Non-geometric fluxes & Tadpole conditions for exotic branes

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1. Introduction

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Introduction

Fluxes play a crucial role in string theory for moduli stabilisation, which is crucial for phenomenology

In this talk we will consider the low energy four dimensional theories that result when geometric and non-geometric fluxes are turned on

Here geometric means anything that has a ten-dimensional origin

Example: CY O3-orientifold of IIB with NS and RR 3-form fluxes turned on compatibly with susy results in $\mathcal{N} = 1$ supergravity with GVW superpotential

$W = \int (F_3 - iSH_3) \wedge \Omega$

Introduction

Fluxes induce a gauging in the four dimensional low energy effective supergravity action

Gauging is described in terms of the embedding tensor

de Wit, Samtleben, Trigiante (2002)

Maximal theory in D=4: embedding tensor in the **912** of $E_{7(7)}$

Decomposing the **912** under $SO(6,6) \times SL(2,\mathbb{R})$ one finds

$$\mathbf{912} = (\mathbf{32},\mathbf{3}) \oplus (\mathbf{220},\mathbf{2}) \oplus (\mathbf{352},\mathbf{1}) \oplus (\mathbf{12},\mathbf{2})$$

one further breaks $SL(2,\mathbb{R})$ to $\mathbb{R}^+$ and selects the reprs

$$\mathbf{32}_2 \oplus \mathbf{220}_1 \oplus \mathbf{352}_0 \oplus \mathbf{220}_{-1} \oplus \mathbf{32}_{-2}$$

corresponding to the "fluxes"

$$F_\alpha \qquad H_{MNP} \qquad P_{M\dot{\alpha}} \qquad H'_{MNP} \qquad F'_{\dot{\alpha}}$$

Introduction

The F_α in the $\mathbf{32}_2$ are the RR fluxes

$$F_\alpha \to \begin{cases} F_a \quad F_{abc} \quad F_{abcde} & \text{(IIB)} \\ F \quad F_{ab} \quad F_{abcd} \quad F_{abcdef} & \text{(IIA)} \end{cases}$$

T-duality rule:

$$F_{a_1 \dots a_n} \xrightarrow{T^b} F_{a_1 \dots a_n b}$$

The H_{MNP} in the $\mathbf{220}_1$ are the NS fluxes

$$H_{MNP} \to H_{abc} \quad f_{ab}{}^c \quad Q_a{}^{bc} \quad R^{abc}$$

The Q and R fluxes are non-geometric

T-duality rule:

$$H_{abc} \xrightarrow{T^c} f_{ab}{}^c \xrightarrow{T^b} Q_a{}^{bc} \xrightarrow{T^a} R^{abc}$$

Shelton, Taylor, Wecht (2005)

Introduction

One derives the form of the superpotential simply applying T-duality on known superpotential. For instance in IIA one gets

$$W = \int (H_3 + fJ_c + QJ_c^{(2)} + RJ_c^{(3)}) \wedge \Omega_c$$

Aldazabal, Cámara, Font, Ibáñez (2006)

By T-duality starting from H_{abc} the components $f_{ab}{}^b$ and $Q_a{}^{ab}$ can not be turned on. We will always put them to zero

NS fluxes

We consider non-geometric fluxes in a specific model: IIA/IIB $T^6/(\mathbb{Z}_2 \times \mathbb{Z}_2)$ orientifold

Aldazabal, Cámara, Font, Ibáñez (2006)

$T^6 = \bigotimes_{i=1}^{3} T^2_{(i)}$

Each torus has coordinates (x^i, y^i), basis of closed 2-forms is

$\omega_i = dx^i \wedge dy^i$

Kahler form:

$J = \sum_i A_i \omega_i$

Holomorphic 3-form:

$\Omega = (dx^1 + i\tau_1 dy^1) \wedge (dx^2 + i\tau_2 dy^2) \wedge (dx^3 + i\tau_3 dy^3)$

NS fluxes

O3 IIB orientifold: divide out by $\Omega_P(-1)^{F_L}\sigma_B$ where

$\sigma_B(x^i) = -x^i \qquad \sigma_B(y^i) = -y^i$

Complex moduli are

- complex structure moduli

  $U_i = \tau_i$

- complex Kahler moduli

  $J_{\rm c} = C_4 + \frac{i}{2} e^{-\phi} J \wedge J = i \sum_i T_i \tilde{\omega}_i$

- axion-dilaton

  $S = e^{-\phi} + i C_0$

NS fluxes

O6 IIA orientifold: perform three T-dualities along $x^1 \;\; x^2 \;\; x^3$ (mirror symmetry)

Involution is now

$\sigma_A(x^i) = x^i \qquad \sigma_A(y^i) = -y^i$

τ_i are now real

Complexified holomorphic 3-form is

$\Omega_{\rm c} = C_3 + i\mathrm{Re}(C\Omega) = iS(dx^1 \wedge dx^2 \wedge dx^3) + iU_i(dx \wedge dy \wedge dy)^i$

Complex Kahler moduli are

$J_{\rm c} = B + iJ = i\sum_i T_i\omega_i$

IIB and IIA moduli related by mirror symmetry as $T_i \leftrightarrow U_i$

NS fluxes

We now turn on the geometric fluxes

In IIB, only F_3 and H_3 can be turned on, leading to the GVW superpotential which has the form

$$W_B = P_1(U) + SP_2(U)$$

In IIA, the superpotential is

$$W_A = \int [e^{J_c} \wedge F_{RR} + \Omega_c \wedge (H_3 + fJ_c)]$$

Grimm, Louis (2005)

Villadoro, Zwirner (2005)

This has the form

$$W_A = P_1(T) + U + S + UT + ST$$

Clearly the two do not match under mirror symmetry

NS fluxes

IIB NS fluxes	IIA NS fluxes
$H_{x^1x^2x^3}$	$R^{x^1x^2x^3}$
$H_{y^ix^jx^k}$	$Q_{y^i}{}^{x^jx^k}$
$H_{y^iy^jx^k}$	$f_{y^iy^j}{}^{x^k}$
$H_{y^1y^2y^3}$	$H_{y^1y^2y^3}$
$Q_{x^k}{}^{x^ix^j}$	$f_{x^ix^j}{}^{x^k}$
$Q_{y^j}{}^{x^iy^k}$	$f_{x^iy^j}{}^{y^k}$
$Q_{y^k}{}^{x^ix^j}$	$H_{x^ix^jy^k}$
$Q_{x^j}{}^{x^iy^k}$	$Q_{x^i}{}^{x^jy^k}$
$Q_{x^i}{}^{y^jy^k}$	$R^{x^iy^jy^k}$
$Q_{y^i}{}^{y^jy^k}$	$Q_{y^i}{}^{y^jy^k}$

IIB: only H and Q fluxes.

IIA: odd y's for H and Q and even y's for f and R

NS fluxes

Due to the Q flux, the IIB superpotential becomes

$$W_B = \int (F_3 - iSH_3 + Q \cdot J_{\mathrm{c}}) \wedge \Omega$$

which has the form

$$W_B = P_1(U) + SP_2(U) + TP_3(U)$$

Due to the Q and R fluxes, the IIA superpotential becomes

$$W_A = \int [e^{J_{\mathrm{c}}} \wedge F_{RR} + \Omega_{\mathrm{c}} \wedge (H_3 + fJ_{\mathrm{c}} + QJ_{\mathrm{c}}^{(2)} + RJ_{\mathrm{c}}^{(3)})]$$

which has the form

$$W_A = P_1(T) + SP_2(T) + UP_3(T)$$

The two expressions match under mirror symmetry

NS fluxes

The fluxes induce RR tadpoles

The D3/O3 tadpole in IIB has the form

$\int C_4 \wedge H_3 \wedge F_3$

By T-duality, this is mapped in IIA to the D6/O6 term

$\int C_7 \wedge (H_3 F_0 + f \; F_2 + Q F_4 + R F_6)$

which also leads to the IIB D7 tadpole

$\int C_8 \wedge Q F_3$

All tadpole conditions have to be taken into account for consistency

P, H', F' fluxes

In the IIB theory, by S-duality the $Q_a{}^{bc}$ flux is mapped to a new flux $P_a{}^{bc}$

Aldazabal, Cámara, Font, Ibáñez (2006)

This flux belongs to the 'gravitino' representation $P_{M\dot{\alpha}}$, which is the **352** of $SO(6,6)$

By decomposing the whole representation under $GL(6,\mathbb{R})$ one gets

$$P_{M\dot{\alpha}} \rightarrow \begin{cases} P_a \quad P_a{}^{b_1 b_2} \quad P_a{}^{b_1 \dots b_4} \quad P^{a,b_1 b_2} \quad P^{a,b_1 \dots b_4} \quad P^{a,b_1 \dots b_6} \\ \\ P_a{}^b \quad P_a{}^{b_1 b_2 b_3} \quad P_a{}^{b_1 \dots b_5} \quad P^{a,b} \quad P^{a,b_1 b_2 b_3} \quad P^{a,b_1 \dots b_5} \end{cases}$$

where the first line is IIB and the second line is IIA

Bergshoeff, Penas, FR, Risoli (2015)

The fluxes $P^{a,b_1 \dots b_p}$ belong to mixed symmetry representations (completely antisymmetric part vanishes)

P, H', F' fluxes

What happens to a given flux under T-duality?

We should remember that the fluxes belong to a vector-spinor representation

We should treat the a upstairs and downstairs indices as forming the vector index M, while the b indices form the spinor representation

As a consequence, one derives the following T-duality rules

$$P_a{}^{b_1 \dots b_p} \xrightarrow{T^a} P^{a, b_1 \dots b_p a}$$

$$P_a{}^{b_1 \dots b_p} \xrightarrow{T^{b_p}} P_a{}^{b_1 \dots b_{p-1}}$$

$$P^{a, b_1 \dots b_p} \xrightarrow{T^{b_p}} P^{a, b_1 \dots b_{p-1}}$$

We are only interested in the following components: if the a index is down, it is different from any of the b indices, while if it is up it has to be parallel to the b indices

P, H', F' fluxes

We now consider our orientifold model and we want to map $P_a{}^{bc}$ in IIB to the fluxes of IIA

Performing 3 T-dualities from IIB to IIA along the three x directions one therefore obtains

IIB P fluxes	IIA P fluxes
$P_{x^i}{}^{x^j x^k}$	P^{x^i,x^i}
$P_{y^i}{}^{x^j x^k}$	$P_{y^i}{}^{x^i}$
$P_{x^i}{}^{y^j x^k}$	$P^{x^i,x^i x^j y^j}$
$P_{x^i}{}^{y^j y^k}$	$P^{x^i,x^i x^j x^k y^j y^k}$
$P_{y^i}{}^{y^j x^k}$	$P_{y^i}{}^{x^i x^j y^j}$
$P_{y^i}{}^{y^j y^k}$	$P_{y^i}{}^{x^i x^j x^k y^j y^k}$

But in the IIA theory more fluxes are allowed...

P, H', F' fluxes

IIB P fluxes	IIA P fluxes
$P_{x^i}{}^{x^j x^k}$	P^{x^i, x^i}
$P_{y^i}{}^{x^j x^k}$	$P_{y^i}{}^{x^i}$
$P_{x^i}{}^{y^j x^k}$	$P^{x^i, x^i x^j y^j}$
$P_{x^i}{}^{y^j y^k}$	$P^{x^i, x^i x^j x^k y^j y^k}$
$P_{y^i}{}^{y^j x^k}$	$P_{y^i}{}^{x^i x^j y^j}$
$P_{y^i}{}^{y^j y^k}$	$P_{y^i}{}^{x^i x^j x^k y^j y^k}$
$P^{x^i, x^1 x^2 x^3 y^i}$	$P_{x^i}{}^{y^i}$
$P^{y^i, x^1 x^2 x^3 y^i}$	P^{y^i, y^i}
$P^{x^i, x^i x^j y^i y^k}$	$P_{x^i}{}^{y^i x^k y^k}$
$P^{x^i, x^i y^1 y^2 y^3}$	$P_{x^i}{}^{x^j x^k y^1 y^2 y^3}$
$P^{y^i, y^i x^i y^j x^k}$	$P^{y^i, y^i x^j y^j}$
$P^{y^i, y^1 y^2 y^3 x^i}$	$P^{y^i, y^1 y^2 y^3 x^j x^k}$

P, H', F' fluxes

The flux $P^{1,4}$ of the IIB theory is mapped under S-duality to $Q'^{1,4}$, which belongs to the T-duality family

$$H'_{MNP} \rightarrow \; R'^{a_1 a_2 a_3} \;\; Q'^{a_1, b_1 b_2 b_3 b_4} \;\; f'^{a_1 a_2, b_1 \dots b_5} \;\; H'^{a_1 a_2 a_3, b_1 \dots b_6}$$

All these fluxes are non-geometric

T-duality rule:

$$R'^{abc} \xrightarrow{T_d} Q'^{d,abcd} \xrightarrow{T_e} f'^{de,abcde} \dots$$

Using the rule, we can once again map $Q'^{1,4}$ of IIB to the corresponding IIA fluxes in our orientifold model by performing three T-dualities along x's

By including all the fluxes that are allowed in IIA, we discover that we also have to include $H'^{3,6}$ in IIB

P, H', F' fluxes

IIB NS$'$ flux	IIA NS$'$ flux
$Q'^{x^i,x^ix^jx^ky^i}$ $Q'^{x^i,x^ix^jy^iy^k}$ $Q'^{x^i,x^iy^iy^jy^k}$ $Q'^{y^i,x^ix^jx^ky^i}$ $Q'^{y^i,y^ix^iy^jx^k}$ $Q'^{y^i,y^iy^jy^kx^i}$	$R'^{x^kx^jy^i}$ $Q'^{x^k,x^ky^kx^jy^i}$ $f'^{x^kx^j,x^jy^iy^jy^kx^k}$ $Q'^{y^i,x^ix^jx^ky^i}$ $f'^{x^jy^i,y^ix^iy^jx^kx^j}$ $H'^{x^kx^jy^i,x^1y^1x^2y^2x^3y^3}$
$H'^{x^1x^2x^3,x^1y^1x^2y^2x^3y^3}$ $H'^{x^jx^ky^i,x^1y^1x^2y^2x^3y^3}$ $H'^{y^1y^2y^3,x^1y^1x^2y^2x^3y^3}$ $H'^{x^ky^iy^j,x^1y^1x^2y^2x^3y^3}$	$R'^{y^1y^2y^3}$ $Q'^{y^i,y^ix^iy^ky^j}$ $H'^{y^1y^2y^3,x^1y^1x^2y^2x^3y^3}$ $f'^{y^jy^i,x^iy^ix^jy^jy^k}$

P, H', F' fluxes

The IIB flux $H'^{3,6}$ is mapped under S-duality to $F'^{3,6}$, belonging to the T-duality family

$$F'_\alpha \rightarrow \begin{cases} F'^{a_1,b_1\dots b_6} \quad F'^{a_1a_2a_3,b_1\dots b_6} \quad F^{a_1\dots a_5,b_1\dots b_6} & \text{(IIB)} \\ F^{a_1\dots a_6} \quad F^{a_1a_2,b_1\dots b_6} \quad F^{a_1\dots a_4,b_1\dots b_6} \quad F^{a_1\dots a_6,b_1\dots b_6} & \text{(IIA)} \end{cases}$$

Again, all these fluxes are non-geometric

T-duality rule:

$$F'^{a_1\dots a_6} \xrightarrow{T_{a_1}} F'^{a_1,a_1\dots a_6} \xrightarrow{T_{a_2}} F'^{a_1a_2,a_1\dots a_6} \dots$$

Using the rule, in our orientifold model we map the IIB flux $F'^{a_1a_2a_3,b_1\dots b_6}$ to the IIA fluxes by performing three T-dualities along the x directions

P, H', F' fluxes

IIB F' flux	IIA F' flux
$F'^{x^1x^2x^3,x^1y^1x^2y^2x^3y^3}$	$F'^{x^1y^1x^2y^2x^3y^3}$
$F'^{x^jx^ky^i,x^1y^1x^2y^2x^3y^3}$	$F'^{x^iy^i,x^1y^1x^2y^2x^3y^3}$
$F'^{y^1y^2y^3,x^1y^1x^2y^2x^3y^3}$	$F'^{x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3}$
$F'^{x^ky^jy^i,x^1y^1x^2y^2x^3y^3}$	$F'^{x^iy^ix^jy^j,x^1y^1x^2y^2x^3y^3}$

P, H', F' fluxes

By including all the allowed fluxes, in IIB one generates the superpotential

$$W_B = \int [(F_3 - iSH_3) + (Q - iSP_1^2)J_c - (P^{1,4} - iSH'^{1,4})J_c^2 + (H'^{3,6} - iSF'^{3,6}) \cdot J_c^3] \wedge \Omega$$

which is mapped to the IIA expression

$$W_A = \int e^{J_c} \wedge [F_{\mathrm{RR}} - H_{\mathrm{NS}} \cdot \Omega_c + P \cdot \Omega_c^2 - H_{\mathrm{NS}'} \cdot \Omega_c^3 + F_{\mathrm{RR}'} \cdot \Omega_c^4]$$

Both expressions are cubic polynomials in the moduli T and U and are at most linear in S

The IIB superpotential was originally obtained in

Aldazabal, Andés, Cámara, Graña (2010)

Exotic branes

Precisely like the NS fluxes, all the other fluxes also induce tadpoles that must be cancelled by introducing branes

The NS fluxes induce charges for the RR potentials

The $P_a{}^{bc}$ flux induces a charge for the S-dual of the D7-brane

$\int E_8 \wedge P_1^2 H_3$

Aldazabal, Cámara, Font, Ibáñez (2006)

What happens to this brane under T-duality?

The full web of branes of the maximal theories in any dimensions has been derived in a series of papers

Bergshoeff, FR (2011)

Bergshoeff, Marrani, FR (2012)

Exotic branes

We classify the branes according to how their tension scales with the dilaton in the string frame, $T \sim g_S^{\alpha}$

- $\alpha = 0$: fundamental branes
- $\alpha = -1$: D-branes
- $\alpha = -2$: NS 5-branes
- $\alpha = -3$: S-dual of D7-brane

In D=4 we are interested in space-filling branes. These branes are charged under 4-form potentials, and we know the $SO(6,6)$ representations of all these potentials

- $\alpha = -1 : C_{4,\dot{\alpha}}$ $(\mathbf{32})$
- $\alpha = -2 : D_{4,MNPQ}$ $(\mathbf{495})$
- $\alpha = -3$: $E_{4,MN\dot{\alpha}}$ $(\mathbf{1728})$

Where do the branes in these representations come from?

Exotic branes

For D-branes ($\alpha = -1$) you just need the potentials of the 10-dim theory

For NS branes ($\alpha = -2$) you need the mixed-symmetry potentials

$D_6 \quad D_{7,1} \quad D_{8,2} \quad D_{9,3} \quad D_{10,4}$

The extra indices correspond to the fact that the corresponding brane solution must have isometries

Lozano-Tellechea, Ortín (2001)

Bergshoeff, Ortín, FR (2011)

$D_{7,1} \rightarrow D_{6x,x}$ KK monopole

$D_{8,2} \rightarrow D_{6xy,xy}$ T-fold

de Boer, Shigemori (2010)

These branes are exotic

Exotic branes

For the $\alpha = -3$ brane one needs the potentials

$$E_{4,MN\dot\alpha} \rightarrow \begin{cases} E_8 \;\; E_{8,2} \;\; E_{8,4} \;\; E_{9,2,1} \;\; E_{8,6} \;\; E_{9,4,1} \;\; E_{10,2,2} \;\; E_{10,4,2} \;\; E_{10,6,2} \\ \\ E_{8,1} \;\; E_{8,3} \;\; E_{9,1,1} \;\; E_{8,5} \;\; E_{9,3,1} \;\; E_{9,5,1} \;\; E_{10,3,2} \;\; E_{10,5,2} \end{cases}$$

where the first line is IIB and the second is IIA

We find the following T-duality rule:

- $\alpha = -1:$ $\quad 0 \longleftrightarrow 1 \qquad C_{\dots} \xrightarrow{T^x} C_{\dots x}$
- $\alpha = -2:$ $\quad 0 \longleftrightarrow 1,1 \qquad D_{\dots} \xrightarrow{T^x} D_{\dots x,x}$

  $1 \longleftrightarrow 1 \qquad D_{\dots x} \xrightarrow{T^x} D_{\dots x}$
- $\alpha = -3:$ $\quad 0 \longleftrightarrow 1,1,1 \qquad E_{\dots} \xrightarrow{T^x} E_{\dots x,x,x}$

  $1 \longleftrightarrow 1,1 \qquad E_{\dots x} \xrightarrow{T^x} E_{\dots x,x}$

Exotic branes

The rule applies to all values of α

$$\alpha = -n \ : \qquad \underbrace{a, a, ..., a}_{p} \overset{T_a}{\longleftrightarrow} \underbrace{a, a, ..., a}_{n-p}$$

In the maximal theory in D=4, the lowest value of α for space-filling branes is -7

Using these rules, we find that starting with E_8 in the IIB orientifold model and mapping to the IIA theory and back to IIB, we can fill the whole set of space-filling branes that can be consistently included to cancel the tadpoles generated by the fluxes

Apart from the D-branes, with $\alpha = -1$, and the family containing the S-dual of the D7, with $\alpha = -3$, we get also branes with $\alpha = -5$ and $\alpha = -7$

Exotic branes

The E potentials, with $\alpha = -3$

IIB		IIA	
potential	internal component	internal component	potential
E_8	$E_{x_i y_i x_j y_j}$	$E_{x_i y_i x_j y_j x_k, x_i x_j x_k, x_k}$	$E_{9,3,1}$
$E_{8,4}$	$E_{x_i y_i x_j x_k, x_i y_i x_j x_k}$	$E_{x_i y_i x_j x_k, y_i}$	$E_{8,1}$
	$E_{x_i y_i x_j y_j, x_i y_i x_j y_j}$	$E_{x_i y_i x_j y_j x_k, y_i y_j x_k, x_k}$	$E_{9,3,1}$
	$E_{x_i y_i x_j y_k, x_i y_i x_j y_k}$	$E_{x_i y_i x_j y_j x_k, y_i x_k y_k, x_k}$	$E_{9,3,1}$
	$E_{x_i y_i y_j y_k, x_i y_i y_j y_k}$	$E_{x_i y_i x_j y_j x_k y_k, y_i x_j y_j x_k y_k, x_j x_k}$	$E_{10,5,2}$
$E_{9,2,1}$	$E_{x_i y_i x_j y_j x_k, x_i x_k, x_i}$	$E_{x_i x_j y_j x_k, x_j}$	$E_{8,1}$
	$E_{x_i y_i x_j y_j y_k, x_i y_k, x_i}$	$E_{y_i x_j y_j x_k y_k, x_j x_k y_k, x_k}$	$E_{9,3,1}$
	$E_{x_i y_i x_j y_j x_k, y_i x_k, y_i}$	$E_{x_i y_i x_j y_j x_k, x_i y_i x_j, y_i}$	$E_{9,3,1}$
	$E_{x_i y_i x_j y_j y_k, y_i y_k, y_i}$	$E_{x_i y_i x_j y_j x_k y_k, x_i y_i x_j x_k y_k, y_i x_k}$	$E_{10,5,2}$
$E_{10,4,2}$	$E_{x_1 y_1 x_2 y_2 x_3 y_3, x_i y_i x_j y_j, x_i y_i}$	$E_{y_i x_j y_j x_k y_k, y_i y_j x_k, y_i}$	$E_{9,3,1}$
	$E_{x_1 y_1 x_2 y_2 x_3 y_3, x_i y_i x_j x_k, x_j x_k}$	$E_{x_i y_i y_j y_k, y_i}$	$E_{8,1}$
	$E_{x_1 y_1 x_2 y_2 x_3 y_3, x_i y_j x_k y_k, x_i y_j}$	$E_{y_i x_j y_j x_k y_k, x_j y_j y_k, y_k}$	$E_{9,3,1}$
	$E_{x_1 y_1 x_2 y_2 x_3 y_3, x_i y_i y_j y_k, y_j y_k}$	$E_{x_1 y_1 x_2 y_2 x_3 y_3, y_i x_j y_j x_k y_k, y_j y_k}$	$E_{10,5,2}$

Exotic branes

The G potentials, with $\alpha = -5$

IIB		IIA	
potential	component	component	potential
$G_{10,4,2}$	$G_{10,x^iy^ix^jy^j,x^iy^i}$	$G_{10,x^iy^ix^jy^jx^k,x^k}$	$G_{10,5,3,1}$
	$G_{10,x^iy^jx^ky^k,x^iy^j}$	$G_{10,x^iy^jx^ky^kx^j,x^jy^jx^k,x^j}$	
	$G_{10,x^iy^ix^jx^k,x^jx^k}$	$G_{10,x^iy^ix^kx^j,x^i}$	$G_{10,4,1}$
	$G_{10,x^iy^iy^jy^k,y^jy^k}$	$G_{10,x^1y^1x^2y^2x^3y^3,x^ix^jy^jx^ky^k,x^jx^k}$	$G_{10,6,5,2}$
$G_{10,5,4,1}$	$G_{10,x^iy^ix^jy^jx^k,x^iy^ix^jx^k,x^j}$	$G_{10,x^iy^iy^jx^k,y^i}$	$G_{10,4,1}$
	$G_{10,x^iy^ix^jy^jx^k,x^jy^jy^ix^k,y^i}$	$G_{10,x^iy^ix^jy^jx^k,x^iy^iy^j,y^i}$	$G_{10,5,3,1}$
	$G_{10,x^ky^kx^jy^jy^i,x^jy^jx^ky^i,x^k}$	$G_{10,x^iy^ix^jy^jy^k,x^iy^iy^j,x^i}$	
	$G_{10,x^jy^jx^ky^ky^i,x^ky^ky^iy^j,y^j}$	$G_{10,x^1y^1x^2y^2x^3y^3,x^iy^ix^jy^jy^k,x^iy^j}$	$G_{10,6,5,2}$
$G_{10,6,2,2}$	$G_{10,x^1y^1x^2y^2x^3y^3,x^iy^i,x^iy^i}$	$G_{10,x^jy^jx^ky^ky^i,y^ix^kx^j,y^i}$	$G_{10,5,3,1}$
	$G_{10,x^1y^1x^2y^2x^3y^3,y^iy^j,y^iy^j}$	$G_{10,x^iy^ix^ky^ky^j,x^ix^ky^j,y^j}$	
	$G_{10,x^1y^1x^2y^2x^3y^3,x^iy^j,x^iy^j}$	$G_{10,x^jy^jx^ky^kx^i,x^jy^jx^k,y^j}$	
	$G_{10,x^1y^1x^2y^2x^3y^3,x^ix^j,x^ix^j}$	$G_{10,y^iy^jx^ky^k,x^k}$	$G_{10,4,1}$
$G_{10,6,6,2}$	$G_{10,x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3,x^iy^i}$	$G_{10,x^jy^jx^ky^ky^i,y^jy^iy^k,y^i}$	$G_{10,5,3,1}$

Exotic branes

The I potentials, with $\alpha = -7$

IIB		IIA	
potential	component	component	potential
$I_{10,6,6,2}$	$I_{10,x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3,x^iy^i}$	$I_{10,x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3,x^jy^ix^k}$	$I_{10,6,6,3}$
$I_{10,6,6,6}$	$I_{10,x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3}$	$I_{10,x^1y^1x^2y^2x^3y^3,x^1y^1x^2y^2x^3y^3,y^iy^jy^k}$	$I_{10,6,6,3}$

Exotic branes

Using all our T-duality rules we can now figure out what are all the tadpole conditions induced by all our fluxes and which branes can be included to cancel these tadpoles

All tadpoles have the form

$\int \text{potential (flux) (flux)}$

potential	flux·flux
C	$H \cdot F$
E	$H \cdot P + F \cdot H'$
G	$H \cdot F' + H' \cdot P$
I	$H' \cdot F'$

Conclusions

- Symmetry $SL(2,\mathbb{Z})^7$: fluxes belong to $(\mathbf{2},\mathbf{2},\mathbf{2},\mathbf{2},\mathbf{2},\mathbf{2},\mathbf{2})$.

  Aldazabal, Cámara, Font, Ibáñez (2006)

  We have determined the representations of all the branes
- We have an explicit expression for the superpotential with all fluxes included from both the IIB and IIA perspective
- We have a new T-duality rule for all the fluxes
- We have a universal T-duality rule for all the branes in string theory
- We have a complete consistent expression for tadpole conditions including exotic branes

Conclusions

To be done:

- Study the brane sector
- Study moduli stabilisation
- Consider different models
- Embed in DFT/EFT
- Dynamics of exotic branes