Fluxes of internal abelian gauge field strength $P$.

- Heterotic/Type I strings on $T^6$ or on $K3 \times T^2$.

(Proceedings, Stony Brook: Michelson, Taylor, Vafa: ...)

\[ \int_{\mathcal{M}_g} \omega = 0 \]

Fluxes of internal $n$-form field strength $H^{(n)}$.

- Type II/B on $K3 \times T^2$ or on Calabi-Yau 3-folds.

Several possibilities:

constitute an interesting class of string vacua.

String compactifications with internal background fluxes

Introduction
(I) Type I String Compactifications

Non-commutative Internal Space $\Leftrightarrow$

Consider a Type I string with D6-branes and internal magnetic background fields turned on.

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Further plan of the talk:

II) Type I String Compactifications

Non-commutativity in non-commutative string

III) Type II/II' heterotic string dualities in the presence of fluxes

Geting the standard model from strings

Further plan of the talk:

Giddings, Kachru, Polchinski

Introduction of warped space-times

Generation of chiral fermions

Gauge symmetry breaking (Green-Schwarz terms)

Points in the moduli space

Supergravity might be partially restored at some

Supergravity breaking - scalar potential

Effects after compactification:

Background fluxes cause in general several interesting

Introduction

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This leads to the following deformed commutators

\[ 0 = T_{\phi \phi} \]

The vacua of the theory are defined by the F-term conditions:

\[ f_2 = f_3 = f_4 = f_5 = 0 \]

\[ \lambda = \lambda' = \lambda'' = \lambda''' = 0 \]

\[ Y = N = 4 \]

\[ \lambda = N = 4 \]

Non-commutative torus:

Large gauge group with rank 16

Non-chiral fermions

\[ N = 4 \text{ supersymmetry} \]

\[ N = 4 \text{ super Yang-Mills gauge theory} \]

3 adjoint chiral superfields \( \phi \leftrightarrow 3 \) (complex internal coordinates, Jeffrey-Leblon basis)

\[ \mathcal{E} = N = 4 \text{ SYM gauge theory} \]

Field theory interpretation of internal non-commutative field theory interpretation of internal non-commutative backgrounds

(II) Type I string compactifications
A non-commutative torus is equivalent to some $SU(2,Z)$ string compactification. The transformation to a commutative one (Monita et al.)

Diagram:

- T-duality maps the $D2$-brane with $F_{11}$-flux to a $D1$-brane with $F_{11}$-flux.
- T-duality applies to boundary conditions.

Type I string compactifications:

Consider $T^2$ with parameters $R_1, R_2$ and $b = 0.1/2$. 

Non-commutativity parameter of the torus:

$$\theta = \frac{\theta}{2\pi}$$

Electric charges $q_1, q_2$ - winding no. of $D2$-brane.

Magnetic charges $m_1, m_2$ - Chan no.

$$m_1 R_1 = \frac{m_1 R_1}{\theta} + \frac{m_2 R_2}{\theta} = \frac{m_1 R_1}{\theta} + \frac{m_2 R_2}{\theta} = \frac{m_1 R_1}{\theta} + \frac{m_2 R_2}{\theta}$$
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\[ \mathfrak{g} \text{ gauge group: } \prod_{N} U(1)^{1,2} = O(2N) \]

\[ \Phi \text{ stacks of } N \text{ D}9\text{-branes with fluxes } \Phi \text{ in } X \]

(II) Non-supersymmetric configuration:

\[ \text{Stacks of } 2N \text{ D}9\text{-branes with } F = 0 \]

(i) Supersymmetric configuration:

Open string spectrum in 4 dimensions:

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Four-dimensional orientifold compactifications

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Type I string compactifications

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Type I string compactifications with background fluxes

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The worldsheet parity \( \mathbb{Z} \).

The \( \mathbb{Z}_2 \) cycles of \( \mathbb{Z}_2 \).

The complex structure \( \mathbb{C} \).

The product of \( \mathbb{C} \) non-compactified tori with background angles \( r \) on each of the \( 3 \) tori (D5-branes wrapping through in all \( X \)) directions.

\[ \mathbb{Z}_2 \mathbb{Z}_2 \mathbb{Z}_2 \mathbb{Z}_2 \ldots \]

The dual picture:

\[ \Phi \text{ stacks of } N \text{ D}9\text{-branes with fluxes } \Phi \text{ in } X \]

and add \( N \) D9\text{-branes with fluxes \[ \Phi = 0 \]}

\[ \prod_{k=1}^{\Phi} \mathbb{Z}_2 \]

Parameters \( \mathbb{C} \), \( \mathbb{C} \), \( \mathbb{C} \), \( \mathbb{C} \), \( \mathbb{C} \), \( \mathbb{C} \).

Now compactify Type I string (Type I string compactifications)
This ensures the absence of non-Abelian anomalies.

\[ I_2 = 0. \]

\[ I_3 = 0. \]

Note that \( I_1 \) is even for \( \nu \) even.

\[ \frac{\partial \mu}{\partial f} + \frac{\partial \nu}{\partial f} = \frac{\partial \mu}{\partial I} \]

Finally, the tadpole cancellation conditions read:

- **Matter-Stop**:
  - **Annulus**:
  - **Klein-bottle**

"Tadpole cancellation:"

**Type I string compactifications**

\[ \text{Brane:} \]

Number of families: Intersection numbers \( f \) of different

\[ [(s + v) I + (v) I] + [(n N) I + (n N) I] \]

Chiral Fermions:

**Type I string compactifications**
There is a Higgs sector similar to the MSSM. There are 3 generations of quarks and leptons.

\[ C = n(e^3) \times n(\nu^3) \times (\tau^2) \times (\nu^2) \]\n
They found a model with four stacks of D6-branes and

\[ N_3 = 3, N_4 = 2, N_5 = 1 \]

This leads to the following chiral spectrum with 3 genus-

\[
\begin{pmatrix}
3 & 1 & 0 \\
0 & 1 & -2 \\
-2 & -1 & 0
\end{pmatrix}
\]

Consistent choice of wrapping numbers:

In order to get three generations we choose \( \text{gen} = 1/2 \).

\[ C = n(e^3) \times n(\nu^3) \times (\tau^2) \times (\nu^2) \]

The search for the standard model
This expression can be also derived from the Born-Infeld action for a Dp-brane

\[ \phi \theta \psi \rho \sigma \tau \int \mathcal{L} \, dx^0 \]

with \( \phi \theta \psi \rho \sigma \tau \sim \sigma(\psi, \rho, \sigma, \tau) \)

\[ \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) + \xi \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) \]

\[ \phi \theta \psi \rho \sigma \tau \sim \sigma(\psi, \rho, \sigma, \tau) \]

All NS tadpoles arise from the following scalar potential:

\[ \frac{\sigma(\psi, \rho, \sigma, \tau)}{\xi} \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) + \xi \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) \]

(II) Complex structure (geometric) tadpoles:

\[ \xi \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) + \xi \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) \left( \frac{\phi \theta \psi \rho \sigma \tau}{\xi} \right) \]

(II) Type I string compactifications

Stability

(II) 1-Type I string compactifications
\[ (v^2)_0 w u - (v^2)_1 X^t w = u - f^t v \wedge (e)_H H \int = W \]

\[ \int (t^t) H H \int = v^m \quad \int (e)_H H \int = e \quad \int (f)_H H \int = 0 \]

\textbf{Type IIa on $\mathbb{R}^4$: Ramond-Ne form fluxes:}

\[ \int \tau^u + \tau^u w = (T)_w \]

where $\tau^u$ and $\tau^u w = I X$ and $\tau^u H$.\[ (v^2)_0 (T)_w - (v^2)_1 X^t w = (T)_H + \frac{1}{2} H \wedge \tau^u \int = W \]

\textbf{Type IIA on Calabi-Yau 3-folds:}

\[ (t^t) H H \int = I \tau^u w \quad \int (e)_H H \int = e \]

\textbf{Type IIb on $\mathbb{R}^4$: Ramond and NS-3 form fluxes:}

\textbf{3.1. Type II strings on Calabi-Yau 3-folds}

\textbf{Background Fluxes in Type II and Heterotic String I String Compactifications:}

\textbf{Structured: $SU(3) \times SU(2)$ on Type I.}

\textbf{Type II on $\mathbb{R}^4$:}

\[ \{ \mathfrak{g} + \mathfrak{c} \} \]

\textbf{E.9. Orbifold models:}

\textbf{A particular discrete symmetry of the toroidal model by}

\textbf{Freeze out complex structure moduli as dynamical fields.}

\textbf{Possible way out:}

\[ \text{the non-supersymmetric toroidal compactification.} \]

\textbf{Emergence:}

\textbf{Hence the non-supersymmetric toroidal compactification.}

\textbf{So the torus is dynamically pushed to the degeneration.}

\textbf{Meaning of NS tadpoles: Vanishing of tadpoles (mini-}

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Scalar potential:
\[
\left( \frac{\partial}{\partial \theta} + \lambda \right) u = 0 \quad u = M
\]

(SYM):
\[
2 = N = \text{adjoint mass term in SYM(2)}
\]

Superpotential (adjoint mass term in SYM):
\[
\frac{2}{m_w} = \left( \frac{\partial}{\partial \theta} \right) \int \frac{m_w}{H} \int \frac{H}{m_w}
\]

Dual fluxes:
\[
0 \rightarrow \frac{\partial}{\partial \theta} = \left( \frac{\partial}{\partial \theta} \right) \text{vol}(\mathbb{C})
\]

Type II: Vanishing 2-cycle plus vanishing 4-cycle:

Type II: Seiberg-Witten field theory point:

Background fluxes in type II and heterotic strings:

Type II: The whole quantum volume of CY N shrikks:

Corresponding superpotential M and scalar potential:

\[
M = 2 = N
\]

Be due to some vanishing cycles \( C_0 \) of the CY.

These superpotentials generally break \( N = 2 \) supersymmetry.
$S$: gaugino condensate
\[
L = L_{\phi} + S_{\phi} = L_{\phi} + \int \frac{1}{2} \int \sqrt{|g|} \left( \nabla \phi \right)^2 + \int \frac{1}{2} \int \sqrt{|g|} \left( \nabla \phi \right)^2 + W
\]

Superpotential due to fluxes:

Type IIB on non-compact CY with fluxes $N$ D3-

Large $N$-duality:

Singularity (geometric engineering):

It makes sense to study the field theory dynamics by

...
IIA H-fluxes which involve the same $\psi_H$:

\[ \int_{\mathbb{R}^6} f = \int_{\mathbb{R}^6} f \]

These heterotic F-fluxes are precisely dual to the type

\[ \int_{\mathbb{R}^6} f = \int_{\mathbb{R}^6} f \]

IIA H-fluxes which involve the same $\psi_H$:

\[ \int_{\mathbb{R}^6} f = \int_{\mathbb{R}^6} f \]

These six-dimensional gauge fields strengths can provide

\[ \phi_{\text{D-field, Wilson lines}}, \phi_{\text{D-field, Wilson lines}} \]

Then we get heterotic Abelian gauge fields in six dimensions

\[ \phi_{\text{D-field, Wilson lines}}, \phi_{\text{D-field, Wilson lines}} \]

Then we get the following fluxes:

1. \( \phi_{\text{F-fluxes}} \)
2. \( \phi_{\text{F-fluxes}} \)
3. \( \phi_{\text{F-fluxes}} \)
4. \( \phi_{\text{F-fluxes}} \)

These fluxes can be seen as gauge fluxes of six-dimensional

\[ \int_{\mathbb{R}^6} f = \int_{\mathbb{R}^6} f \]

H-fluxes which involve $\psi_H$:

\[ \int_{\mathbb{R}^6} f = \int_{\mathbb{R}^6} f \]
So we can consider heterotic gauge fluxes on $\Sigma$. Further to your dimensions on $\Sigma$, we can also view the heterotic compactification.

Alternatively, we can also view the heterotic compactification.

Type II string duality

So these fluxes apparently break the heterotic/type IIA string duality.

However, the type IIA fluxes $\Omega, \Omega'$ and $\Omega''$, which do not involve $\Sigma$, are not present on the heterotic side. Hence these fluxes from $\Sigma$ are not present. However, there are no chiral fermions due to gauge fields. These fluxes from $\Sigma$ are not present, and there are no anomaly-generating Green-Schwartz terms in the 4d effective action.

The duality between these fluxes can be proven by comparing the scalar potentials of the corresponding backgrounds.

Background fluxes in type II and heterotic strings
and its M-theory embedding via C2 manifolds. Type II A? This is important for the large N-duality.

What is the dual of the type IIB NS 5-form fluxes in the dual string picture? Is it possible to recognize the string set of H- resp. F-fluxes, but is apparently broken. The type II heterotic string duality holds for a sub-set of fluxes.

The geometry can be constructed, and tachyon free models with 3 generations of quarks and lepton, \( C = SU(3)^3 \times SU(2)^2 \times U(1) \), and stable non-commutative cones, dual to intersecting branes.

Type I compactifications with F-fluxes → Type I compactifications with F-fluxes →

IV) Conclusions