# Fake supersymmetry with tadpole potentials

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# Summary

- Inspired by (susy + Bianchi) $\Rightarrow$ equations of motion (EoMs): **susy-like** first-order equations

$$\left.\begin{aligned} D_M\varepsilon &= 0\,, \\ \mathcal{O}\varepsilon &= 0\,, \end{aligned}\right\} \quad \Rightarrow \quad \text{EoMs for } \textbf{non-susy strings}.$$

- **Energy**-like 2-form, potentially addressing stability

$$E^{MN} = -\bar{\varepsilon}\Gamma^{MNP}D_P\varepsilon\ .$$

# Background: spacetime from strings

EoMs from conformal invariance of sigma model: double expansion in $g_s$ and $\alpha'$

$$S \sim \frac{1}{(\alpha')^4} \int d^{10}x \sqrt{-g} \sum_{n,m=0}^{\infty} g_s^{-2+n} (\alpha')^m \mathcal{O}_{2+2m} \,.$$

In principle any solution is a consistent string background. However:

1. Solve second-order EoMs
2. Check perturbative stability
3. Understand non-perturbative behaviour

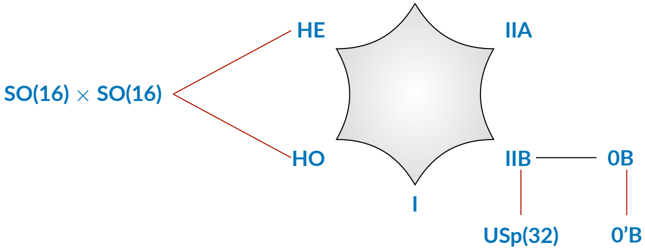
$\rightarrow$ simple ansatz, simple internal manifold, simple decays.

Susy:

- Protection of terms in the action.
- First-order equations.
- Use of spinors: energy, G-structures, bispinor equations, ...
- Dynamical obstruction to decays.

# Non-susy tachyon-free string theories in 10D

- Type IIB with $O9^+$ and 32 $\overline{D9}$: USp(32) [Sugimoto 1999].
- Orientifold of bosonic 0B: 0'B [Sagnotti 1995].
- Heterotic: $SO(16) \times SO(16)$ [Alvarez-Gaume, Ginsparg, Moore, Vafa 1986; Dixon, Harvey 1986].



Generic feature without susy: “tadpole” scalar potential

$$\delta S = - \int \sqrt{-g}\; T\, e^{\gamma\phi} \,,$$

- Residual NS-NS tension, from sources or vacuum energy.
- From worldsheet: non-standard counterterm in $\sigma$-model renormalization [Fischler, Susskind 1986; Callan, Lovelace, Nappi, Yost 1986-7-8].

**Runaway potential**, bad for existence and stability of vacua.

# Fake supersymmetry

Romans mass deformation in IIA $\leftrightarrow$ vacuum energy: susy-like equations for tadpole potentials?

Fake susy, following [Freedman, Nunez, Schnabl, Skenderis 2003]: define operators $D_M$ and $\mathcal{O}$ such that

$$
\begin{aligned}
D_M \varepsilon &= 0 \,, \\
\mathcal{O} \varepsilon &= 0 \,,
\end{aligned}
$$

together with the Bianchi identities, imply the EoMs.

Fake susy with tadpole potentials [SR 2023]:

- For gravity and the dilaton, it is possible. Simplest possibility:

$$D_M \varepsilon = (\nabla_M + \mathcal{W}(\phi)\Gamma_M)\,\varepsilon \;,$$
$$\mathcal{O}\varepsilon = (d\phi + g(\phi))\,\varepsilon \;.$$

- Includes the codimension-one solutions of [Dudas, Mourad 2000]

$$ds^2 = e^{2A(y)}\eta_{\mu\nu}dx^\mu dx^\nu + dy^2 \;.$$

  These are **perturbatively stable** [Basile, Mourad, Sagnotti 2018; Mourad, Sagnotti 2023].

- No new vacuum solution: change spinor ansatz?

- Fluxes: simplest possible extension, e.g. for Sugimoto

$$D_M\varepsilon = \left(\nabla_M + \mathcal{W}(\phi)\Gamma_M + \frac{1}{16}e^{\phi}F\Gamma_M\right)\varepsilon\ ,$$
$$\mathcal{O}\varepsilon = \left(d\phi + g(\phi) + \frac{1}{16}e^{\phi}\Gamma^M F\Gamma_M\right)\varepsilon\ ,$$

$+$ Bianchi do **not** imply EoMs.
However, recall

$$S \sim \frac{1}{(\alpha')^4}\int d^{10}x\sqrt{-g}\sum_{n,m} g_s^{-2+n}(\alpha')^m\mathcal{O}_{2+2m}\ .$$

Kinetic terms of the forms might be loop-corrected.

# Energy

Following [Witten 1981; Giri, Martucci, Tomasiello 2021], spinorial energy

$$I(\varepsilon) = \int_\Sigma \nabla_N E^{MN} d\Sigma_M \,, \qquad E^{MN} = -\bar{\varepsilon}\Gamma^{MNP}\nabla_P \varepsilon \,.$$

Inspired by susy, for asymptotically flat spacetimes $I(\varepsilon) = I(\varepsilon_0) = -\bar{\varepsilon}_0\gamma^\mu\varepsilon_0 P_\mu$.

Using the fake $D_M$ operator,

$$\nabla_M E^{MN} = \overline{D_M\varepsilon}\Gamma^{MPN} D_P\varepsilon + \frac{1}{2}\bar{\varepsilon}\,(\text{Gravity EoM})^{MN}\,\Gamma_M\varepsilon - \frac{1}{8}\overline{\mathcal{O}\varepsilon}\Gamma^N\mathcal{O}\varepsilon \,.$$

Positivity follows if a genearalized Witten condition holds: $\Gamma^m D_m\varepsilon = 0$.

Dudas-Mourad is a zero-energy solution. Is it stable, then?

- Spinorial energy needs control on boundary behaviour. Counterexample with cubic $\mathcal{W}(\phi)$.

- Indication that instability comes from boundary effects. Matches with Dudas-Mourad as 8-brane $+$ EtW defect [Blumenhagen, Font 2000; Antonelli, Basile 2019; Mourad, Sagnotti 2020-3; Angius, Buratti, Calderón-Infante, Delgado, Huertas, Minnino, Uranga 2020-1-2; SR 2022; Blumenhagen, Cribiori, Kneissl, Makridou, Wang 2022-3; ...].

# Conclusions and outlook

- Fake susy for non-susy strings. Gravity $+$ dilaton

$$
\begin{aligned}
D_M\varepsilon &= \left(\nabla_M + \mathcal{W}(\phi)\Gamma_M\right)\varepsilon \ , \\
\mathcal{O}\varepsilon &= \left(d\phi + g(\phi)\right)\varepsilon \ .
\end{aligned}
$$

- No simple inclusion of fluxes. Loop-corrected EoMs?

- Spinorial energy definition

$$
E^{MN} = -\bar{\varepsilon}\Gamma^{MNP}D_P\varepsilon \ ,
$$

  but stability still unclear.