$\mathcal{N}$ Goldstini

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Motivation

$\rightarrow$ Supersymmetry is spontaneously broken.

$\rightarrow$ In the low energy it is then non-linearly realized.

$\rightarrow$ This can be done with constrained superfields.

$N = 1$ *goldstino*

Nilpotent goldstino superfield

Rocek '78, Lindstrom, Rocek '79, Casalbuoni, De Curtis, Dominici, Feruglio, Gatto '89

- We can break SUSY with a chiral superfield

$$X = A + \sqrt{2}\,\theta G + \theta^2 F.$$

- SUSY broken: $\delta G_\alpha = -f\,\epsilon_\alpha + \cdots$
- In the formal limit $m_A \to \infty$ the scalar decouples.
- This is described by imposing the superspace constraint

$$X^2 = 0 \to X = \frac{G^2}{2F} + \sqrt{2}\,\theta^\alpha G_\alpha + \theta^\alpha \theta_\alpha F.$$

Volkov–Akulov from X

- The simplest supersymmetric Lagrangian is

$$\mathcal{L} = \int d^4\theta X\overline{X} + \left\{ \int d^2\theta\, f\, X + c.c. \right\} .$$

- In component form (after eliminating F) we get

$$\mathcal{L} = -f^2 + i\partial_m \overline{G}\overline{\sigma}^m G + \frac{1}{4f^2}\overline{G}^2 \partial^2 G^2 - \frac{1}{16f^6} G^2 \overline{G}^2 \partial^2 G^2 \partial^2 \overline{G}^2 .$$

Komargodski, Seiberg '09

- Fermion D.O.F. $\neq$ Boson D.O.F.
- $\delta G_\alpha = -f\epsilon_\alpha - (i/2f)\sigma^m_{\alpha\dot{\alpha}}\overline{\epsilon}^{\dot{\alpha}}\partial_m G^2 + \cdots$

Constraints on matter multiplets

Removing scalars

Brignole, Feruglio, Zwirner '97, Komargodski, Seiberg '09

- We have another chiral superfield ($\overline{D}_{\dot{\alpha}} Y = 0$)

$$Y = y + \sqrt{2}\theta\chi^Y + \theta^2 F^Y.$$

- We can have

$$X\,Y = 0.$$

- This gives

$$y = \frac{G\,\chi^Y}{F} - \frac{G^2}{2F^2} F^Y.$$

There are many constraints in the literature, is there a generic prescription?

Removing any selected component

Dall'Agata, Dudas, FF '16

- For a generic superfield

$$Q = q + \theta\chi^{Q} + \cdots$$

- We propose the (irreducible) constraint

$$X\overline{X}\,Q = 0.$$

- This removes only the lowest component

$$q = \frac{G\,\chi^{Q}}{\sqrt{2}F} + \cdots$$

- To remove more components we combine, for example: $X\overline{X}D_{\alpha}Q = 0$ removes also χ^{Q}.

From irreducible constraints

$\rightarrow$ All known constraints are explained.

$\rightarrow$ We can build new constrained superfields.

$\rightarrow$ This corresponds to formal decoupling of eliminated fields.

Future directions

$\rightarrow$ Relation to other methods.

$\rightarrow$ Applications in supergravity and cosmology.

$\rightarrow$ What happens for $N > 1$? (The equivalent of $X^2 = 0$?)

N goldstini

Broken $N = 2$ in low energy

Cribiori, Dall'Agata, FF '16

- For $N = 2$ we need to describe two goldstini

$$\delta G_\alpha = \xi_\alpha \mathcal{F} + \cdots$$
$$\delta \tilde{G}_\alpha = \tilde{\xi}_\alpha \mathcal{F} + \cdots$$

  and the aux. field $\mathcal{F}$ which gets the vev.

- We propose the $N = 2$ chiral superfield $\overline{D}_{\dot{\alpha}}\mathcal{X} = 0 = \overline{\tilde{D}}_{\dot{\alpha}}\mathcal{X}$ with constraints

$$\mathcal{X}\tilde{D}_\alpha D_\beta \tilde{D}_\gamma \mathcal{X} = 0,$$
$$\mathcal{X}\tilde{D}_\alpha D_\beta D_\gamma \mathcal{X} = 0.$$

- We "guessed" them by following E. Kandelakis '86.

- The solution gives in $N = 2$

$$\mathcal{X} = \frac{G^2 \tilde{G}^2}{4\mathcal{F}^3} + \theta \frac{G\tilde{G}^2}{\sqrt{2}\mathcal{F}^2} + \tilde{\theta} \frac{\tilde{G}G^2}{\sqrt{2}\mathcal{F}^2} + \theta^2 \frac{\tilde{G}^2}{2\mathcal{F}} + \tilde{\theta}^2 \frac{G^2}{2\mathcal{F}}$$
$$+ 2\,\theta\tilde{\theta}\frac{G\tilde{G}}{\mathcal{F}} + \sqrt{2}\,\tilde{\theta}^2\theta G + \sqrt{2}\,\theta^2\tilde{\theta}\tilde{G} + \theta^2\tilde{\theta}^2\mathcal{F}.$$

- The simplest Lagrangian is

$$\mathcal{L} = \int d^8\theta \mathcal{X}\overline{\mathcal{X}} + f \int d^4\theta \mathcal{X} + c.c.$$

and in component form we find

$$\mathcal{L} = -f^2 + i\partial_m \overline{G}\,\overline{\sigma}^m G + i\partial_m \overline{\tilde{G}}\,\overline{\sigma}^m \tilde{G} + \cdots$$

Broken $N = 2$ as constrained $N = 1$

- We can express $\mathcal{X}$ as $N = 1$ constrained superfields

$$\mathcal{X} = X\,\overline{H}^{\alpha}\overline{H}_{\alpha} + \sqrt{2}X\,\overline{H}^{\alpha}\tilde{\theta}_{\alpha} + \tilde{\theta}^2 X.$$

- Where (for $\overline{D}_{\dot\alpha}H_{\dot\beta} = 0$)

$$X^2 = 0\;,\;\; X\overline{X}D_{\beta}H_{\dot\alpha} = 0\;,\;\; X\overline{X}D^2H_{\dot\alpha} = 0.$$

- We reduce the $N = 2$ model to the $N = 1$ Lagrangian

$$\mathcal{L} = \int d^4\theta \left(X\overline{X} - \left|\partial_m\left(\frac{X\overline{H}^2}{2}\right)\right|^2 + i\partial_m(X\overline{H}^{\alpha})\sigma^m_{\alpha\dot\alpha}(\overline{X}H^{\dot\alpha})\right) + f\left(\int d^2\theta X + c.c.\right).$$

Future directions

$\rightarrow$ General N? *(Cribiori, Dall'Agata, FF '16)*

$\rightarrow$ Couple to $N = 2$ supergravity.

$\rightarrow$ What is the UV origin? *(FF, Kočí, von Unge '16)*

Thank you!