Higher-Derivative Supergravity, α'-Corrections and Phenomenological Applications

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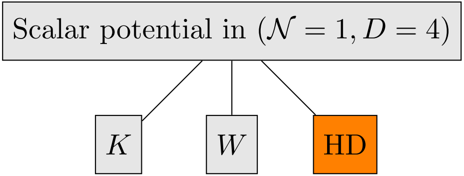
Based on (DC, Louis, Westphal [1505.03092]), (Broy, DC, Pedro, Westphal [1509.00024]) and (DC [160x.xxxxx])

XXVIII Workshop Beyond the Standard Model

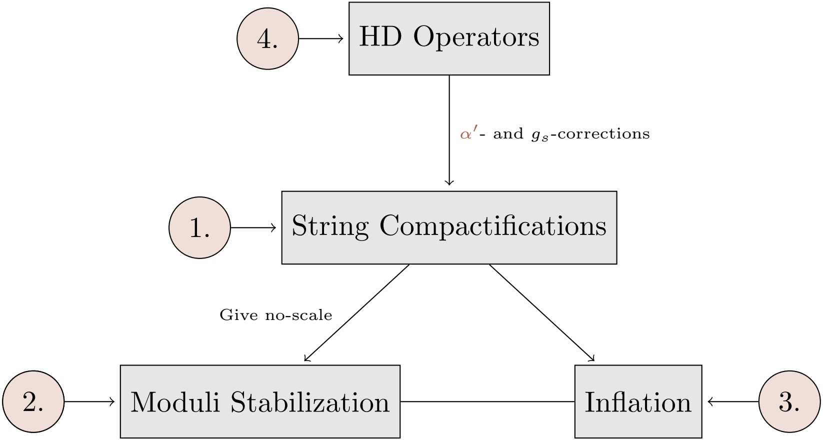
Introduction



In effective supergravity: $V_{M_p} < V_{HD}$

- Literature on HD: Case studies:
  [Cecotti et al '87, Buchbinder et al '94, Baumann et al '11, Khoury et al '11, Koehn et al '12, Farakos et al '12]
- General analysis of V_{HD} still missing! $\rightarrow$ Work in Progress

Relevance for String Theory + Cosmology



perturbative stabilization,
lift additional directions

η-Problem,
Model building

α'-corrections for String Compactifications

- IIB/CY Orientifold and flux $\to$ T_i flat directions
- Little is known about α'-, g_s-corrections
- Type IIB (closed string) $(\alpha')^3$-corrections are **not fully known** (Best so far: Quintic action [Liu, Minasian '13])

$$\boxed{S_{(\alpha')^3} \supset \int \mathrm{d}^{10}x\Big(\underbrace{R^4}_{\text{fully known!}} + \underbrace{R^3 G_3^2}_{\subset V_{\alpha'}} + \underbrace{R^2 G_3^4}_{??} + \ldots\Big)}$$

- [Becker, Becker, Haack, Louis '01]:

$$R^4 \text{ in 10D} \xrightarrow{\text{compactify}} \delta K(T_i) \longrightarrow V_{\alpha'}$$

Higher-derivative Correction: Strategy

- At leading order: T_i shift-symmetric no-scale model
$\Rightarrow$ Only F^4-corrections can appear by HD (more later)
- F^4-terms induced by $R^2G_3^4$, but these are unknown (even the tensor structure)!
- Luckily: $\exists$ 'clean' supergravity lift of F^4:

$$\mathcal{O} \sim \mathcal{T}\mathcal{D}\Phi\mathcal{D}\Phi\bar{\mathcal{D}}\bar{\Phi}\bar{\mathcal{D}}\bar{\Phi} \supset \mathcal{T}|\partial\phi|^4 - \mathcal{T}|F|^4$$

Strategy: Use BBHL 'trick': Compute $|\partial T_i|^4$ from R^4-terms and match to $\mathcal{O}$ to determine $|F|^4$

F^4-Correction

[DC, Louis, Westphal '15]

- Setup: Single deformation, neglect warping
- Result: $\mathcal{T} \sim \int c_2 \wedge J$
- Extrapolate to arbitrary $h_{1,1}$ by using no-scale structure:

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

- Π_i defined via $\Pi_i = \int c_2 \wedge \hat{D}_i$, in Kähler-cone basis semi-positive
- 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

$$\langle \tau_i \rangle \sim \Pi_i \ , \qquad \langle \mathcal{V} \rangle \sim |W_0|^3 (\lambda/\hat{\xi})^{3/2}$$

- Fully perturbative! Minimum depends only on topological information of CY
- $m_{3/2}/m_{KK}$ should be small $\Rightarrow$ favors CY with $h_{1,1} \simeq h_{2,1} \gg 1$ and $|W_0|$ large

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

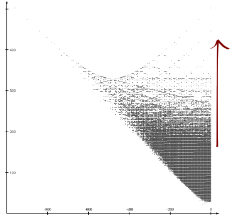


Fig. 1: $h_{11} + h_{12}$ vs. Euler number $\chi = 2(h_{11} - h_{12})$ for all pairs (h_{11}, h_{12}) with $h_{11} \leq h_{12}$.

Inflation from $(\alpha')^3$-corrections

[Broy, DC, Pedro, Westphal '15]

Can we use the F^4-term to generate a potential for a Kähler modulus-inflaton?

- Kreuzer-Skarke list: $h_{1,1} + h_{1,2} \geq 20$
  $\Rightarrow$ Easier to start with LVS, since $\chi < 0$
- Need mass hierarchy $\Rightarrow$ use $K3$-fibered CY as in fibre inflation [Cicoli, Burgess, Quevedo '08]
- LVS leaves volume of $K3$-fibre τ_1 flat
- F^4 generates a potential for inflation
- Minima can be generated by F^4 and g_s-corrections

Inflation from $(\alpha')^3$-corrections

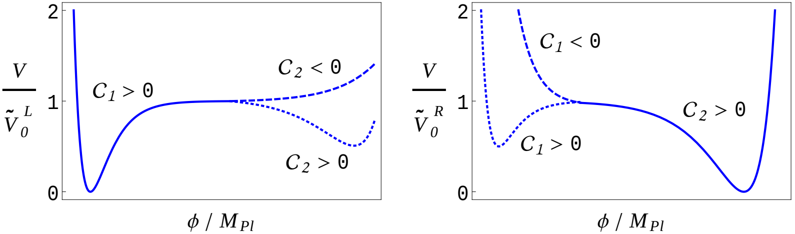
[Broy, DC, Pedro, Westphal '15]

- After uplifting to Minkowski: Starobinsky-type potentials

$$V(\phi) = V_0(1 - \beta e^{\nu\phi})^2$$

- Depending on signs of Π_1 and Π_2: inflation to the left $\nu_L = -2/\sqrt{3}$ or to the right $\nu_R = 1/\sqrt{3}$

- $n_s \simeq 0.96 \ldots 0.97$, $\qquad r \simeq 10^{-2} \ldots 10^{-3}$



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

[Buchbinder, Kuzenko '94], [DC, to appear]

- To determine λ we need a general understanding of HD
- First understand rigid $\mathcal{N} = 1$: General V for chiral superfield Φ

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

Higher-Derivative Supergravity

[DC, to appear]

- $\mathcal{N}=1, D=4$ old minimal: $(R, G_{\alpha\dot{\alpha}}, W_{\alpha\beta\gamma}) \rightarrow$ extra auxiliaries $\rightarrow$ A lot more complicated!
- Essentially all operators contribute to scalar potential
- List of relevant four-derivative operators determined: $28 \rightarrow (3+5)$ operators!
- Computation of component action tedious, but completed

Special situation for shift-symmetric no-scale models:
<u>Only F-term corrections</u> at leading order, many cancellations!

Conclusions

- HD operators relevant for (string-) cosmology, in particular since they modify V
- New $(\alpha')^3$-corrections for IIB/CY-Orientifold determined $\rightarrow$ Model-independent stabilization of T_i !?
- Useful for inflationary model building

Future Directions:

- KK-reduce $(\alpha')^3 R^4$-terms and solve system relating the ∂^4-terms to general HD supergravity (5 operators)
- Methods can easily be extended to IIA or heterotic. Also localized sources are interesting (See talk of S. Bielleman)
- If $\lambda < 0 \rightarrow$ test the stabilization for explicit examples

Thanks for your attention!

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