Non-Geometric Flux Compactifications

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Dimensional Oxidation of Non-Geometric Fluxes in Type II Orientifolds

Ralph Blumenhagen, Xin Gao, D.H., Pramod Shukla

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T-Duality

String Theory

extended objects in 10D spacetime $\rightarrow$ compactify 6 dimensions

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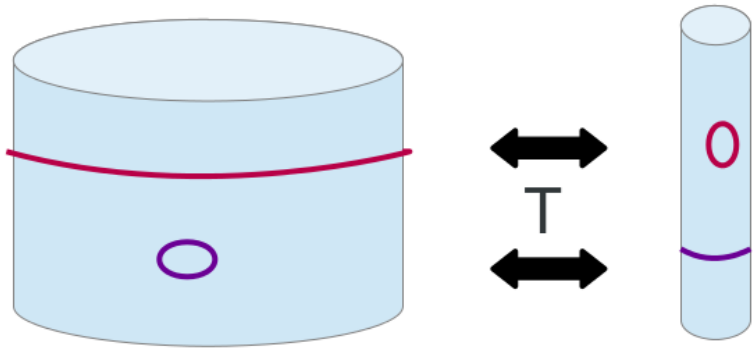

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String Theory

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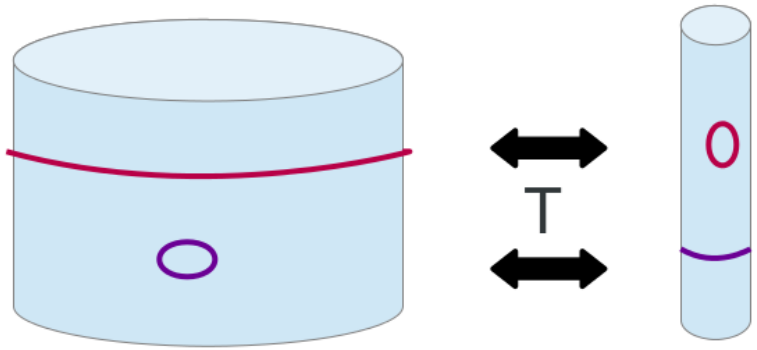

strings can wind around extra dimensions

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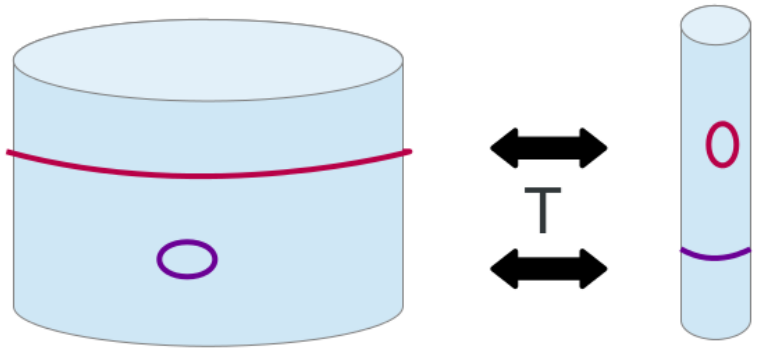

strings can wind around extra dimensions

T-Duality

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T-Duality between type IIA and IIB string theory

IIA compactified with radius R

$\updownarrow$ T

IIB compactified with radius $\sim \frac{1}{R}$

same particle content

same physics

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e.g. type II compactified on a circle

type IIA		type IIB
C_*, C_μ	$\leftrightarrow$	$C_0, C_{*\mu}$
$C_{*\mu\nu}, C_{\mu\nu\rho}$	$\leftrightarrow$	$C_{\mu\nu}, C_{*\mu\nu\rho}$
$G_{*\mu}, B_{*\mu}$	$\leftrightarrow$	$B_{*\mu}, G_{*\mu}$

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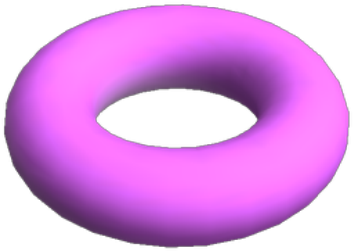
NSNS-flux $H \sim dB$

Non-Geometric Fluxes

T-Duality mixes G and B $\Rightarrow$ change of geometry



H_{ijk}

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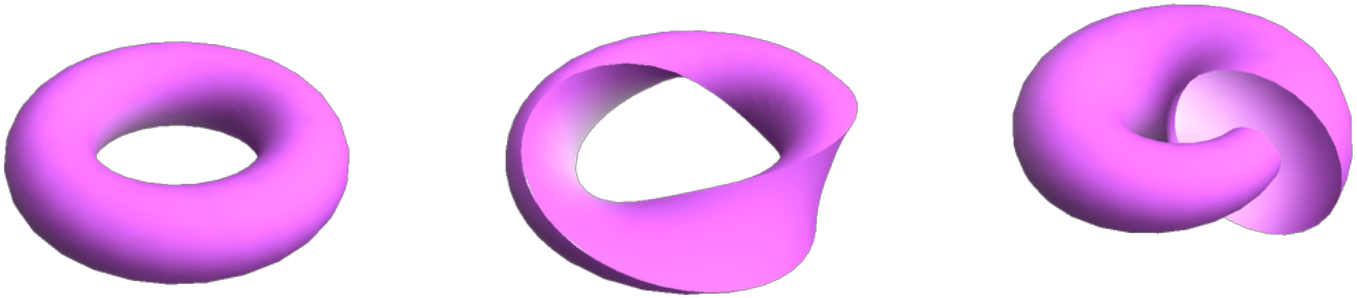

$$H_{ijk} \quad \overset{T_k}{\longleftrightarrow} \quad F_{ij}{}^{k} \quad \overset{T_j}{\longleftrightarrow} \quad Q_i{}^{jk}$$

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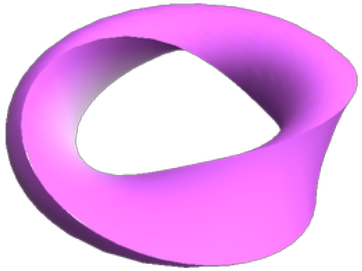
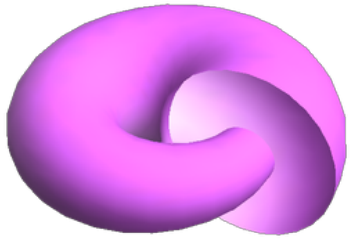

$$H_{ijk} \xleftrightarrow{T_k} F_{ij}{}^{k} \xleftrightarrow{T_j} Q_i{}^{jk} \xleftrightarrow{T_i} R^{ijk}$$

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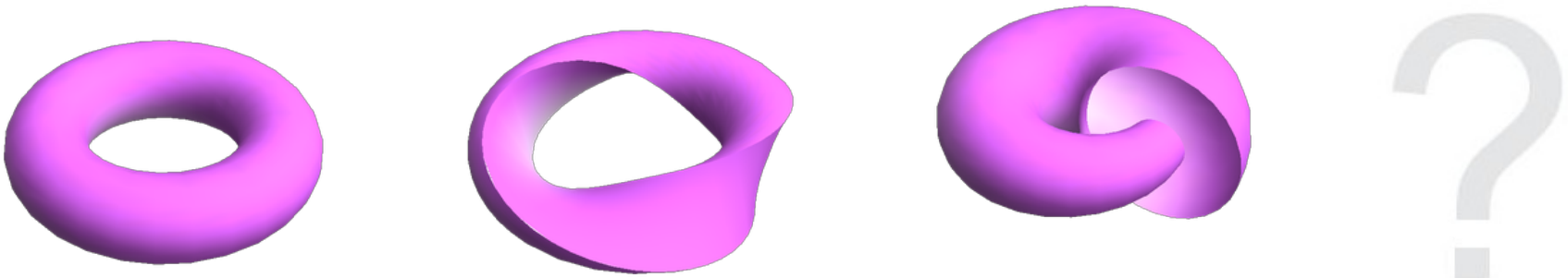

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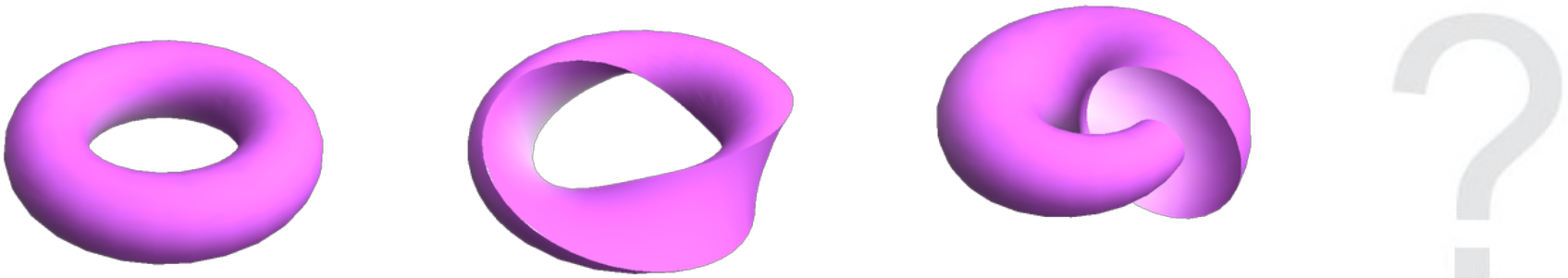

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T-Duality between IIA and IIB requires the presence of *all* of these fluxes

not clear if this is allowed

G and B cannot describe Q and R flux

4D Theory with Non-Geometric Fluxes

add non-geometric fluxes to the superpotential:

[Shelton, Taylor, Wecht]

$$W \sim \int \Omega \wedge \left(S\, H + F \cdot J + Q \cdot J \wedge J + R \cdot J \wedge J \wedge J \right)$$

moduli: scalar fields which arise through extra dimensions

The superpotential generates a scalar potential via

$$V_F = e^K \left(G^{i\bar{\jmath}} D_i W \, D_{\bar{\jmath}} \overline{W} - 3|W|^2 \right)$$

potential in 4D

Phenomenology

Moduli Stabilization

moduli fields - not (yet) observed $\Rightarrow$ heavy

$\rightarrow$ full stabilization only with non-geometric fluxes

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Supersymmetry Breaking

string theory is supersymmetric - the observed world is not

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Vacuum Energy

slightly positive vacuum energy observed

$\rightarrow$ only with non-geometric fluxes

10D Theory with Non-Geometric Fluxes

Only H-flux:

$$V_F = V_{action}$$

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dimensional reduction: $10D \rightarrow 4D$

dimensional oxidation: $10D \leftarrow 4D$

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Procedure: for simplicity: toroidal orientifold with only 7 moduli

all fluxes constant

i) compute scalarpotential V_F from W

ii) oxidize action which reduces to V_F

10D Theory with Non-Geometric Fluxes - NSNS sector

Result

$$S = \frac{1}{2}\int d^{10}x\, e^{-2\phi}\sqrt{-g}\,\mathcal{F}_{IJK}\mathcal{F}_{I'J'K'}\left(\frac{1}{4}\mathcal{H}^{II'}\eta^{JJ'}\eta^{KK'} - \frac{1}{12}\mathcal{H}^{II'}\mathcal{H}^{JJ'}\mathcal{H}^{KK'}\right)$$

is the action which reduces to V_F!

with

$$\mathcal{H}_{IJ} = \begin{pmatrix} G^{ij} & -G^{ik}B_{kj} \\ B_{ik}G^{kj} & G_{ij} - B_{ik}G^{kl}B_{lj} \end{pmatrix} \qquad \eta_{IJ} = \begin{pmatrix} 0 & \delta^i{}_j \\ \delta_i{}^j & 0 \end{pmatrix}$$

and

$$\mathcal{F}_{ijk} = H_{ijk}\,, \quad \mathcal{F}^i{}_{jk} = F^i{}_{jk}\,, \quad \mathcal{F}_k{}^{ij} = Q_k{}^{ij}\,, \quad \mathcal{F}^{ijk} = R^{ijk}$$

Double Field Theory

more degrees of freedom than G and B needed to describe all fluxes

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- winding coordinates $\rightarrow$ doubled degrees of freedom
- describes T-Duality and non-geometric fluxes

$\Rightarrow$ oxidized action of the same form in both NSNS- and RR-sector

BUT

doubled theory not physical $\rightarrow$ constraints$\rightarrow$ kill half of the fluxes

$\rightarrow$ is it really possible to assume background values for all of these fluxes?

Conclusions

Summary

- dimensional oxidation to 10D (for toroidal type II orientifolds)
- similar to Double Field Theory action

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Future directions

- which fluxes simultaneously?
- further studies of deSitter vacua and non-geometric model building
- generalization of oxidation procedure to Calabi Yau manifolds with non-geometric fluxes $\rightarrow$ work in progress

Thank You !

10D Theory with Non-Geometric Fluxes - BackUp

The NSNS part of the oxidized action reads

$$S = \frac{1}{2}\int d^{10}x\,\sqrt{-g}\Big(\mathcal{L}^{\mathrm{H}} + \mathcal{L}^{\mathrm{F}} + \mathcal{L}^{\mathrm{Q}} + \mathcal{L}^{\mathrm{R}} + \mathcal{L}^{\mathrm{HQ}} + \mathcal{L}^{\mathrm{FR}}\Big)$$

the following orbits of fluxes appear in the action:

$$\begin{aligned}
\mathfrak{H}_{ijk} &= \overline{H}_{ijk} + 3\,\overline{F}^{m}{}_{[\underline{ij}}\,B_{m\underline{k}]} + 3\,\overline{Q}_{[\underline{i}}{}^{mn}B_{m\underline{j}}\,B_{n\underline{k}]} + \overline{R}^{mnp}B_{m[\underline{i}}B_{n\underline{j}}B_{p\underline{k}]}\\
\mathfrak{F}^{i}{}_{jk} &= \overline{F}^{i}{}_{jk} + 2\,\overline{Q}_{[\underline{j}}{}^{mi}B_{m\underline{k}]} + \overline{R}^{mni}B_{m[\underline{j}}B_{n\underline{k}]}\\
\mathfrak{Q}_{k}{}^{ij} &= \overline{Q}_{k}{}^{ij} + \overline{R}^{mij}B_{mk}\\
\mathfrak{R}^{ijk} &= \overline{R}^{ijk}
\end{aligned}$$

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with

$$\mathcal{L}^{\rm H} = -\frac{e^{-2\phi}}{12}\mathfrak{H}_{ijk}\,\mathfrak{H}_{i'j'k'}\,g^{ii'}\,g^{jj'}\,g^{kk'}\,, \qquad \mathcal{L}^{\rm HQ} = \frac{e^{-2\phi}}{2}\mathfrak{H}_{mni}\,\mathfrak{Q}_{i'}{}^{mn}\,g^{ii'}$$

$$\mathcal{L}^{\rm F} = -\frac{e^{-2\phi}}{4}\Big(2\,\mathfrak{F}^{m}{}_{ni}\,\mathfrak{F}^{n}{}_{mi'}\,g^{ii'} + \mathfrak{F}^{i}{}_{jk}\,\mathfrak{F}^{i'}{}_{j'k'}\,g_{ii'}g^{jj'}g^{kk'}\Big)$$

$$\mathcal{L}^{\rm Q} = -\frac{e^{-2\phi}}{4}\Big(2\,\mathfrak{Q}_{m}{}^{ni}\,\mathfrak{Q}_{n}{}^{mi'}\,g_{ii'} + \mathfrak{Q}_{k}{}^{ij}\,\mathfrak{Q}_{k'}{}^{i'j'}\,g_{ii'}g_{jj'}g^{kk'}\Big)$$

$$\mathcal{L}^{\rm R} = -\frac{e^{-2\phi}}{12}\mathfrak{R}^{ijk}\,\mathfrak{R}^{i'j'k'}\,g_{ii'}g_{jj'}g_{kk'}\,, \qquad \mathcal{L}^{\rm RF} = \frac{e^{-2\phi}}{2}\mathfrak{F}^{i}{}_{mn}\,\mathfrak{R}^{mni'}\,g_{ii'}$$

10D Theory with Non-Geometric Fluxes - BackUp

The RR sector and the D-term:

$$S = \frac{1}{2}\int d^{10}x\,\sqrt{-g}\,\mathcal{L}^{\rm RR} + S_D$$

$$\mathcal{L}^{\rm RR} = -\frac{1}{2}\sum_{p=0,2,4,6} |G^{(p)}|^2$$

$$V_{D6} = -\frac{1}{2}e^K t_1 t_2 t_3 \Big[s\,\tau_{135} - u_1\,\tau_{146} - u_2\,\tau_{236} - u_3\,\tau_{245}\Big]$$

with

$$\tau_{ijk} = \overline{H}_{ijk}\,\overline{G}^{(0)} + 3\,\overline{F}^{m}{}_{[\underline{ij}}\overline{G}^{(2)}_{m\underline{k}]} - \frac{3}{2}\overline{Q}_{[\underline{i}}{}^{mn}\overline{G}^{(4)}_{mn\underline{jk}]} - \frac{1}{6}\overline{R}^{mnp}\overline{G}^{(6)}_{mnpijk}$$