No-Scale Supergravity and Approximate Global Symmetries

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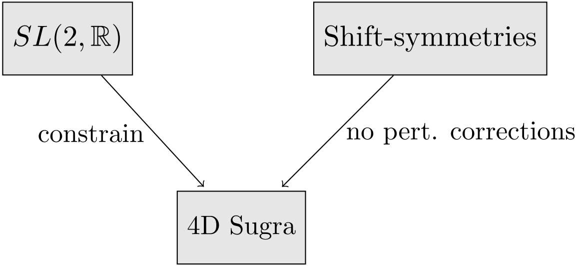
based on work in progress with Burgess, Cicoli, Krippendorf, Quevedo
and occasionally on [DC, Zarate 1509.00855]

String Pheno 2017

Motivation

- We know from WGC talks: No global symmetries in QG
- But: there are **approximate global symmetries**, e.g.



- Relevant for building models of Inflation

Motivation 2

- In this talk: **Geometric moduli** mostly in IIB
- Computing their action is tedious: Hard to include α', g_s-corrections [Becker, Becker, Berg, Grimm, Haack, Kang, Körs, Louis, Sjörs, Weissenbacher and many more]
- If inflaton: No symmetry to protect from corrections?
- There is a symmetry for these guys: global **'scale-invariance'**. Appears with **no-scale structure**

$$V = 0$$

Questions:

A. scale-invariance $\rightarrow$ no-scale?
B. for string compactifications?

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A: 4D Perspective

4D Scale-invariance and no-scale

- Assumptions: 4D Supergravity with
  - A. chiral multiplets T_α with shift-symmetry
  - B. chiral multiplets N_a
  - C. scale invariance of the type

$$T_\alpha \to \lambda^{w_\alpha} T_\alpha \,, \quad N_a \to N_a \,, \quad g_{\mu\nu} \to \lambda^w g_{\mu\nu} \,, \quad \mathcal{L} \to \lambda^w \mathcal{L} \quad (*)$$

- Scale-invariance requires that $G = K + \ln(|W|^2)$ transforms as

$$e^{-G} \to \lambda^w e^{-G}$$

- Under these assumptions G is no-scale if

$$w_1 = w_2 = \cdots = w/3 \quad (**)$$

- Then $G = -\log Y_3$, first mentioned in: [Ferrara, Kounnas, Zwirner 94']

However: Caution is Advised

[DC, Zarate '15]

- However: These no-scale models are extremely special and form 'a measure zero subset of the space of all shift-symmetric no-scale models'

- No-scale $\not\Longrightarrow$ scale-invariance ,
Seen e.g. via linear multiplet-formulation where

$$\tilde{K} = \mathrm{Log}(Y_3) + F_1$$

- Scale-invariant no-scale Kahler manifolds are also topologically distinct from those without scale-invariance

B: 10D Perspective

Heterotic/CY_3

- For 10D heterotic, classically exact: [Witten '84]

$$g \to \lambda g \ , \qquad \varphi \to \lambda^{-1}\varphi \ , \qquad S_{het} \to \lambda^4 S_{het}$$

$\Rightarrow$ Tells us only that axio-dilaton is 'no-scale'

- Additionally: [Burgess, Font, Quevedo '86]

$$\varphi \to \sqrt{\mu}\varphi \ , \qquad \kappa_{10} \to \mu^{-1}\kappa_{10} \ , \qquad S_{het} \to \mu^{-2} S_{het}$$

- The combination implies no-scale and scale-invariance of previous type for Het/CY_3
- Expected to hold classically [Nilles '86]

IIB Supergravity

- What about type IIB?

$$S_{IIB} = \int *\mathbf{1}\left[R - \frac{|\partial\tau|^2}{\mathrm{Im}(\tau)^2} - \frac{|G_3|^2}{\mathrm{Im}(\tau)} - \tilde{F}_5^2\right] + \int \frac{1}{\mathrm{Im}(\tau)} C_4 \wedge G_3 \wedge \bar{G}_3$$

- Two distinct scale invariances: w_τ associated with $SL(2,\mathbb{R})$

$$g \to \lambda g\ , \qquad \tau \to \lambda^{w_\tau}\tau\ , \qquad G_3 \to \lambda^{1+\frac{w_\tau}{2}} G_3\ ,$$
$$\tilde{F}_5 \to \lambda^2 \tilde{F}_5\ , \qquad S_{IIB} \to \lambda^4 S_{IIB}$$

- Solutions with 4D $\mathcal{N} = 1$ are more complicated.
  Complication: Localised sources, which individually break scale-invariance: E.g. D3-branes

IIB Supergravity: GKP

- Existence of scale-invariance is background-dependent!
- Let's consider [Kachru, Giddings, Polchinski '01]
- For GKP: tadpole cancellation $\rightarrow$ (classical) scale-invariance preserved
- Work out 4D scaling:

$$\mathrm{d}s^2_{(10)} = g_{\mu\nu}(x)\mathrm{d}x^\mu \mathrm{d}x^\nu + g_{mn}(x,y)\mathrm{d}y^m \mathrm{d}y^n \ ,$$

$$\mathcal{V}_E \rightarrow \lambda^3 \mathcal{V}_E \ , \qquad \mathcal{V}_E = I_{\alpha\beta\gamma} t^\alpha t^\beta t^\gamma$$

Crucial Rescalings:

$$T_\alpha = \mathcal{V}_{E,t^\alpha} \rightarrow \lambda^2 T_\alpha \ , \quad \frac{\int G_3 \wedge \bar{G}_3}{\tau + \bar{\tau}} \rightarrow \frac{1}{\lambda} \frac{\int G_3 \wedge \bar{G}_3}{\tau + \bar{\tau}} \ , \quad g_4^E \rightarrow \lambda^4 g_4^E$$

IIB Supergravity: GKP

- Is not $(*)$ and $(**)$!
- However, use $\mathcal{M} = \mathcal{M}_\tau \times \mathcal{M}_T$ to obtain $(*)$ and $(**)$ by reshuffling weights

Intermediate result:

GKP solution: $\mathcal{M} = \mathcal{M}_\tau \times \mathcal{M}_T$ + Shift-symmetry + 10D scale-invariance $\Rightarrow$ $(*)$ and $(**)$ $\Rightarrow$ no-scale

- Can be extended to also include odd-moduli, open string moduli

When does the argument fail?

A. In quantum theory $\sim g_s$-effects by e.g. flux-quantisation

B. At higher order in α' by explicitly breaking scale-invariance

C. At leading order after accounting for warping since $\mathcal{M} \neq \mathcal{M}_\tau \times \mathcal{M}_T$ [Martucci '14],[Martucci '16]. Here the model is still no-scale!

Conclusions

- IIB supergravity enjoys approximate scale invariance
- Can explain no-scale of GKP at leading order and weak warping
- $\sim$ analogue of shift-symmetry for Kähler moduli
- Also applies to IIA/M-theory, but limited applications for 4D there. Also F-theory?
- No-scale for type IIB remains elusive as of now

Thanks for your attention!