Goldstino condensation

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Plan:

$\rightarrow$ Motivation

$\rightarrow$ Goldstino condensation at large N

$\rightarrow$ Outlook

Motivation

Dark Energy in String Theory/Supergravity means

$$\rho_{DE} \sim V_{4D} = f^2 - 3m_{3/2}^2 > 0 \quad \Longrightarrow \quad \underline{\text{Supersymmetry Breaking.}}$$

We will focus on non-linear SUSY because:

1. NL-SUSY underlines many EFTs with broken SUSY.

   See e.g. Dudas, Dall'Agata, FF '16, Dall'Agata, FF, Cribiori '17

2. For "anti-brane uplifts" the supersymmetry breaking is described by sectors with non-linear supersymmetry.

   See e.g. Kallosh, Wrase '14, Bergshoeff, Dasgupta, Kallosh, Van Proeyen, Wrase '15, Dasgupta, Emelin and McDonough '16

Goldstino: An indispensable part of uplifts

Salient features of NL-SUSY in Volkov–Akulov model *('73)*

- The (N=1) goldstino Lagrangian

$$\mathcal{L}_{VA} = -f^2 - i\overline{G}\,\partial\!\!\!/\,G + \frac{1}{4f^2}\overline{G}^2\partial^2 G^2 - \frac{1}{16f^6}G^2\overline{G}^2\partial^2 G^2 \partial^2 \overline{G}^2\,,$$

  and generates the uplift when coupled to SG.

- The non-linear SUSY is

$$\delta G_\alpha = -f\xi_\alpha - (i/2f)\partial\!\!\!/_{\alpha\dot{\alpha}}\,G^2\,\overline{\xi}^{\dot{\alpha}} + \ldots$$

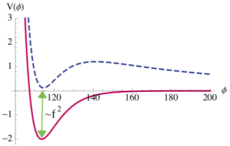
We want to understand if the non-linear terms are spectators or they have any physical significance/impact.

Goldstino condensation: A threat to uplifts

- If there is a condensate of the form

  $$\langle i\overline{G}\,\not{\partial}\, G\rangle \neq 0\,,$$

  then this may potentially ruin uplifts.



(uplift Kachru, Kallosh, Linde, Trivedi '03)

- Due to the non-linear terms, the goldstini may produce such condensates.

- We will discuss the simplest model where goldstino condensation can be studied convincingly.

Goldstino condensation at large N

FF, Matteo Morittu ’22

- We can work with N copies of 4D Dirac goldstini

$$\mathcal{L} = -\mathrm{N}f^2 \det[\mathcal{A}_m{}^a] \;= -\mathrm{N}f^2 + i\overline{G}^A \partial\!\!\!/ G^A + \ldots$$

with $A = 1, \ldots, \mathrm{N}$, with cut-off $\Lambda \ll \sqrt{f}$, where

$$\mathcal{A}_m{}^a = \delta_m^a + \frac{i}{2\mathrm{N}f^2}\left(\overline{G}^A \gamma^a \partial_m G^A - \partial_m \overline{G}^A \gamma^a G^A\right) ,$$

and $\delta G^A = -f\xi^A + \ldots$

- The theory can be written as

$$\mathcal{L} = -\mathrm{N}f^2 \det[e_m{}^a] + \mathrm{N}f^2 C_a{}^m (e_m{}^a - \mathcal{A}_m{}^a) ,$$

making the path integral Gaussian in the fermions.

- We can perform the Gaussian integral over the fermions, to find formally

$$Z_F \sim \left(\det[iC_a{}^m \gamma^a \partial_m]\right)^{\mathrm{N}} ,$$

and then the action for the bosons reads

$$S = \mathrm{N} \times \Big\{ -f^2 \int d^4x \left[\det[e_n{}^b] - C_a{}^m (e_m{}^a - \delta_m{}^a) \right] \\ -i \,\mathrm{tr} \log \left[iC_a{}^m \gamma^a \partial_m \right] \Big\} .$$

- Restore momentarily $\hbar$ and notice an "effective" $\hbar$ as

$$\hbar_{eff} = \hbar/\mathrm{N} ,$$

infinitesimal at large N and theory behaves "classically".

- We want to find new stationary points therefore we can focus on

$$C_a{}^m = (1+h)\,\delta_a{}^m\,, \quad e_m{}^a = (1-\phi)\,\delta_m{}^a\,.$$

- The potential reads

$$V(h,\phi) = \mathrm{N}\left\{f^2\left[(1-\phi)^4 + 4(1+h)\phi\right] - \frac{\Lambda^4}{16\pi^2}\log\left[(1+h)^2\right]\right\}.$$

- We can readily eliminate h to get an effective $V(\phi)$; an "effective potential" for the condensate to search for critical points.

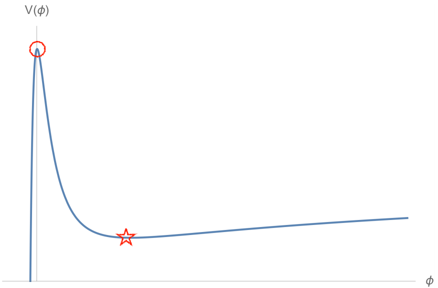
- The potential has a new stationary point at

$$\phi_{GC} \simeq 1 \, ,$$

with

$$V(\phi_{GC}) \ll \mathrm{N}\, f^2 \, ,$$

thus ruining uplifts.



- We interpret this as a goldstino condensate because classically

$$\phi = -\frac{i}{8\mathrm{N}f^2}\left(\overline{G}^A\gamma^m\partial_m G^A - \partial_m\overline{G}^A\gamma^m G^A\right) \, .$$

Outlook

→ Large N: GC quite robust under higher derivative goldstino self-couplings / typical matter coupling of NL-SUSY.

→ Using “exact RG flow”, we are studying the 4D goldstino condensate also at N=1, which is physically more relevant. *Dall’Agata, Emelin, FF, Morittu ’22, ’23*

→ Our findings apply to anti-branes and can ruin uplifts, and inflationary models.

→ Our results resonate with gravitino condensation. *E.g. Jasinschi, Smith ’83, Alexandre, Houston, Mavromatos ’13-’15*

Thank you