Higher-Derivative Supergravity and Applications to String Cosmology

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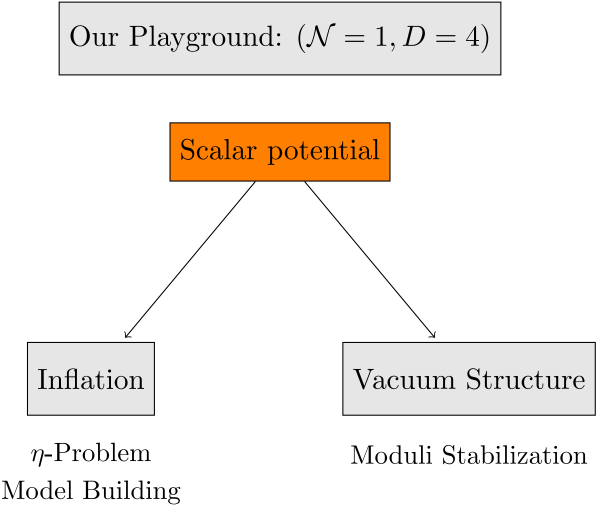
Based on [1605.00651] and (DC, Louis, Westphal [1505.03092])

String Pheno 2016

Introduction



Scalar Potential in $(\mathcal{N} = 1, D = 4)$

$$\boxed{\text{Global: } V_F = F^2 + V_{\text{HD}}}$$

- F^2 from K, W
- V_{HD} via SUSY from HD

$$\boxed{\text{For SUGRA EFT: } V_{M_p} < V_{\text{HD}}}$$

Literature on SUSY HD:
[Cecotti et al '87, Buchbinder et al '94, Baumann et al '11, Khoury et al '11, Koehn et al '12, Farakos et al '12]

$$\boxed{\text{Here: General attempt on HD and } V_{\text{HD}}}$$

Higher-Derivative Operators in Rigid $\mathcal{N} = 1$

[Buchbinder, Kuzenko '94], [DC, '16]

First: Consider rigid $\mathcal{N} = 1$

- Chiral superfield $\Phi = (A, \chi, F)$
- General V for chiral superfield Φ:

$$\boxed{\text{'Kähler potential'}\ K(\Phi, \bar{\Phi}, D^2\Phi, \bar{D}^2\bar{\Phi}) \text{ and } W(\Phi)}$$

- Anti-chiral HD Multiplet $D^2\Phi = (F, \partial\chi, \Box A)$
- Geometrically: V lives on cotangent-bundle

Higher-Derivative Supergravity
[DC, '16]

Setup: $\mathcal{N} = 1$ old minimal $(g_{\mu\nu}, \psi_\mu, M, b_a)$ + chiral matter

- $V_{\rm HD}$ much more involved ! Form only conjectured
- Instead classification of leading + next-to-leading order operators
- Toolkit for computation of component action (extending [Baumann, Green '11])
- $\mathcal{O}(\mathcal{D}^4)$ operators: $28 \to (3+6)$, component actions computed

Application 1: Supersymmetric Vacua

- M_4-vacua: **No effect** from V_{HD} (also in [Cecotti et al '87])
- AdS_4-vacua: V_{HD} matters, e.g. moduli spaces expected to be absent (fits also with 3D SCFTs [Cordova et al '16])

($\exists$ also $AdS_3 \times \mathbb{R}$, $\mathbb{R} \times S^3$ and pp-wave backgrounds for $\langle b_a \rangle \neq 0$
$\rightarrow$ only in pure HD Sugra [Kuzenko '16])

Application 2: Shift-symmetric No-Scale Models

Only F-term corrections at leading order
$\rightarrow$ Relevant for String Compactifications

Application 3: α'-corrections

- α'-, g_s-corrections encode truly stringy information
- E.g. Bulk Type IIB $(\alpha')^3$-corrections

$$\boxed{S_{(\alpha')^3} \supset \int \mathrm{d}^{10}x\, e R^4}$$

- Consider IIB/CY w. O-planes and flux
  $\rightarrow T_i$ flat directions
  $\rightarrow \alpha'$-corrections relevant for stabilization
- E.g. [Becker et al '01]: R^4 sources correction to 4D K
  (α'-terms in F-theory in Raffaele's talk tomorrow)

$$\boxed{\text{Matching of 4D } \partial^4\text{-terms from } R^4 \text{ now } \checkmark}$$

Higher-derivative Operators: Incomplete Matching

[DC, Louis, Westphal '15]

- Idea: Match simple operator which corrects V

$$\mathcal{A}\,\mathcal{D}T\mathcal{D}T\bar{\mathcal{D}}\bar{T}\bar{\mathcal{D}}\bar{T} \supset \mathcal{A}\,|\partial T|^4 - \mathcal{A}\,|F_T|^4$$

- Strategy: $|\partial T|^4$ from R^4-terms and match
- Result: $\mathcal{A} \sim \int c_2 \wedge J$

$$\boxed{V_{F^4} = \underbrace{\lambda}_{?}|W_0|^4 \frac{\Pi_i t^i}{\mathcal{V}^4}}$$

- $\Pi_i = \int c_2 \wedge \hat{D}_i$

- Flux-compactifications so far: $(k_{ijk}, h_{1,1}, h_{1,2}, \text{fluxes})$
  $\Rightarrow$ Information of c_2 new!

Perturbative Moduli Stabilization
[DC, Louis, Westphal '15]

Taking just BBHL and F^4-term:

If $\lambda < 0$ then for any CY3 with $\chi > 0$ the potential has a non-susy AdS minimum, fixing all τ_i

- Fully perturbative! Minimum depends only on topological information of CY
- Trustworthy?

$\boxed{\text{Need to know } \lambda!}$

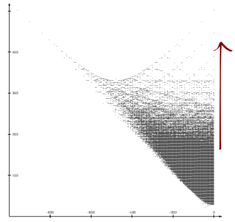


Fig. 1: $h_{11}+h_{12}$ vs. Euler number $\chi = 2(h_{11}-h_{12})$ for all pairs (h_{11}, h_{12}) with $h_{11} \leq h_{12}$.

F^4 Stabilization for LVS

[Cicoli, DC, de Alwis, Muia, to appear]

- Swiss-Cheese geometry:

$$\mathcal{V} = \mathcal{F}(\tau_1, \ldots, \tau_{N_L}) - \tau_s^{3/2}$$

- LVS: $(\alpha')^3 F^2 \oplus W_{np}$ stabilize $\mathcal{V}$ and τ_s
- $N_L - 1$ flat directions

If $\lambda < 0$ then F^4 term stabilizes all $N_L - 1$ flat directions

- Volume stabilization unaffected by F^4 term
- Tune in for Michele's talk tomorrow!

Conclusions

- HD relevant for (string-) cosmology, here: V
- New $(\alpha')^3$-corrections! $\rightarrow$ Relevant for moduli stabilization
- Useful for inflationary model building [Broy, DC, Pedro, Westphal '15]

Future Directions:

- KK-reduce $(\alpha')^3 R^4$-terms and solve system relating the ∂^4-terms to general HD supergravity (6 operators)
- Methods useful also for localized sources (Talk of Sjoerd on Monday)

Thanks for your attention!