Tensor towers and (2,0) theories

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[FB, T. Grimm, S. Hohenegger, 1206.1600, 1209.3017, 1302.2918]

Outline

- Motivation: six-dimensional (2,0) theories
- Five-dimensional approach
- Quantum properties of massive tensors in five dimensions
- Main features of a Lagrangian description with manifest supersymmetry and non-Abelian gauging
- Conclusions & outlook

The puzzle of six-dimensional (2,0) theories

- Six-dimensional (2,0) superconformal algebra: 16 supercharges, chiral
  - Superconformal algebra with the largest spacetime dimension [Nahm 78]
- String theory and M-theory ⟶ interacting QFTs with this symmetry algebra
  - Type IIB on singular K3
  - Stack of M5-branes [Witten 95] [Strominger 95] [Witten 95]
- Non-trivial isolated fixed point of RG flow
  - no dimensionful nor dimensionless parameter
- Field content: selfdual tensors (i.e. chiral two-forms), scalars, spinors
- Dimensional reduction on a circle ⟶ maximally supersymmetric YM

$$g^2_{\mathrm{YM}} = R$$

Five-dimensional approach

- No 6d Lagrangian for interacting (2,0) theories where all symmetries are manifest
- Many technical difficulties
  - selfduality and 6d covariance [Siegel 84] [Henneaux, Teitelboim 88] [McClain, Yu, Wu 90] [Pasti, Sorokin, Tonin 97] [Belov, Moore 06]
  - no vectors ⟶ covariant derivative?
  - no tunable parameter
- Five-dimensional approaches
  - (2,0) conjectured to be equivalent to SYM at non-perturbative level [Douglas 10] [Lambert, Papageorgakis, Schmidt-Sommerfeld 10]
  - Deconstructing proposals [Lambert, Papageorgakis, Schmidt-Sommerfeld 12]
- We follow a different five-dimensional strategy

KK-inspired towers of 5d massive tensors

[Ho, Huang, Matsuo 11]

A closer look at 5d massive tensors

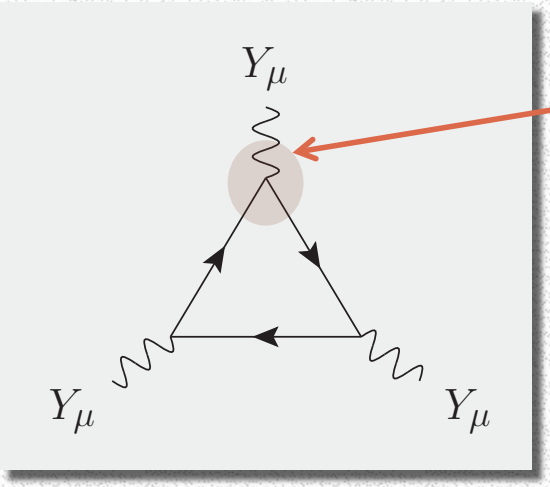
- A 6d selfdual tensor on a circle yields a tower of 5d massive 'selfdual' tensors
  - first-order, parity violating EOM [Townsend, Pilch, van Nieuwenhuizen 84]
- Close analogy with fermionic parity violating representations of the little group SO(4)

SO(4) rep	6d field	5d field	5d free EOM
$(1/2,0)$	spin-1/2 Weyl fermion	spin-1/2 Dirac fermion	$(i\gamma^\mu\partial_\mu - m)\psi = 0$
$(1/2,1)$	spin-3/2 Weyl fermion	spin-3/2 Dirac fermion	$(i\gamma^{\rho\mu\sigma}\partial_\mu - m\,\gamma^{\rho\sigma})\psi_\sigma = 0$
$(1,0)$	selfdual tensor	complex tensor	$(i*d - m)B_2 = 0$

- 6d chirality ⟶ sign of the 5d mass term (physical mass = $|m|$)

Parity anomalies of massive 5d fields

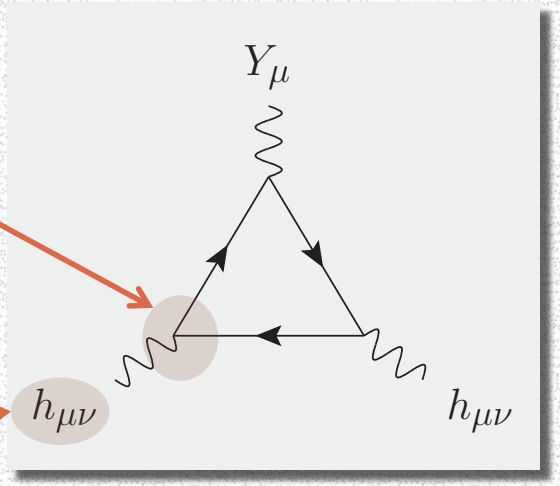
Parity violating massive fields induce Chern-Simons terms at one loop



minimal coupling to U(1) vector

$$\partial_\mu \to \partial_\mu - iqY_\mu$$

minimal coupling to gravity



metric fluctuation

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

Parity anomalies of massive 5d fields

Parity violating massive fields induce Chern-Simons terms at one loop

$$-\frac{\mathrm{sgn}(m)q^3}{48\pi^2}\,k\int Y\wedge dY\wedge dY \qquad -\frac{\mathrm{sgn}(m)q}{384\pi^2}\,\kappa\int Y\wedge \mathrm{tr}\,\mathcal{R}\wedge\mathcal{R}$$

independent of the mass scale!

- Numerical coefficients depend on the kind of field running in the loop

	spin-1/2	spin-3/2	tensor
k	1	5	−4
κ	1	−19	8

- Well-known result for spin-1/2 [Witten 96] [Intriligator, Morrison, Seiberg 97]

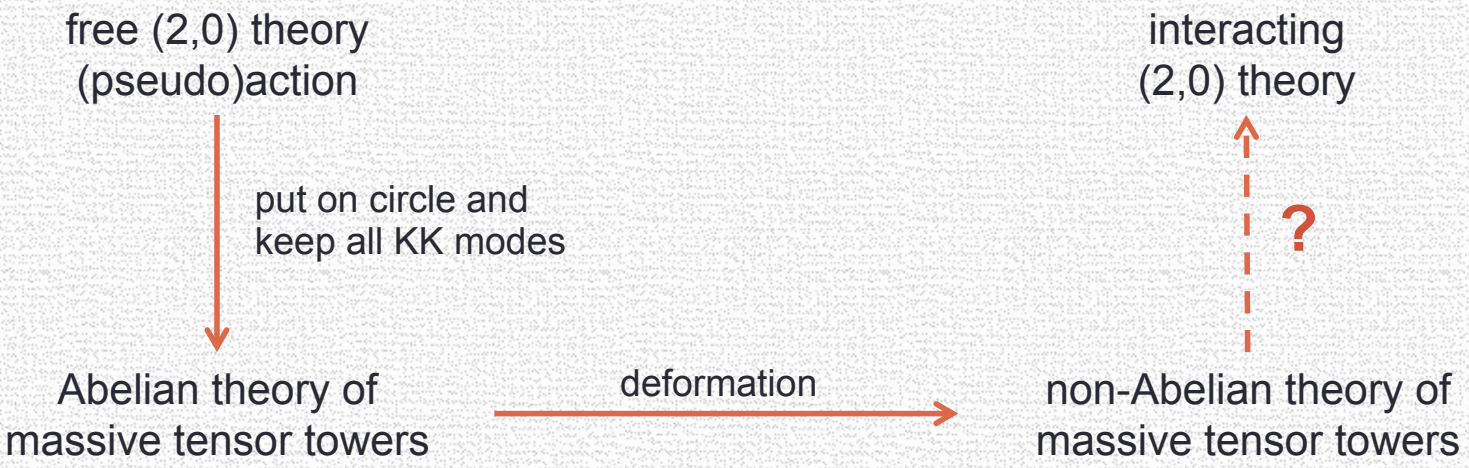
A 5d window on 6d anomalies

- These corrections to the 5d effective action survive after massive fields are integrated out
- Quantum correction to classical KK reduction
- Connection to 6d anomalies:

  Anomaly cancellation in 6d puts constraints on quantum CS terms in 5d

- Test for possible 6d origins of a given 5d theory [FB, T. Grimm, S. Hohenegger 13]
- Results tested against geometric predictions in the context of M-theory to F-theory duality in 6d [FB, T. Grimm 11]
- Similar mechanism in 4d F-theory framework [Cvetic, Grimm, Klevers 12]

A 5d route to interacting (2,0) theories



- ✓ Avoid all complications of 6d Lagrangians for tensors
- ✓ Make contact with supersymmetric field theory and gauged supergravity literature
- ■ 6d Lorentz manifest symmetry is sacrificed
- ■ No straightforward uplift to 6d after deformation
- A way to capture robust features of (2,0) theories (anomalies)

Abelian tensor towers…

- From a selfdual tensor on a circle
  - massless vector A with field strength $F = dA$
  - KK tower of complex, massive tensors B_n
- 5d action for zeromode + massive tower

$$S_{5\mathrm{d}} = \int \frac{1}{2g^2_{\mathrm{YM}}} F \wedge *F + \sum_{n=1}^{\infty} \left[i\overline{B}_n \wedge dB_n - m_n \overline{B}_n \wedge *B_n \right]$$

gauge coupling
$g^2_{\mathrm{YM}} = R$

KK mass
$m_n = n/R$

… and non-Abelian deformation

Proposal for non-Abelian deformation

1) promote vector zeromodes to gauge connection
2) promote tensor excited modes to adjoint matter

[Ho, Huang, Matsuo 11]

$$S_{5\mathrm{d}} = \int \frac{1}{2g_{\mathrm{YM}}^2} \mathrm{tr}\left[F \wedge *F\right] + \sum_{n=1}^{\infty} \mathrm{tr}\left[i\overline{B}_n \wedge DB_n - m_n \overline{B}_n \wedge *B_n\right]$$

$F = dA + \frac{1}{2}[A, A]$

$DB_n = dB_n + [A, B_n]$

- 6d origin of this mechanism is unclear
- It can capture a rich subset of 6d couplings among massive and massless dof's

Supersymmetric extension: strategy

- Gauged supergravities with 16 supercharges in 5d
  - no non-Abelian gauging of tensors [Schoen, Weidner 06]
- We aim at realizing manifestly 8 supercharges
- Useful tool: rigid superconformal formalism of

  [Bergshoeff, Cucu, De Wit, Gheerardyn, Halbersma, Vandoren, Van Proeyen 02]

physical dof's	additional vector multiplet
all dof's of (2,0) theory on a circle: • vector-tensor multiplets • hypermultiplets	background multiplet: • scalar ~ radius • vector ~ KK vector

- Gauging with group $G \times U(1)$
- After truncation of additional vector multiplet, $U(1)$ gauging gives KK masses

Supersymmetric extension: features

- All bosonic and fermionic dof's of (2,0) theory on a circle
- Manifest supersymmetry under 8 supercharges
- Democratic gauging of tensor multiplets and hypermultiplets
- All couplings are specified in terms of group theoretical invariants and KK level
  - Interplay between adjoint index and KK-level → affine Lie algebras?
- Sanity checks
  - truncate tensors → SYM with maximal supersymmetry
  - switch gauging off → Abelian theory with maximal supersymmetry

Conclusions & outlook

- Five-dimensional approach to (2,0) theories
  - Massive tensor towers and deformation in five dimensions
- Massive tensors with parity violating action
- One-loop Chern-Simons terms
- Quantum KK reduction and window on 6d anomalies
- Proposal for 5d deformation
- Lagrangian with all dof's, manifest supersymmetry, and non-Abelian group

- Generalize tensor parity anomalies to non-Abelian case
- Explore conformal anomaly of a stack of M5-branes
  - reproduce N^3 scaling
- Clarify connection with other proposals
  - KK modes and YM instantons

Thank you for your attention!