

SUPERPOTENTIALS :
Gaugings , fluxes and condensates

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on works with

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Some relevant issues

- string compactifications \rightarrow massless scalars \rightarrow MODULI
 - good : new scales
 - bad :
 - origin of these VEV's
 - generation of masses
- } "MODULI STABILIZATION"
- fundamental theories $D=10$ or $D=11$ with 16 or 32 sup. ch. models relevant for phenomenology $D=4$ with $N=1$ SUSY
 - during the compactification \rightarrow generation of a superpotential
 - can stabilize some moduli
 - affects the further $N=1 \rightarrow N=0$
 - provides $\langle V \rangle$

Some relevant issues

- unified picture

cosmological constant



- two low-energy tools:

- $\langle F_{[n]} \rangle \rightarrow$ non trivial superpotentials (FLUXES)

- $N = 1 \rightarrow N = 0$ at **small scale** (TeV)

local susy \rightarrow non-perturbative effects
such as gaugino condensates

[Ferrara, Girardello, Nilles 1983, Derendinger, Ibanez, Nilles 1985,
Kounnas, Porrati 1987, Dine, Rahn, Seiberg, Witten 1985]

Summary

- Fluxes in the perturbative superpotential as gaugings in the $N=4$ supergravity and $N=1$ projection: a short review [see talk by C. Kounnas]
 - effective $D=4$ theory approach [DKPZ] complementary to the usual $D=10$
- The non-perturbative superpotential
 - origin: gaugino condensation $\langle \lambda\lambda \rangle$
 - aim: breaking of the left over supersymmetry
 - consistent treatment: perturbative plus non perturbative superpotential

The fundamental theory

Massless bosonic sector: **gravitational** plus **antisymmetric tensors**

- at $D = 11$: M-theory $G_{\mu\nu}$, $F^{[4]}$

- at $D = 10$: String theory

- Heterotic $G_{\mu\nu}$, Φ , $H^{[3]}$

- Type IIA $G_{\mu\nu}$, Φ , $H^{[3]}$, $F^{[2]}$, $F^{[4]}$

- Type IIB $G_{\mu\nu}$, Φ , $H^{[3]}$, $F^{[1]}$, $F^{[3]}$, $F^{[5]}$

$\underbrace{\hspace{10em}}_{\text{NS-NS}}$

$\underbrace{\hspace{10em}}_{\text{R-R}}$

The effective theory

Heterotic, type I or type II with 16 supercharges : $N=4$ supergravity in $D=4$

- very constrained structure

only freedom :

- gauging of some vectors

(a)

« gauged $N=4$ supergravity »

- projection $N=4 \rightarrow N=1$

 (b)

- (a) and (b) universally encode the data of the underlying fundamental theory :

- unique bridge : $D=10$ plus fluxes \leftrightarrow $D=4$ low-energy superpotential
- remote control : bottom - up

$N=4$ Supergravity

- massless spectrum

- 1 gravitational multiplet : 1 graviton, 2 scalars, 6 graviphotons, 4 gravitinos, ...
- n vector multiplets : $n \times (1 \text{ vector, } 6 \text{ scalars, } \dots)$

- « . . . » : among others, many auxiliary fields with non-linear constraints upon elimination

- scalar manifold : $\frac{SO(1,1)}{U(1)} \times \frac{SO(6,n)}{SO(6) \times SO(n)} \quad 2+6n$

- gauge group : $U(1)^{6+n} \quad d_{kin} = -\frac{1}{4} \sum_{A=1}^{6+n} \mathcal{N}_{AB}(\Phi) F_{\mu\nu}^A F_{\mu\nu}^B$

non-minimal couplings

- duality group : $SU(1,1) \times SO(6,n)$

$N=4$ gauged supergravity

- gauging procedure: promotion

$$U(1)^m \rightarrow G \subset SU(1,1) \times SO(6,n)$$

$$\dim G = m \leq 6+n$$

- parameters:

- structure constants f_{AB}^C
- duality phases S

- constraints:

- Jacobi identities $\ll f f + f f + f f = 0 \gg$
- gauge invariance $f_{A(B} \mathcal{N}^D = 0$

- effect: mass matrix for gravitinos

$$M_{3/2} \sim \varphi(s) f_{ABC} \Phi^A \Phi^B \Phi^C \quad (\Phi^A \text{ in } SO(4) \text{ repr.})$$

[de Roo, Wagemans, Bergshoeff, Koh, Sezgin, ... '80', de Wit, Tziannas, Samtleben,

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Schoen, Weidner '00']

$$N=4 \rightarrow N=1$$

- implement a **projection pattern** that captures a class of string compactifications
- accordingly

- R-symmetry: $SU(4) \rightarrow U(1)$

- moduli sector $\rightarrow \{z_i\}$

- gravitino mass: $m_{3/2} = e^K W$

- scalar potential: $V = e^K \left(\sum_I |W - (z_i + \bar{z}_i) \partial_i W|^2 - 3 |W|^2 \right)$

- **stabilization** of (some) z_i

- $\langle V \rangle \sim \Lambda$

- match the scalars of gauged supergravity with those of the string theory

P.M. Petropoulos - Ecode Polye technique

Flux dictionary

- Dimensional reduction of the $D=10$ theory following the $N=4 \rightarrow N=1$ prescription
- field redefinitions for the scalars
- matching with the low-energy perturbative superpotential

$$P_{TAB}^c \rightarrow \text{flux numbers}$$

Example: $\mathbb{Z}_2 \times \mathbb{Z}_2$ Projection

Keeping only the S, T_A, U_A $A = 1, 2, 3$

- scalar manifold $\frac{SU(1,1)}{U(1)} \times \prod_{A=1}^3 \frac{SO(2,2)}{SO(2) \times SO(2)}$

- perturbative superpotential $W = \text{polynomial in } S, T_A, U_A$

- heterotic $W = W(T_A, U_A)$

- IIB orientifold $D3/D7$ $W = W(S, U_A)$

- IIA orientifold $D6$ $W = W(S, T_A, U_A)$

can be all stabilized [DKPZ]

Note:

- details and examples of this “bottom-up” technique by Costas Koumfas
- huge literature on the “top-down” side: [Taylor, Vafa '99, Grana, Polchinski '02, Polchinski '02, Kadru, Liu, Schulz, Tivedi '02; review by Grana '05]
- P.M. Petropoulos - Ecole Polytechnique

