Decoupling the Gravity Multiplet from Supergravity

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C. Cheung, FDE, J. Thaler; arXiv:1104.2598 [hep-ph], arXiv:1104.2600 [hep-ph].

Motivation

SUSY symmetry of nature $\Rightarrow$ SUGRA

Not all of the SUGRA formalism relevant
for phenomenology at colliders and in cosmology

Our Goal: Framework to Simplify Supergravity Calculations

decoupling the gravity multiplet from matter fields
and
accounting for SUGRA effects

Conformal SUGRA

Minimal SUGRA: gauge fixing of conformal SUGRA

Gates et al, NPB 147(1979), FP 58(1983); Linch et al, PRD 68(2003), [hep-th/0209060].

Gauge Fixing in Superspace: Conformal Compensator Formalism

Usual superspace of global SUSY + conformal compensator superfield $\mathbf{\Phi}$

$$\mathcal{L}_{\rm SUGRA} = -3 \int d^4\theta \; \mathbf{\Phi}^\dagger \mathbf{\Phi} \; e^{-\mathbf{K}/3} + \int d^2\theta \; \mathbf{\Phi}^3 \; \mathbf{W} + \text{h.c.}$$

$$+ \frac{1}{4} \int d^2\theta \; \mathbf{f}_{ab} \mathbf{W}^{a\alpha} \mathbf{W}^b_\alpha + \text{h.c.} + \ldots\ldots$$

Standard Gauge Fixing

Lowest and fermionic components of $\mathbf{\Phi}$ are pure gauge mode:

$$\mathbf{\Phi} = 1 + \theta^2 F_\phi$$

Naive application of standard $\mathbf{\Phi}$:

neglect terms in $\ldots\ldots \Rightarrow$ incorrect answers in many cases

Problematic Terms

Standard choice for $\mathbf{\Phi}$: mixing between gravity and matter multiplets

Graviton normalization and kinetic mixing

$C\,R/6$

E.H. action normalization

Graviton/matter mixing

Gravitino kinetic mixing

$i\xi\sigma^{\mu\nu}\partial_\mu\psi_\nu + \text{h.c.}$

Gravitino/matter mixing

Non-canonical gravitino

Grativitino mass phase

$-z^\dagger\psi_\mu\sigma^{\mu\nu}\psi_\nu + \text{h.c.}$

Gravitino mass real

C, ξ and z functions of matter fields

Additional terms must be taken into account in the calculations

Standard gauge fixing:

need to work with component fields

no simple interpretations in terms of superfields

The Kugo-Uehara gauge

Gauge Freedoms

Lowest and fermionic components of $\mathbf{\Phi}$ pure gauge modes

They can be fixed to any values by an appropriate gauge choice

Kugo-Uehara gauge

Enough freedom for $C = -3$, $\xi_\alpha = 0$, $Arg[z] = 0$ to all orders in fields

$$\mathbf{\Phi} = \exp\left[\frac{1}{3}\left(K/2 - i\,\mathrm{Arg}\,W\right)\right] \times \left\{1, \frac{K_i \chi^i}{3}, F_\phi\right\}$$

Kugo and Uehara, NPB B222(1983).

Hidden problem of KU gauge

Mixing with vector auxiliary field b_μ: $b_\mu \partial^\mu \phi$

Integrating out b_μ $\Rightarrow$ gravity/matter mixing

Need to work again with component fields

A Novel Gauge Fixing

A less stringent gauge choice

$C = -3$, $\xi_\alpha = 0$, $Arg[z] = 0$ to linear order in field fluctuations

Cheung, FDE, Thaler, arXiv:1104.2598 [hep-ph].

$$\mathbf{\Phi} = e^{\mathbf{Z}/3}(1 + \theta^2 F_\Phi), \qquad \mathbf{Z} = \langle K/2 - i \, \mathrm{Arg}\, W \rangle + \langle K_i \rangle \mathbf{X}^i$$

Coupling with the vector auxiliary field?

Gauge fixing $\Rightarrow$ $b_\mu = 0 + \mathcal{O}(1/M_{\rm Pl})$ $\Rightarrow$ $1/M_{\rm Pl}^2$ suppressed operators

No need to perform component manipulations

Gravity multiplet decoupled from matter fields calculations

Phenomenological SUGRA Lagrangian

$$\mathcal{L}_{\rm SUGRA} = -3 \int d^4\theta \, \mathbf{\Phi}^\dagger \mathbf{\Phi} \, e^{-\mathbf{K}/3} + \int d^2\theta \, \mathbf{\Phi}^3 \, \mathbf{W} + \text{h.c.} + \frac{1}{4} \int d^2\theta \, \mathbf{f}_{ab} \mathbf{W}^{a\alpha} \mathbf{W}^b_\alpha + \text{h.c.} + \mathcal{O}(1/M_{\rm Pl})$$

$$\mathbf{\Phi} = e^{\mathbf{Z}/3}(1 + \theta^2 F_\Phi), \qquad \mathbf{Z} = \langle K/2 - i \, \text{Arg}\, W \rangle + \langle K_i \rangle \mathbf{X}^i$$

Applications: Fermionic Spectra

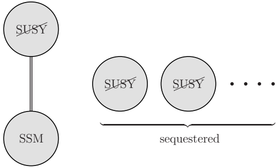
N sequestered ~~SUSY~~ sectors: $\text{SUSY}^N \equiv \otimes \prod_{i=1}^{N} \text{SUSY}_i$

Gravity explicitly breaks to diagonal SUSY

N goldstini η_i in the theory:

- linear combination η_{long} eaten by the gravitino
- $N-1$ goldstini in the spectrum

Cheung, Nomura, Thaler, JHEP 1003 (2010) [arXiv:1002.1967 [hep-ph]].



Minimal scenario: N sequestered sectors, F and D breaking, $\langle K_i \rangle = 0$

$$m_\eta = 2\, m_{3/2}$$

Modulus field with shift symmetry (almost "no-scale" SUSY breaking)

massless modulino

Cheung, FDE, Thaler, arXiv:1104.2600 [hep-ph].

Summary

Supergravity Computations without Gravity Complications

C. Cheung, FDE, J. Thaler, arXiv:1104.2598 [hep-ph].

$$\mathcal{L}_{\text{SUGRA}} = -3 \int d^4\theta \, \boldsymbol{\Phi}^\dagger \boldsymbol{\Phi} \, e^{-\boldsymbol{K}/3} + \int d^2\theta \, \boldsymbol{\Phi}^3 \, \boldsymbol{W} + \text{h.c.} + \frac{1}{4} \int d^2\theta \, \boldsymbol{f}_{ab} \boldsymbol{W}^{a\alpha} \boldsymbol{W}^b_\alpha + \text{h.c.} + \mathcal{O}(1/M_{\text{Pl}})$$

$$\boldsymbol{\Phi} = e^{\boldsymbol{Z}/3}(1 + \theta^2 F_\Phi), \qquad \boldsymbol{Z} = \langle K/2 - i \operatorname{Arg} W \rangle + \langle K_i \rangle \boldsymbol{X}^i$$

The Spectrum of Goldstini and Modulini

C. Cheung, FDE, J. Thaler, arXiv:1104.2600 [hep-ph].

Fermionic spectra calculation directly in superspace