Partial Supergravity Breaking and the Effective Action of Consistent Truncations

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arXiv:1409.0867 (T. Grimm, AK, S. Lüst)
arXiv:1402.3529 (T. Grimm, AK)

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Introduction

Do consistent truncations yield proper effective actions?

Consistent truncation:

- ✗ keep only a finite set of Kaluza-Klein(KK)-modes
- ✗ solutions of lower-dimensional theory lift to higher-dimensional theory
- ✗ used for phenomenology

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consistent truncation:
finite set of KK-modes

proper effective theory:
infinite set of KK-modes

Do the quantum corrections from massive modes coincide on both sides?

Test setups with known effective action!

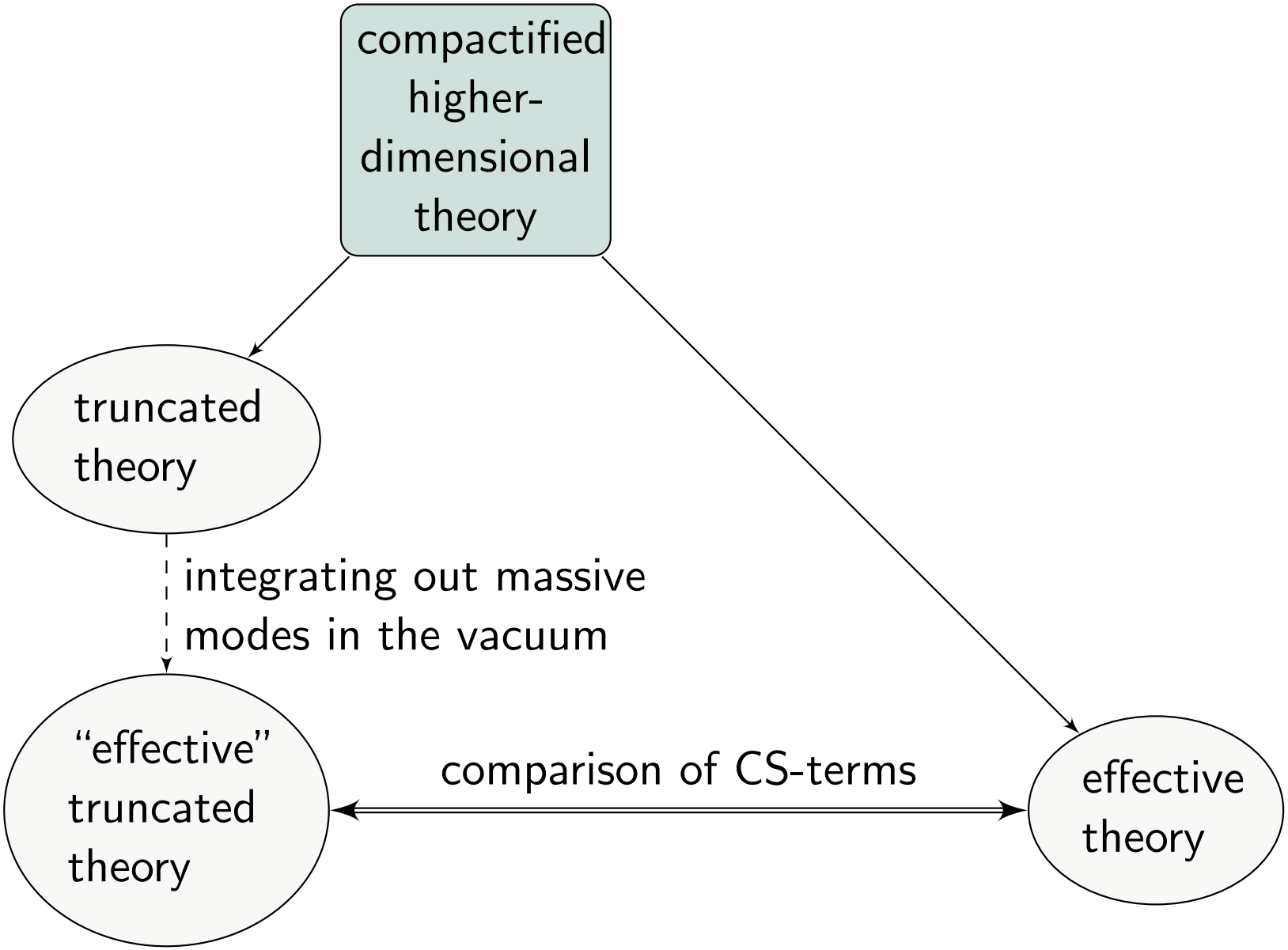
Investigated consistent truncations (to five dimensions):

- M-theory on $SU(2)$-structure manifolds:
  Calabi-Yau vacua
- type IIB supergravity on squashed Sasaki-Einstein manifolds:
  $\mathcal{N} = 2$ AdS_5 vacua

Investigated quantum corrections:

- gauge one-loop Chern-Simons terms
- gravitational one-loop Chern-Simons terms

General Considerations



Consider vacua, which preserve half of the supersymmetry:

truncated theory

5D $\mathcal{N} = 4$ gauged supergravity

$\Downarrow$ spontaneous supersymmetry breaking

vacuum

5D $\mathcal{N} = 2$ supergravity

Developed tool to calculate the spectrum and the classical Chern-Simons terms in the theory around the vacuum, given:

- embedding tensors of the $\mathcal{N} = 4$ gauged supergravity
- scalar VEVs

Integrate out massive modes in the vacuum:

- gauge one-loop Chern-Simons terms $\int k_{IJK}\, A^I \wedge F^J \wedge F^K$
- gravitational one-loop Chern-Simons terms $\int k_I\, A^I \wedge \mathrm{tr}(R \wedge R)$

One-loop Chern-Simons coefficients k_{IJK}, k_I from massive

- spin-1/2 fermions
- spin-3/2 fermions
- self-dual tensors (first-order kinetic term)

running in the loop.

[Bonetti, Grimm, Hohenegger]
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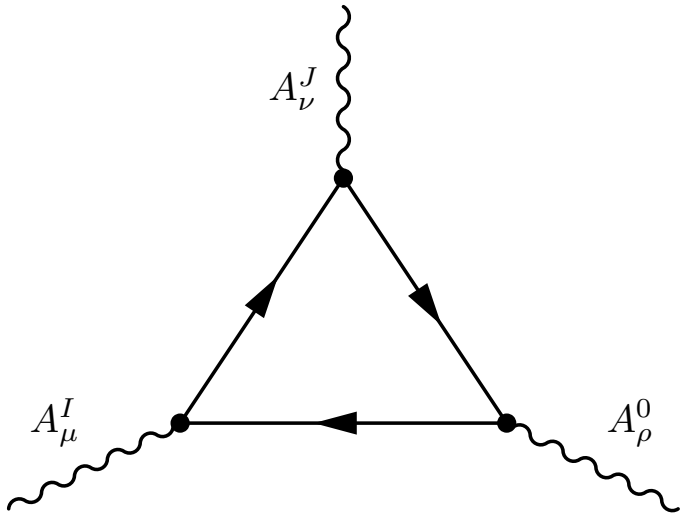
One-loop correction independent of mass scale!

Integrate out:



spin-1/2 fermion

$$k_{IJK} = \tfrac{1}{2} q_I q_J q_K \,\mathrm{sign}(m)$$

tensor

$$k_{IJK} = -2 q_I q_J q_K \,\mathrm{sign}(m)$$

spin-3/2 fermion

$$k_{IJK} = -\tfrac{5}{2} q_I q_J q_K \,\mathrm{sign}(m)$$

m: mass of the mode

q_I: charge under the Abelian gauge field A^I

Necessary condition for a proper effective action from the truncations:

The one-loop Chern-Simons terms of the truncated theory and the genuine effective action have to match!

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Special case: genuine effective action has **no** one-loop Chern-Simons terms

$\Rightarrow$ Necessary condition for the consistent truncation:

The massive modes

- are uncharged.
- arrange in long multiplets, if the R-symmetry is not gauged.
- come in real (non-chiral) representations.
- cancel non-trivially between different multiplets.

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Consistent truncation of M-theory on $SU(2)$-structure Manifolds

- lift of type IIA on $SU(2)$-structure manifolds
  [Danckaert, Kashani-Poor, Louis, Martínez-Pedrera, Minasian, Spanjaard, Triendl]
- 5D $\mathcal{N} = 4$ gauged supergravity
- $\mathcal{N} = 2$ Calabi-Yau vacua $\equiv$ Calabi-Yau manifolds with $\chi = 0$
- effective action of M-theory on Calabi-Yau manifolds known
  (no one-loop Chern-Simons terms)

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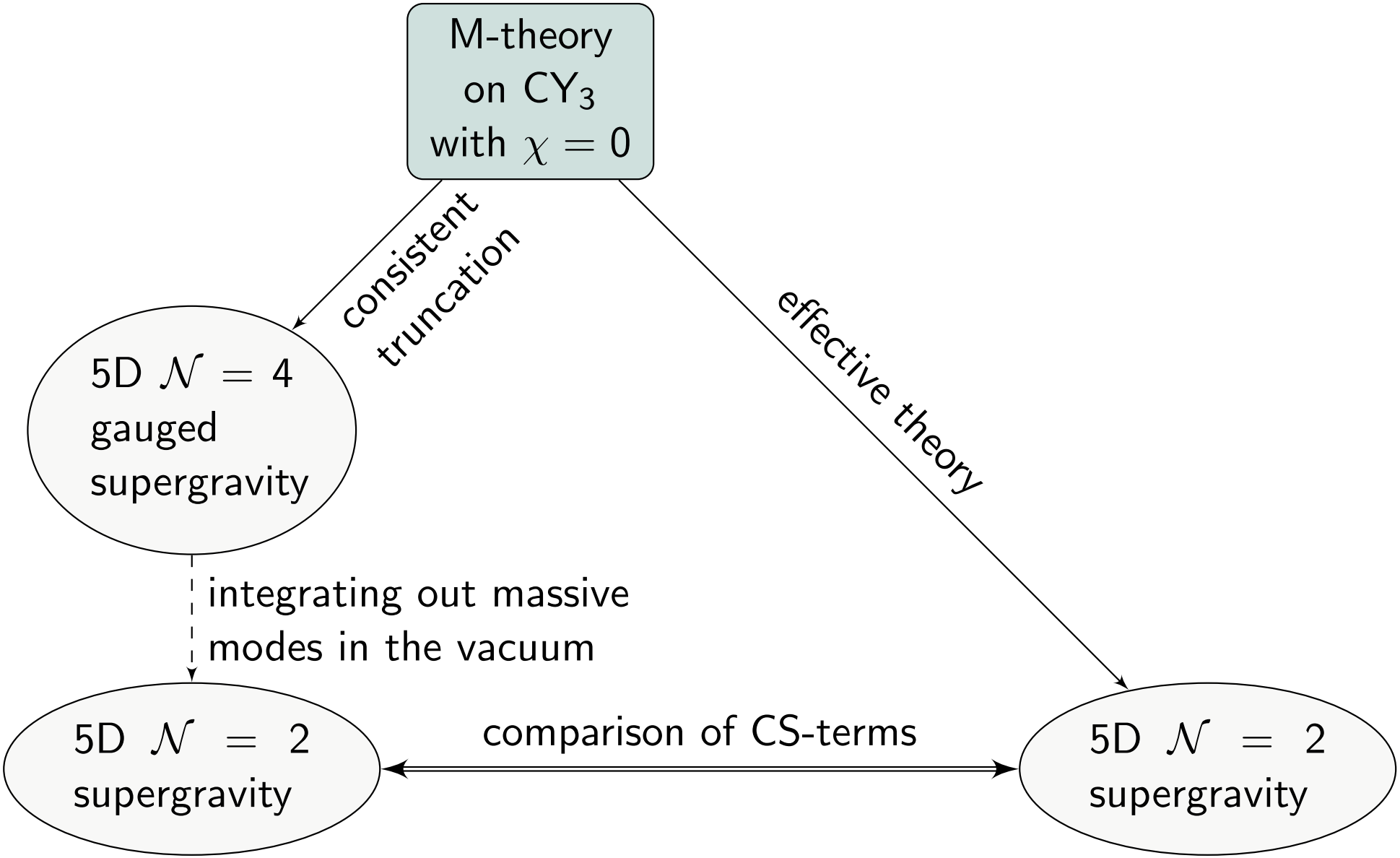
$\Rightarrow$ **Test the "effective" action of the consistent truncation:**

- calculate spectrum and classical Chern-Simons terms of the Calabi-Yau vacua
- evaluate one-loop Chern-Simons terms
- compare "effective" action of consistent truncation with genuine effective action


M-theory on CY_3 with $\chi = 0$
consistent truncation
effective theory
5D $\mathcal{N} = 4$ gauged supergravity
integrating out massive modes in the vacuum
5D $\mathcal{N} = 2$ supergravity
comparison of CS-terms
5D $\mathcal{N} = 2$ supergravity

Results for the Enriques Calabi-Yau ($\chi = 0$):

- 1 missing vector multiplet and 1 missing hypermultiplet in the consistent truncation (at the massless level)
- classical Chern-Simons terms can be matched (taking the missing vector into account)
- no massive charged modes in the consistent truncation
  $\Rightarrow$ no one-loop Chern-Simons terms
  $\Rightarrow$ consistent with the genuine effective action

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Reason for absence of massive charged modes:

- no isometries for full $SU(3)$-holonomy
- no massless Kaluza-Klein vectors
- no massive modes charged under massless vectors

Investigate setups **with** isometries!

Type IIB Supergravity on squashed Sasaki-Einstein manifolds

Truncation found by

[Cassani, Dall'Agata, Faedo, Liu, Szepietowski, Zhao, Gauntlett, Varela]

- 5D $\mathcal{N} = 4$ gauged supergravity
- $\mathcal{N} = 2$ AdS_5 vacua (e.g. S^5)
- meaning of effective action in AdS space???

$\Rightarrow$ **Procedure:**

- calculate spectrum and classical Chern-Simons terms of the $\mathcal{N} = 2$ AdS_5 vacua
- evaluate one-loop Chern-Simons terms

General results for $\mathcal{N} = 2$ $\mathbf{AdS}_5$ vacua:

- gauged $U(1)$ R-symmetry
- massive charged modes
- gauge one-loop Chern-Simons term cancels:
  - ✗ massive charged real multiplets
  - ✗ non-trivial cancellations between different massive charged multiplets (gauged R-symmetry!!!)
- gravitational Chern-Simons term non-zero

Interpretation???

Conclusions

- investigation of "effective" action from consistent truncations
- used partial supergravity breaking in 5D
- evaluation of one-loop Chern-Simons terms
- comparison with the genuine effective action
- first example: M-theory on $SU(2)$-structure manifolds with Calabi-Yau vacuum
  $\Rightarrow$ no massive charged modes, effective action of truncation consistent
- second example: type IIB supergravity on squashed Sasaki-Einstein manifolds
  $\Rightarrow$ gauge one-loop Chern-Simons cancels non-trivially, gravitational Chern-Simons term non-zero, effective action?

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Future Directions:

- find further examples with isometries
- in 3D: M-theory on $Spin(7)$-manifolds/Calabi-Yau fourfolds with vanishing Euler number

Thank You!