
# Anti-brane uplifts and goldstino condensates

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We will focus on non-linear SUSY:

1. We want to understand the properties of this key effect which 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. Bergshoeff, Dasgupta, Kallosh, Van Proeyen, Wrase '15, Dasgupta, Emelin and McDonough '16*

Non-linear supersymmetry is central in understanding the properties of Dark Energy within String Theory.

## Take-away message:

- Non-linear supersymmetry shows an instability towards goldstino condensation. *Dall'Agata, Emelin, FF, Morittu '22*
- This result persists in supergravity and seems related the gravitino condensation instability. *See e.g. Jasinschi, Smith '83,'84, Alexandre, Ellis, Houston, Mavromatos '13-'15*
  *(See also talk by N. Mavromatos)*
- Our results resonate with de Sitter skepticism. *See e.g. Danielsson, Van Riet '18, Obied, Ooguri, Spodyneiko, Vafa '18, Andriot '18*

Plan:

$\rightarrow$ Non-linear supersymmetry

$\rightarrow$ ERG and goldstino condensation

$\rightarrow$ Consequences for uplifts

$\rightarrow$ Outlook

- The Volkov–Akulov model is

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

- This EFT is defined with a cut-off $\Lambda \leq \sqrt{f}$, and we want to lower it to uncover the existence of composite states à la Nambu–Jona-Lasinio.

- In terms of *linear SUSY* it is described by *(See also talk by E. Dudas)*

$$K = X\overline{X} , \quad W = fX + \frac{1}{2}TX^2 ,$$

where the variation of $T$ gives $X^2 = 0$, which gives

$$X = G^2/2F \implies \text{NL SUSY.}$$

*Rocek '78, Casalbuoni, De Curtis, Dominici, Feruglio, Gatto '89*

- We use an Exact RG flow (i.e. Polchinski equation) to lower the cut-off and uncover the existence of composite states.

- Due to known complexity of the ERG equations, approximations are needed anyhow (e.g. LPA).

- To preserve SUSY we track only the interactions that can be described by a $K$ and $W$, and the ERG takes the form

$$\frac{d}{dt_{RG}} K \sim (\#) \frac{\partial W}{\partial \Phi^i} \frac{\partial \overline{W}}{\partial \overline{\Phi}^i} + (\#) \frac{\partial^2 K}{\partial \Phi^i \partial \overline{\Phi}^i} \, .$$

We apply SLPA to the Volkov–Akulov, of which we have the $K$ and the $W$, and check if $T$ becomes propagating.

- The chiral model for the composite states is

$$K = \alpha|X|^2 + \beta|T|^2 + g|T|^2|X|^2 + \frac{1}{4}q|X|^4\,, \quad W = fX + \frac{1}{2}TX^2\,.$$

- We find for $t_{RG} = \log \Lambda/\Lambda' \ll 1$ that

$$\alpha \simeq 1\,,\ \beta \simeq \frac{1}{16\pi^2}t^2\,,\ g \simeq \frac{2t}{\Lambda'^2}\,,\ q \simeq \frac{2t}{\Lambda'^2}\,,\ f \gtrsim \Lambda^2\,.$$

- Around the "V–A" point $T = X = 0$ we find tachyons

$$V = f^2\,, \quad V'' < 0\,.$$

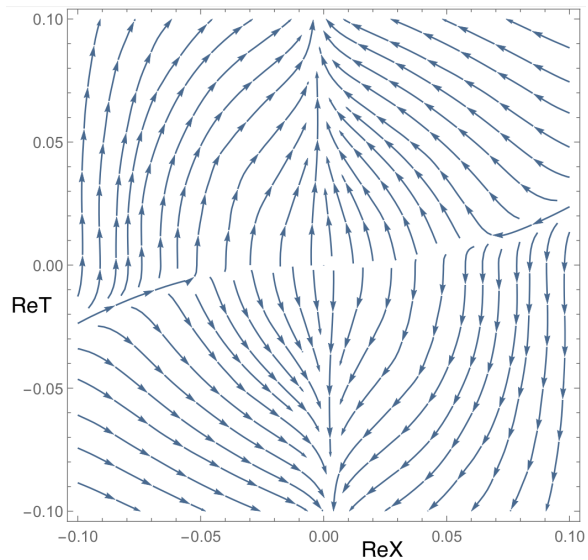
- You can imagine the composite states to have the form

$$X \sim G^2/f\,, \quad T \sim \partial^2\overline{G}^2/f^2\,.$$

# A new problem for anti-brane uplifts?

- The V–A model is easily coupled to 4D N=1 supergravity to get de Sitter. *See e.g. Lindstrom, Rocek '79, Bergshoeff, Freedman, Kallosh, Van Proeyen '15*
- Doing the ERG within supergravity is actually beyond the state-of-the-art.
- We simply directly couple the effective theory at $\Lambda'$ to supergravity.

1. Tachyons persist in SG.
2. Similarly due to NL SUSY of $\overline{\text{D3}}$, also in KKLT.
3. Agreement with gravitino condensates bibliography.



## *What next?*

- We want to go beyond the SLPA - better control over the ERG results.
- Where do the tachyons stop? - Some other stable vacuum? - Supersymmetric vacuum?
- We need to go beyond the state-of-the-art in ERG to include quantum effects from supergravity.
- We would like to identify these tachyons with some open or closed string sector.
- What happens for $N > 1$ or matter couplings?

Thank you