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

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Arnold Sommerfeld Center
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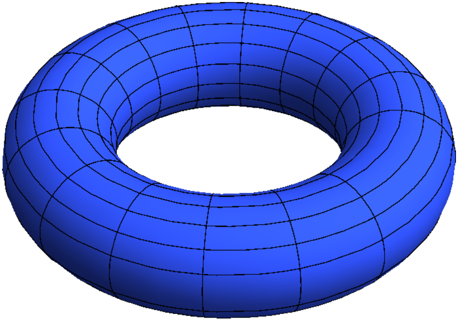
March 22, 2013

Spacetime geometry “seen” by point particles

- general relativity: spacetime = smooth manifold



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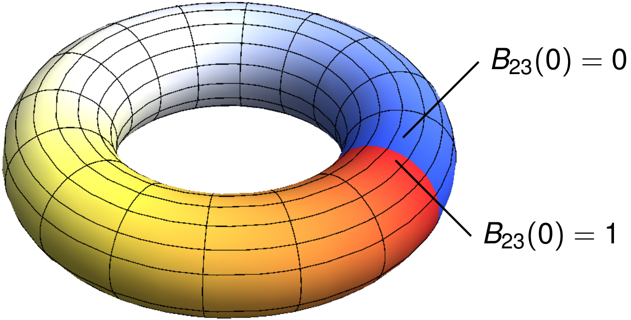

- fields are connected by gauge transformations

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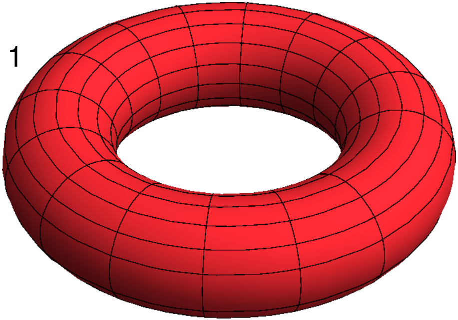
$H_{123} = \partial_{[1} B_{23]} = 1$



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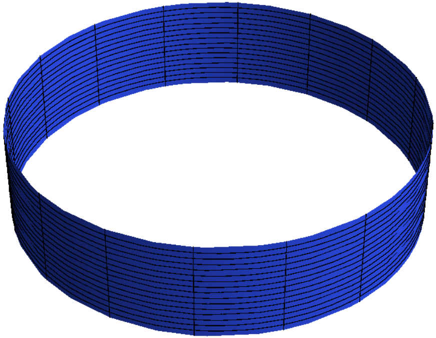

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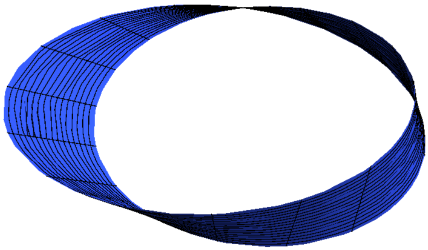

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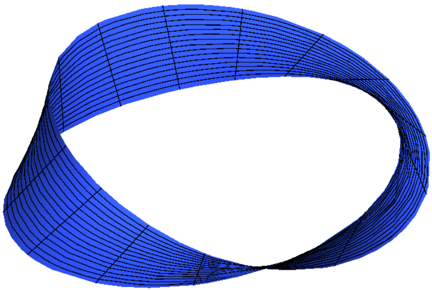

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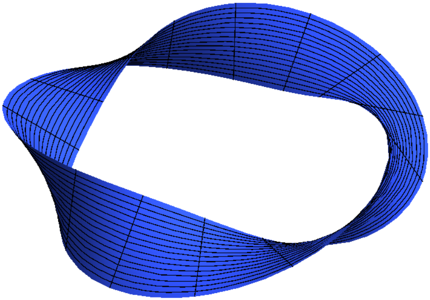

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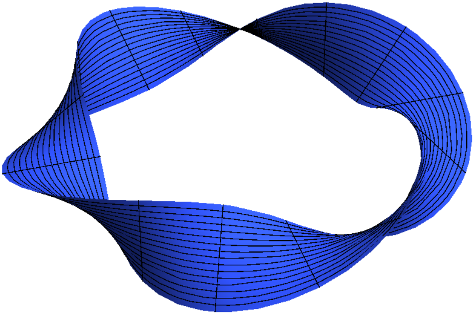

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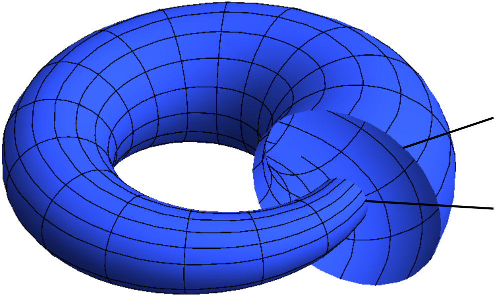

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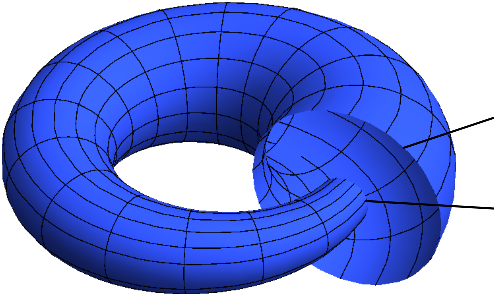

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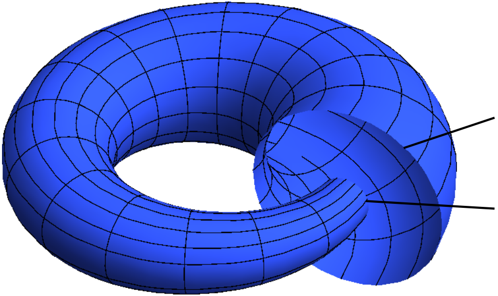

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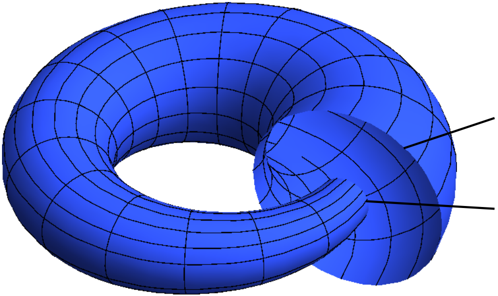

- new interesting properties like non-commutativity
- compactifications lead to gauged SUGRA
  - moduli stabilization
  - effective cosmological constant
  - spontaneous SUSY breaking

How to find these interesting backgrounds?

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

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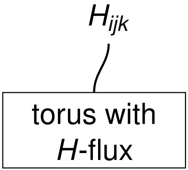

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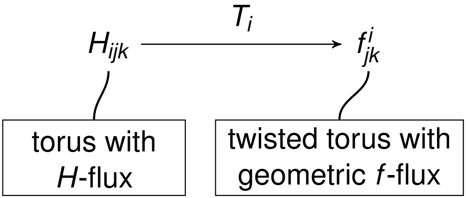

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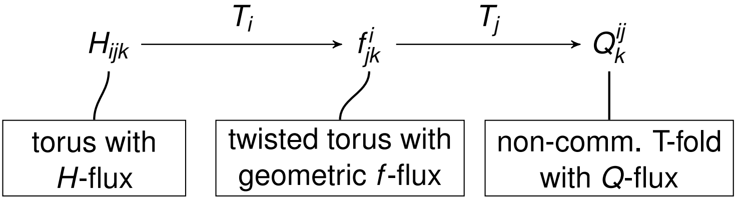

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$$H_{ijk} \xrightarrow{T_i} f^i_{jk} \xrightarrow{T_j} Q^{ij}_k \xrightarrow{T_k} R^{ijk}$$

H_{ijk}	f^i_{jk}	Q^{ij}_k	R^{ijk}
torus with *H*-flux	twisted torus with geometric *f*-flux	non-comm. T-fold with *Q*-flux	non-ass. with *R*-flux

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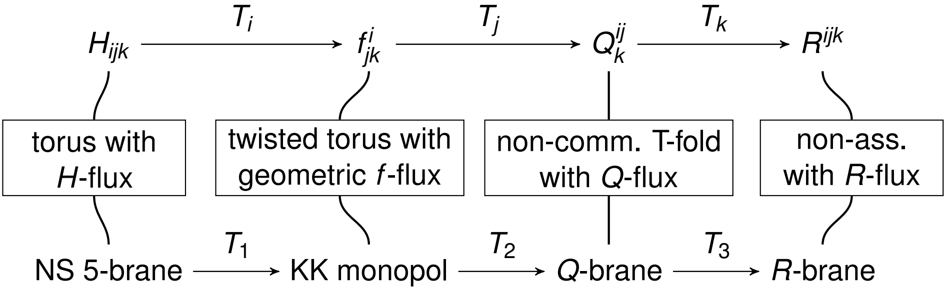

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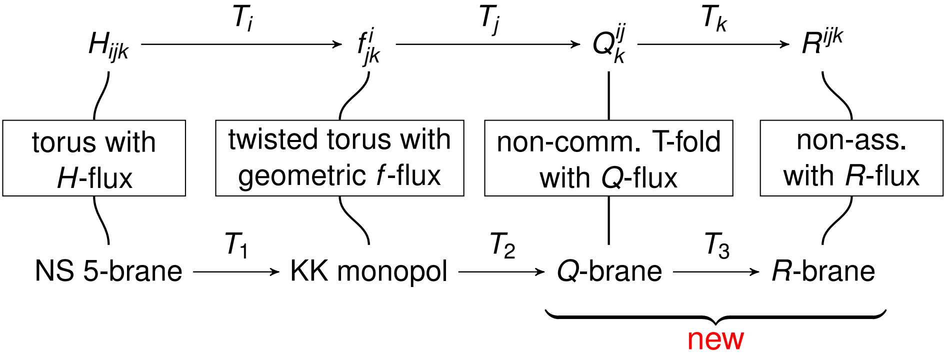

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NS 5-brane

- 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
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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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- solution of NS effective action

Kaluza-Klein monopol

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

(Buscher, 1987)

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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

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

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Q-brane

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- globally well defined
- solution of the refined NS action

$$\tilde{S} = \int \mathrm{d}^{10}x\,\sqrt{|\tilde{G}|}e^{-2\tilde{\phi}}\left(\tilde{\mathcal{R}} + 4(\partial\tilde{\phi})^2 - \frac{1}{4}Q^2\right)$$

Field redefinition

- fields are **not** globally well defined

? how to evaluate integrals for compactification

! field redefinition (D. Andriod, O. Hohm, M. Larfors, D. Lüst, P. Patalong,2012)

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

$$d\tilde{s}^2_{\mathrm{Qint}} = \frac{1}{h(r)}\left(dy^2 + dy'^2\right) + h(r)(dy^3)^2 + \sum_{i=4,5,6}(dy^i)^2$$

$$e^{\tilde{\phi}} = \frac{1}{\sqrt{h(r)}} \qquad \beta^{y,y'} = -A_2(y^3) \quad \text{and} \quad Q_3^{y,y'} = \partial_{y^3}\beta^{y,y'} = -\partial_{x^3}h$$

- globally well defined
- solution of the refined NS action

$$\tilde{S} = \int \mathrm{d}^{10}x\,\sqrt{|\tilde{G}|}e^{-2\tilde{\phi}}\left(\tilde{\mathcal{R}} + 4(\partial\tilde{\phi})^2 - \frac{1}{4}Q^2\right)$$

- simplifies calculations considerably

Backgrounds for IIA and IIB with fluxes

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4 intersecting NS 5-branes (IIA)

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

common $x_\perp$ of
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NS5′	$\otimes$	$\otimes$	$\otimes$		$\otimes$			$\otimes$		$\otimes$
NS5″	$\otimes$	$\otimes$	$\otimes$			$\otimes$		$\otimes$	$\otimes$	
NS5‴	$\otimes$	$\otimes$	$\otimes$			$\otimes$	$\otimes$			$\otimes$

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- $h(r) = Hx^3$ according to "harmonic superposition rules"

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

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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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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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- non-geometric configuration

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

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

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

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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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- BUT: field redefinition

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

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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)