

D-terms and F-terms from D7-brane fluxes

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Motivation

String theory



Low energy description

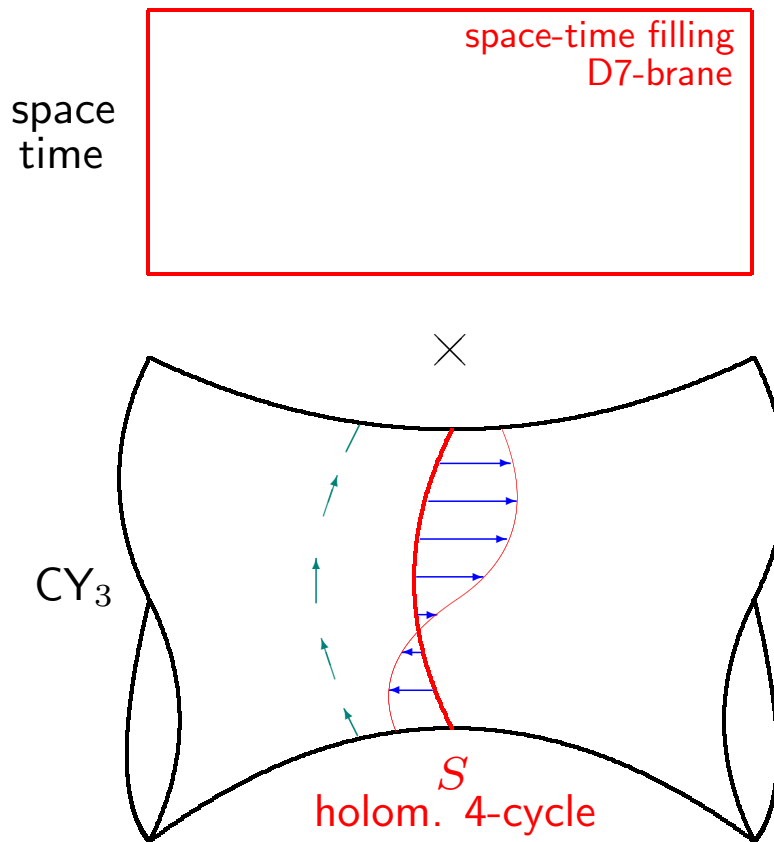
Particle Physics:
(Minimal supersymmetric)
Standard Model

Cosmology:
Positive cosmology constant
(metastable) deSitter vacua

Motivation

- D-brane scenarios in Type II string theories
 - see Angel Uranga's talk
- In the following: Focus on low energy effective action of D7-brane in Calabi-Yau orientifold compactifications
 - Lüst, Reffert, Stieberger; Cámara, Ibáñez, Uranga; Louis, HJ
 - Standard model on D7-branes
 - Lüst, Reffert, Stieberger; Cámara, Ibáñez, Uranga; Ibáñez
 - Hidden sector on D7-branes
 - Kachru, Kallosh, Linde, Trivedi; Deneff, Douglas, Florea; Görlich, Kachru, Tripathy, Trivedi
 - Internal D7-brane fluxes to generate metastable deSitter vacua
 - Burgess, Kallosh, Quevedo
 - Discuss flux-induced D- and F-terms of D7-brane fluxes
 - Lüst, Mayr, Reffert, Stieberger; Berglund, Mayr; Louis, HJ

D7-brane spectrum



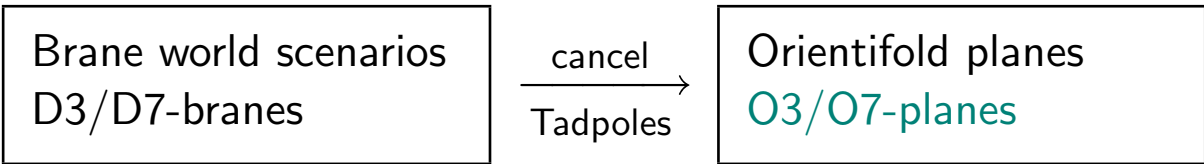
- Massless bosonic & fermionic spectrum yields:

$\mathcal{N} = 1$ multiplets	fields	multiplicity
vector	(A_μ, λ)	1
chiral	(ζ^A, χ^A)	$h^{2,0}(S)$
chiral	(a_I, χ_I)	$h^{0,1}(S)$

- Stack of N D7-branes:
Multiplets transform in the adjoint of $U(N)$

Bulk: Type IIB Calabi-Yau orientifold

- Consistency: D-branes require **negativ tension objects**



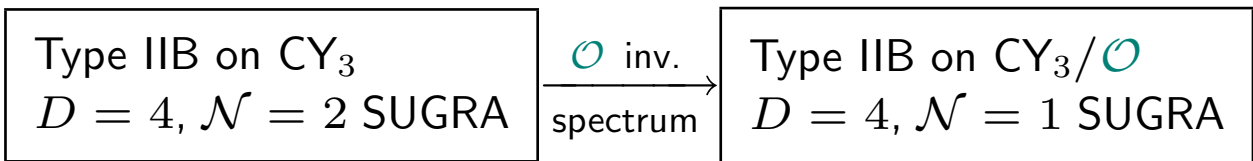
- IIB Calabi-Yau orientifolds: Mod out \mathbb{Z}_2 action \mathcal{O} .
For **O3/O7-planes**:

$$H^{p,q}(CY_3) = H_+^{p,q}(CY_3) \oplus H_-^{p,q}(CY_3)$$

$$J \in H_+^{1,1}(CY_3) \quad \Omega \in H_-^{3,0}(CY_3)$$

Acharya, Aganagic, Hori, Vafa; Brunner, Hori

- Low energy effective theory on CY_3/\mathcal{O}

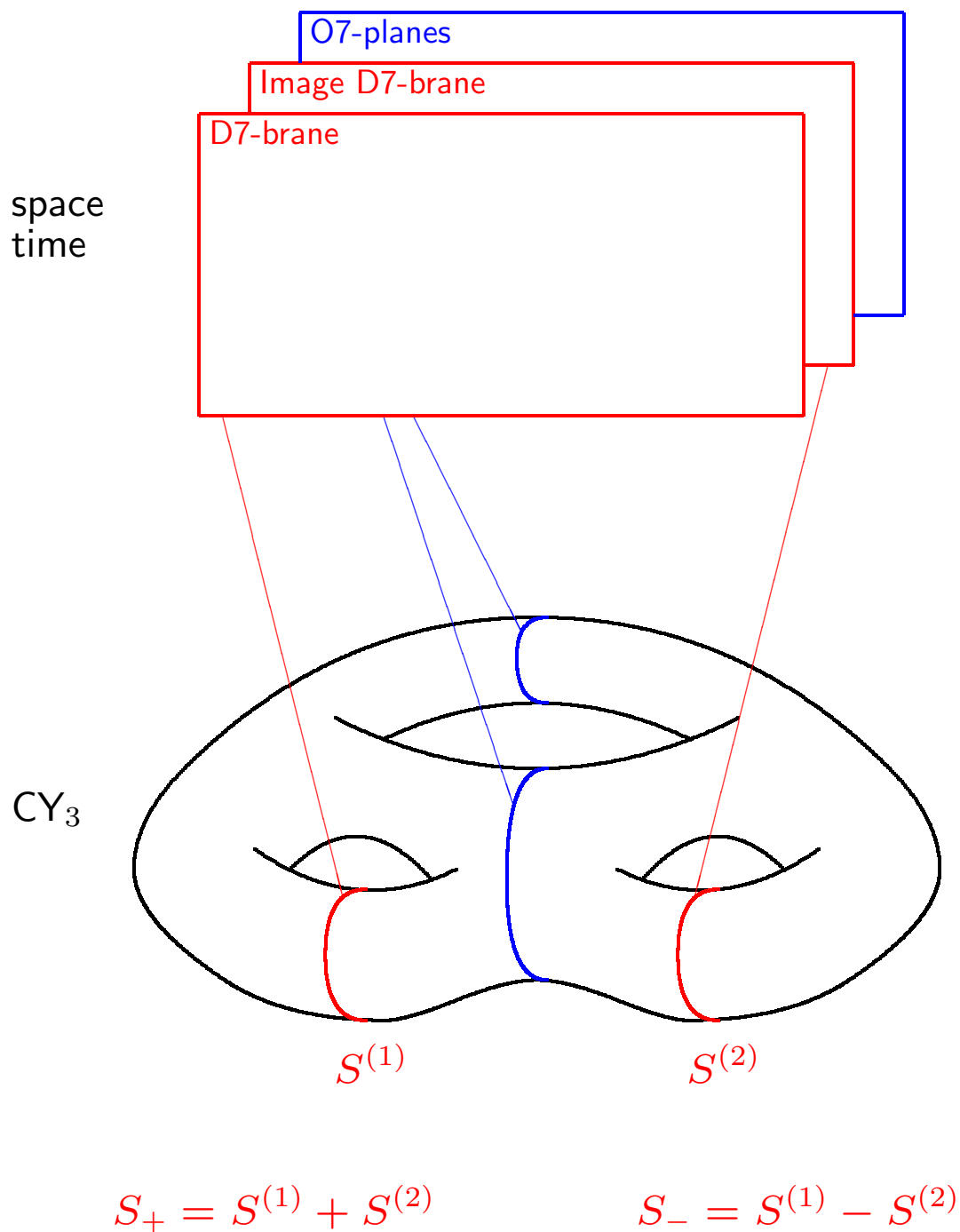


D'Auria, Ferrara, Trigiante; Grimm, Louis

- $D = 4, \mathcal{N} = 1$ bulk Calabi-Yau orientifold spectrum

multiplet	multiplicity	4D-fields	10D-fields
gravity	1	$g_{\mu\nu}$	g_{MN}
vector	$h_+^{2,1}$	$V^{\hat{\alpha}}$	$C^{(4)}$
chiral	$h_-^{2,1}$	$z^{\tilde{a}}$	Ω
	$h_-^{1,1}$	G^a	$B, C^{(2)}$
	$h_+^{1,1}$	T_α	$J, C^{(4)}$
	1	S	$\phi, C^{(0)}$

D7-brane Calabi-Yau orientifolds



D7-brane action

- Dirac-Born-Infeld & Chern-Simons action:

$$S_{\text{DBI}}^{\text{sf}} = -\mu_7 \int_{\mathcal{W}} d^8 \xi e^{-\phi} \sqrt{-\det(\varphi^*(g + B) - 2\pi\alpha' F)}$$

$$S_{\text{CS}} = \mu_7 \int_{\mathcal{W}} \varphi^* \left(\sum_q C^{(q)} e^B \right) e^{-2\pi\alpha' F}$$

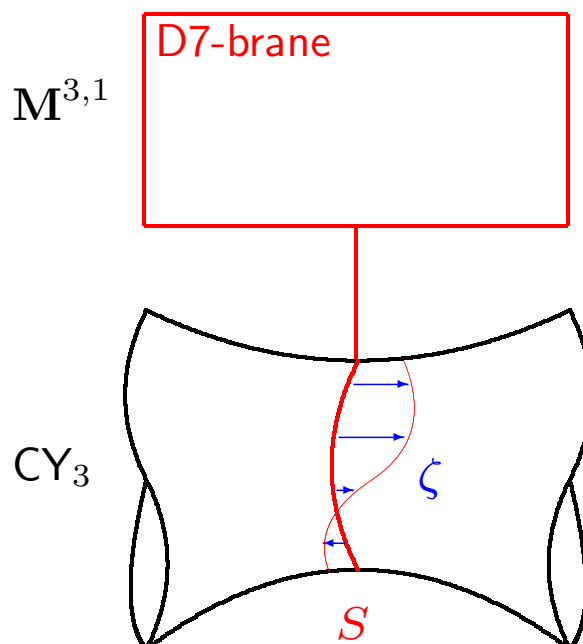
μ_7, α' Coupling constants

$\varphi : \mathcal{W} \hookrightarrow M^{9,1}$ Dynamics of the D7-brane

- Dynamics of fermionic fields:



- (Super-)Normal coordinate expansion:



$D = 4$ Effective action

D7-brane:

Dirac-Born-Infeld action
Chern-Simons action

Bulk theory:

Type IIB SUGRA
in $D = 10$

Normal
coordinate
expansion

Kaluza-Klein
on CY_3/\mathcal{O}

$D = 4$ $\mathcal{N} = 1$
SUGRA action

$\mathcal{N} = 1, D = 4$ SUGRA Lagrangian

- General $\mathcal{N} = 1, D = 4$ SUGRA Lagrangian:

K Kähler potential

f gauge kinetic couplings

V_F, V_D F-term and D-term scalar potential

- Generic Kähler potential for D-branes in IIB orientifolds:

$$K = -\ln \left(-i \int_Y \Omega \wedge \bar{\Omega} \right) - \ln (-i (\tau - \bar{\tau})) - 2 \ln \mathcal{K}$$

Ω holom. three-form of CY_3

τ type IIB dilaton

\mathcal{K} volume of Y

- Definition of the chiral variables
(complex structure of the target space manifold)

$$\tau(S, \zeta) = S + \zeta \cdot \bar{\zeta}$$

$$\Omega = \Omega(z)$$

$$\mathcal{K} = \mathcal{K}(S, G, T, \zeta, a)$$

D7-brane gauge theory

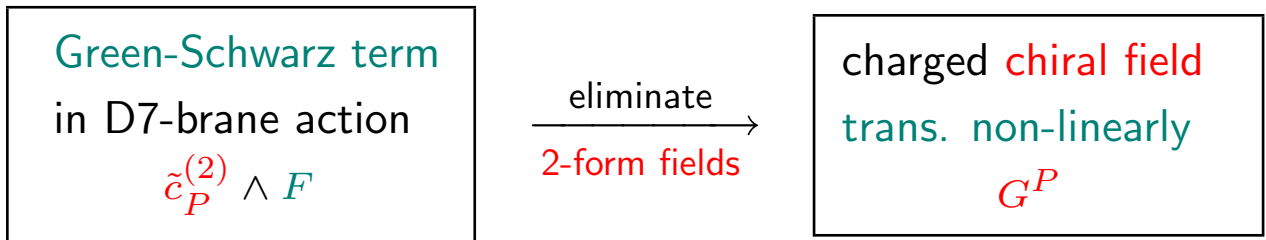
- Gauge kinetic function of D7-brane $U(1)$ gauge theory:

$$f^{\text{D7}} \sim \mu_7 T_\Lambda \quad \text{Re } T_\Lambda \sim \text{Volume of } S$$

- Bulk SUGRA action has a set of global shift symmetries:

$$G^a \rightarrow G^a + \theta^a$$

- Charged **chiral field** from a Green-Schwarz term:



- One charged **chiral field** transforming non-linearly:

$$\nabla G^P = dG^P - 4\mu_7 A$$

- D-term for the charged field G^P :

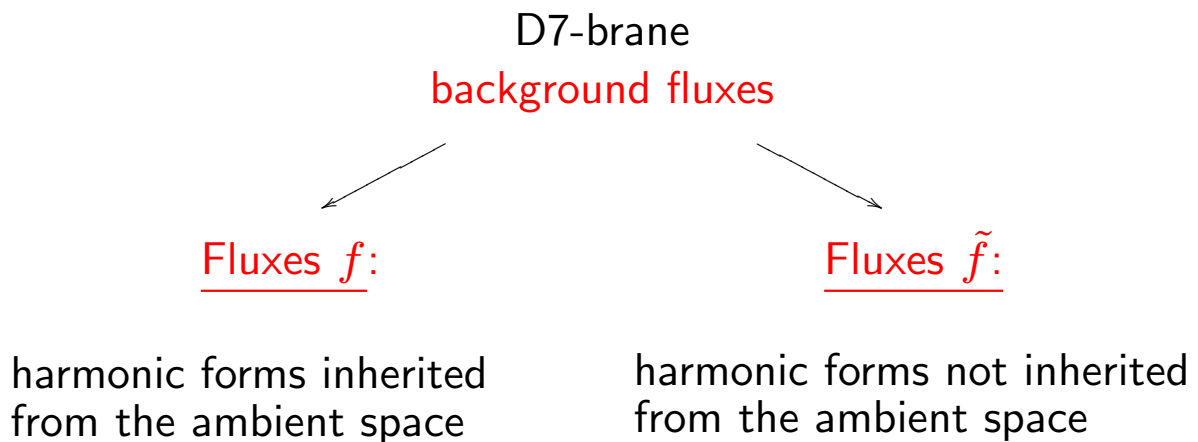
$$D \sim \frac{1}{\mathcal{K}} \int_{S_-} J \wedge B \quad V_D \sim \frac{1}{\text{Re } T_\Lambda} D^2$$

- Note $D = 0$ is a solution with $B = 0$.

D7-brane background fluxes I

Lüst, Mayr, Reffert, Stieberger; Berglund, Mayr; Louis, HJ

Background fluxes for the field strength $F_{\mu\nu}$ of the $U(1)$ gauge theory on the worldvolume of the D7-brane.



$$Q^D \sim \int_{S_-} J \wedge f$$

$$\tilde{Q}^D \sim \int_{S_-} J \wedge \tilde{f}$$

$$\tilde{Q}_A^F \sim \int_{S_+} s_A \wedge \tilde{f}$$

$$A = 1, \dots, h^{2,0}$$

D-terms and F-terms determined from:

$$\begin{aligned} \mathcal{L}_{\text{Couplings}}^{\mathcal{N}=1} &= e^{K/2} \left(\mathcal{D}W \chi \sigma^\mu \bar{\psi}_\mu + \mathcal{D}\bar{W} \bar{\chi} \bar{\sigma}^\mu \psi_\mu \right) \\ &+ \mathcal{D} \psi_\mu \sigma^\mu \bar{\lambda} - \mathcal{D} \bar{\psi}_\mu \bar{\sigma}^\mu \lambda + \dots \end{aligned}$$

D7-brane background fluxes II

- Computation of fermionic terms:

$$D \rightarrow D - Q^D - \tilde{Q}^D \Rightarrow D \sim \int_{S_-} J \wedge (B - f - \tilde{f})$$

$$W_{S_+} \sim \tilde{Q}_A^F \zeta^A \sim \int_{S_+} s_A \zeta^A \wedge \tilde{f}$$

- Supergravity analysis: Confirms D-term

$$G^a \xrightarrow{\substack{\text{adjustment of} \\ \text{of chiral fields}}} G^a = G^a(f)$$

$$\tilde{Q}^D \xrightarrow{\substack{\text{new charged} \\ \text{chiral fields}}} T_\alpha \text{ modify D-term by } \tilde{Q}^D$$

- $D=0$ is a solution $\leftrightarrow B$ is not projected out by \mathcal{O}
- Holomorphic Chern-Simons-Theory: Confirms F-term

$$W_Y = \int_Y \Omega \wedge \text{Tr} \left(A \wedge \bar{\partial} A + \frac{2}{3} A \wedge A \wedge A \right)$$

dimensional
reduction
↓

$$W_{S_+} = \int_{S_+} s_A \zeta^A \wedge \tilde{f}$$

Kachru, Katz, Lawrence, McGreevy; Lerche, Mayr, Warner; Louis, HJ

Example: One Kähler modulus

- Calabi-Yau orientifold with $h_+^{1,1} = 1$ and $h_-^{1,1} = 0$
Bulk moduli: S, T Brane moduli: ζ

- Kähler potential:

$$K(S, T, \zeta) = -\ln [-i(S - \bar{S}) + 2i \zeta \cdot \bar{\zeta}] - 3 \ln [T + \bar{T}]$$

- **D-term** from D7-flux charge \tilde{Q}^D :

$$V_D \sim \frac{1}{T + \bar{T}} \left(\frac{\tilde{Q}^D}{T + \bar{T}} - \sum_i q_i |X_i|^2 \right)^2$$

X_i multiplets of charge q_i from D-brane intersections

Burgess, Kallosh, Quevedo

- **F-term** from D7-flux charges \tilde{Q}^F :

$$V_F \sim \left(\tilde{Q}^F \cdot \tilde{Q}^F \right) \frac{1 + e^\phi \zeta \cdot \bar{\zeta}}{(T + \bar{T})^3}$$

- If T stabilized by non-perturbative effects:
mechanism to uplift AdS vacua

Kachru, Kallosh, Linde, Trivedi

- Gauge transformation: $\delta T \neq 0$
 $\Rightarrow W_{\text{gaugino}} \sim e^{-aT}$ is modified

Binétruy, Dudas

Conclusions

- Computed $\mathcal{N} = 1$ supergravity spectrum and determined effective action for a D7-brane in a Calabi-Yau orientifold model.
- Discussed two types of internal D7-brane fluxes.
- Derived flux-induced D- and F-terms by a fermionic computation.
- Analyzed a simple model and confirmed the proposed D-term structure of Burgess, Kallosh and Quevedo.
- However: Only for specific D7-brane fluxes and a very special class of Calabi-Yau geometries D7-fluxes provide for a source to uplift AdS vacua.