

Flux compactifications and moduli fixing

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- The compactification geometry is parameterized in terms of neutral scalars in 4d (moduli)
 - **Kähler moduli:** « volumes »
 - **Complex structure moduli:** « shapes »
 - **Universal axion-dilaton:** string coupling constant
 - **Open string moduli:** positions and Wilson lines of D-branes
- In a standard compactification there can be **hundreds or even thousands of such fields!!**
- If String Theory describes the observed physics, it should contain a **mechanism to give masses to all these fields**

Background fluxes

- Starting from a compactification to 4d on a given compact space, we can **switch on magnetic fluxes on it**.
- In String Theory there are potentials of different degrees:

p-form potential \implies (p+1)-form field strength

$$A_i$$

$$F_{ij} = 2\partial_{[i}A_{j]}$$

$$C_{ij}$$

$$F_{ijk} = 3\partial_{[i}C_{jk]}$$

$$B_{ij}$$

$$H_{ijk} = 3\partial_{[i}B_{jk]}$$

...

...

- Fluxes do not admit a simple description in CFT \implies better to **analyze 4d effective supergravity**

- **Effective superpotentials**, obtained from dimensional reduction of the 10d effective action

- Canonical example: 3-form fluxes

[Gukov, Vafa, Witten '99]

$$W = \int_{\mathcal{M}_6} (F_3 - iSH_3) \wedge \Omega$$

fluxes

axion-dilaton modulus

complex structure moduli

- At the minima of the scalar potential, complex structure and axion-dilaton moduli (plus some open string moduli) are fixed.

- Independent of the Kähler moduli \Rightarrow no-scale models

(vanishing tree-level cosmological constant, even for non-supersymmetric vacua)

$$\sum_{\hat{i}, \hat{j}} K^{\hat{i}\hat{j}} \partial_{\hat{i}} K \bar{\partial}_{\hat{j}} K = 3 \Rightarrow V = e^K \sum_{i, j \neq \hat{i}, \hat{j}} K^{i\bar{j}} D_i W \bar{D}_{\bar{j}} \bar{W}$$

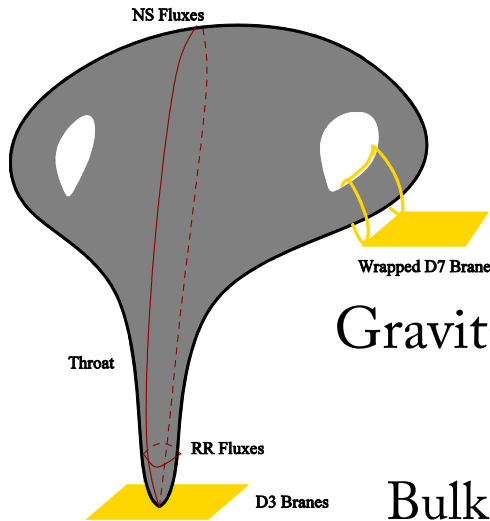
- Reduced supersymmetry

- Fluxes backreact the geometry



warped throats, Randall-Sundrum like effects

[Giddings, Kachru, Polchinski '01]



$$ds^2 = e^{2A} \eta_{\mu\nu} dx^\mu dx^\nu + e^{-2A} ds^2_{\mathcal{M}_6}$$

Gravitationally red-shifted mass scales \Rightarrow string modes at the TeV ??

Bulk modes: $W_0 \mathcal{V}^{-1} (m_{3/2}) \ll \mathcal{V}^{-2/3} (\text{KK}) \ll \mathcal{V}^{-1/2} (M_s)$

Localized (warped) modes: $W_0 e^{A_m} \mathcal{V}^{-1/3} (m_{3/2}) \sim e^{A_m} \mathcal{V}^{-1/3} (\text{KK}) \sim e^{A_m} \mathcal{V}^{-1/3} (M_s)$

But what about the remaining moduli?? How can they be stabilized??

Several possibilities...

[Shelton, Taylor, Wecht '05]

[Aldazabal, PGC, Font, Ibanez '06]

1. Add more exotic fluxes.

- The 4d theory admits further deformations (gaugings) of the same kind
- **More obscure higher dimensional origin** (torsion, T-folds, U-folds...)
- Related to ordinary fluxes by **chains of perturbative and non-perturbative dualities**
- **Superpotentials depending also on the Kähler moduli**
- Tension between moduli stabilization and chirality

2. Add non-perturbative effects and/or string corrections to the 4d effective action

(c.f. Max's talk)

- Gaugino condensation, instanton effects... [Kachru, Kallosh, Linde, Trivedi '03]

- **Large volume scenarios** [Conlon, Quevedo, Suruliz '05]

$$W = W_{\text{flux}} + C e^{aT}$$

Fluxes and moduli fixing are therefore relevant for:

- Supersymmetry breaking and soft-breaking terms (c.f. Matthew's talk)
- Cosmological models
- Generating mass hierarchies
- Lifting instanton zero modes (c.f. Max's talk)
- Understanding dualities

What is happening these days??

- Searches for de Sitter vacua
- Better understanding of the relation between fluxes and gauged supergravity
- Algebraic tools to systematically analyze the structure of vacua
- Better understanding of warp effects
- Generalized geometry