KU LEUVEN

New FI D-terms in Supergravity - *Part I*

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Corfu 2018

How is N=1 SUSY broken?

$\rightarrow$ F-term (chiral multiplet).

$\rightarrow$ D-term ($U(1)$ gauge multiplet).

$\rightarrow$ Other methods (complex linear, etc).

Fayet–Iliopoulos D-term

→ A gauge multiplet contains the component fields

$$V_{\mathrm{WZ}} = -\theta\sigma^m\overline{\theta}A_m - i\overline{\theta}^2\theta^\alpha\lambda_\alpha + i\theta^2\overline{\theta}_{\dot\alpha}\overline{\lambda}^{\dot\alpha} + \frac{1}{2}\theta^2\overline{\theta}^2\mathrm{D}\,.$$

→ The simplest model with a Fayet–Iliopoulos term is

$$\mathcal{L} = \frac{1}{4}\left(\int d^2\theta\, W^2(V) + \mathrm{c.c.}\right) - 2\xi\int d^4\theta\, V$$

$$= -\frac{1}{4}F^{mn}F_{mn} - i\lambda\sigma^m\partial_m\overline{\lambda} + \frac{1}{2}\mathrm{D}^2 - \xi\,\mathrm{D}\,.$$

→ The auxiliary field gets a vev: $\langle \mathrm{D}\rangle = \xi$.

→ The goldstino is: $\delta\lambda_\beta = -i\xi\,\epsilon_\beta + \cdots$

How do we embed $-\xi D$ *in supergravity?*

Plan

$\rightarrow$ Freedman model and R-symmetry gauging.

$\rightarrow$ New model without R-symmetry gauging.

$\rightarrow$ Matter couplings etc $\rightarrow$ *See M. Tournoy talk - Part II.*

FI terms with gauged R-symmetry

Freedman '77

The Noether method

- The gauge field of SUSY is the gravitino ψ^{α}_{m}, with supersymmetry transformation

$$\delta\psi_{m\alpha} = -2\,\partial_m\epsilon_\alpha + \cdots$$

- We start from $-e\,\xi\,\mathrm{D}$ and perform the Noether procedure

$$\partial_m\,\epsilon_\alpha(x) \to \psi_{m\alpha}\,.$$

- At some point we have to cancel

$$-ie\xi\,\epsilon^{klmn}\left(\overline{\psi}_k\overline{\sigma}_l\epsilon - \overline{\epsilon}\,\overline{\sigma}_l\psi_k\right)\partial_n A_m\,.$$

- Therefore we have to add

$$\mathcal{L}_{\psi\psi A} = \frac{i}{2} e \xi \, \epsilon^{klmn} \overline{\psi}_k \overline{\sigma}_l \psi_n A_m \,,$$

and the gravitino gets charged under $U(1)_{FI}$.

$\rightarrow$ The FI term in supergravity requires R-symmetry gauging by A_m.

$\rightarrow$ This has constraints on the gravitino mass.

- Once we complete the procedure we have (on-shell)

$$e^{-1}\mathcal{L}\Big|_{\lambda=0} = -\frac{1}{2}R + \frac{1}{2}\epsilon^{klmn}\left(\overline{\psi}_k \overline{\sigma}_l \mathcal{D}_m \psi_n - \psi_k \sigma_l \mathcal{D}_m \overline{\psi}_n\right)$$
$$-\frac{1}{4}F_{mn}F^{mn} + \frac{i}{2} e \xi \epsilon^{klmn} \overline{\psi}_k \overline{\sigma}_l \psi_n A_m - \frac{1}{2}\xi^2 \,.$$

FI terms without gauged R-symmetry

Cribiori, Tournoy, FF, Van Proeyen '17

- We observe that $\lambda_\alpha/\mathrm{D}$ has a very nice property

$$\delta\left(i\frac{\lambda_\alpha}{\mathrm{D}}\right) = \epsilon_\alpha + \cdots$$

- To cancel the term

$$-ie\xi\,\epsilon^{klmn}\left(\overline{\psi}_k\overline{\sigma}_l\epsilon - \overline{\epsilon}\,\overline{\sigma}_l\psi_k\right)\partial_n A_m$$

during the Noether procedure, we introduce instead the term

$$-e\xi\,\epsilon^{klmn}\left(\overline{\psi}_k\overline{\sigma}_l\frac{\lambda}{\mathrm{D}} - \frac{\overline{\lambda}}{\mathrm{D}}\,\overline{\sigma}_l\psi_k\right)\partial_n A_m\,.$$

Supersymmetry has to be broken and by assumption: $\langle \mathrm{D}\rangle \neq 0$.

A new FI D-term

- In superspace we have

$$\mathcal{L}_{New\ FI} = 8\,\xi \int d^4\theta\, E\, \frac{W^2\overline{W}^2}{\mathcal{D}^2 W^2 \overline{\mathcal{D}}^2 \overline{W}^2}\, \mathcal{D}^\alpha W_\alpha$$

$$= -e\,\xi\,\mathsf{D} + \xi\,\mathcal{O}\left(\lambda, \overline{\lambda}\right) \ .$$

- Gravitino not charged under $U(1)_{FI} \rightarrow$ No $U(1)_R$ gauging.

- In superspace the full supergravity coupling is

$$\mathcal{L} = -3\left(\int d^2\Theta\, 2\mathcal{E}\, \mathcal{R} + c.c.\right) + \left(\int d^2\Theta\, 2\mathcal{E}\, W_0 + c.c.\right)$$

$$+\frac{1}{4}\left(\int d^2\Theta\, 2\mathcal{E}\, W^2(V) + c.c.\right) + \mathcal{L}_{NEW\ FI}\,.$$

The new term coupled to pure supergravity

- And in components (on-shell)

$$e^{-1}\mathcal{L}\Big|_{\lambda=0} = -\frac{1}{2}R + \frac{1}{2}\epsilon^{klmn}\left(\overline{\psi}_k\overline{\sigma}_l\mathcal{D}_m\psi_n - \psi_k\sigma_l\mathcal{D}_m\overline{\psi}_n\right)$$
$$-\frac{1}{4}F_{mn}F^{mn} - \left(\frac{1}{2}\xi^2 - 3|W_0|^2\right)$$
$$-\overline{W}_0\psi_a\sigma^{ab}\psi_b - W_0\overline{\psi}_a\overline{\sigma}^{ab}\overline{\psi}_b\,.$$

Further properties of new D-terms

$\rightarrow$ No smooth supersymmetric limit.

$\rightarrow$ Electric-magnetic duality of the full theory:

$$F_{mn} \rightarrow \epsilon_{mnkl}F^{kl}\,.$$

$\rightarrow$ String theory / D brane origin?

Thank you