Smeared versus localized sources in flux compactifications

Timm Wrase

Cornell University

Based on:

TW, Zagermann 1003.0029

Blåbäck, Danielsson, Junghans, Van Riet, TW, Zagermann 1009.1877

String Vacuum Project meeting Fall 2010

Classical type II flux compactifications

- Most constructions of dS vacua use non-perturbative effects for moduli stabilization
- dS after uplift which breaks explicitly SUSY

KKLT, Large Volume

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Villadoro, Zwirner hep-th/0503169
DeWolfe, Giryavets, Kachru, Taylor hep-th/0505160
Cámara, Font, Ibáñez hep-th/0506066

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KKLT, LARGE VOLUME

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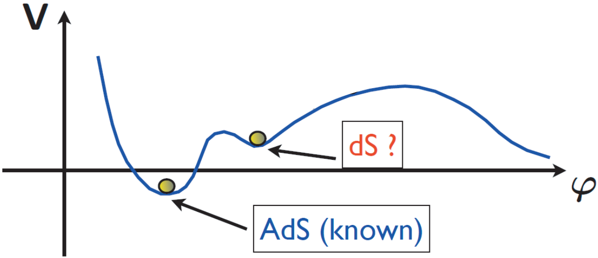

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Can we find classical dS vacua?

Hertzberg, Tegmark, Kachru, Shelton, Ozcan 0709.0002 [astro-ph]

Type II supergravity

The classical ingredients for type II supergravity theories are

RR-fluxes F_p, NSNS H-flux, R_6, Oq-planes, ...

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For smeared Oq-planes we find a 4D scalar potential

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where $\rho = (vol_6)^{1/3}$ and ϕ is the dilaton.

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When is $\partial_\rho V = \partial_\phi V = 0$ and $V > 0$ possible?

Hertzberg, Kachru, Taylor, Tegmark 0711.2512 [hep-th]

We can evade a no-go theorem involving ρ and ϕ with the following minimal ingredients

Curvature	IIA	IIB
$V_{R_6} \sim -R_6 \leq 0$	O4, H, F_0	O3, H, F_1
$V_{R_6} \sim -R_6 > 0$	O4, F_0 O4, F_2 O6, F_0	O3, F_1 O3, F_3 O3, F_5 O5, F_1

Hertzberg, Kachru, Taylor, Tegmark 0711.2512 [hep-th]
Silverstein 0712.1196 [hep-th]
Haque, Shiu, Underwood, Van Riet 0810.5328 [hep-th]
Caviezel, Koerber, Körs, Lüst, TW, M. Zagermann 0812.3551 [hep-th]
Flauger, Robbins, Paban, TW 0812.3886 [hep-th]
Danielsson, Haque, Shiu, Van Riet 0907.2041 [hep-th]
de Carlos, Guarino, Moreno 0907.5580, 0911.2876 [hep-th]
Caviezel, TW, Zagermann 0912.3287 [hep-th]
TW, Zagermann 1003.0029 [hep-th]
Danielsson, Koerber, Van Riet 1003.3590 [hep-th]

Danielsson, Haque, Koerber, Shiu, Van Riet, TW 1011.xxxx [hep-th]

Smeared versus localized sources

- O-planes are localized objects
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When is smearing $\delta(Oq) \approx 1$ a valid approximation?

Negative curvature $R_6 < 0$ requires (in the localized case)

large warping or large stringy corrections

Douglas, Kallosh 1001.4008 [hep-th]

An example with BPS sources

Giddings, Kachru and Polchinski found localized no-scale Minkowski solutions with O3-planes

Giddings, Kachru, Polchinski hep-th/0105097

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smeared case

H, F_3, O3

$$ds^2 = ds_4^2 + ds_6^2$$

$$0 = \mathrm{d}F_5 = H \wedge F_3 - \tilde{\mu}_3$$

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localized case

H, F_3, O3, F_5, A

$$ds^2 = e^{2A} ds_4^2 + e^{-2A} ds_6^2$$

$$\mathrm{d}F_5 = H \wedge F_3 - \tilde{\mu}_3 \delta(O3)$$

Smeared vs. localized sources

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An example with BPS sources

- Can solve the 10D equations of motions in both cases
- Find no-scale Minkowski vacua
- Internal space is (conformally) Ricci-flat

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But localization effects are large

$$\nabla^2 e^{-4A} = -e^{-\phi}|H|^2 + \tilde{\mu}_3 \delta(O3)$$

An example with BPS sources

- Can solve the 10D equations of motions in both cases
- Find no-scale Minkowski vacua
- Internal space is (conformally) Ricci-flat
- Complex structure moduli and ϕ are stabilized

smeared case

$$F_3 = -e^{-\phi} \star_6 H$$

localized case

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An example with BPS sources

BUT

$$F_3 = -e^{-\phi} \star_6 H = -e^{-\phi} \star_6 H$$

since warp factor cancels: $\star_6 H \approx \sqrt{\det\left(e^{2A} g_6\right)} \left(e^{-2A} g_6^{-1}\right)^3 H$

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Moduli values at minimum unchanged!

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smeared: H and F_3 stabilize moduli

localized: $\tilde{\mu}_3 \delta(O3), F_5, A$ give corrections of equal size

$\Rightarrow$ corrections from $\tilde{\mu}_3 \delta(O3), F_5, A$ cancel each other

A T-dual example with BPS sources

T-duality along one H-flux direction $\leftrightarrow$ Douglas, Kallosh

$$\begin{array}{ccc} H & \to & R_6 < 0 \\ F_3 & \to & F_4 \\ O3 & \to & O4 \\ F_5 & \to & F_4 \\ A & \to & A \end{array}$$

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$$\begin{aligned} H &\rightarrow R_6 < 0 \\ F_3 &\rightarrow F_4 \\ O3 &\rightarrow O4 \\ F_5 &\rightarrow F_4 \\ A &\rightarrow A \end{aligned}$$

Conclusions remain unchanged:

- Douglas, Kallosh $\Rightarrow$ warping effects are large
- But again smeared moduli values are unaffected

Note: $\int \sqrt{g_{10}} R_6 < 0 \quad \Rightarrow \quad V_{R_6} > 0$

(no 'uplift' to dS, solutions are Minkowski)

Smeared vs. localized sources

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An example with non-BPS sources

Replace $O3$-plane by $\overline{D3}$-brane:

smeared case

$$\mathrm{H},\ F_3,\ \overline{D3}$$

$$ds^2 = ds_4^2 + ds_6^2$$

$$0 = \mathrm{d}F_5 = H \wedge F_3 - \mu_3$$

localized case

$$\mathrm{H},\ F_3,\ \overline{D3},\ F_5,\ A,\ \ldots$$

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- Find AdS solutions $V = V_{F_3} + V_H - V_{R_6} + V_{\overline{D3}} < 0$
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- volume moduli stabilized: e.g. $R_{ij}^{S^3} = \frac{1}{2}\mathrm{e}^{-\phi}|H|^2 g_{ij}^{S^3}$

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- volume moduli stabilized: e.g. $R_{ij}^{S^3} = \frac{1}{2}\mathrm{e}^{-\phi}|H|^2 g_{ij}^{S^3}$
- no SUSY but volume and dilaton masses above BF bound

An example with non-BPS sources

localized case

H, F_3, $\overline{D3}$, F_5, A, …

$$ds^2 = e^{2A} ds_4^2 + ds_6^2$$

$$dF_5 = H \wedge F_3 - \mu_3 \delta(O3)$$

- (Assume) $F_1 = 0$, $F_3 = -e^{-\phi} \star_6 H$ for arbitrary g_6
- Combine eoms for F_3, H, F_5 and external Einstein:

$$e^{-2A} R_4 = -(1+1)\mu_3 \delta(\overline{D3})$$

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The smeared solution cannot be localized?

BPS versus non-BPS sources

BPS condition in GKP

$$\frac{1}{4}(T^m_m - T^\mu_\mu)^{\rm loc} \geq \mu_3 \rho_3^{\rm loc}$$

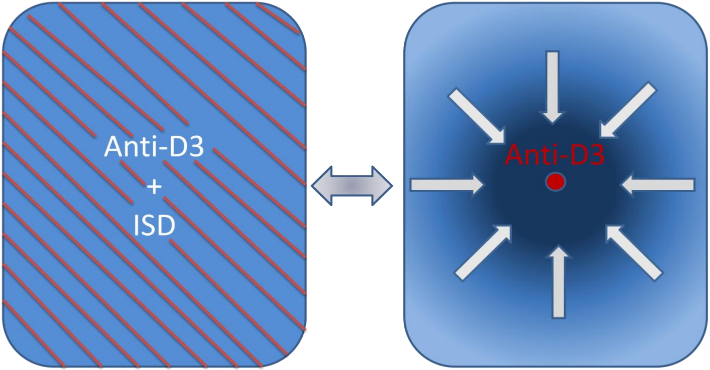
For $O3$, $D3$ and $\overline{D3}$ we have $T^m_m = 0$.

	O3	$\overline{D3}$	D3
$\rho_3^{\rm loc}$	$-\frac{1}{4}$	-1	1
$-\frac{1}{4}T^\mu_\mu$	$\mu_3\rho_3^{\rm loc}$	$-\mu_3\rho_3^{\rm loc}$	$\mu_3\rho_3^{\rm loc}$
BPS	✓	×	✓

Force between $\overline{D3}$ and fluxes H, F_3

$\Rightarrow$ no static localized solution

non-BPS sources



smeared case localized case

Localization effects

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Yes!

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Yes! But so are the fluxes!

$$\frac{1}{\lambda^2}\nabla^2 e^A = \frac{1}{\lambda^{2p}}|\text{flux}|_p^2$$

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Are there regions of small warping $e^A \approx 1$ and $(\nabla A)^2 \ll 1$?

Not really:

$$\nabla^2 e^A = e^A \nabla^2 A + e^A (\nabla A)^2 \approx \nabla^2 A = |\text{flux}|_p^2$$

Conclusion:

- Explicit examples:
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  - non-BPS solutions problematic
- Localization effects comparable to fluxes

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THANK YOU!