Non-commutative IIA and IIB geometries from *Q*-branes and their intersection

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Arnold Sommerfeld Center
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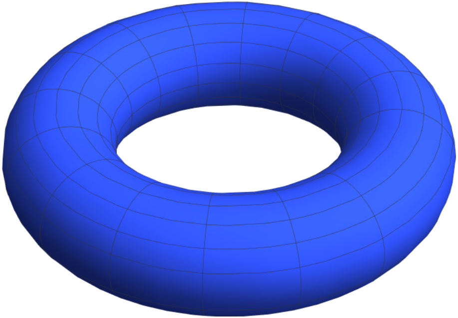
March 22, 2013

Spacetime geometry “seen” by point particles

- general relativity: spacetime = smooth manifold



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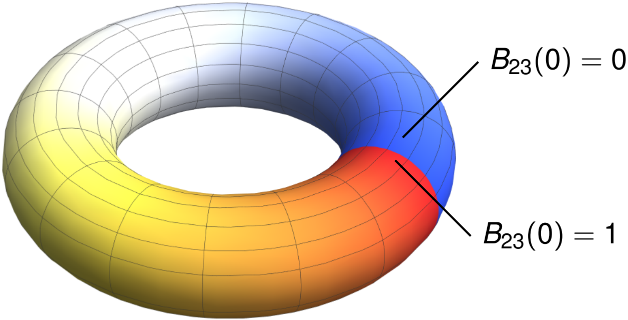

- fields are connected by gauge transformations

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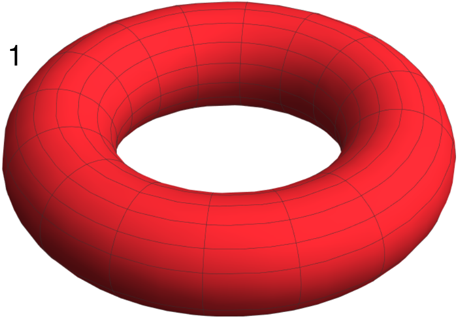
$H_{123} = \partial_{[1} B_{23]} = 1$



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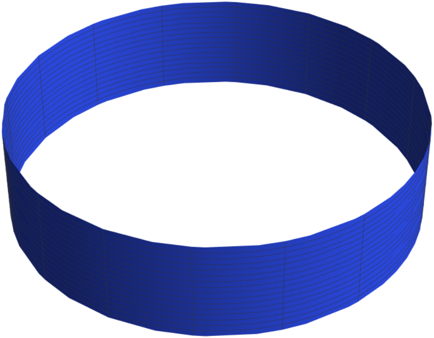

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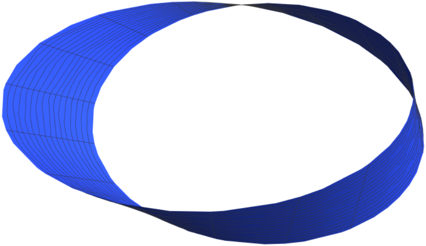

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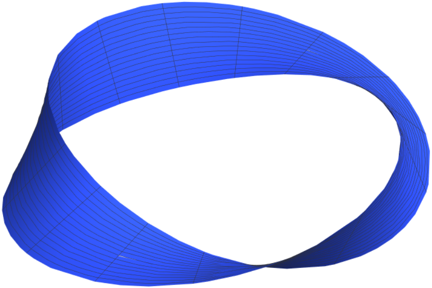

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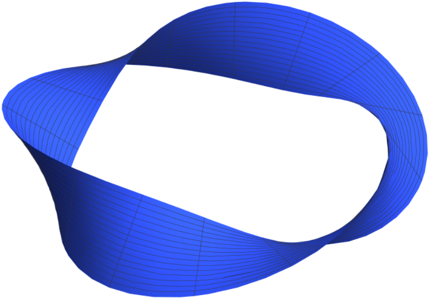

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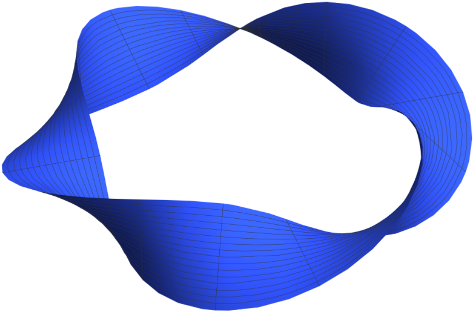

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Strings have a different perspective:

- closed strings also wind around the torus → T-duality

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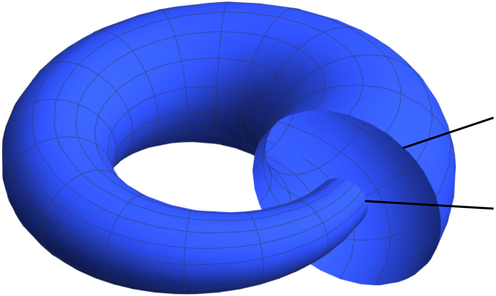

circles with radius

R

and

$1/R$

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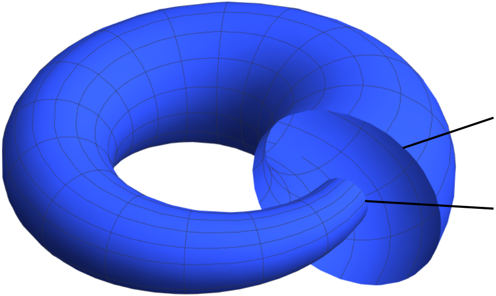

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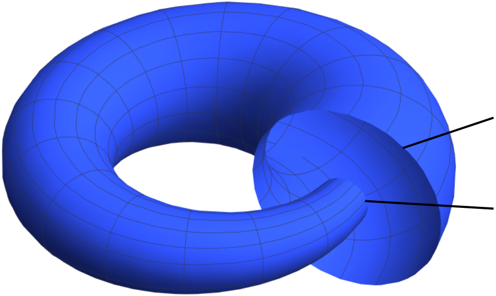

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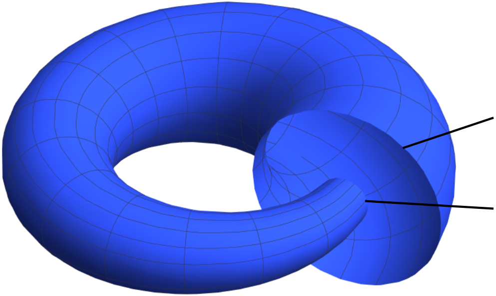

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- new interesting properties like non-commutativity
- compactifications lead to gauged SUGRA
  - moduli stabilization
  - effective cosmological constant
  - spontaneous SUSY breaking

How to find these interesting backgrounds?

1. geometric string theory background **with fluxes**

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H_{ijk}

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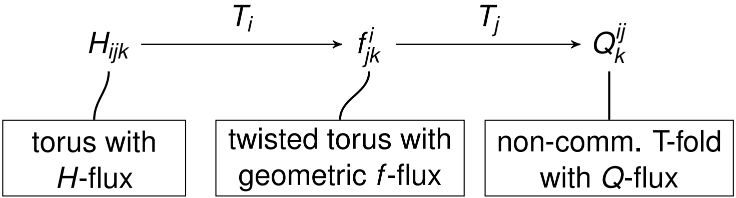

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non-comm. T-fold with Q-flux

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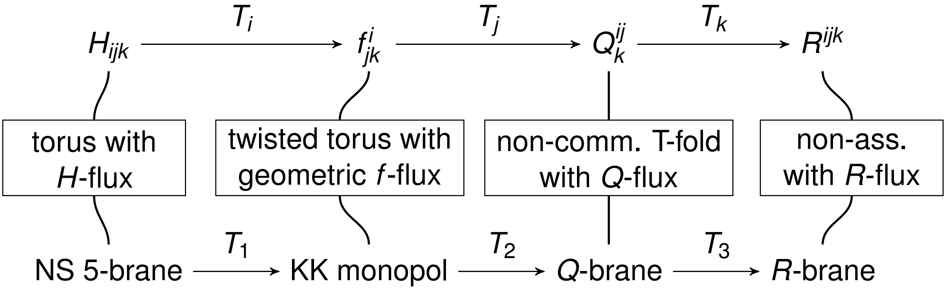

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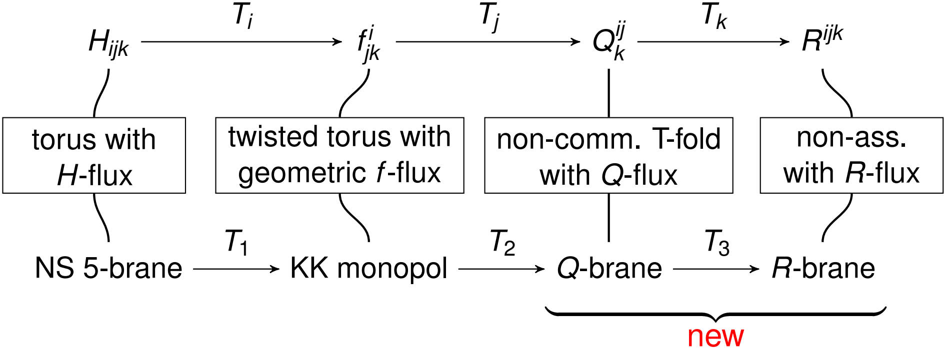

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$$\underbrace{\hphantom{Q\text{-brane} \xrightarrow{T_3} R\text{-brane}}}_{\text{new}}$$

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NS 5-brane

- brane charged under the Kalb-Ramond field B

	uncompact				compact on torus $y^i \sim y^i + 2\pi$					
	x^0	x^1	x^2	x^3	y^1	y^2	y^3	y^4	y^5	y^6
NS 5	⊗	⊗	⊗					⊗	⊗	⊗

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$$ds^2_{NS5} = \sum_i (dx^i_{\|})^2 + h(r) \sum_k (dx^k_{\perp})^2 \qquad e^{\phi} = \sqrt{h(r)}$$

$$H_{mnp} = \epsilon_{mnpq} \partial_q h(r)$$

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Kaluza-Klein monopol

- T-Duality along y^1 (isometry) with Buscher rules

(Buscher, 1987)

	x^0	x^1	x^2	x^3	y	y^2	y^3	y^4	y^5	y^6
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- A_2 and A_3 components of one-form gauge field

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- A_2 and A_3 components of one-form gauge field
- we choose gauge $A_3 = 0$
- remaining component A_2 ($= B_{y^1,y^2}$ of NS 5-brane) is connected with h

$$\partial_{y^3} A_2 = \partial_{x^3} h$$

- T-Duality along y^1 and y^2 (isometries)

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$$A_2(x^3, y^3) \neq A_2(x^3, y^3 + 2\pi)$$

already considered by
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- for $h(r) = Qx^3$ we get T-fold with Q flux

Q-brane

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Q	⊗	⊗	⊗		•	•		⊗	⊗	⊗

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$$(\tilde{G}^{-1} + \beta)^{-1} \equiv \tilde{\mathcal{E}}^{-1} = \mathcal{E} = G + B$$

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- simplifies calculations considerably

Backgrounds for IIA and IIB with fluxes

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	x^0	x^1	x^2	x^3	y^1	y^2	y^3	y^4	y^5	y^6
NS5	$\otimes$	$\otimes$	$\otimes$		$\otimes$		$\otimes$		$\otimes$	
NS5′	$\otimes$	$\otimes$	$\otimes$		$\otimes$			$\otimes$		$\otimes$
NS5″	$\otimes$	$\otimes$	$\otimes$			$\otimes$		$\otimes$	$\otimes$	
NS5‴	$\otimes$	$\otimes$	$\otimes$			$\otimes$	$\otimes$			$\otimes$

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NS5$'$	$\otimes$	$\otimes$	$\otimes$		$\otimes$			$\otimes$		$\otimes$
NS5$''$	$\otimes$	$\otimes$	$\otimes$			$\otimes$		$\otimes$	$\otimes$	
NS5$'''$	$\otimes$	$\otimes$	$\otimes$			$\otimes$	$\otimes$			$\otimes$

common $x_\perp$ of all branes

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$$H_{y^2,y^4,y^6} = H_{y^2,y^5,y^3} = H_{y^1,y^6,y^3} = H_{y^1,y^5,y^4} = H$$

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- in near horizon limit $x^3 \to 0$ we get $\mathrm{AdS}_4 \times \mathrm{T}^6$

4 *Q*-branes (IIA)

- T-Duality along y^1, y^2, y^3 and y^4 (isometries)

	x^0	x^1	x^2	x^3	y^1	y^2	y^3	y^4	y^5	y^6
	$\otimes$	$\otimes$	$\otimes$		$\otimes$		$\otimes$		$\otimes$	
	$\otimes$	$\otimes$	$\otimes$		$\otimes$			$\otimes$		$\otimes$
	$\otimes$	$\otimes$	$\otimes$			$\otimes$		$\otimes$	$\otimes$	
	$\otimes$	$\otimes$	$\otimes$			$\otimes$	$\otimes$			$\otimes$

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	x^0	x^1	x^2	x^3	y^1	y^2	y^3	y^4	y^5	y^6
Q	$\otimes$	$\otimes$	$\otimes$		$\otimes$	$\bullet$	$\otimes$	$\bullet$	$\otimes$	
Q'	$\otimes$	$\otimes$	$\otimes$		$\otimes$	$\bullet$	$\bullet$	$\otimes$		$\otimes$
Q''	$\otimes$	$\otimes$	$\otimes$		$\bullet$	$\otimes$	$\bullet$	$\otimes$	$\otimes$	
Q'''	$\otimes$	$\otimes$	$\otimes$		$\bullet$	$\otimes$	$\otimes$	$\bullet$		$\otimes$

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Q	$\otimes$	$\otimes$	$\otimes$		$\otimes$	$\bullet$	$\otimes$	$\bullet$	$\otimes$	
Q'	$\otimes$	$\otimes$	$\otimes$		$\otimes$	$\bullet$	$\bullet$	$\otimes$		$\otimes$
Q''	$\otimes$	$\otimes$	$\otimes$		$\bullet$	$\otimes$	$\bullet$	$\otimes$	$\otimes$	
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- non-geometric configuration

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Q'''	$\otimes$	$\otimes$	$\otimes$		$\bullet$	$\otimes$	$\otimes$	$\bullet$		$\otimes$

- non-geometric configuration
- near horizon limit with $x = 1 + Q^2\Big((y^5)^2 + (y^6)^2\Big)$

$$ds_{4Q\text{int}} = \frac{1}{x}\sum_{i=1}^{4}(dy^i)^2 + \sum_{j=5,6}(dy^j)^2$$

$$-B_{24} = B_{13} = \frac{Qy^6}{x} \qquad B_{14} = B_{23} = \frac{Qy^5}{x}$$

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- globally well defined representation
- in near horizon limit: flat torus with four Q-fluxes

  $$Q_6^{24} = -Q_6^{13} = -Q_5^{14} = -Q_5^{23} = Q\,,$$

  and IIA superpotential

  $$W_Q = Q_6^{24} S T_1 T_2 + Q_5^{23} T_1 T_2 U_1 + Q_5^{14} T_1 T_2 U_2 + Q_6^{13} T_1 T_2 U_3$$

1 *H*-flux, 1 *Q*-flux and 2 *f*-fluxes (IIA)

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NS 5	$\otimes$	$\otimes$	$\otimes$		$\otimes$		$\otimes$		$\otimes$	
KK$'$	$\otimes$	$\otimes$	$\otimes$		$\otimes$			$\otimes$		$\otimes$
Q''	$\otimes$	$\otimes$	$\otimes$			$\otimes$		$\otimes$	$\otimes$	
KK$'''$	$\otimes$	$\otimes$	$\otimes$			$\otimes$	$\otimes$			$\otimes$

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- non-geometric background

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- BUT: field redefinition

$$(\tilde{G}^{-1} + \beta)^{-1} = G + B$$

does not give globally well defined $\tilde{G}$ and β

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KK$'$	⊗	⊗	⊗		⊗		•	⊗		⊗
Q''	⊗	⊗	⊗		•	⊗	•	⊗	⊗	
KK$'''$	⊗	⊗	⊗		•	⊗	⊗			⊗

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We need a more general field redefinition with the corresponding fluxes and superpotentials!

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When you are curious about *Q*- and *R*-branes,
you can have a look at arXiv:1303.1413 (F. Haßler, D. Lüst, 2013)