Constrained superfields in string cosmology

Timm Wrase

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

INSTITUTE FOR THEORETICAL PHYSICS

DESY

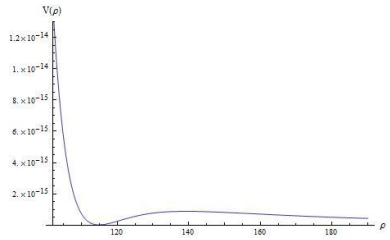
September 27th, 2017

Based on:

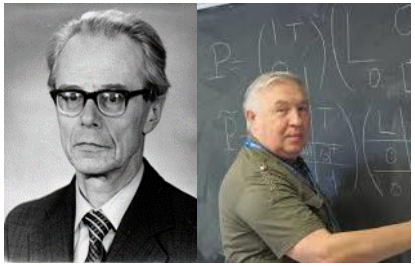
R. Kallosh, B. Vercnocke, TW 1606.09245
B. Vercnocke, TW 1605.03961
E. Bergshoeff, K. Dasgupta, R. Kallosh, A. Van Proeyen, TW 1502.07627
R. Kallosh, TW 1411.1121

FWF
Der Wissenschaftsfonds.

Outline

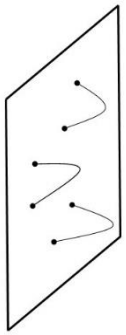


- KKLT dS vacua in string theory



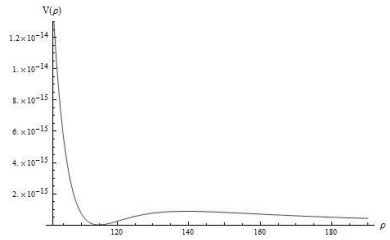
- The nilpotent chiral superfield

- Constrained multiplets from D3-branes

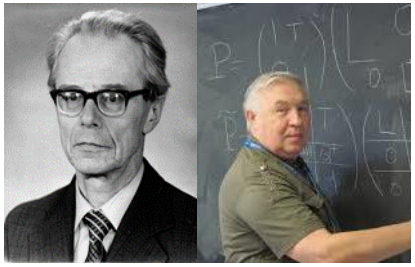


- Conclusion

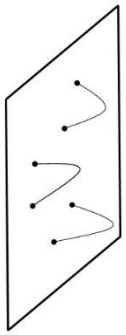
Outline



- KKLT dS vacua in string theory



- The nilpotent chiral superfield



- Constrained multiplets from D3-branes

- Conclusion

dS vacua in string theory

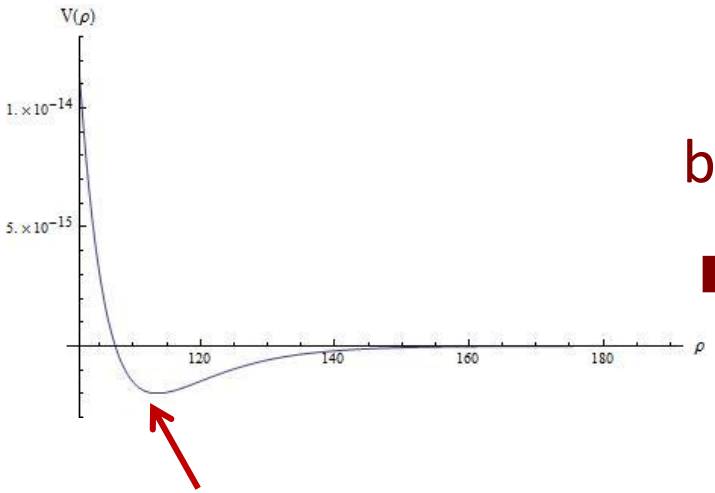
- The first dS vacua in string theory were constructed over a decade ago

Kachru, Kallosh, Linde, Trivedi hep-th/0301240

Balasubramanian, Berglund, Conlon, Quevedo hep-th/0502058

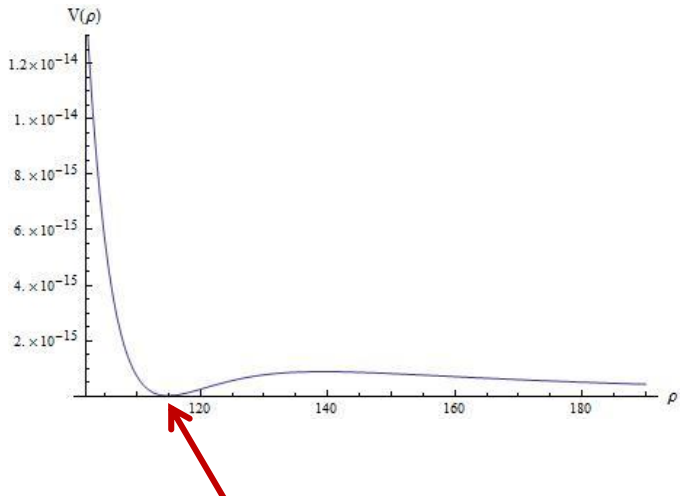
Conlon, Quevedo, Suruliz hep-th/0505076

- They were obtained via a two step procedure:



AdS vacuum

Adding an anti-D3-brane "uplift"



dS vacuum

dS vacua in string theory

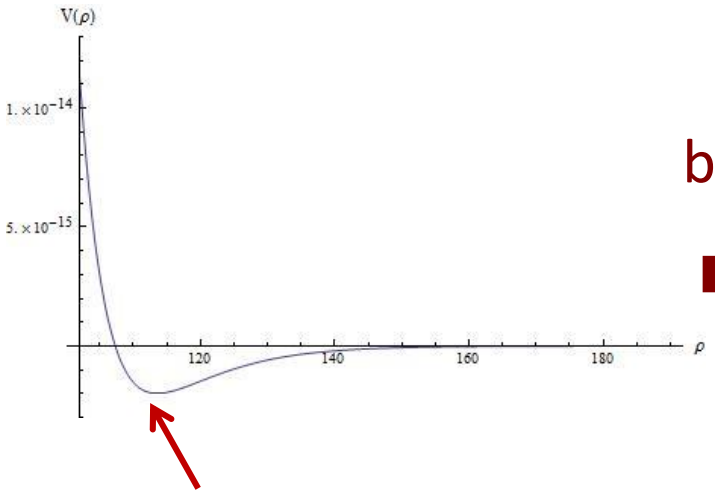
- The first dS vacua in string theory were constructed over a decade ago

Kachru, Kallosh, Linde, Trivedi hep-th/0301240

Balasubramanian, Berglund, Conlon, Quevedo hep-th/0502058

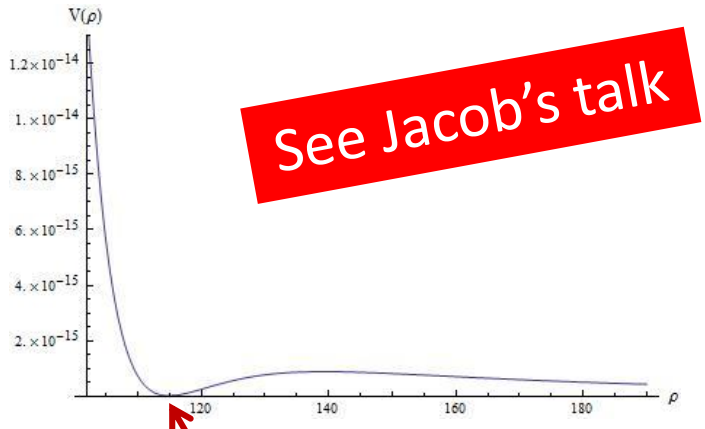
Conlon, Quevedo, Suruliz hep-th/0505076

- They were obtained via a two step procedure:



AdS vacuum

Adding an anti-D3-brane "uplift"



dS vacuum

See Jacob's talk

dS vacua in string theory

- The uplifting term *seems* to explicitly break supersymmetry

$$V = e^{K}\left(K^{I\bar{J}} D_I W \overline{D_J W} - 3|W|^2\right) + \frac{\mu^4}{(T+\bar{T})^2}$$

$$K = -3\log(T+\bar{T})$$
$$W = W_0 - A\, e^{-aT}$$

dS vacua in string theory

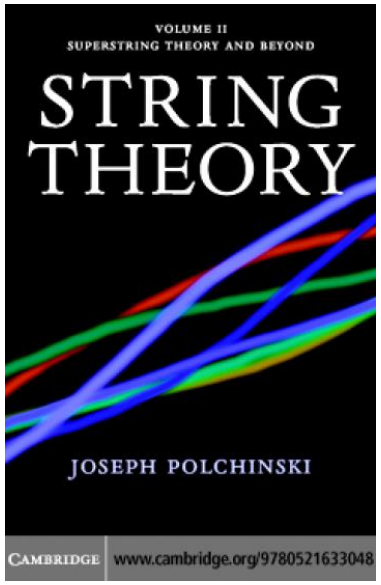
- The uplifting term *seems* to explicitly break supersymmetry

$$V = e^{K}\left(K^{I\bar{J}} D_I W \overline{D_J W} - 3|W|^2\right) + \frac{\mu^4}{(T+\bar{T})^2}$$

$$K = -3\log(T+\bar{T})$$
$$W = W_0 - A\, e^{-aT}$$

- Can we package the uplift term into K, W or D?

dS vacua in string theory



momentum is measured by the integral of the corresponding current over the world-sheet boundary,

$$\frac{1}{2\pi\alpha'}\int_{\partial M} ds\,\partial_n X'^9 \,, \tag{13.2.3}$$

which up to normalization is just the (0 picture) vertex operator for the collective coordinate, with zero momentum in the Neumann directions.

We conclude by analogy that the D-brane also spontaneously breaks 16 of the 32 spacetime supersymmetries, the ones that are explicitly broken by the open string boundary conditions. The integrals

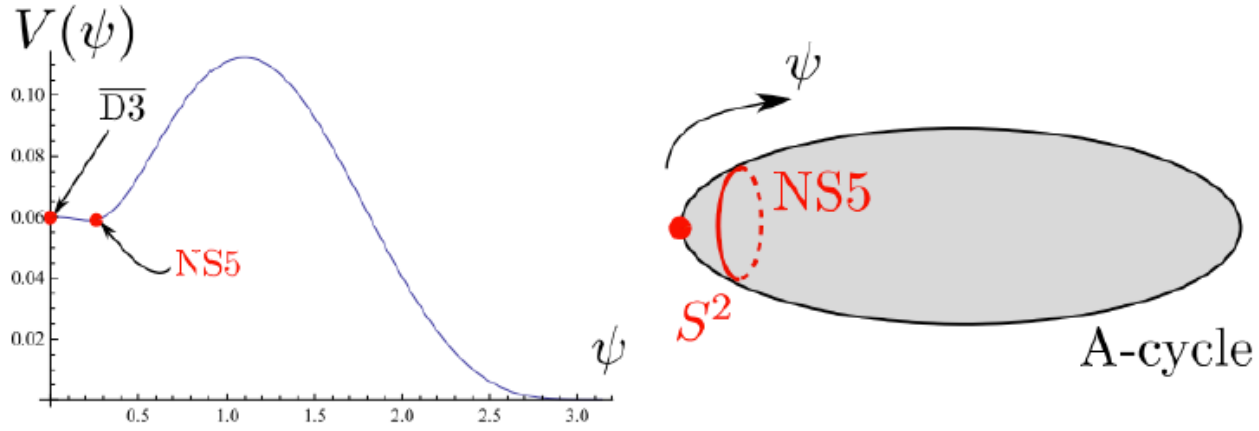
$$\int_{\partial M} ds\,\mathscr{V}'_\alpha = -\int_{\partial M} ds\,(\beta^9\tilde{\mathscr{V}}')_\alpha \,, \tag{13.2.4}$$

which measure the breaking of supersymmetry, are just the vertex op-

dS vacua in string theory

- The anti-D3-brane can decay to a SUSY vacuum, hence it is an excited state in a SUSY theory

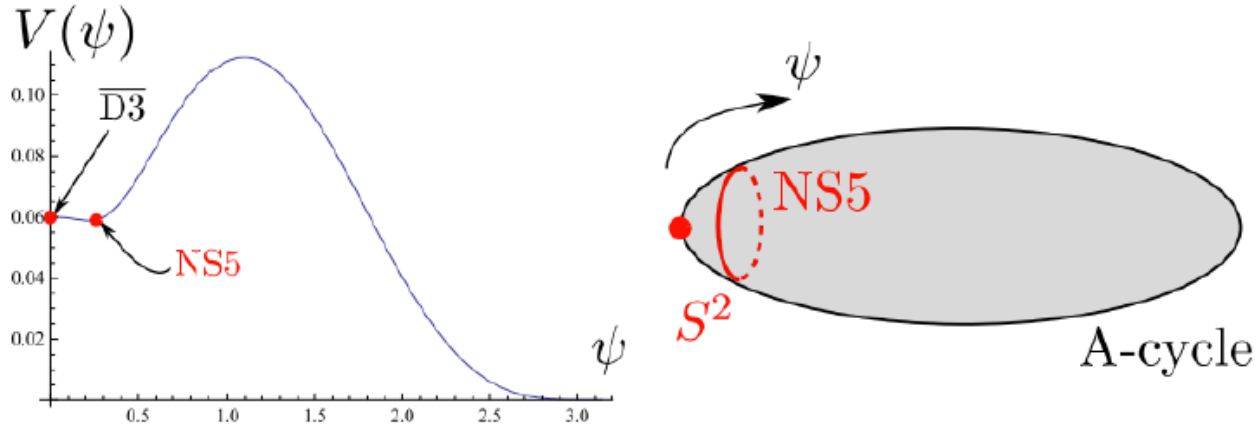
Kachru, Pearson, Verlinde hep-th/0112197



dS vacua in string theory

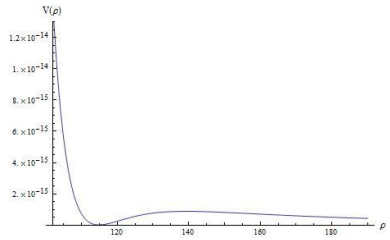
- The anti-D3-brane can decay to a SUSY vacuum, hence it is an excited state in a SUSY theory

Kachru, Pearson, Verlinde hep-th/0112197

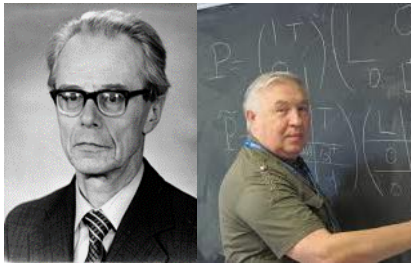


- How can we describe the uplift term in terms of W and K or as an D-term?

Outline

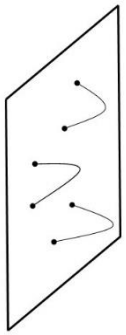


- KKLT dS vacua in string theory



- The nilpotent chiral superfield

- Constrained multiplets from D3-branes



- Conclusion

The nilpotent chiral superfield

- SUSY 101: supersymmetry relates bosons and fermions

The nilpotent chiral superfield

- SUSY 101: supersymmetry relates bosons and fermions

Not necessarily!

The nilpotent chiral superfield

- SUSY 101: supersymmetry relates bosons and fermions

Not necessarily!

- If we break supersymmetry we expect a massless goldstone fermion χ, the goldstino
- Is the neutrino a goldstone particle?

Volkov, Akulov 1972, 1973

The nilpotent chiral superfield

- SUSY 101: supersymmetry relates bosons and fermions

Not necessarily!

- If we break supersymmetry we expect a massless goldstone fermion χ, the goldstino
- Is the neutrino a goldstone particle?

Volkov, Akulov 1972, 1973

$$S_{VA} = -\int E^0 \wedge E^1 \wedge E^2 \wedge E^3, \qquad E^\mu = dx^\mu + \bar{\chi}\gamma^\mu d\chi$$

- Invariant under: $\delta_\epsilon \chi = \epsilon + (\bar{\chi}\gamma^\mu \epsilon)\partial_\mu \chi$

The nilpotent chiral superfield

- SUSY 101: supersymmetry relates bosons and fermions

Not necessarily!

- If we break supersymmetry we expect a massless goldstone fermion χ, the goldstino
- Is the neutrino a goldstone particle? No, but interesting!

Volkov, Akulov 1972, 1973

$$S_{VA} = -\int E^0 \wedge E^1 \wedge E^2 \wedge E^3, \qquad E^\mu = dx^\mu + \bar{\chi}\gamma^\mu d\chi$$

- Invariant under: $\delta_\epsilon \chi = \epsilon + (\bar{\chi}\gamma^\mu \epsilon)\partial_\mu \chi$

The nilpotent chiral superfield

$$S_{VA} = -\int E^0 \wedge E^1 \wedge E^2 \wedge E^3$$

$$E^\mu = dx^\mu + \bar{\chi}\gamma^\mu d\chi = dx^\nu\left(\delta_\nu^\mu + \bar{\chi}\gamma^\mu \partial_\nu \chi\right)$$

- Invariant under: $\delta_\epsilon \chi = \epsilon + (\bar{\chi}\gamma^\mu \epsilon)\partial_\mu \chi$

The nilpotent chiral superfield

$$S_{VA} = -\int E^0 \wedge E^1 \wedge E^2 \wedge E^3$$

$$E^\mu = dx^\mu + \bar{\chi}\gamma^\mu d\chi = dx^\nu\left(\delta_\nu^\mu + \bar{\chi}\gamma^\mu \partial_\nu \chi\right)$$

- Invariant under: $\delta_\epsilon \chi = \epsilon + (\bar{\chi}\gamma^\mu \epsilon)\partial_\mu \chi$
- There is only one fermion!
- Supersymmetry is non-linearly realized
- Supersymmetry is spontaneously broken

The nilpotent chiral superfield

$$S_{VA} = -\int E^0 \wedge E^1 \wedge E^2 \wedge E^3$$

$$E^\mu = dx^\mu + \bar{\chi}\gamma^\mu d\chi = dx^\nu\left(\delta^\mu_\nu + \bar{\chi}\gamma^\mu \partial_\nu \chi\right)$$

- Invariant under: $\delta_\epsilon \chi = \epsilon + (\bar{\chi}\gamma^\mu \epsilon)\partial_\mu \chi$

$$S_{VA} = -\int d^4x (1 + \bar{\chi}\gamma^\mu \partial_\mu \chi + \cdots)$$

The nilpotent chiral superfield

$$S_{VA} = -\int E^0 \wedge E^1 \wedge E^2 \wedge E^3$$

$$E^\mu = dx^\mu + \bar{\chi}\gamma^\mu d\chi = dx^\nu\left(\delta_\nu^\mu + \bar{\chi}\gamma^\mu \partial_\nu \chi\right)$$

- Invariant under: $\delta_\epsilon \chi = \epsilon + (\bar{\chi}\gamma^\mu \epsilon)\partial_\mu \chi$

$$S_{VA} = -\int d^4x (1 + \bar{\chi}\gamma^\mu \partial_\mu \chi + \cdots)$$

- The action is fixed by the kinetic term and the non-linear transformation:

$$\mathcal{O}(\chi^1) \xleftarrow{\delta_\epsilon} \mathcal{O}(\chi^2) \xrightarrow{\delta_\epsilon} \mathcal{O}(\chi^3) \xleftarrow{\delta_\epsilon} \mathcal{O}(\chi^4) \xrightarrow{\delta_\epsilon} \dots$$

The nilpotent chiral superfield

- In $N = 1$ supersymmetry in 4d we can have a so called nilpotent chiral superfield

Volkov, Akulov 1972, 1973
Rocek; Ivanov, Kapustnikov 1978
Lindstrom, Rocek 1979
Samuel, Wess 1983
Casalbuoni, De Curtis, Dominici, Feruglio, Gatto 1989
Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441

- This can be thought of as a chiral superfield that squares to zero

$$S = s + \sqrt{2}\theta\chi + \theta^2 F, \qquad S^2 = 0$$

The nilpotent chiral superfield

- In $N = 1$ supersymmetry in 4d we can have a so called nilpotent chiral superfield

Volkov, Akulov 1972, 1973
Rocek; Ivanov, Kapustnikov 1978
Lindstrom, Rocek 1979
Samuel, Wess 1983
Casalbuoni, De Curtis, Dominici, Feruglio, Gatto 1989
Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441

- This can be thought of as a chiral superfield that squares to zero

$$S = s + \sqrt{2}\theta\chi + \theta^2 F, \qquad S^2 = 0$$

$$S^2 = 0 \quad \Rightarrow \quad s^2 = 2\sqrt{2}s\theta\chi = \theta^2(2sF - \chi\chi) = 0$$

The nilpotent chiral superfield

- In $N = 1$ supersymmetry in 4d we can have a so called nilpotent chiral superfield

Volkov, Akulov 1972, 1973
Rocek; Ivanov, Kapustnikov 1978
Lindstrom, Rocek 1979
Samuel, Wess 1983
Casalbuoni, De Curtis, Dominici, Feruglio, Gatto 1989
Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441

- This can be thought of as a chiral superfield that squares to zero

$$S = s + \sqrt{2}\theta\chi + \theta^2 F, \qquad S^2 = 0$$

$$S^2 = 0 \quad \Rightarrow \quad s^2 = 2\sqrt{2}s\theta\chi = \theta^2(2sF - \chi\chi) = 0$$

$$s = \frac{\chi\chi}{2F} = \frac{\chi_1\chi_2}{F} \quad \Rightarrow \quad s\chi = 0 \ \text{ and } \ s^2 = 0$$

The nilpotent chiral superfield

$$S = \frac{\chi\chi}{2F} + \sqrt{2}\theta\chi + \theta^2 F$$

- These nilpotent chiral superfields consists only of fermions!

The nilpotent chiral superfield

$$S = \frac{\chi\chi}{2F} + \sqrt{2}\theta\chi + \theta^2 F$$

- These nilpotent chiral superfields consists only of fermions!
- Supersymmetry is non-linearly realized and spontaneously broken ($F \neq 0$)

The nilpotent chiral superfield

$$S = \frac{\chi\chi}{2F} + \sqrt{2}\theta\chi + \theta^2 F$$

- These nilpotent chiral superfields consists only of fermions!
- Supersymmetry is non-linearly realized and spontaneously broken ($F \neq 0$)
- There are a variety of different actions but all are related to S_{VA} via non-linear field redefinitions

Kuzenko, Tyler 1009.3298, 1102.3043

The nilpotent chiral superfield

- The bosonic supergravity action for a single nilpotent field $s^2 = 0$ is very simple Antoniadis, Dudas, Ferrara, Sagnotti 1403.3269

$$K = s\bar{s}$$
$$W = c_0 + c_1 s$$

The nilpotent chiral superfield

- The bosonic supergravity action for a single nilpotent field $s^2 = 0$ is very simple Antoniadis, Dudas, Ferrara, Sagnotti 1403.3269

$$K = s\bar{s}$$
$$W = c_0 + c_1 s$$

- The bosonic action is obtained as usual with the additional simplification that $s = \bar{s} = 0$

$$V = e^K (K^{s\bar{s}} D_s W \overline{D_s W} - 3|W|^2) = |c_1|^2 - 3|c_0|^2$$

$$1 \qquad 1 \qquad D_s W\Big|_{s=0} = \partial_s W + W \partial_s K\Big|_{s=0} = c_1$$

0

The nilpotent chiral superfield

- The bosonic supergravity action for a single nilpotent field $s^2 = 0$ is very simple Antoniadis, Dudas, Ferrara, Sagnotti 1403.3269

$$K = s\bar{s}$$
$$W = c_0 + c_1 s$$

- The bosonic action is obtained as usual with the additional simplification that $s = \bar{s} = 0$

$$V = e^K (K^{s\bar{s}} D_s W \overline{D_s W} - 3|W|^2) = |c_1|^2 - 3|c_0|^2$$

- Trivial to get $V > 0$, SUSY broken since $D_s W = \partial_s W = c_1$

$\Rightarrow$ It is trivial to get dS vacua in SUGRA!

The nilpotent chiral superfield

- The bosonic supergravity action for a single nilpotent field $s^2 = 0$ is very simple Antoniadis, Dudas, Ferrara, Sagnotti 1403.3269

$$K = s\bar{s}$$
$$W = c_0 + c_1 s$$

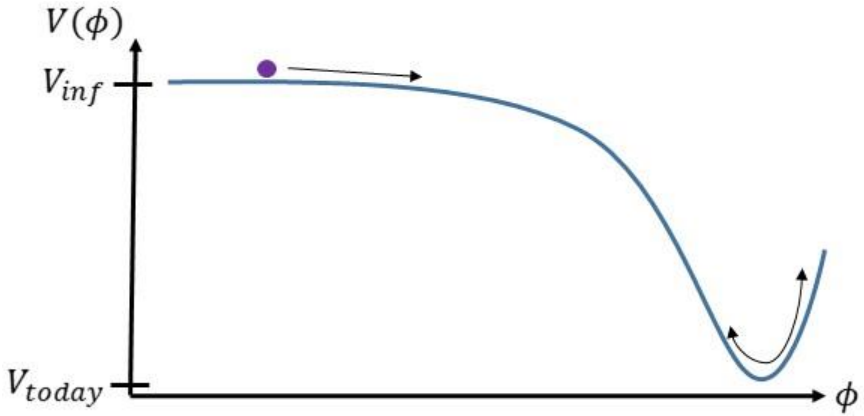
- The bosonic action is obtained as usual with the additional simplification that $s = \bar{s} = 0$

$$V = e^K (K^{s\bar{s}} D_s W \overline{D_s W} - 3|W|^2) = |c_1|^2 - 3|c_0|^2$$

- Trivial to get $V > 0$, SUSY broken since $D_s W = \partial_s W = c_1$
- χ is the Goldstino and gets eaten by the gravitino

Inflation in supergravity

- Very interesting possibilities for cosmological model building, i.e. inflation and dS vacua



See Marco's talk

Antoniadis, Dudas, Ferrara, Sagnotti	1403.3269
Ferrara, Kallosh, Linde	1408.4096
Kallosh, Linde	1408.5950
Dall'Agata, Zwirner	1411.2605
Kallosh, Linde, Scalisi	1411.5671
Carrasco, Kallosh, Linde Roest	1504.05557
Scalisi	1506.01368
Carrasco, Kallosh, Linde Roest	1506.01708
Hasegawa, Yamada	1509.04987
Ferrara, Kallosh, Thaler	1512.00545
Carrasco, Kallosh, Linde	1512.00546
Dudas, Heurtier, Wieck, Winkler	1601.03397
Kallosh, Linde, TW	1602.07818
Farakos, Kehagias, Racco, Riotto	1605.07631
Scalisi	1607.01030
McDonough, Scalisi	1609.00364
Dalianis, Farakos	1705.06717
Argurio, Coone, Heurtierd, Mariott	1705.06788
Kallosh, Linde, Roest, Yamada	1705.09247

More Constrained Multiplets

- There are many more constrained multiplets:

Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441
Dall'Agata, Ferrara, Zwirner 1509.06345
Ferrara, Kallosh, Thaler 1512.00545
Dall'Agata, Farakos 1512.02158
Ferrara, Kallosh, Van Proeyen, TW 1603.02653
Kallosh, Karlsson, Mosk, Murli 1603.02661
Dall'Agata, Dudas, Farakos 1603.03416

$$S^2 = 0, \qquad S\,Y = 0, \qquad S\,W_\alpha = 0, \qquad S(\Phi - \bar{\Phi}) = 0, \ldots$$

More Constrained Multiplets

- There are many more constrained multiplets:

Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441
Dall'Agata, Ferrara, Zwirner 1509.06345
Ferrara, Kallosh, Thaler 1512.00545
Dall'Agata, Farakos 1512.02158
Ferrara, Kallosh, Van Proeyen, TW 1603.02653
Kallosh, Karlsson, Mosk, Murli 1603.02661
Dall'Agata, Dudas, Farakos 1603.03416

$$S^2 = 0, \qquad S\,Y = 0, \qquad S\,W_\alpha = 0, \qquad S(\Phi - \bar{\Phi}) = 0, \ldots$$

chiral multiplet S $\rightarrow$ Goldstino χ

More Constrained Multiplets

- There are many more constrained multiplets:

Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441
Dall'Agata, Ferrara, Zwirner 1509.06345
Ferrara, Kallosh, Thaler 1512.00545
Dall'Agata, Farakos 1512.02158
Ferrara, Kallosh, Van Proeyen, TW 1603.02653
Kallosh, Karlsson, Mosk, Murli 1603.02661
Dall'Agata, Dudas, Farakos 1603.03416

$$S^2 = 0, \qquad S\,Y = 0, \qquad S\,W_\alpha = 0, \qquad S(\Phi - \bar{\Phi}) = 0, \ldots$$

chiral multiplet Y $\rightarrow$ fermion λ

More Constrained Multiplets

- There are many more constrained multiplets:

Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441
Dall'Agata, Ferrara, Zwirner 1509.06345
Ferrara, Kallosh, Thaler 1512.00545
Dall'Agata, Farakos 1512.02158
Ferrara, Kallosh, Van Proeyen, TW 1603.02653
Kallosh, Karlsson, Mosk, Murli 1603.02661
Dall'Agata, Dudas, Farakos 1603.03416

$$S^2 = 0, \qquad S\,Y = 0, \qquad S\,W_\alpha = 0, \qquad S(\Phi - \bar{\Phi}) = 0, \ldots$$

field strength multiplet $W_\alpha \rightarrow$ gauge field A_μ

More Constrained Multiplets

- There are many more constrained multiplets:

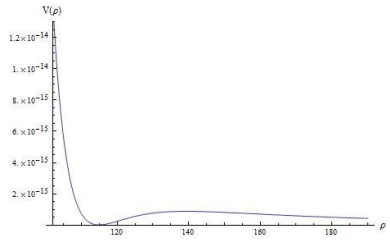
Brignole, Feruglio, Zwirner hep-th/9709111
Komargodski, Seiberg 0907.2441
Dall'Agata, Ferrara, Zwirner 1509.06345
Ferrara, Kallosh, Thaler 1512.00545
Dall'Agata, Farakos 1512.02158
Ferrara, Kallosh, Van Proeyen, TW 1603.02653
Kallosh, Karlsson, Mosk, Murli 1603.02661
Dall'Agata, Dudas, Farakos 1603.03416

$$S^2 = 0, \qquad S\,Y = 0, \qquad S\,W_\alpha = 0, \qquad S(\Phi - \bar{\Phi}) = 0, \ldots$$

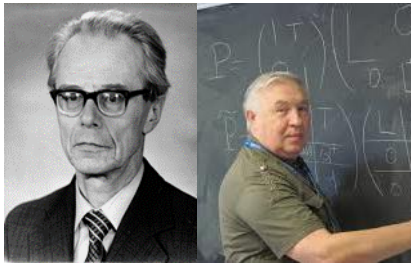
chiral multiplet Φ $\rightarrow$ real scalar ϕ

Outline

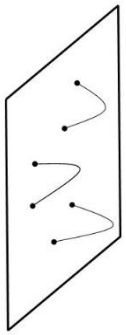
- KKLT dS vacua in string theory



- The nilpotent chiral superfield



- Constrained multiplets from D3-branes



- Conclusion

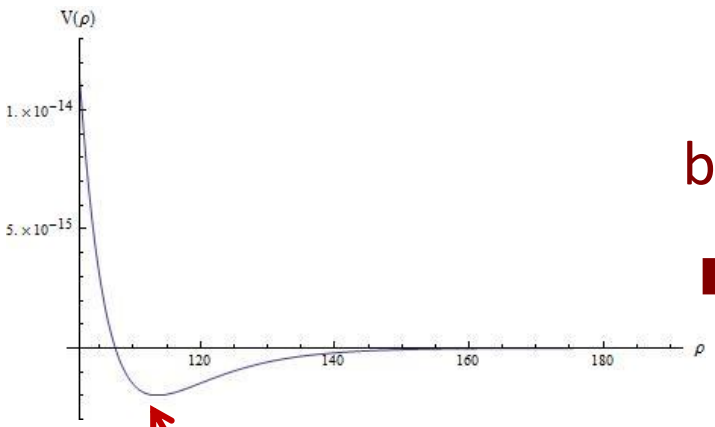
dS vacua in string theory

Kachru, Kallosh, Linde, Trivedi hep-th/0301240

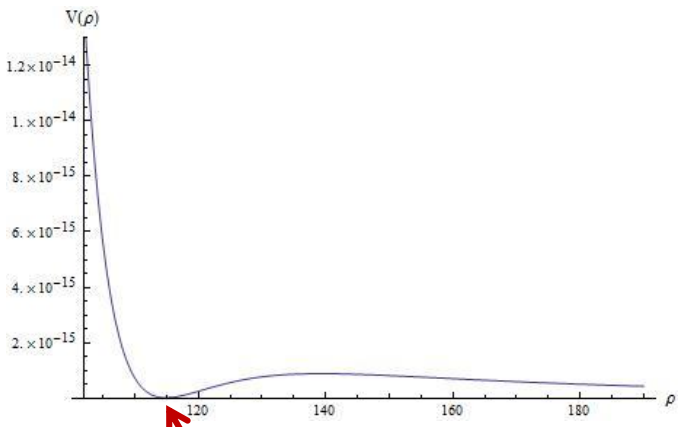
Balasubramanian, Berglund, Conlon, Quevedo hep-th/0502058

Conlon, Quevedo, Suruliz hep-th/0505076

dS vacua construction are often a two step procedure:



Adding an anti-D3-brane "uplift"



AdS vacuum

dS vacuum

The nilpotent chiral superfield

- A very interesting observation

Ferrara, Kallosh, Linde 1408.4096

$$K = -3\ln(T+\bar{T}) + s\bar{s}$$
$$W = W_0 + Ae^{-aT} + \mu^2 s$$

- The bosonic part of the scalar potential for $s^2 = 0$ is

$$V = V_{KKLT} + \frac{\mu^4}{(T+\bar{T})^3}$$

The nilpotent chiral superfield

- Similarly for warping

Ferrara, Kallosh, Linde 1408.4096

$$K = -3\ln(T + \bar{T} - s\bar{s})$$
$$W = W_0 + Ae^{-aT} + \mu^2 s$$

- The bosonic part of the scalar potential for $s^2 = 0$ is

$$V = V_{KKLT} + \frac{\mu^4}{3(T + \bar{T})^2}$$

The nilpotent chiral superfield

- Similarly for warping

Ferrara, Kallosh, Linde 1408.4096

$$K = -3\ln(T + \bar{T} - s\bar{s})$$
$$W = W_0 + Ae^{-aT} + \mu^2 s$$

- The bosonic part of the scalar potential for $s^2 = 0$ is

$$V = V_{KKLT} + \frac{\mu^4}{3(T + \bar{T})^2}$$

- The second term is exactly what is expected for an anti-D3-brane uplift!
- Seems to hint at a connection to D-branes

The nilpotent chiral superfield

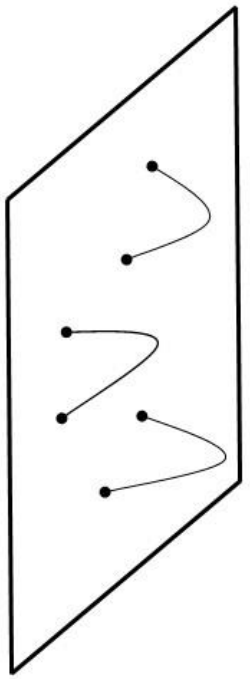
- This nilpotent superfield also arises in string theory for example from anti-D3-branes in KKLT and LVS

Choi, Falkowski, Nilles, Olechowski hep-th/0503216
McGuirk, Shiu, Ye 1206.0754
Ferrara, Kallosh, Linde 1408.4096
Kallosh, TW 1411.1121
Bergshoeff, Dasgupta, Kallosh, Van Proeyen, TW 1502.07627
Kallosh, Quevedo, Uranga 1507.07556
Bandos, Martucci, Sorokin, Tonin 1511.03024
Aparicio, Quevedo, Valandro 1511.08105
García-Etxebarria, Quevedo, Valandro 1512.06926
Dasgupta, Emelin, McDonough 1601.03409
Retolaza, Uranga 1605.01732
Vercnocke, TW 1605.03961
Kallosh, Vercnocke, TW 1606.09245
Bandos, Heller, Kuzenko, Martucci, Sorokin 1608.05908
Aalsma, van der Schaar, Vercnocke 1703.05771
Garcia del Moral, Parameswaran, Quiroz, Zavala 1707.07059

D-branes 102

Let us recall some facts about D-branes *in flat space*:

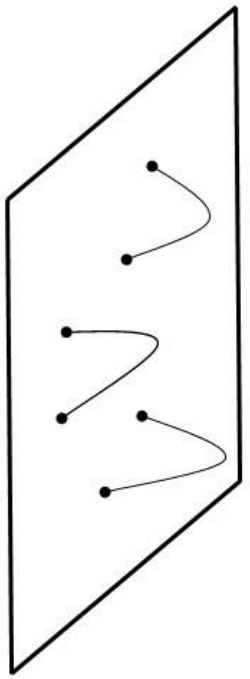
- The D-brane breaks half of the supersymmetry *spontaneously* and the other half is linearly realized
- Example: a D3-brane
- It preserve 16 linearly realized supercharges, i.e. $N = 4$ in 4d
- The worldvolume fields $A_\mu, \lambda^0, \phi^i, \lambda^i, i = 1, 2, 3$ can be package into an $N = 4$ multiplet



D-branes 102

Let us recall some facts about D-branes *in flat space*:

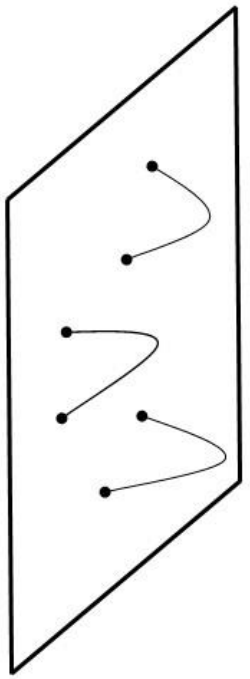
- The D-brane breaks half of the supersymmetry *spontaneously* and the other half is linearly realized
- Example: a D3-brane
- 16 supercharges are spontaneously broken at the string scale $\mathcal{O}(\alpha')$
- The Goldstone fermions aka Goldstinos are λ^0 and $\lambda^i, i = 1, 2, 3$



D-branes 102

Let us recall some facts about D-branes *in flat space*:

- The D-brane breaks half of the supersymmetry *spontaneously* and the other half is linearly realized
- The 16 *spontaneously* broken supersymmetries are non-linearly realized
- The D-brane action is invariant under 16 linear and 16 non-linear SUSY trafos
- We can extend this to more interesting backgrounds



D-branes

Recall some facts about D3-branes *in CY_3 flux compactifications*:

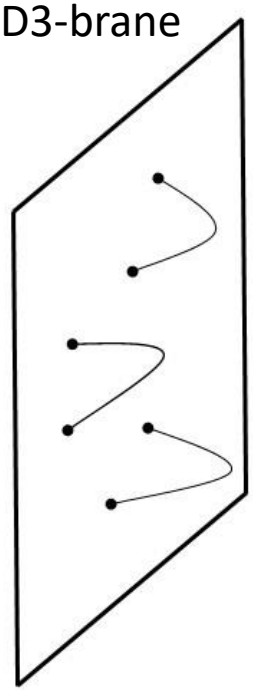
- The CY_3 background preserves 8 supersymmetries
- The O3/O7 projection/fluxes break this down to 4d $N = 1$

D-branes

Recall some facts about D3-branes *in CY_3 flux compactifications*:

- The CY_3 background preserves 8 supersymmetries
- The O3/O7 projection/fluxes break this down to 4d $N = 1$

D3-brane



The D3 preserves this linear SUSY.

The worldvolume fields form $N = 1$ multiplets:

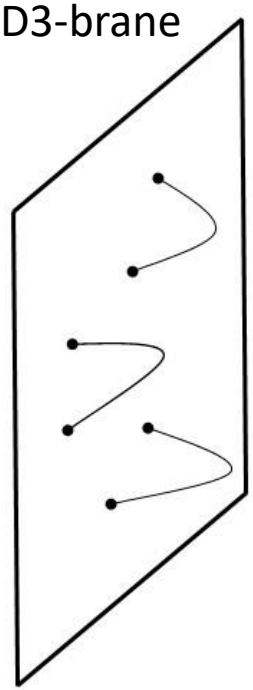
$$(A_\mu, \lambda^0)$$
$$(\phi^i, \lambda^i)$$

D-branes

Recall some facts about D3-branes *in CY_3 flux compactifications*:

- The CY_3 background preserves 8 supersymmetries
- The O3/O7 projection/fluxes break this down to 4d $N = 1$

D3-brane



The D3 preserves this linear SUSY.

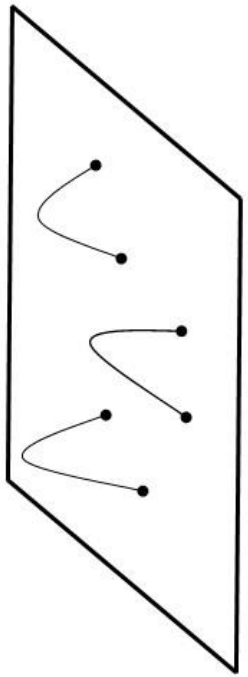
The worldvolume fields form $N = 1$ multiplets:

$$(A_\mu, \lambda^0)$$
$$(\phi^i, \lambda^i)$$

The anti-D3 breaks this linear SUSY spontaneously.

What happens to the worldvolume fields $A_\mu, \lambda^0, \phi^i, \lambda^i$?

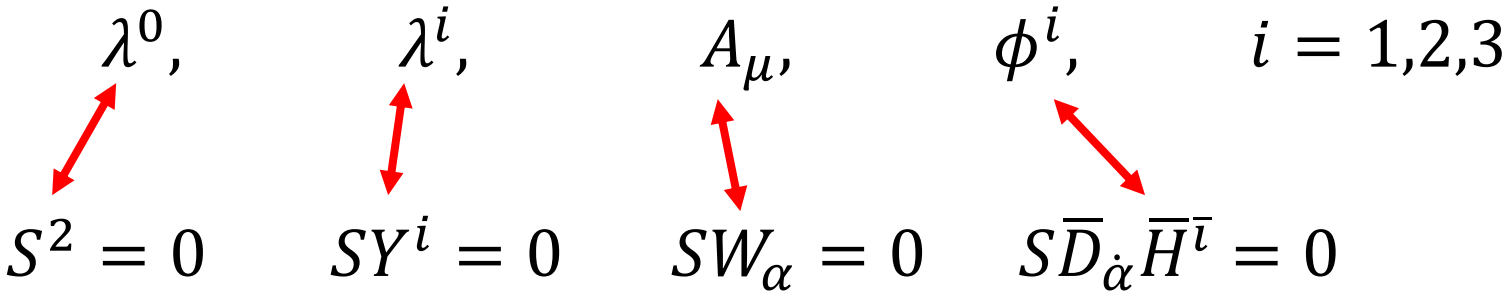
anti-D3-brane



More Constrained Multiplets

- Since the anti-D3-brane breaks supersymmetry spontaneously, we should be able to package all worldvolume fields into $N = 1$ multiplets

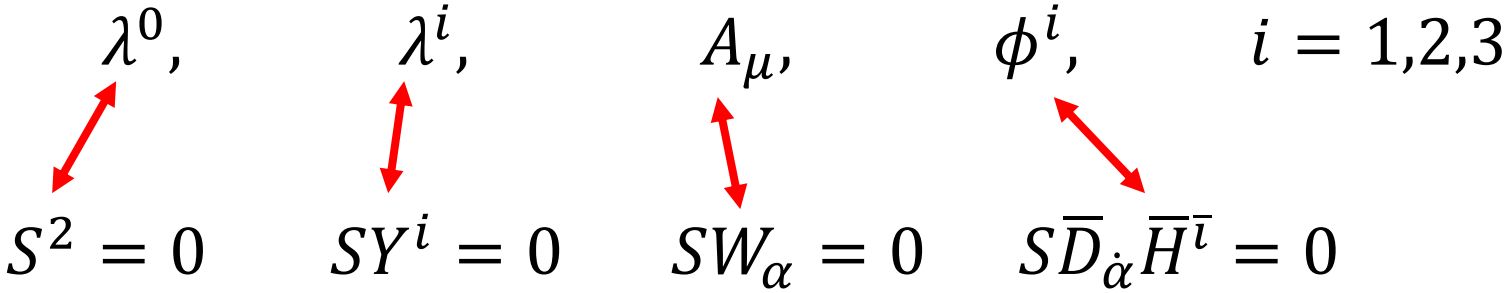
- The anti-D3-brane worldvolume fields are



More Constrained Multiplets

- Since the anti-D3-brane breaks supersymmetry spontaneously, we should be able to package all worldvolume fields into $N = 1$ multiplets

- The anti-D3-brane worldvolume fields are*



* These identifications are probably not unique.

The action for the fermions

- The fermionic action, i.e. for $S^2 = 0, SY^i = 0$ in a GKP type background has been worked out

  Garcia del Moral, Parameswaran, Quiroz, Zavala 1707.07059

$$K = -\log(\tau + \bar{\tau}) - 3\log(U + \bar{U})$$
$$-3\log\left[(T + \bar{T})\left(1 - \frac{S\bar{S}}{3(\tau+\bar{\tau})(U+\bar{U})^3} - \frac{\delta_{i\bar{\imath}}Y^i\bar{Y}^{\bar{\imath}}}{3(U+\bar{U})^3}\right)\right]$$
$$W = \int G_3 \wedge \Omega + \sqrt{2T_3}\ S + h_{ij}(\tau)Y^iY^j$$

- $h_{ij}(\tau) \propto G_{2,1}^{ISD}$ gives a mass to the λ^i contained in Y^i

Conclusion

- A nilpotent chiral multiplet has started to play an interesting role in cosmological model building
- The nilpotent chiral superfield arises on (anti-) D-branes in string theory

Conclusion

- A nilpotent chiral multiplet has started to play an interesting role in cosmological model building
- The nilpotent chiral superfield arises on (anti-) D-branes in string theory
- There are actually many more constrained multiplets that arise from D-branes that spontaneously break SUSY:

$$S^2 = S\,Y^i = S\,W_\alpha = S\,\overline{D}_{\dot{\alpha}}\overline{H}^{\bar{\imath}} = S(\Phi - \overline{\Phi}) = 0$$

Conclusion

- A nilpotent chiral multiplet has started to play an interesting role in cosmological model building
- The nilpotent chiral superfield arises on (anti-) D-branes in string theory
- There are actually many more constrained multiplets that arise from D-branes that spontaneously break SUSY:

$$S^2 = S\,Y^i = S\,W_\alpha = S\,\overline{D}_{\dot{\alpha}}\overline{H}^{\bar{\imath}} = S(\Phi - \overline{\Phi}) = 0$$

THANK YOU!