On supersymmetry breaking in supergravity

Alessandro Tomasiello

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Introduction

Non-supersymmetric solutions of string theory

- have no compelling geometrical story to tell, so far
  (unlike susy: generalized/exceptional geometry...)
- for AdS, have been conjectured to be unstable
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Today I'll try to address the first two issues

looking at some large classes of examples.

Plan

- Breaking supersymmetry with pure spinors
- Non-BPS AdS_7 solutions
  - Stability
    - perturbative: part of the KK tower
    - non-perturbative: bubbles

Pure spinors

'Pure spinor equations' for BPS solutions [Graña, Minasian, Petrini, AT '05]

$$d_H(e^{3A-\phi}\Phi_+) = 0$$
$$d_H(e^{2A-\phi}\mathrm{Re}\Phi_-) = 0$$
$$d_H(e^{4A-\phi}\mathrm{Im}\Phi_-) = e^{4A} \star \lambda(F)$$

RR flux

NSNS flux

$\Phi_\pm$: even/odd 'pure' forms

+ algebraic comp. condition

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An easy class:

$$ds^2 = S^{-1/2} ds^2_{\mathrm{Mink}_6} + K(S^{-1/2} dz^2 + S^{1/2} ds^2_{\mathbb{R}^3})$$

[motivated by NS5-D6-D8]

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take $\Phi_\pm$ adapted to this metric

⇩

fluxes are determined. Bianchi ⇨ $\Delta_3 S + \frac{1}{2}\partial_z^2 S^2 = 0$ $\quad K = -\frac{4}{F_0}\partial_z S$

rare case where single PDE

$S(x_1, x_2, x_3, z)$

[Legramandi, AT '19]

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$$\begin{array}{c} x_1 \equiv \partial_U V \\ z \equiv \partial_S V \end{array} \;\Rightarrow\; \partial_S^2 V + S \partial_U^2 V = 0$$ 'Tricomi equation'

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$\downarrow$ T^3

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- $S = kz + S_3(x)$ $\Delta_3 S_3 = -k^2$ gen. Green function; analytic solution

can be made compact with O8±

susy breaking:

keep same metric & RR fluxes; change NSNS
impose Bianchi, but not BPS

[Legramandi, AT '19]

$$\Delta_3 S + \tfrac{1}{2}\partial_z^2 S^2 = 0 \quad \rightsquigarrow \quad \boxed{\Delta_3 S + \tfrac{1}{2}\partial_z^2 S^2 + c(c - 2\partial_z S) = 0}$$

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- we have worked out several other classes

taken or generalized from
classif. of $\mathrm{Mink}_4 \times S^2$ solutions

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- Why does this work?

Susy-breaking in AdS7

- All AdS7 solutions in type II:

[Apruzzi, Fazzi, Rosa, AT '13
Apruzzi, Fazzi, Passias, Rota, AT '15;
Cremonesi, AT '15]

$$\frac{1}{\pi\sqrt{2}}ds^2 = 8\sqrt{-\frac{\alpha}{\ddot\alpha}}ds^2_{\mathrm{AdS}_7} + \sqrt{-\frac{\ddot\alpha}{\alpha}}\left(dz^2 + \frac{\alpha^2}{\dot\alpha^2 - 2\alpha\ddot\alpha}ds^2_{S^2}\right)$$

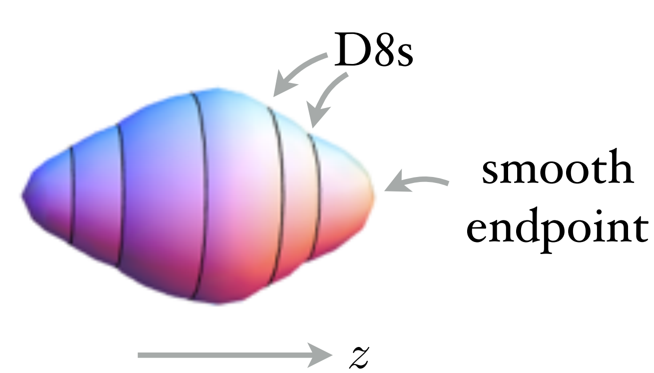
interval

$$e^{\phi} = 2^{1/4}162\pi^{5/2}\frac{(-\alpha/\ddot\alpha)^{3/4}}{\sqrt{\dot\alpha^2 - 2\alpha\ddot\alpha}}$$

$$B = \pi\left(-z + \frac{\alpha\dot\alpha}{\dot\alpha^2 - 2\alpha\ddot\alpha}\right)\mathrm{vol}_{S^2}$$

$$F_2 = \left(\frac{\ddot\alpha}{162\pi^2} + \frac{\pi F_0\alpha\dot\alpha}{\dot\alpha^2 - 2\alpha\ddot\alpha}\right)\mathrm{vol}_{S^2}$$

$\dddot\alpha = F_0$ ⇨ α piecewise cubic



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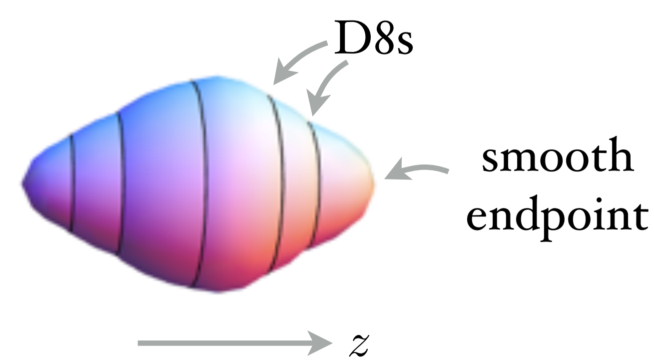
- position of a D8:

$z = k$ =its D6-charge



- $z \in [0, N]$

NS5 flux

- Any AdS7 solution in IIA $\mapsto$ consistent truncation to 'minimal gauged 7d sugra'

[Passias, Rota, AT '15;
Malek, Samtleben, Vall Camell '19]

fields: $g^{(7)}_{\mu\nu}$, A^i_μ, X

[susy vacuum: $X=1$]

uplift:

$$\frac{1}{\pi\sqrt{2}}ds^2 = \frac{120}{V(X)\sqrt{X}}\sqrt{-\frac{\alpha}{\ddot\alpha}}ds^2_{\mathrm{AdS}_7} + X^{5/2}\sqrt{-\frac{\ddot\alpha}{\alpha}}\left(dz^2+\frac{\alpha^2}{\dot\alpha^2-2X^5\alpha\ddot\alpha}ds^2_{S^2}\right)$$

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$\Rightarrow$

- $AdS_7 \to AdS_d \times \Sigma_{7-d}$ comp. & RG flows
- non-susy AdS_7 solution: $X^5 = \frac{1}{2}$

So we get a susy-breaking sister solution:

$$\frac{1}{\pi\sqrt{\cancel{2}}}ds^2 = \overset{12}{\cancel{8}}\sqrt{-\frac{\alpha}{\ddot{\alpha}}}ds^2_{\mathrm{AdS}_7} + \sqrt{-\frac{\ddot{\alpha}}{\alpha}}\left(dz^2 + \frac{\alpha^2}{\dot{\alpha}^2 - \cancel{2}\alpha\ddot{\alpha}}ds^2_{S^2}\right)$$

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- Can we have a 7d theory with more than one susy vacuum?

couple minimal 7d gauged sugra to $\mathrm{SU}(k)^2$ vector multiplets [De Luca, Gnecchi, Lo Monaco, AT '18]

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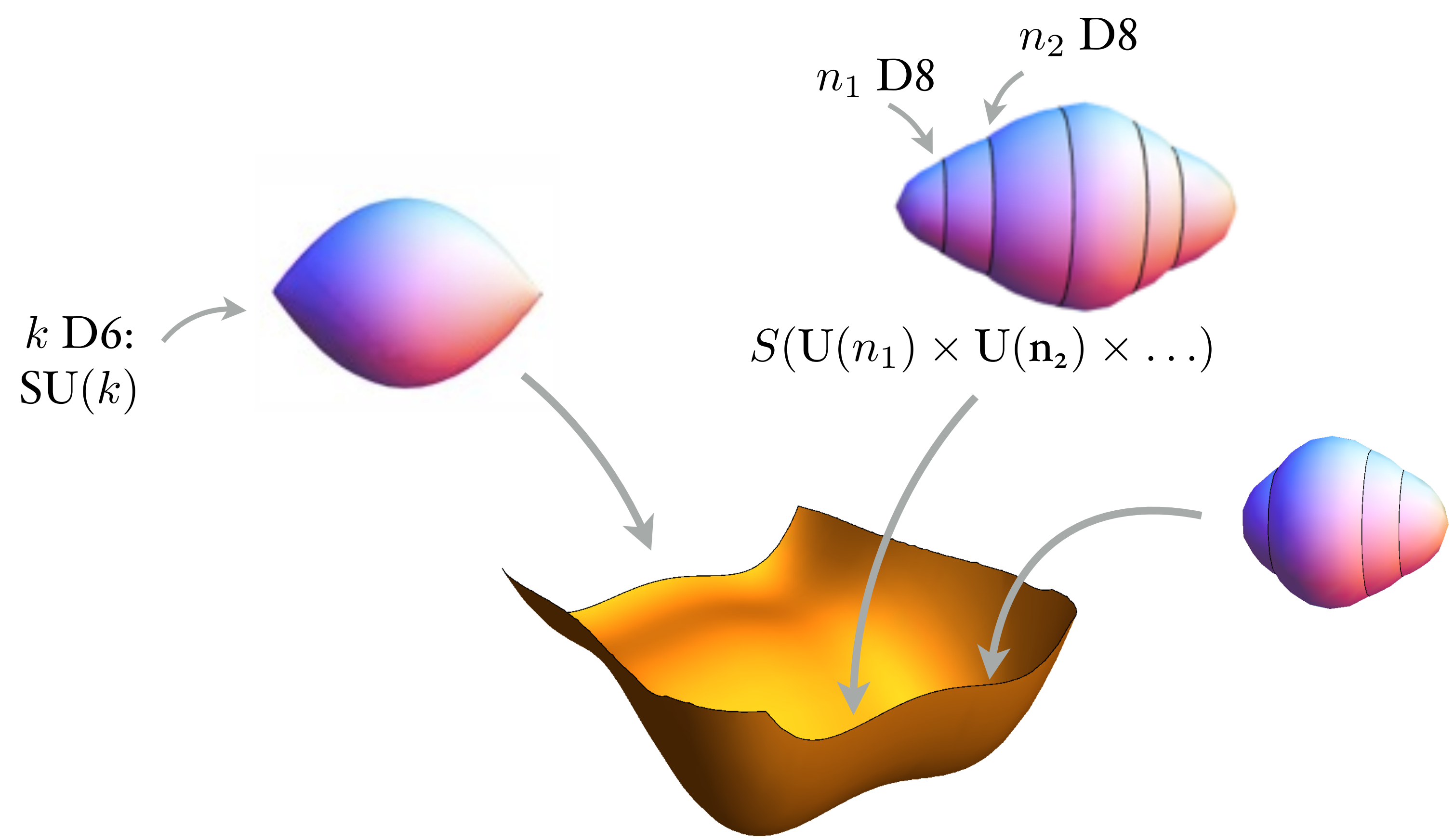
- many nonabelian vacua $\cong$ AdS_7 vacua with different D8 configurations
- susy RG flows $\rightarrow$ Nahm equations. Agree with CFT expectations



AdS7 (in)stability

Possible instabilities:

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Particles with mass negative enough ('BF bound') have solutions that grow in time

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Supersymmetric vacua are protected against both.
But non-supersymmetric ones?

[Breitenlohner, Freedman '82, Gibbons, Hull, Warner '83...]

- ‘Tachyonic’ modes: Full KK computation is challenging.
  - Spin-two masses: simple universal equation [Bachas, Estes ’11]

spectrum of ‘warped Laplacian’ $$\frac{e^{-5A+2\phi}}{\sqrt{\hat{g}}}\partial_m\left(e^{7A-2\phi}\sqrt{\hat{g}}\hat{g}^{mn}\partial_n\right)$$

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    [in units where $L_{\mathrm{AdS}} = 1$]

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⇨ no separation of scales

proof for susy AdS7!

[notice: reasonable est. $M_{\mathrm{KK}} \sim \int e^{4A} R_6$ can fail for solutions with O-planes]

- Spin-zero: we can compute many masses in 7d gauged sugra
  - also: nonabelian DBI ⇨ same results [Apruzzi, De Luca, Gnecchi, Lo Monaco, AT to appear]

potential: $-4\Phi^i\Phi^i - 2\epsilon_{ijk}[\Phi_i, \Phi_j]\Phi_k + [\Phi_i, \Phi_j][\Phi^i, \Phi^j]$ vacua: $[\Phi^i, \Phi^j] = \epsilon^{ijk}\Phi^k$

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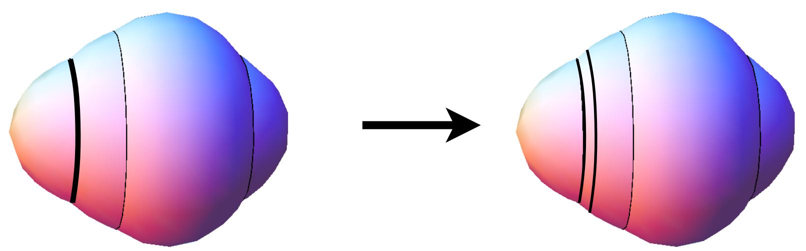
$m^2 = 3(k+2)(k-2) = -12,\ -9,\ 0,\ 15,\ 36,\ \ldots$

below the BF bound!

but this -12 appears only with coincident D8s

plausible scenario:



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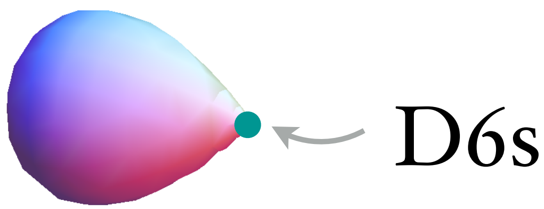
such as the non-susy version of the 'teardrop'



D6s seem to repel.

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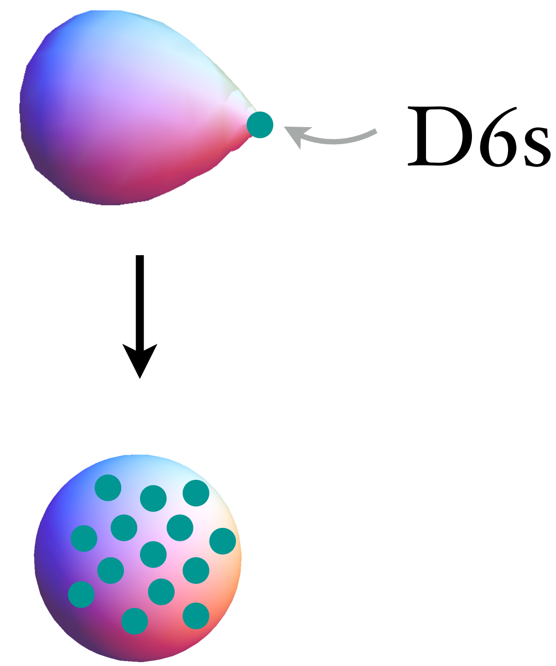

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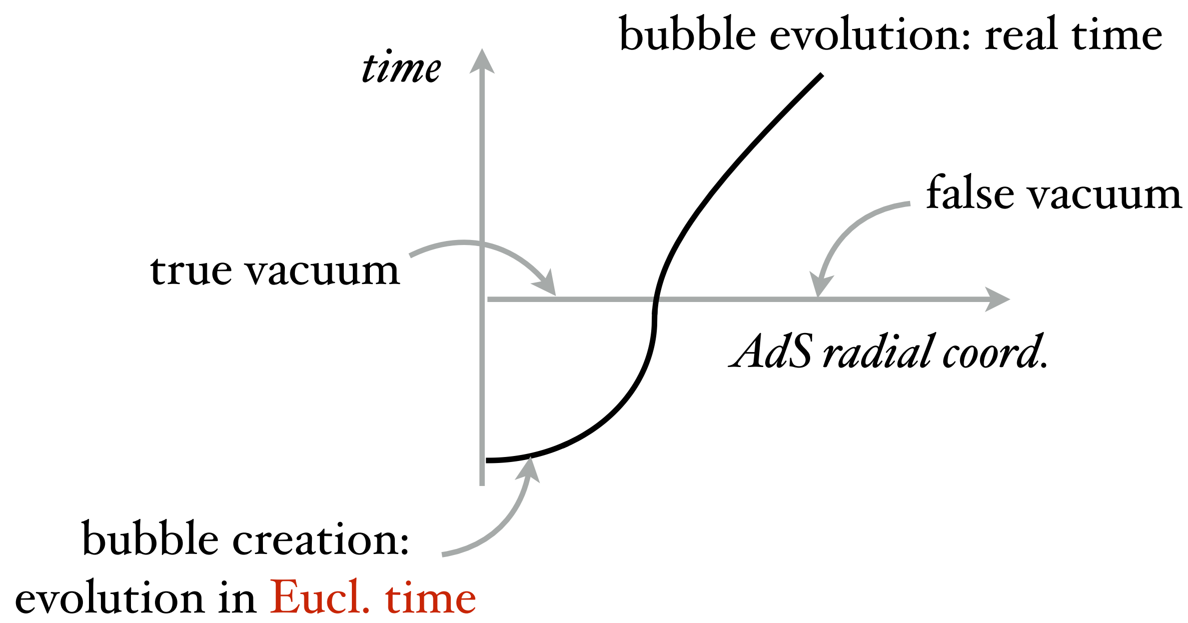
endpoint: D6 smeared solution?

[Blåbäck, Danielsson, Junghans, Van Riet, Wrase, Zagermann ’11]

- ‘Bubbles’.



[Coleman, De Luccia ’80]
[Maldacena, Michelson, Strominger ’98]

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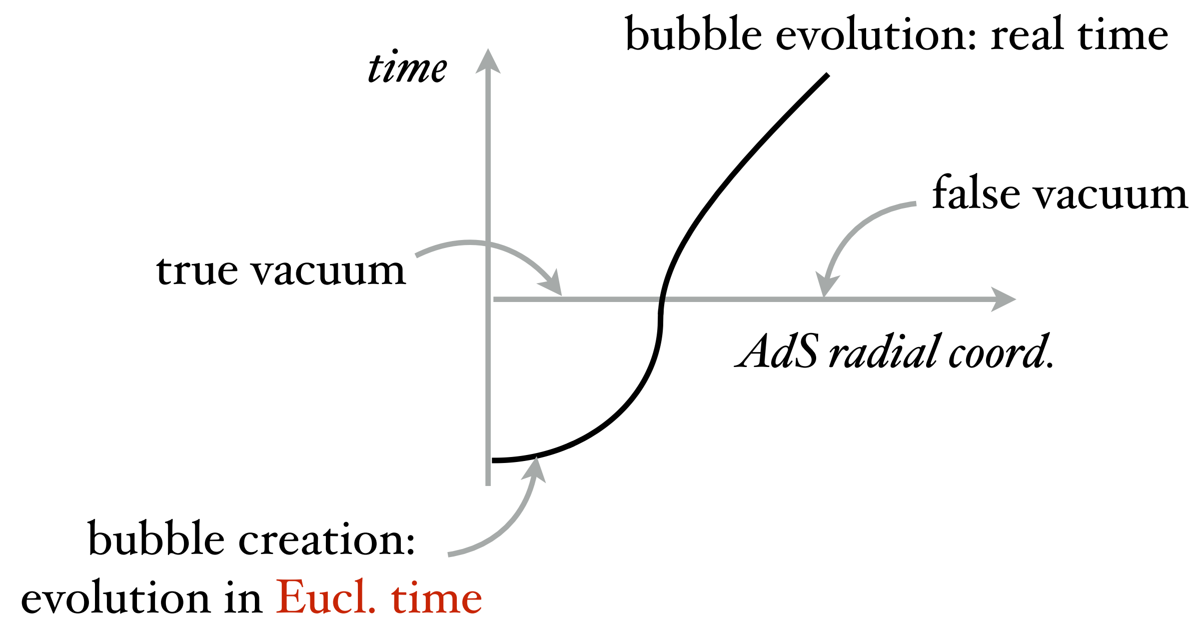

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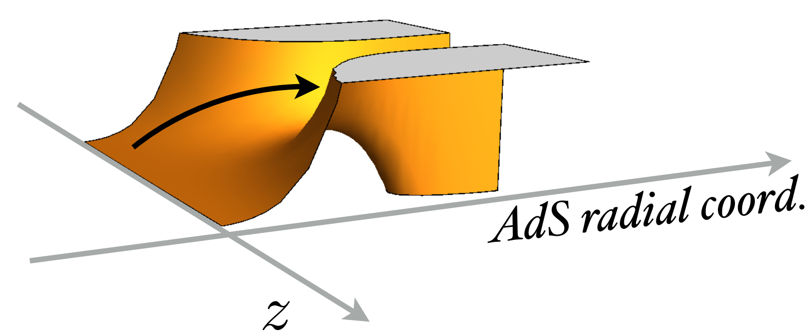
- NS5 bubble.

tunnel effect: NS5 gets created

non-susy case: NS5 potential



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[Ooguri, Vafa ’16,
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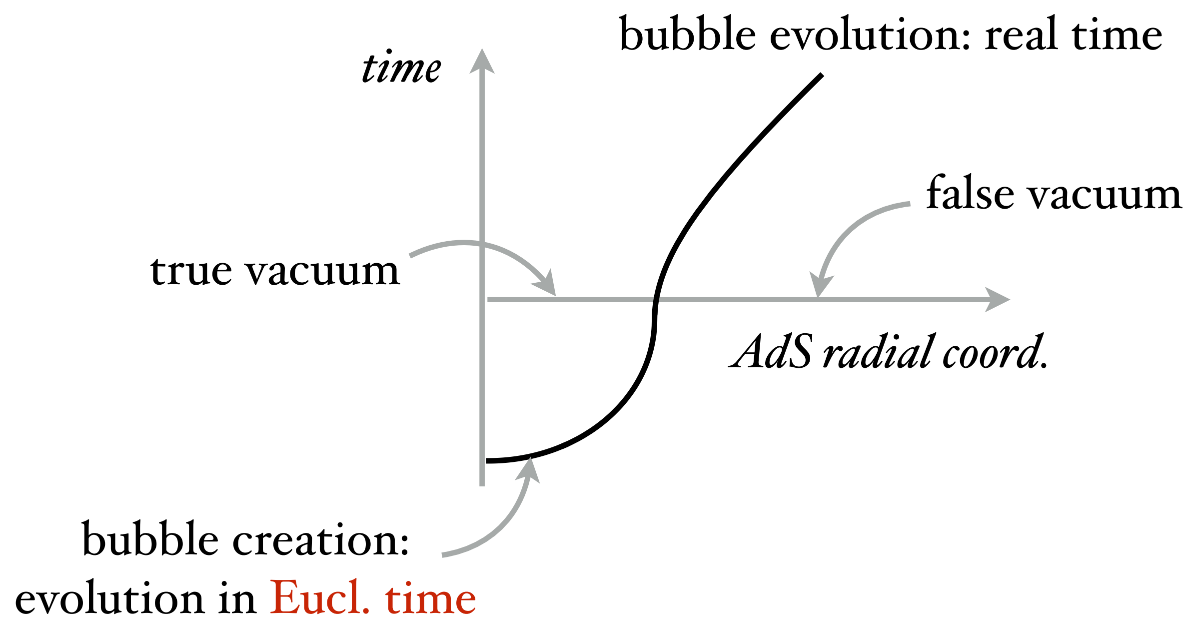

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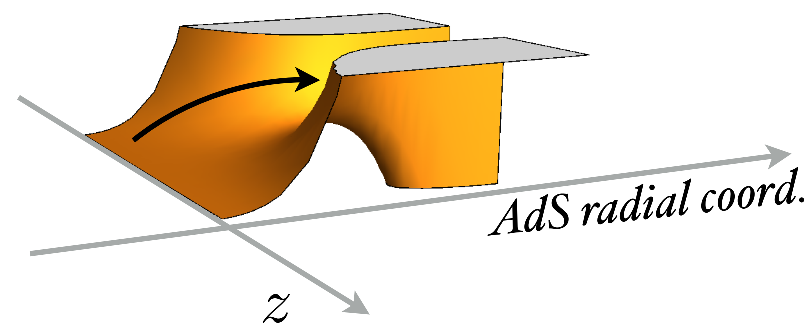

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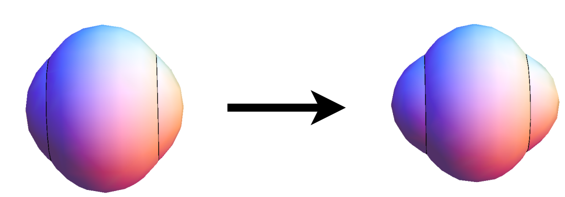
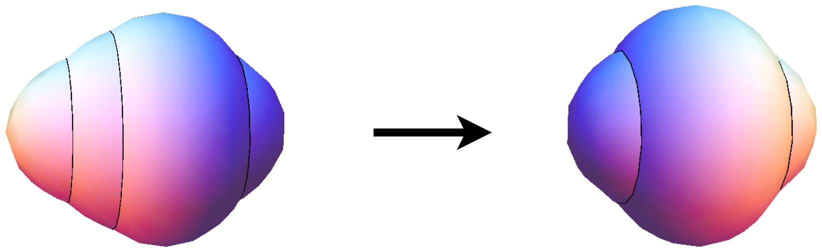
- this process ‘shortens’ the region where $F_0 = 0$



- Other possible tunnel effect:

[motivated by nonabelian potential]



2 D8s combine: one of them keeps all D6 charge, the other tunnels away

- Together these effects seem to rule everything out.

[Apruzzi, De Luca, Gnecchi, Lo Monaco, AT to appear]

Conclusions

- Steps towards procedure to break supersymmetry
  in the Minkowski case [Legramandi, AT '19]

- Older method: consistent truncation. Are non-susy AdS_7 stable?

- Tachyons make D8s repel each other

- Tunnel effects probably make remaining ones unstable