On non-geometric string vacua

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preliminary declaration...

We are working in string theory on

generalised flux compactifications,

at the convergence of two active fields of research: Generalized Geometry and Flux Compactifications.

Let me explain what it is (as simply as I can)...

Outline

A few words on string theory

definition and features

a candidate theory of quantum gravity and other fields ultimately aiming to mimic our physical world (de Sitter, inflationary vacuum, Standard Model etc...)

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2. 5 versions: Type IIA, Type IIB, Type I, Heterotic $SO(32)/E_8 \times E_8$
3. Every theory has a (universal) bosonic supergravity (SUGRA) sector: graviton $g_{\mu\nu}$, 2-form gauge field $B_{\mu\nu}$, scalar (dilaton) ϕ

T-duality is a perturbative symmetry between two string theories with compactified dimensions

How it works for string theories compactified on circles:

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4. **T-duality**: $R \rightarrow \alpha'/R$ and $n \leftrightarrow m$

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$$\Downarrow$$

1. <u>Crucial</u>: T-duality means that string theories with $R \geq \sqrt{\alpha'}$ and $R \leq \sqrt{\alpha'}$ are identified
2. In other words, the string cannot distinguish between big radii and small radii!

Generalization: How T-duality works for string theories compactified on a torus T^d (product of d circles)

$$\Downarrow$$

1. Along the directions (a, b) of T^d, the fields are: g_{ab}, B_{ab} and $\phi = \phi_0$ (frozen out)

T-duality and non-geometry

T-duality on a torus

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   $$\mathcal{H} = \begin{bmatrix} g^{-1} & -g^{-1}B \\ Bg^{-1} & g - bg^{-1}b \end{bmatrix}$$

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4. Crucial: T-duality mixes the metric g with the gauge field B in a non trivial way: the string treats on the same footing the fields g and B!

So... 2 significant slogans by T-duality:

1. The string cannot distinguish between big radii and small radii
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important hints that classical notion of Riemannian geometry breaks down at $l_s \sim \sqrt{\alpha'}$, to be replaced by a stringy geometry.

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2. Non-geometric string backgrounds can be constructed: at the overlap of coordinate charts the transition functions are other than diffeomorphisms and gauge field transformations of $B_{\mu\nu}$

Consider the NS5-brane background, i.e. the $D = 10$ background due to an extended five-dimensional object of string theory called NS5-brane

The NS5-brane has 4 spatial directions orthogonal to it: x^1, x^2, x^3, x^4

Compactifying x^1 and x^2 on circles and performing two T-dualities [De Boer, Shigemori]:

$$\text{NS5-brane} \xrightarrow{x^1, x^2} \text{T-fold}$$

T-duality and non-geometry

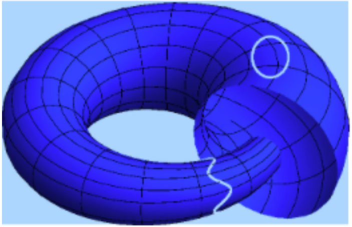
example of a non-geometric background: T-fold

Compactifying x^1 and x^2 on circles and performing two T-dualities [De Boer, Shigemori]:

$$\text{NS5-brane} \xrightarrow{x^1, x^2} \text{T-fold}$$

The T-fold is non-geometric:

The fields g and B match via non-geometric transition functions



T-duality and non-geometry

another view on the T-duality chain

Pointing out that the NS5-brane is charged under the gauge field $B_{\mu\nu}$, with field strength $H_3 = dB_2$...

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can be thought of as a chain of fluxes:

$$H_3 \xrightarrow{x^1} f_3 \xrightarrow{x^2} Q_3$$

1. fluxes : field strengths of gauge form fields

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1. fluxes : field strengths of gauge form fields
2. Q_3: most simple example of non-geometric flux

Steps towards construction of realistic 4D string models :

1. In order to go from D=10 $\rightarrow$ D=4 ... compactify on 6-dimensional manifolds with a non-trivial topology to break SUSY: Calabi-Yau (CY) 3-folds and/or singular limits of them (orbifolds)

Steps towards construction of realistic 4D string models :

1. In order to go from D=10 $\rightarrow$ D=4 ... compactify on 6-dimensional manifolds with a non-trivial topology to break SUSY: Calabi-Yau (CY) 3-folds and/or singular limits of them (orbifolds)
2. Turn on 3-form fluxes with legs on CY in order to generate a four-dimensional potential and give mass to the moduli fields (moduli stabilisation). Moduli fields are 4D massless scalar fields parameterising the geometry of CY and need mass to agree with experiments. Famous moduli stabilisation scenarios are: KKLT, LVS. Also, they try to mimic the microphysics of inflation [Kachru et al.], [Quevedo F. et al]

Flux Compactifications and non-geometry

why?

What about the possibility to compactify turning on non-geometric fluxes (ngf)?

Motivations:

1. T-duality "cries out" for ngf: if you want a 4D model with *generic* geometric fluxes, consistency with T-duality requires ngf
2. Non-geometric (Generalized) flux compactifications allow to stabilise all the moduli at tree-level (in the standard case you have to consider perturbative, non-perturbative corrections)
3. Richness for phenomenology (waiting to be discovered)

One more look at the previous fluxes chain :

$$H_3 \xrightarrow{T} f_3 \xrightarrow{T} Q_3 \xrightarrow{T} R_3$$

1. One can extend this chain considering S-dual of these fluxes: P-fluxes. In a recent paper we have classified P-fluxes in supergravity. [E.A. Bergshoeff , V.A. Penas , F. Riccioni and S.R.]
2. There have been built explicit type IIA/B string models which use the fluxes Q, R [Shelton *et al.*][Aldazabal *et al.*]
3. There is some model of generalised moduli stabilisation reproducing the microphysics of inflation [Blumenhagen *et al.*][Lust *et al.*][Damian C. *et al.*]

Flux Compactifications and non-geometry

perspectives: what we want to know

We are currently looking for...

1. ... finding and studying consistent models of compactification taking into account for all P-fluxes
2. ... describing new generalized flux vacua in terms of equivalent conformal field theories related to compactifications on *special* orbifolds.
3. ... monitoring the models of inflation and trying to understand the role of non-geometric fluxes