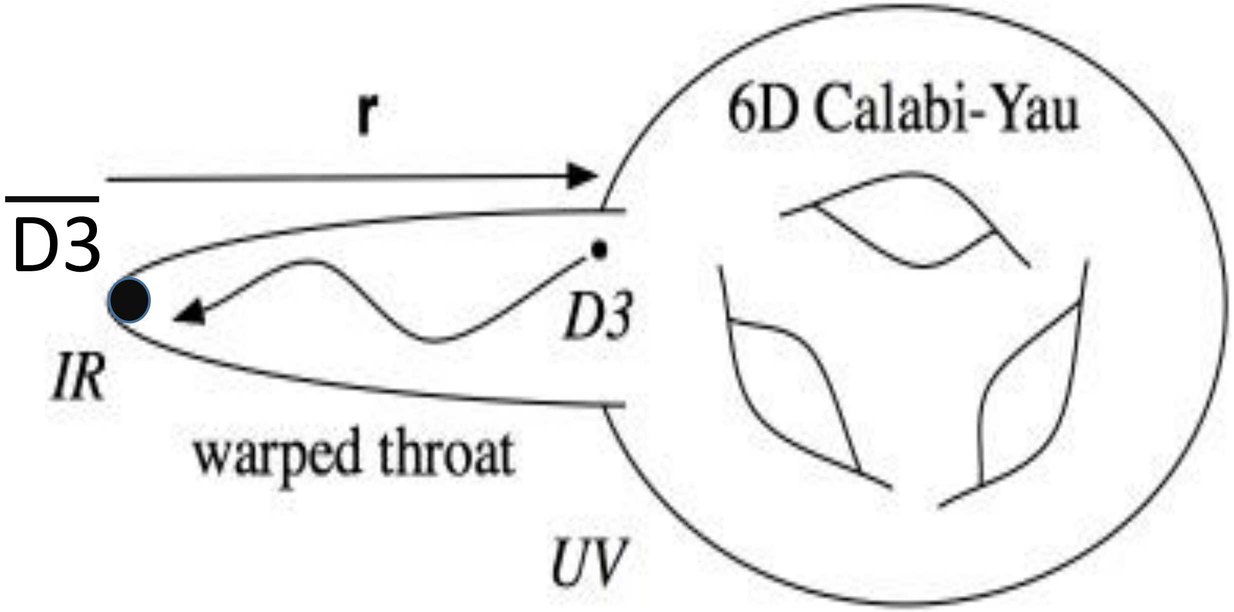
$\boxed{\text{Opposite orientation}}$

1. Holography of dynamical susy breaking [Maldacena & Nastase 2001, KPV 2002, …]
2. dS vacua [KKLT 2003]
3. Inflation [KKLMMT 2004]
4. Microscopic description of near extremal black holes [Bena, Puhm, Vercnocke 2011]

Holography of dynamical susy breaking (in KS gauge theory)

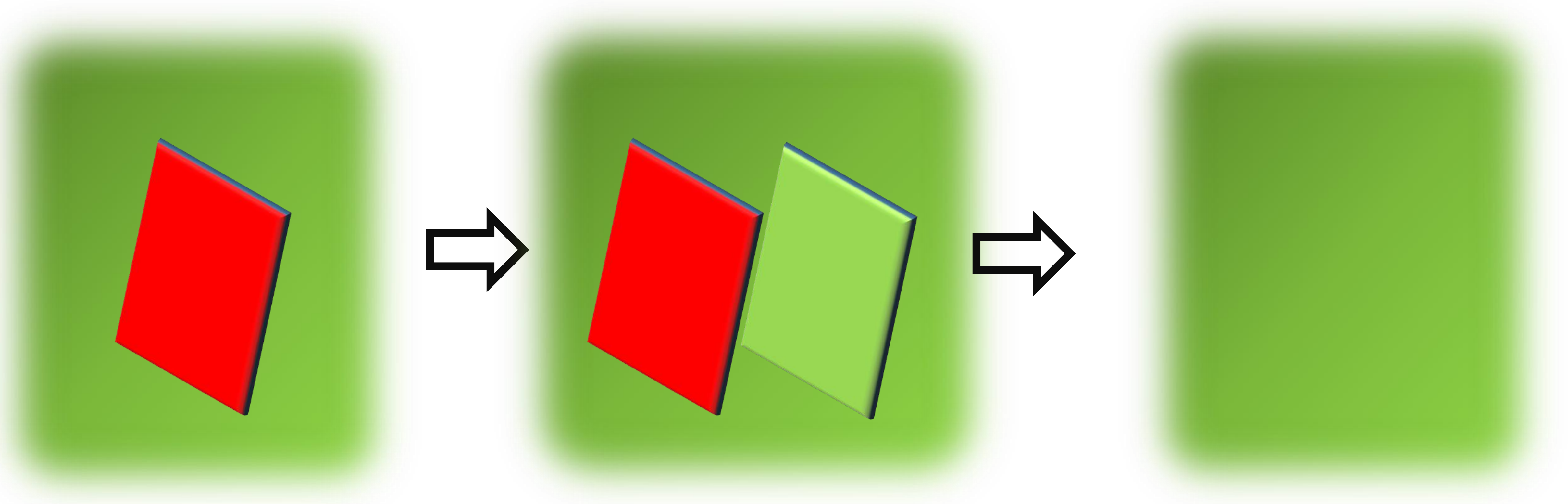
String pheno of dark energy&inflation.





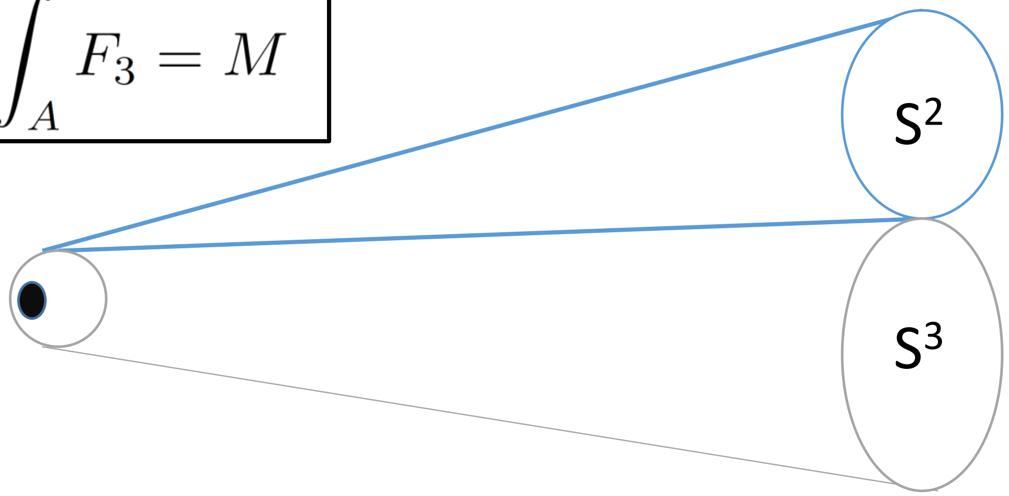
$$\boxed{\delta E = 2T_3 e^{4A}}$$

2. Brane-flux annihilation



Kachru, Pearson, Verlinde (KPV)

$$\boxed{\int_A F_3 = M}$$



- SUGRA IF :

$$\boxed{g_s << 1\,, \quad g_s p >> 1\,, \quad g_s M >> 1}$$

- Locally confined backreaction if :

$$\boxed{p/M << 1}$$

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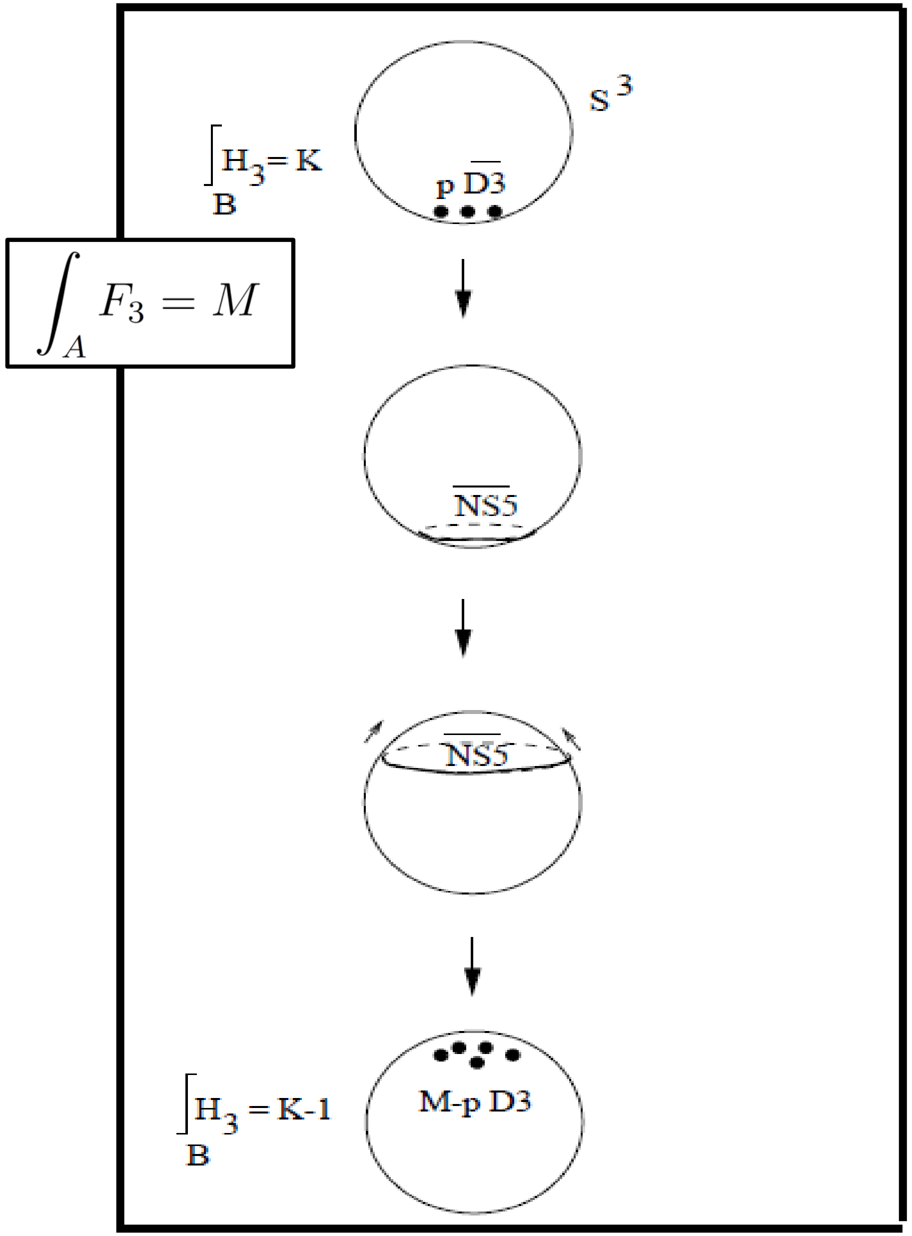

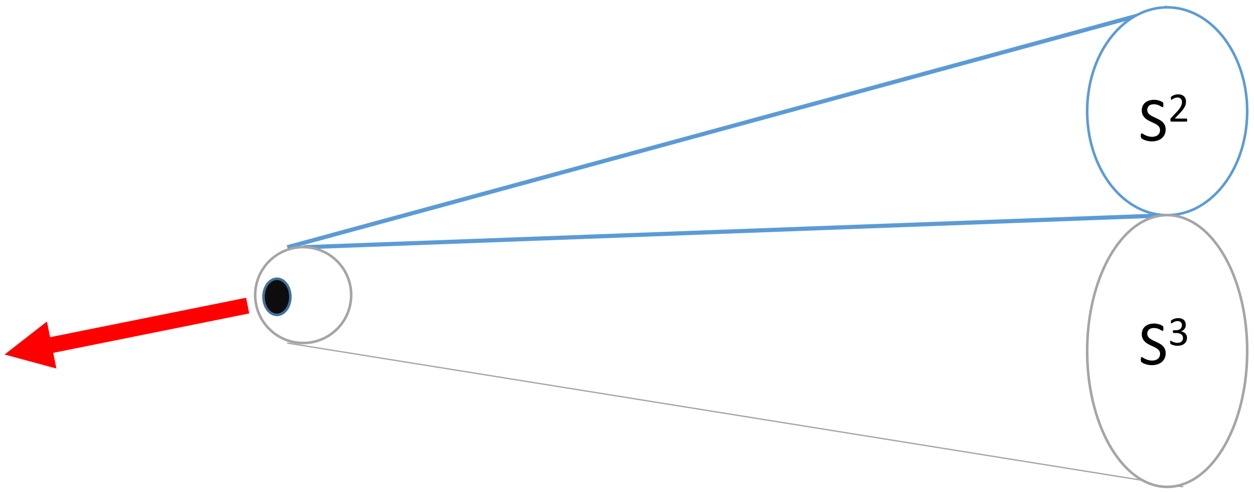

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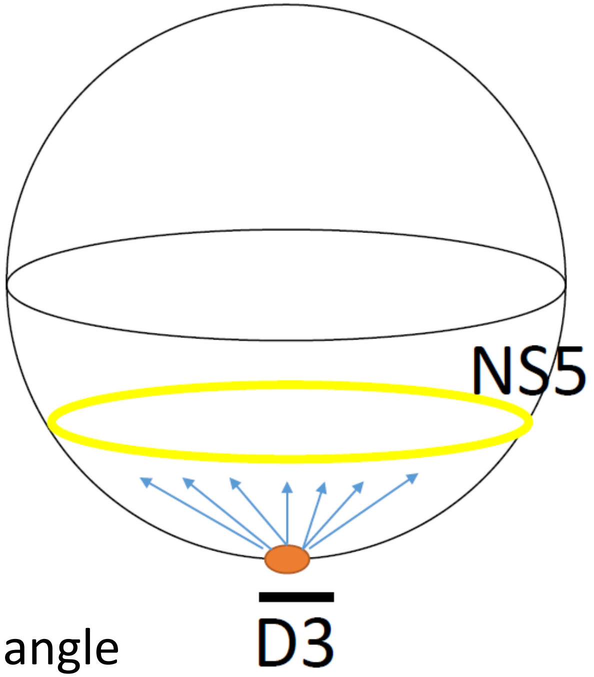
Charges? → NS5 Wess-Zumino action

$$\boxed{\mu_5 \int B_6 + 2\pi\mathcal{F}_2 \wedge C_4 \quad \text{, where} \quad 2\pi\mathcal{F}_2 = 2\pi F_2 - C_2}$$

$$2\pi \int_{S^2} F_2 = 4\pi^2 p \,. \qquad \int_{S^2} C_2 = 4\pi M(\psi - \tfrac{1}{2}\sin(2\psi))$$

ψ=0: p anti-D3 charges & ψ= π : M-p D3 charges



ψ = 3th Euler angle

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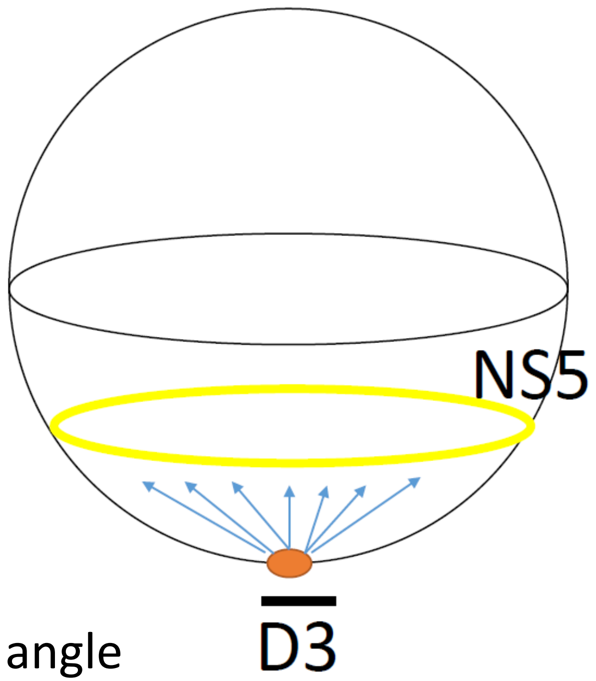


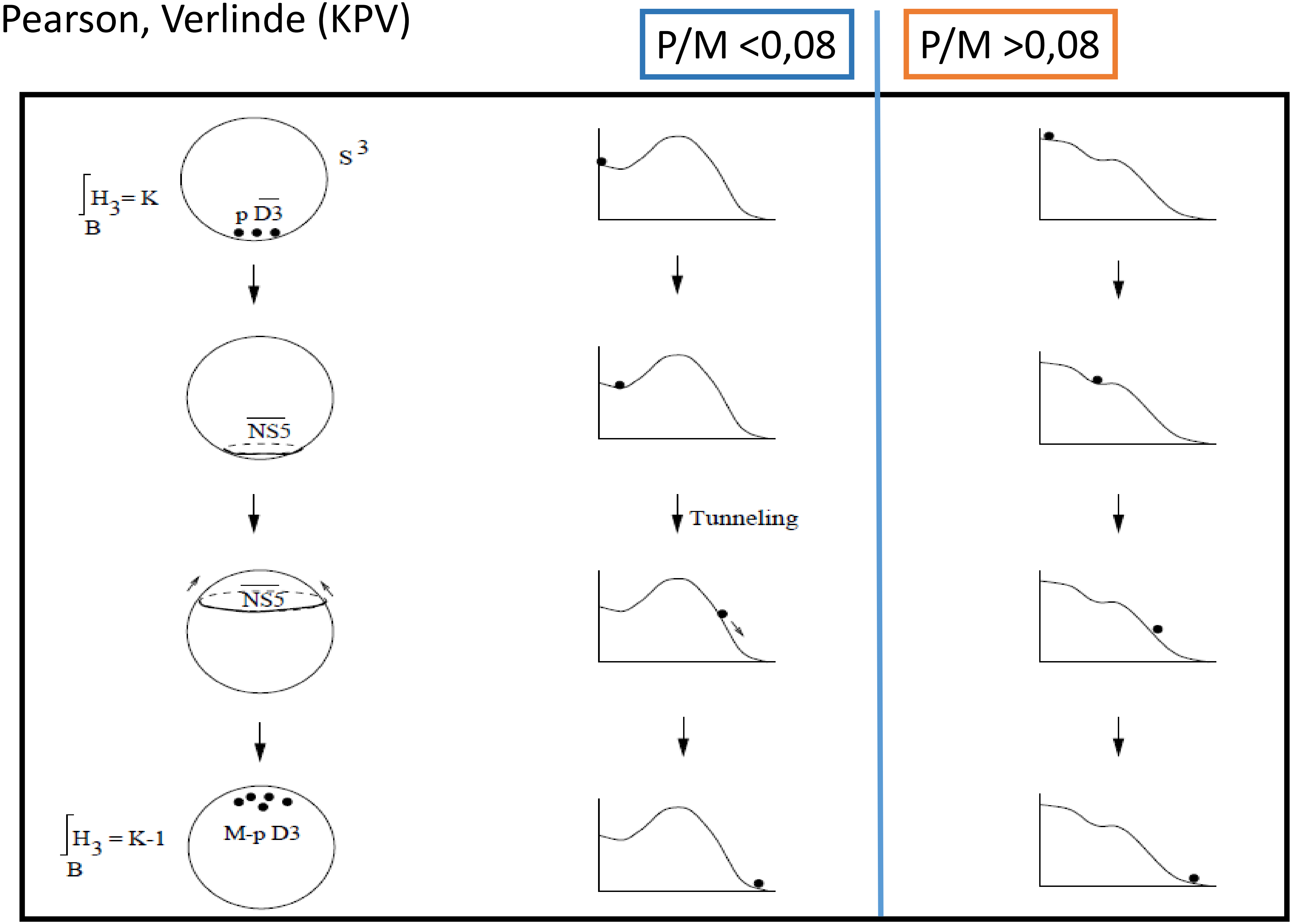
ψ = 3th Euler angle

Energy? → NS5 DBI + WZ action

$$\boxed{V_{eff}(\psi) \sim \frac{1}{\pi}\sqrt{b_0^4 \sin^4\psi + \left(\pi\frac{p}{M} - \psi + \tfrac{1}{2}\sin(2\psi)\right)^2} - \frac{\lambda}{2\pi}(2\psi - \sin(2\psi))}$$

Meta-stable state? Competition between DBI and WZ.

Kachru, Pearson, Verlinde (KPV)

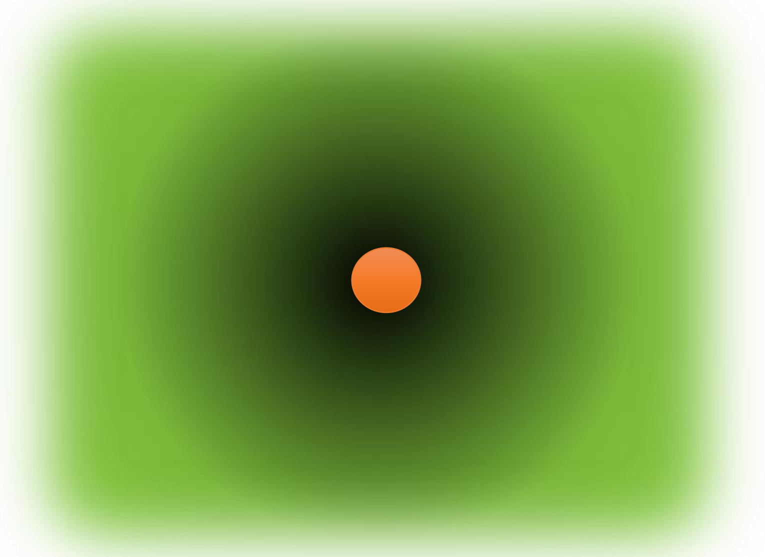


3. Backreaction

KPV computation: no backreaction

Flux attracted towards anti-branes gravitationally *and* magnetically

With backreaction



Can a probe approximation fail (in the probe limit) ?

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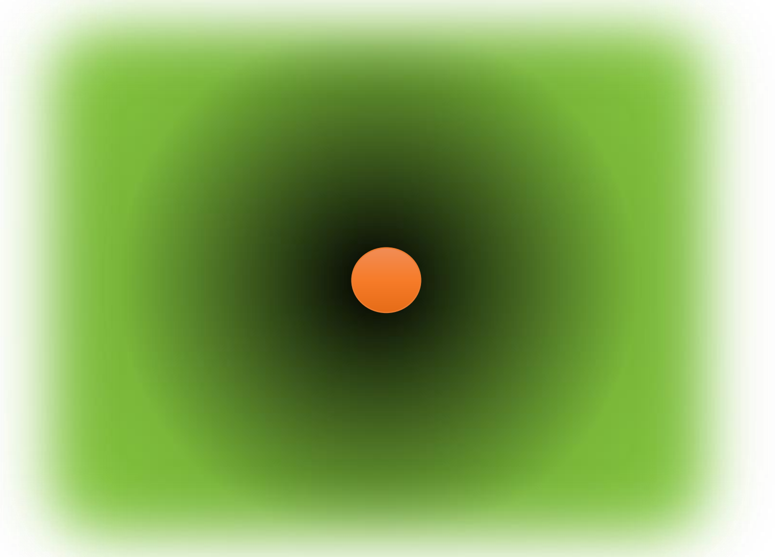

Can a probe approximation fail (in the probe limit) ?

→ Probe limit not understood: NS5 action at weak coupling? (NS5 radius of stringy size)
→ 10D backreaction: infinite fluxclumping!: [Shiu et al, Bena et al, Danielsson et al, Gautason et al];

$$\boxed{e^{-\phi}H^2 \to \infty}$$

????

Anti-D6 brane

[Blaback,Junghans, Danielsson, VR, Wrase, Zagermann (2011); Gautason, Danielsson, VR 2016]

$$
\begin{aligned}
\mathrm{d}s^2 &= \mathrm{e}^{2A}(-e^{-2f}\mathrm{d}t^2 + \mathrm{d}s_6^2) + \mathrm{e}^{2B}[e^{-2f}\mathrm{d}r^2 + r^2\mathrm{d}\Omega_2^2]\ , \\
F_0 &= M\ , \\
H_3 &= -\lambda \mathrm{e}^{\phi} \star_3 F_0\ , \\
F_2 &= -\mathrm{e}^{-7A} \star_3 \mathrm{d}\alpha\ .
\end{aligned}
\quad \Rightarrow \quad
\alpha = \lambda \mathrm{e}^{7A-\phi+f}\ .
$$

Solution described by ODE's! *Not true for anti-Dp with p<6*

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Extremal solution without anti-D6 branes [Janssen, Meessen, Ortin 1999, Imamura 2001] :

$$
\lambda = -1,\ \mathrm{e}^{A} = \mathrm{e}^{-B} = S^{-1/4} \qquad e^{\phi} = g_s S^{-3/4}
$$

$$
\boxed{S = v^2 + \frac{g_s \ell_s N}{4\pi r} - \frac{(M g_s r)^2}{6\ell_s^2}}
$$

Put N=0 → Pure flux throat and add anti-D6 sources at r=0

One can show that α at anti-D6 must be non-zero:

$$\lambda = \alpha_0 e^{-7A+\phi-f} \to \infty ,$$

$$\boxed{e^{-2\phi} H_3^2 \to \infty}$$

But still $$\int_0^R m H_3 < \infty \, ,$$

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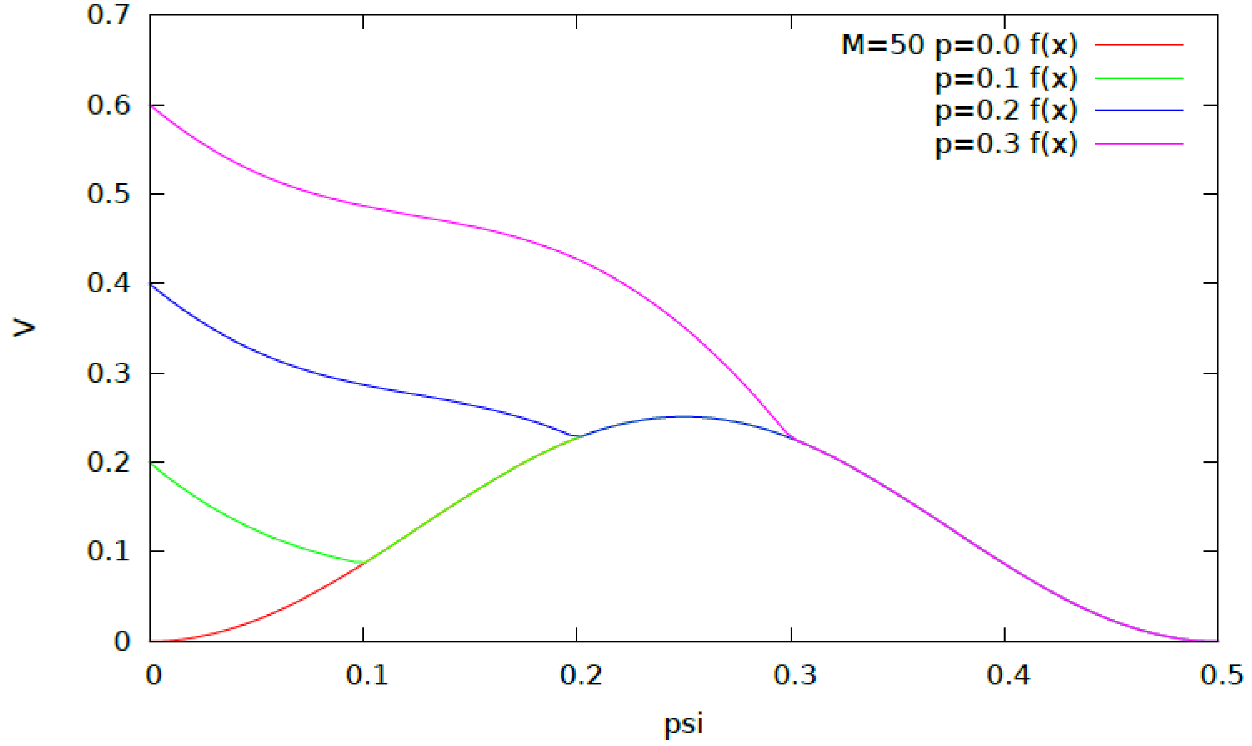
<u>Brane polarization changes back-reaction?</u>

- RR channel (D6→D8) **Smoothens**! But not allowed [Bena, Junghans, Kuperstein, VR, Wrase, Zagermann 2012].
- NSNS channel (D6→ KK5). No, same Ansatz! (…). KK5 does happen?

Probe potential for KK5 Schwinger pair creation:

$$V = \mu_5 g_s^{-1} M v^{-2} \left(\left| \frac{p}{M} - \frac{\Delta\psi}{\ell_s} \right| - \frac{\Delta\psi}{\ell_s} + \frac{p}{M} + \frac{4\pi}{M g_s} \sin^2\left(\frac{\pi\Delta\psi}{\ell_s}\right) \right)$$



Meta-stable if $\boxed{\frac{p}{M} < 0.25\ .}$

Correct for backreaction?

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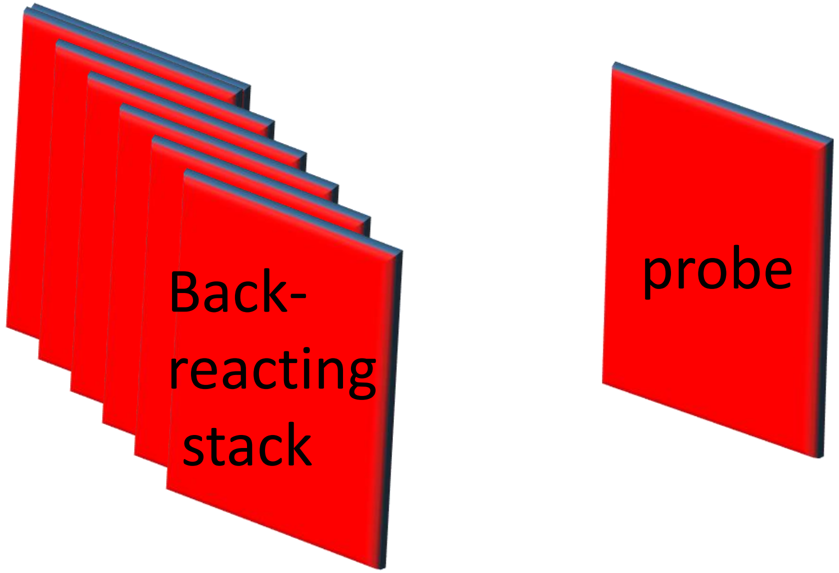

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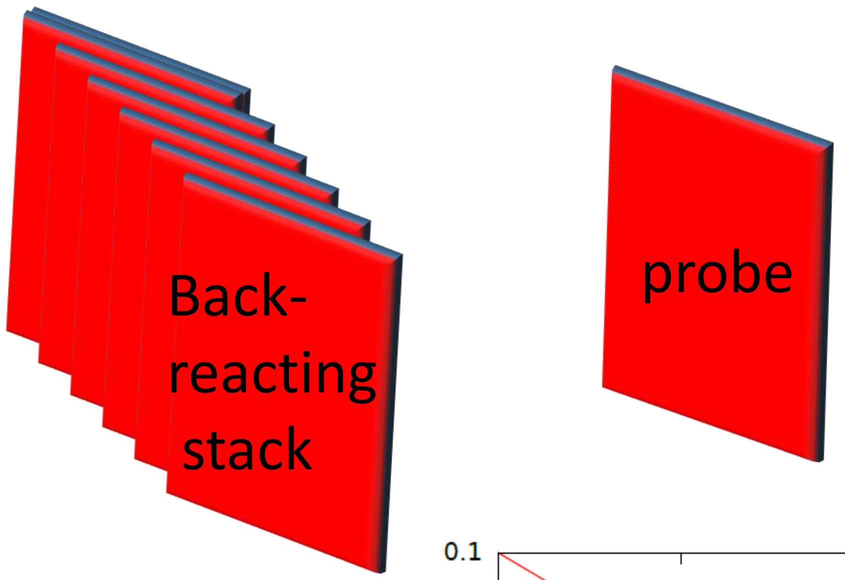
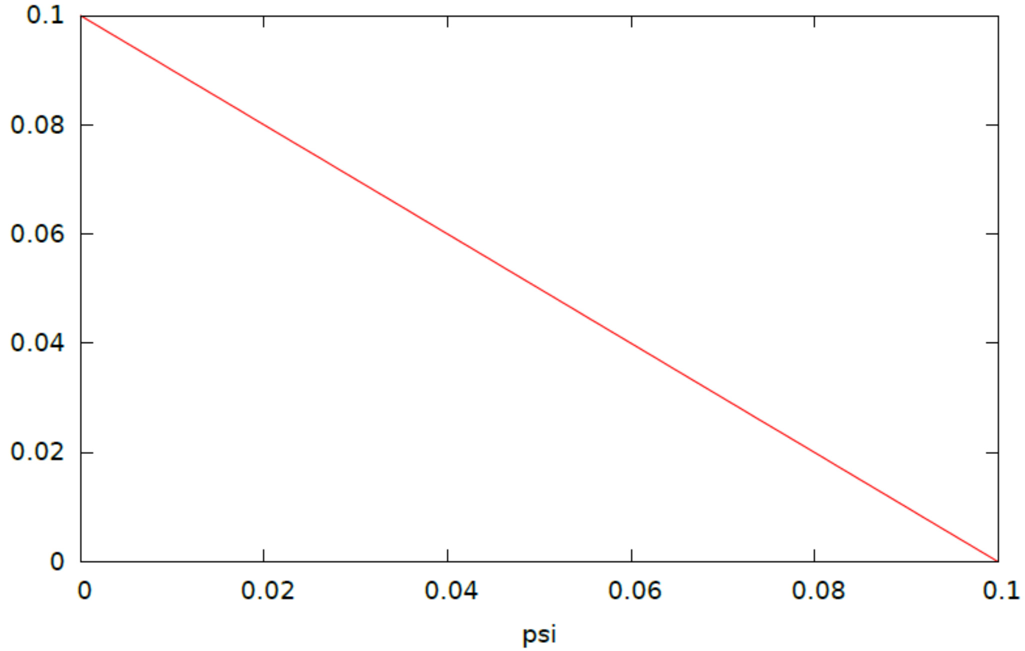
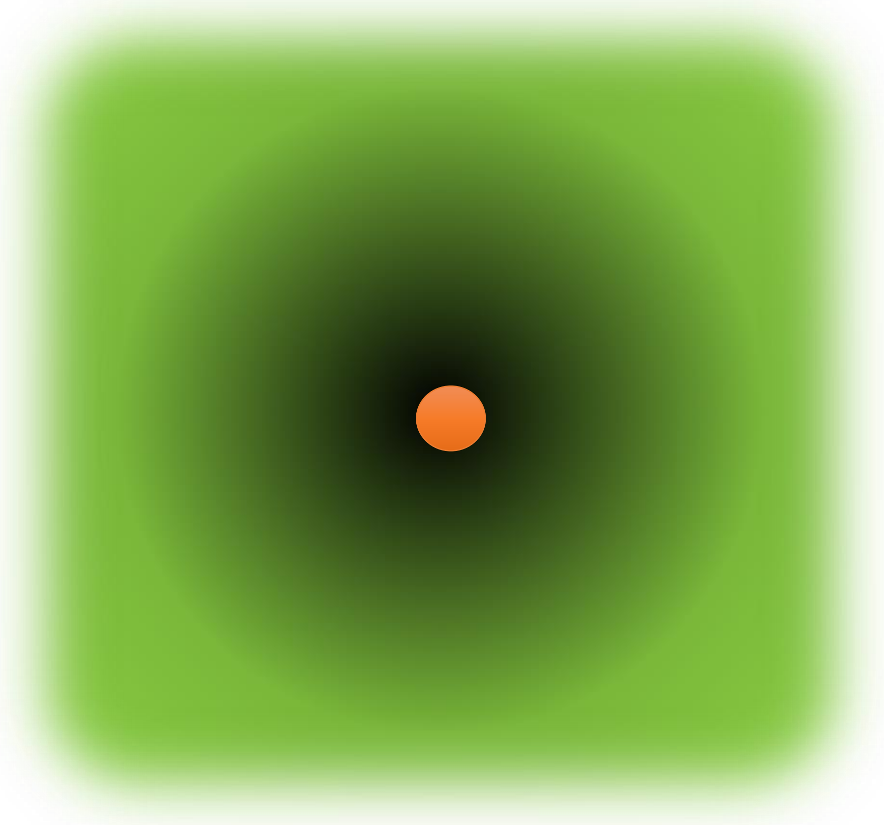




NO META-STABLE STATE

→ DBI contribution redshifted away=flux clumping.

Interpretation singularity? [Blaback, Danielsson, VR 2012, Danielsson, VR 2014]



<u>Resolution of singularity due to **time-dependence**</u>

No vacuum: « side of the hill »

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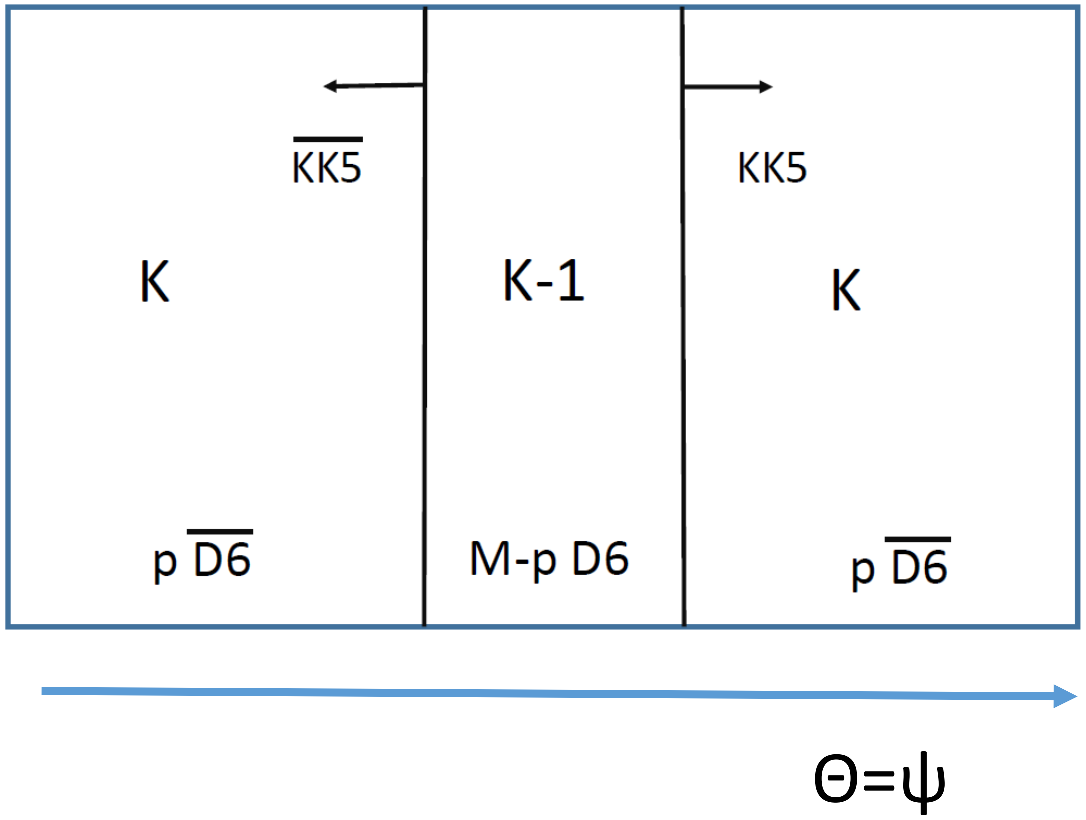
- From SMARR we see that NS5 boundary condition is necessary to avoid divergence.
- <u>= “Good” news</u> for KPV. Boundary condition “exists”[Santos et al?] ?
- However heuristic interpretation Smarr relation is <u>“bad” news</u> for KPV!

4. Conclusion

- Brane backreaction destabilizes meta-stable anti-D6 probe in SUGRA regime.
- Singularity resolved by time-dependence.
- Polchinski et al (2014-2015): probably not true in stringy regime (small p).
- What about anti-D3?
- EFT arguments [Michel, Mintum, Polchinski, Puhm, Saad 2015, Polchinski 2015, Danielsson, Gautason, VR 2016] suggest meta-stable vacua possible for anti-D3; But *big corrections*!
- Same EFT arguments show no meta-stable state at large p for anti-Dk with k>3
- Link with nilpotent chiral superfields? [Van der Schaar, Van der Aalst, Vercnocke, to appear]

BACK UP SLIDES



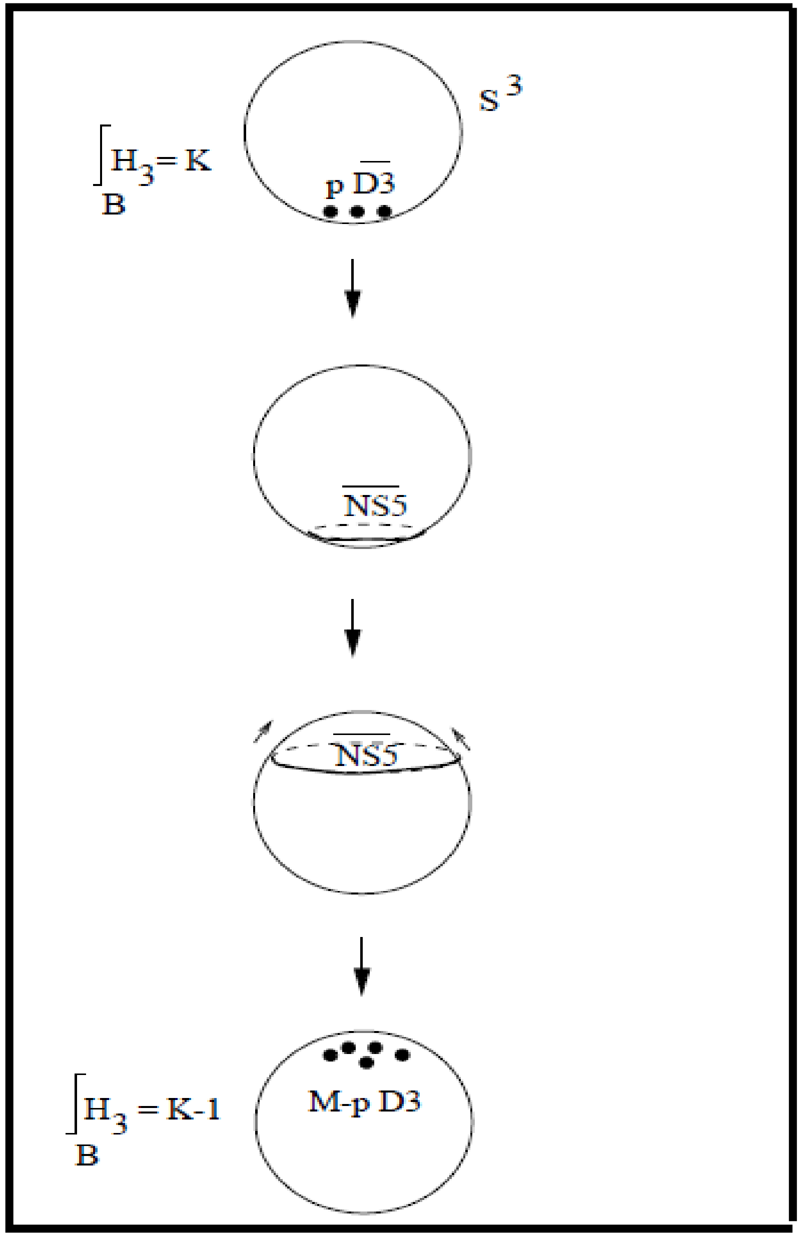
WZ contains term

$$S(\theta) = (n - \theta F_0) \int \iota_k C_7 \ ,$$

Massive T-duality: NS5 carrying anti-D5 charge

$$\int (n - C_0) \wedge C_6$$

Kachru, Pearson, Verlinde (KPV)



- Fluxes carry K x M D3 charges:

$$dF_5 = H \wedge F_3 + Q_3 \delta$$

- If K drops 1 unit [Brown-Bunster instanton]

$$\begin{aligned} Q_{Total} &= Q_{flux} + Q_{D3} + Q_{\bar{D}3} \\ &= KM + 0 - p \\ &= (K-1)M + M - p \\ &= (K-1)M + (M-p) + 0 \end{aligned}$$

- Key processes: **Brane polarisation** (Myers) & bubble nucleation

$$\boxed{\begin{aligned} &\mathrm{d}s^2_{10} = \mathrm{e}^{2A}\left(-e^{2f}\mathrm{d}t^2 + \delta_{ij}\mathrm{d}x^i\mathrm{d}x^j\right) + \mathrm{d}s^2_6\,, \\ &C_4 = \tilde{\star}_4\alpha, \\ &H_3 = -\mathrm{e}^{\phi-4A-f}\,\star_6\left((\alpha+\alpha_0)F_3 + X_3\right)\,. \end{aligned}}$$

General process/principle [Gautason, Truijen, VR (2015)]

- RR tadpole $$\int_M H_3 \wedge F_{6-p} = 2\kappa_{10}^2 Q_p$$

- $$\int_B H_3 \sim K$$
- $$\int_A F_{6-p} \sim M$$
- $$Q \sim N_p$$

$$\boxed{N_p = KM}$$

- Hence

$$\begin{aligned} \text{NSNS decay} \quad &: \quad K \to K-1 \quad , \quad N_p \to N_p - M \, , \\ \text{RR decay} \quad &: \quad M \to M-1 \quad , \quad N_p \to N_p - K \, . \end{aligned}$$

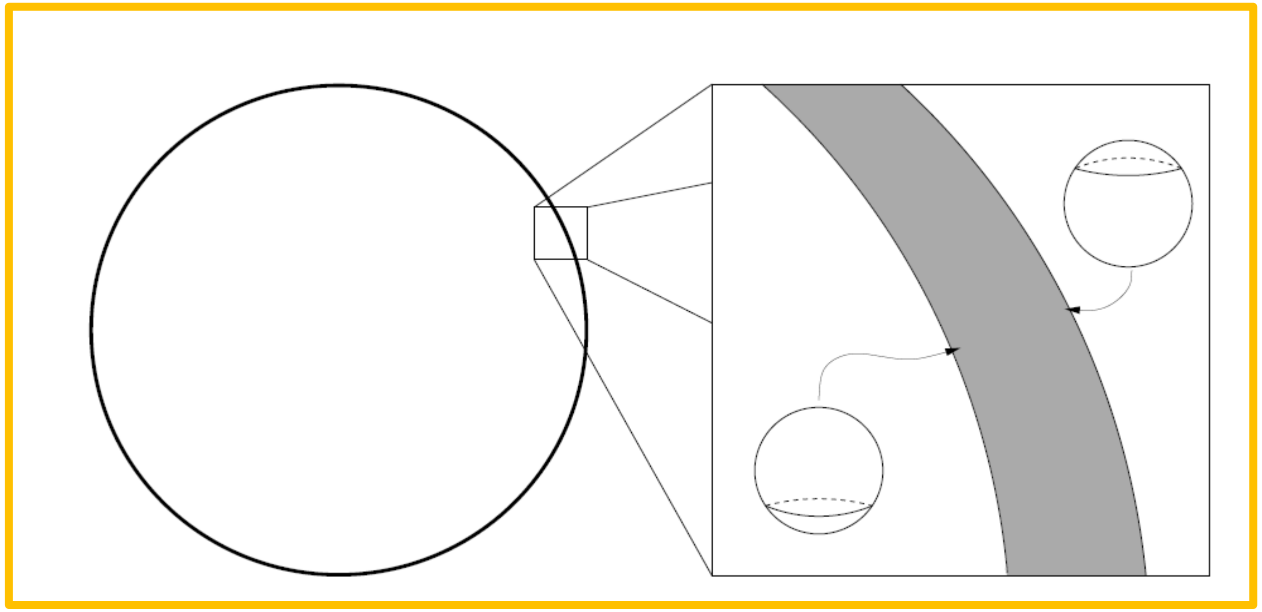
- For p<6:

	Thin wall	$p+1$			A-cycle			B-cycle		
	Op/Dp	$\times$	...	$\times$	$-$	...	$-$	$-$	...	$-$
NSNS decay:	NS5	$\times$	...	$\uparrow$	$\times$	...	$\times$	$-$	...	$-$
RR decay:	D$(p+2)$	$\times$	...	$\uparrow$	$-$	...	$-$	$\times$	...	$\times$

	Thick wall	$p+1$			A-cycle			B-cycle		
	Op/Dp	$\times$	...	$\times$	$-$	...	$-$	$-$	...	$-$
NSNS decay:	NS5	$\times$	...	$\times$	$\times$	...	$\uparrow$	$-$	...	$-$
RR decay:	D$(p+2)$	$\times$	...	$\times$	$-$	...	$-$	$\times$	...	$\uparrow$

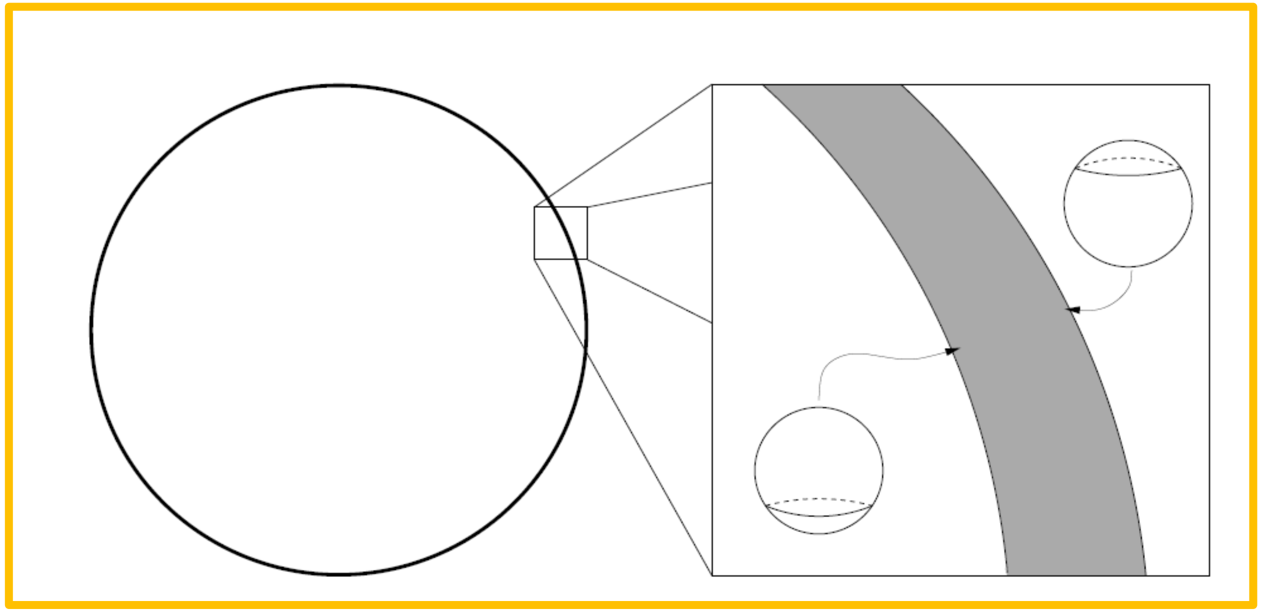
- For p=6 : NSNS thick wall, via KK5 branes inside D6 branes.

WZ couplings for thick wall process (brane decay/nucleation):



$$\mu_{\mathrm{NS5}} \int (\mathrm{d}a_{4-p} - C_{5-p}) \wedge \sigma(C_{p+1}) \ ,$$

$$Q(x) = (2\pi)^{\frac{p-5}{2}} \int_{\Sigma_{5-p}(x)} (\mathrm{d}a_{4-p} - C_{5-p}) \, ,$$



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- Quantised worldvolume flux:

$$\int_{\Sigma_{5-p}(x)} \mathrm{d}a_{4-p} = (2\pi)^{\frac{5-p}{2}} n \, .$$

- Stokes theorem:

$$\int_{x\to 1} C_{5-p} - \int_{x\to 0} C_{5-p} = \int_A F_{6-p} = (2\pi)^{\frac{5-p}{2}} M \ .$$

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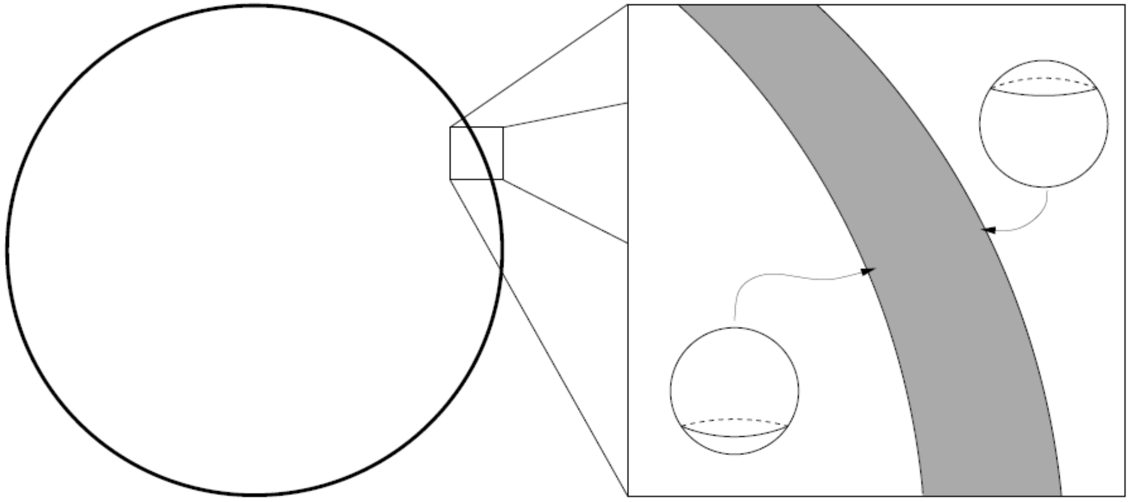

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$$\downarrow$$

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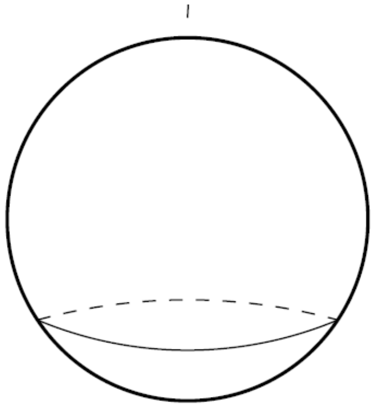
$$Q(0) = n$$



$$Q(1) = n - M \, .$$