Constrained superfields in SUSY and SUGRA

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Why constrained superfields?

$\rightarrow$ Non-linear realization of broken supersymmetry.

$\rightarrow$ Consistency with superspace methods.

$\rightarrow$ Offer a "hint" to the UV theory.

The goldstino sector

Nilpotent goldstino superfield

Rocek '78, Lindstrom, Rocek '79, Casalbuoni, De Curtis, Dominici, Feruglio, Gatto '89, Komargodski, Seiberg '09

- 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

$$X^2 = 0 \to A = \frac{G^2}{2F}.$$

Polonyi model and constrained superfields

- The same setup works in supergravity

$$\mathcal{L} = \int d^2\Theta\, 2\mathcal{E}\left[\frac{3}{8}(\overline{\mathcal{D}}^2 - 8\mathcal{R})e^{-K/3} + W\right] + c.c.$$

with $K = X\overline{X}$ and $W = fX + W_0$.

- In the $G = 0$ gauge the component form is

$$e^{-1}\mathcal{L} = -\frac{1}{2}R + \frac{1}{2}\epsilon^{klmn}(\overline{\psi}_k\overline{\sigma}_l\mathcal{D}_m\psi_n - \psi_k\sigma_l\mathcal{D}_m\psi_n)$$
$$- \overline{W_0}\,\overline{\psi}_a\overline{\sigma}^{ab}\overline{\psi}_b - W_0\,\psi_a\sigma^{ab}\psi_b - |f|^2 + 3|W_0|^2.$$

Dudas, Ferrara, Kehagias, Sagnotti '15, Bergshoeff, Freedman, Kallosh, Van Proeyen '15, Hasegawa and Yamada '15, Antoniadis, Markou '15, Dall'Agata, FF '15

Removing matter component fields

Constrained chiral superfields

Remove complex scalar

- For a chiral superfield Y, remove the scalar component y by imposing

$$X\,Y = 0 \;\rightarrow\; y = \frac{G\,\chi^y}{F} - \frac{G^2}{2F^2} F^y .$$

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

- Naturally describes light fermions. *Cribiori, Dall'Agata, FF '16*

Keep only real scalar

- For a chiral superfield $\mathcal{A}$

$$X\mathcal{A} = X\bar{\mathcal{A}} \;\rightarrow\; \mathcal{A}| = \phi + \text{fermions}$$

Komargodski, Seiberg '09

- Naturally describes inflaton.

Removing any selected component field

Dall'Agata, Dudas, FF '16

- For a generic superfield

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

- We propose the constraint

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

- This removes only the lowest component

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

✓ Use to eliminate more components ($|X|^2 DQ = 0$ for χ^q).

✓ Reproduces all known constraints.

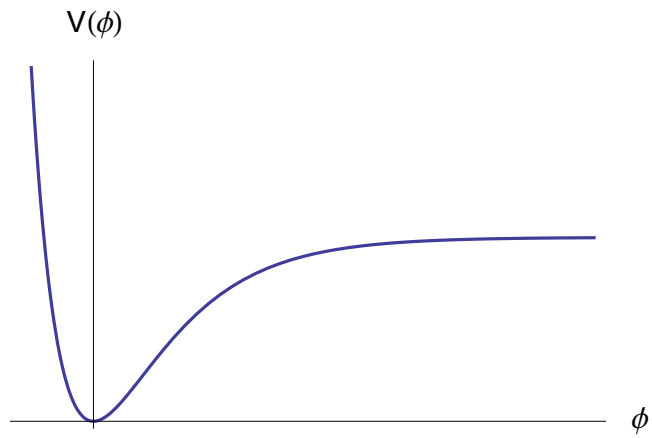
Applications to supergravity cosmology

Inflation in supergravity

- Inflation can be implemented by a single scalar field

$$e^{-1}\mathcal{L} = -\frac{1}{2}R - \frac{1}{2}\partial\phi\partial\phi - V(\phi)$$

with rather flat potential.



Usual issues

- Strongly stabilize other scalars.
- Build the potential.

SUGRA models with X and $\mathcal{A}$

Kahn, Roberts, Thaler '15, Ferrara, Kallosh, Thaler '15, Carrasco, Kallosh, Linde '15, Dall'Agata, FF '15

- A simple example is

$$K = X\bar{X} - \frac{1}{4}(\mathcal{A} - \bar{\mathcal{A}})^2 \ , \ W = g(\mathcal{A}) + X\, f(\mathcal{A})$$

  with $\overline{f(z)} = f(\bar{z})$ and $\overline{g(z)} = g(\bar{z})$.

- In the $G = 0$ gauge, the full Lagrangian is

$$e^{-1}\mathcal{L} = -\frac{1}{2}R + \epsilon^{klmn}\overline{\psi}_k\overline{\sigma}_l\mathcal{D}_m\psi_n - g(\phi)\left(\overline{\psi}_a\overline{\sigma}^{ab}\overline{\psi}_b + \psi_a\sigma^{ab}\psi_b\right)$$
$$-\frac{1}{2}\partial\phi\partial\phi - \left(f(\phi)^2 - 3g(\phi)^2\right).$$

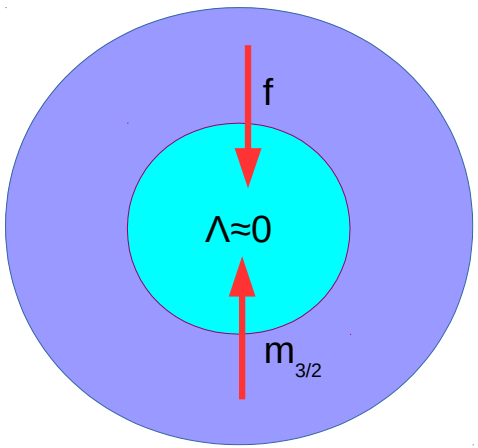
- Model building becomes extremely easy, but there is almost no predictive power.
- Supersymmetry must be broken in the vacuum.

Bousso-Polchinski mechanism in SUGRA

FF, Kehagias, Racco, Riotto '16

- Nilpotent three-form superfields $\rightarrow$ scanning of SUSY breaking scale.
- Three-form supergravity $\rightarrow$ scanning of gravitino mass!
- Small cosmological constant and large gravitino mass

$$\Lambda = \sum_i (f^i)^2 - 3(m_{3/2})^2.$$



Summary - Outlook

- We have discussed the constrained superfields formalism both in SUSY and SUGRA.
- We have presented applications in supergravity cosmology.
- More applications?

Thank you!