

Cosmological Attractors from α -scale Supergravity

Marco Scalisi

based on

Van Swinderen Institute - RUG



"Inflation, de Sitter Landscape and Super-Higgs Effect"
[arXiv: 1411.5671] R. Kallosh, A. Linde and MS

"Cosmological Attractors from α -scale Supergravity"
[arXiv: 1503.07909] D. Roest and MS

"Cosmological α -Attractors and de Sitter Landscape"
[arXiv: 1506.01368] MS

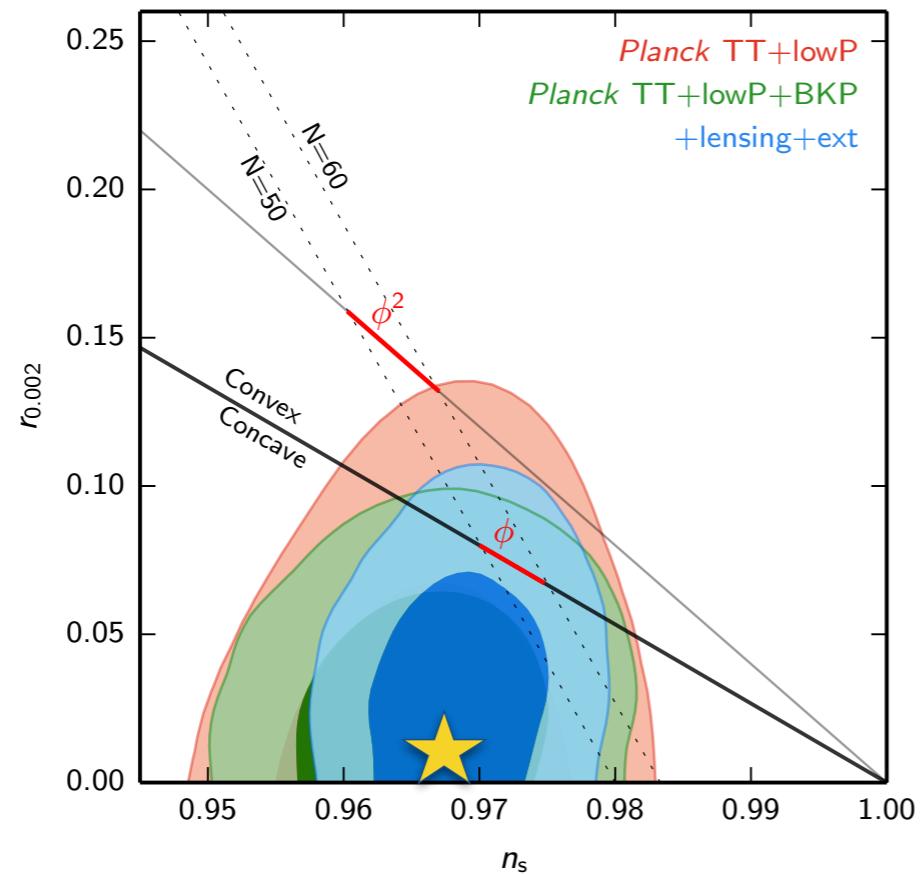
June 11th, 2015 - String Pheno - Madrid

Coordinates



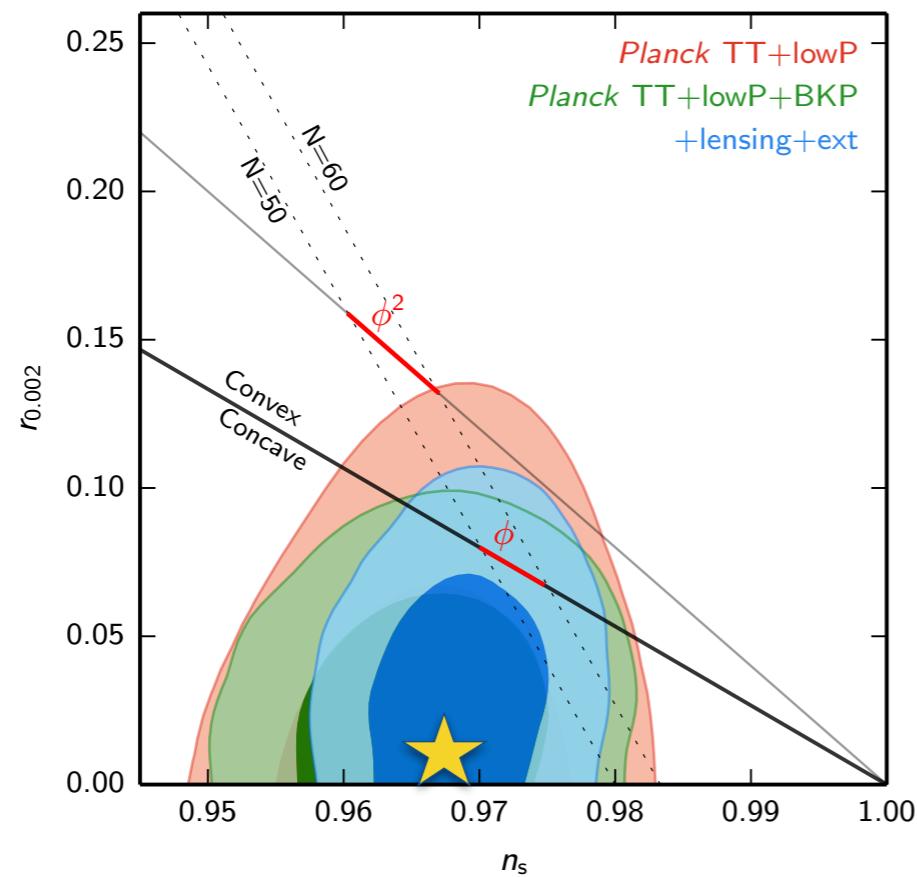
A. Linde & R. Kallosh 's talks on last Monday

“Planck’s coordinates”



$$n_s = 1 - \frac{2}{N} \quad r = \frac{12\alpha}{N^2}$$

“Planck’s coordinates”



$$n_s = 1 - \frac{2}{N} \quad r = \frac{12\alpha}{N^2}$$

Exponential fall-off from de Sitter

$$V = V_0 - V_1 e^{-\sqrt{\frac{2}{3\alpha}}\varphi} + \dots$$

at large values of the canonical normalized field



“Supergravity coordinates”

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

$W = \text{generic}$

“Supergravity coordinates”

$$\begin{array}{c} K = -3\alpha \ln(\Phi + \bar{\Phi}) \\ W = \text{generic} \\ K = -3\alpha \ln (\Phi + \bar{\Phi} - S\bar{S}) \end{array}$$

original formulation
with 2 superfields

$K = -3\alpha \ln (\Phi + \bar{\Phi} - S\bar{S})$

$K = -3\alpha \ln(\Phi + \bar{\Phi})$

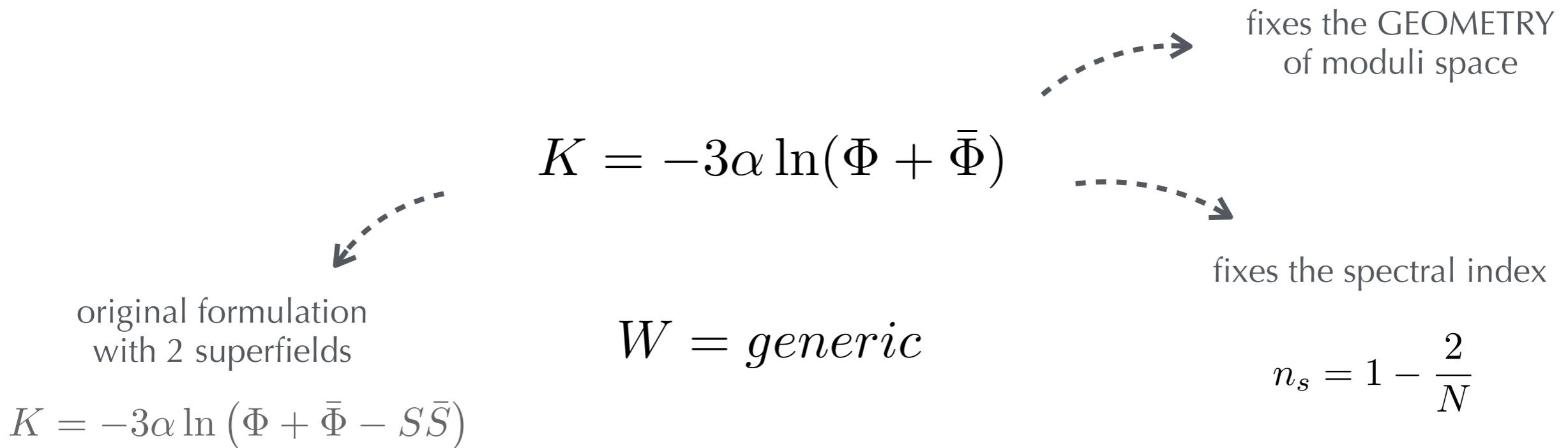
$W = \text{generic}$

fixes the GEOMETRY
of moduli space

fixes the spectral index

$n_s = 1 - \frac{2}{N}$

“Supergravity coordinates”



A large blue bracket encloses the equations for Kähler curvature and the primordial gravitational wave amplitude, connected by a large blue arrow pointing right.

Kähler curvature:

$$R_K = -\frac{2}{3\alpha}$$

primordial gravitational waves:

$$r = \frac{12\alpha}{N^2}$$

α -scale Supergravity

Roest & MS 2015

No-scale supergravity

*Cremmer, Ferrara, Kounnas, Nanopoulos 1983
Ellis, Lahanas, Nanopoulos, K. Tamvakis 1984*

$$K = -3 \ln (\Phi + \bar{\Phi})$$

$$W = 1$$

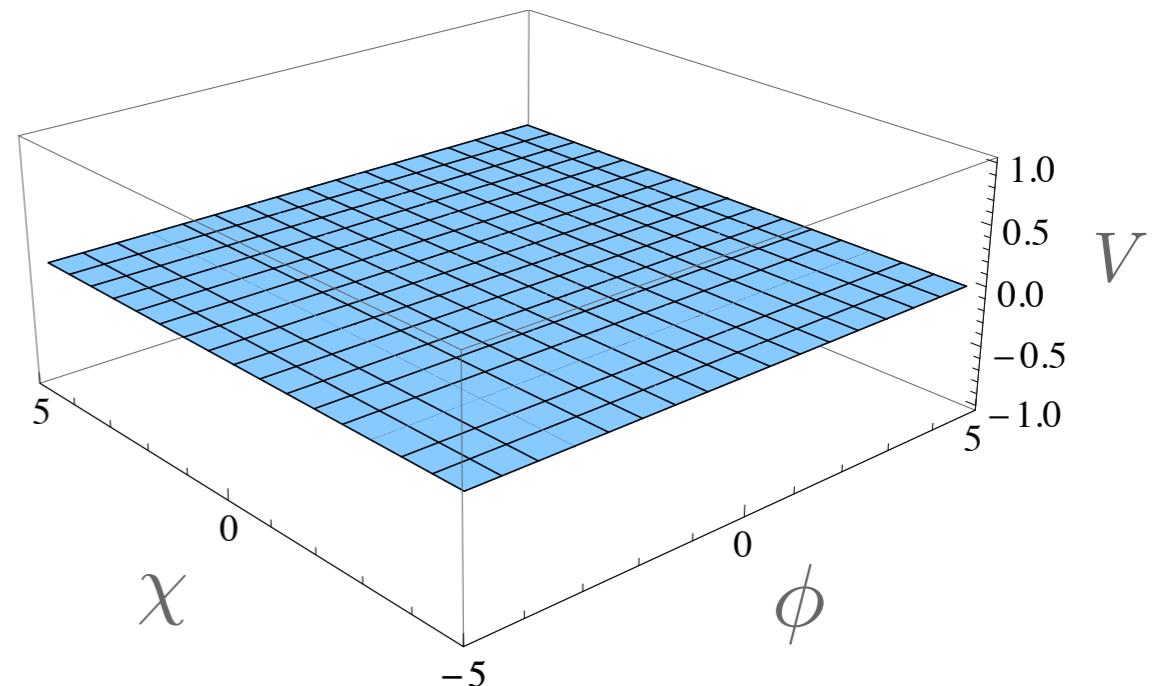
No-scale supergravity

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$$K = -3 \ln (\Phi + \bar{\Phi})$$

$$W = 1$$

$$V = 0 \quad \forall(\phi, \chi)$$



$$\Phi = \phi + i\chi$$

No-scale supergravity

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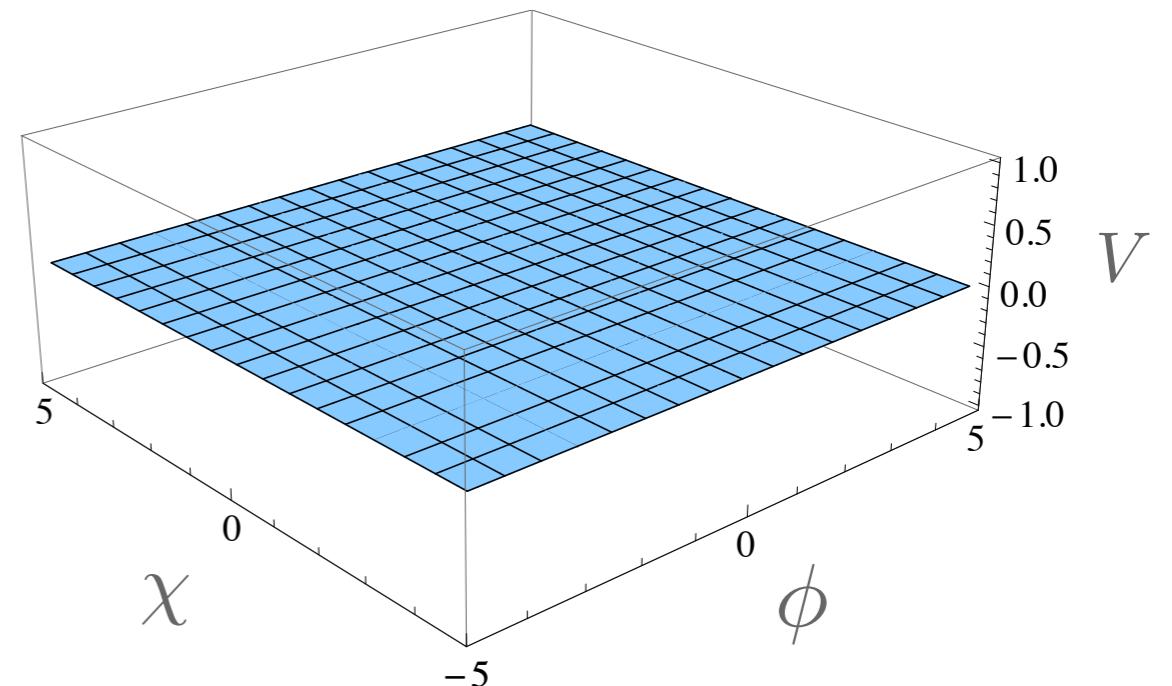


inversion of the field
+
Kähler transformation

$$K = -3 \ln (\Phi + \bar{\Phi})$$

$$W = \Phi^3$$

$$V = 0 \quad \forall(\phi, \chi)$$



$$\Phi = \phi + i\chi$$

No-scale supergravity and dS

Roest & MS 2015

$$K = -3 \ln (\Phi + \bar{\Phi})$$

$$W = 1 - \Phi^3$$

No-scale supergravity and dS

Roest & MS 2015

$$K = -3 \ln (\Phi + \bar{\Phi})$$

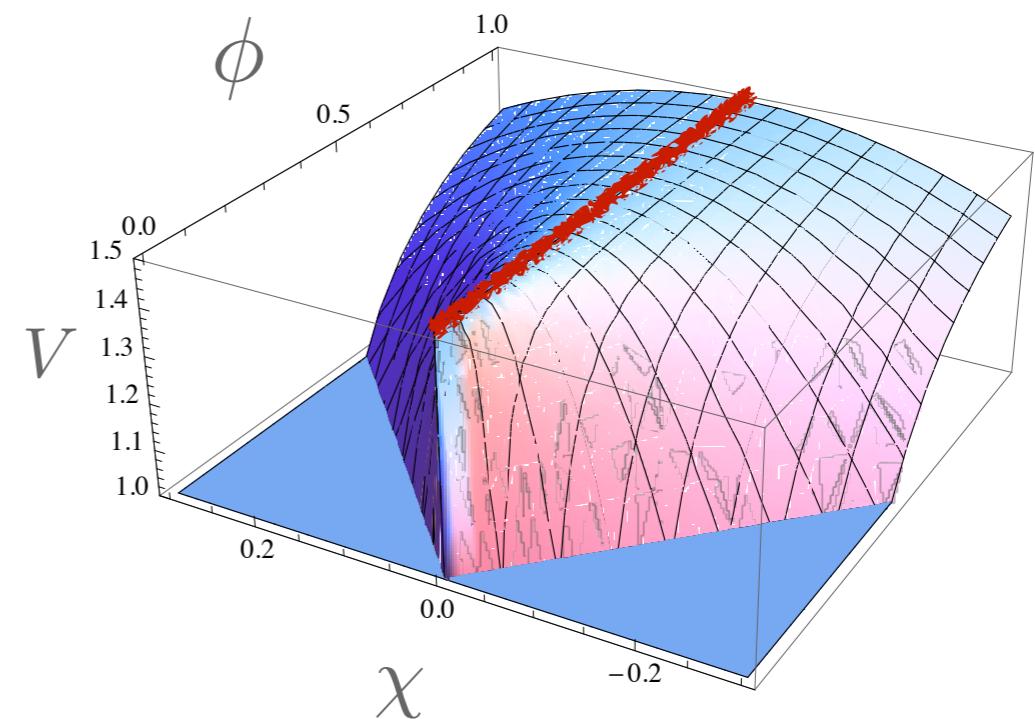
$$V = \frac{3}{2}$$

$$W = 1 - \Phi^3$$

at $\chi = 0$

unstable de Sitter !

$$m_\chi^2 < 0$$



α -scale supergravity and stable dS

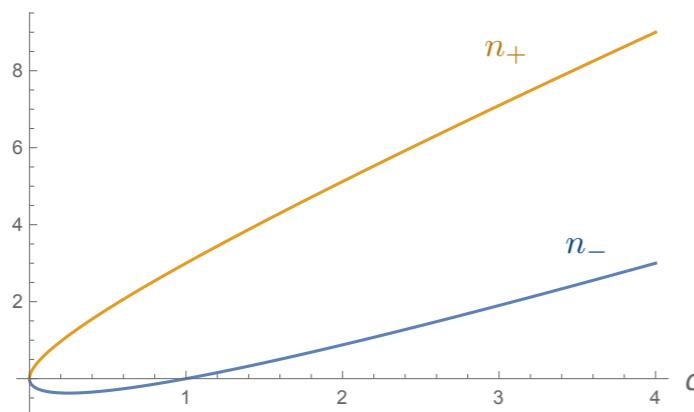
Roest & MS 2015

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

$$W = \Phi^{n_-} - \Phi^{n_+}$$

with

$$n_{\pm} = \frac{3}{2} (\alpha \pm \sqrt{\alpha})$$



α -scale supergravity and stable dS

Roest & MS 2015

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

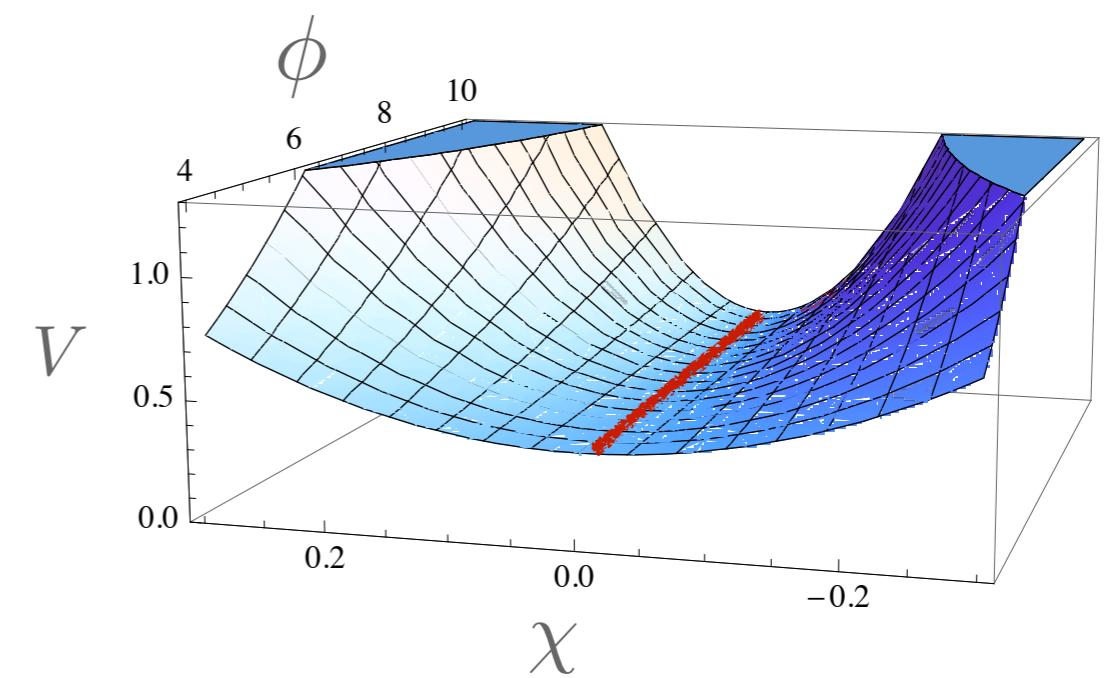
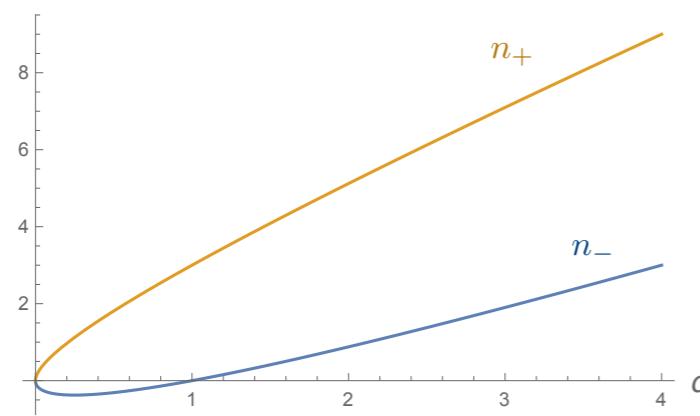
$$V = 3 \cdot 2^{2-3\alpha}$$

$$W = \Phi^{n_-} - \Phi^{n_+}$$

at $\chi = 0$

with

$$n_{\pm} = \frac{3}{2} (\alpha \pm \sqrt{\alpha})$$



stable for $\alpha > 1$

Cosmological Attractors

2 superfields

R. Kallosh, A. Linde 2013

R. Kallosh, A. Linde, D. Roest 2013



R. Kallosh, A. Linde, D. Roest & collaborators



1 superfield

D. Roest, MS 2015

A. Linde 2015

Single superfield α -attractors

Roest & MS 2015

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

$$W = \Phi^{n_-} - \Phi^{n_+} F(\Phi)$$

with

$$F(\Phi) = \sum_n c_n \Phi^n$$

Single superfield α -attractors

Roest & MS 2015

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

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$$V = V_0 - V_1 e^{-\sqrt{\frac{2}{3\alpha}}\varphi} + \dots$$

Single superfield α -attractors

Roest & MS 2015

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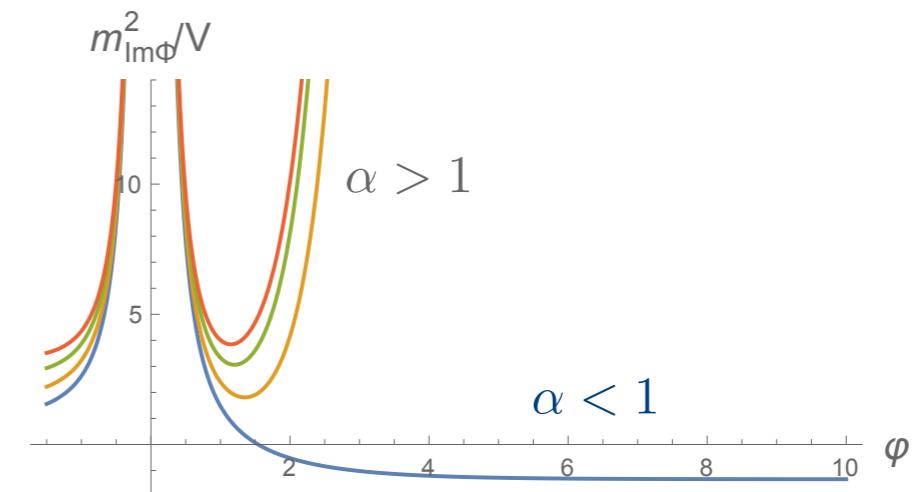
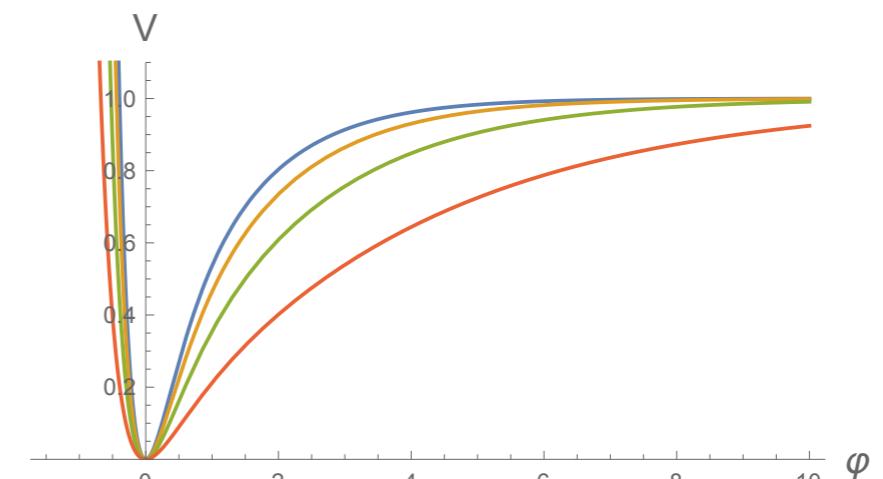
$$F(\Phi) = \sum_n c_n \Phi^n$$



$$V = V_0 - V_1 e^{-\sqrt{\frac{2}{3\alpha}}\varphi} + \dots$$

Simplest example

$$F(x) = 1 + 3\sqrt{\alpha} - 3\sqrt{\alpha}x$$



Single superfield α -attractors

Roest & MS 2015

GEOMETRIC α -ATTRACTORS

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

$$W = \Phi^{n_-} - \Phi^{n_+} F(x)$$

with

$$x \equiv \Phi$$

$$R_K = -\frac{2}{3\alpha}$$

$$\text{stable } \alpha > 1$$

Single superfield α -attractors

Roest & MS 2015

GEOMETRIC α -ATTRACTORS

$$K = -3\alpha \ln(\Phi + \bar{\Phi}) \quad \xrightarrow{\text{---}} \quad \begin{array}{c} \text{K\"ahler transformation} \\ + \\ \text{field redefinition} \\ + \\ \alpha \rightarrow \infty \end{array}$$

$$W = \Phi^{n_-} - \Phi^{n_+} F(x)$$

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Single superfield α -attractors

Roest & MS 2015

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stable $\alpha > 1$

= Kähler transformation
+
field redefinition
+
 $\alpha \rightarrow \infty$ 

building blocks of W

curvature

FLAT α -ATTRACTORS

$$K = -\frac{1}{2} (\Phi - \bar{\Phi})^2$$

$$W = e^{\sqrt{3}\Phi} - e^{-\sqrt{3}\Phi} F(x)$$

with

$$x \equiv e^{-2\Phi/\sqrt{3\alpha}}$$

$$R_K = 0$$

stable $\forall \alpha$

Single superfield α -attractors

Roest & MS 2015

GEOMETRIC α -ATTRACTORS

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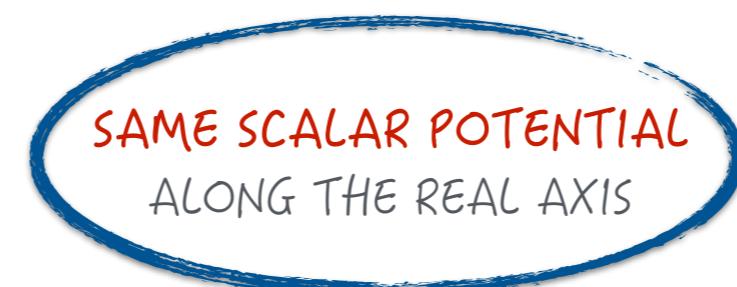
Kähler transformation
 +
 field redefinition
 +
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building blocks of W

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SAME SCALAR POTENTIAL
ALONG THE REAL AXIS



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Single superfield α -attractors

Roest & MS 2015

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Roest & MS 2015

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FLAT α -ATTRACTORS

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$$W = e^{\sqrt{3}\Phi} - e^{-\sqrt{3}\Phi} F(x)$$

α -Attractors + nilpotent sector

$$S^2(x, \theta) = 0$$

MS 2015

Carrasco, Kallosh, Linde 2015

GEOMETRIC α -ATTRACTORS

$$K = -3\alpha \ln(\Phi + \bar{\Phi}) + S\bar{S}$$

= flat limit 

$$W = \Phi^{\frac{3}{2}\alpha} f(x) + Sg(x)$$

with

$$x \equiv \Phi$$

FLAT α -ATTRACTORS

$$K = -\frac{1}{2} (\Phi - \bar{\Phi})^2 + S\bar{S}$$

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generic expansion

$$f(x) = \sum_n a_n x^n$$

 α -Attractors

$$V = V_0 - V_1 e^{-\sqrt{\frac{2}{3\alpha}}\varphi} + \dots$$

$$g(x) = \sum_n g_n x^n$$

α -Attractors + nilpotent sector

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GEOMETRIC α -ATTRACTORS

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$$K = -\frac{1}{2}(\Phi - \bar{\Phi})^2 + S\bar{S}$$

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- Enhancement of the attractor structure
- Stability $\forall \alpha$
- Useful framework to describe inflation, dark energy and SUSY breaking

R. Kallosh's talk

Conclusions

Cosmological α -attractors

- ◆ ...are located at the **sweet spot of Planck!**

$$n_s = 1 - \frac{2}{N} \quad r = \frac{12\alpha}{N^2}$$

- ◆ ...originate from a natural deformations of the no-scale models, dubbed as **α -scale supergravity**, useful for Minkowski and de Sitter model building.

$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

$$W = \Phi^{n_-} - \Phi^{n_+}$$

Cosmological α -attractors

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$$\begin{aligned} K &= -3\alpha \ln(\Phi + \bar{\Phi}) \\ W &= \Phi^{n_-} - \Phi^{n_+} \end{aligned}$$

When α -attractors combined with a nilpotent sector with canonical Kähler

- ◆ **attractor structure is enhanced**
- ◆ **stability for any value of α**
- ◆ more direct connection with **string theory inspired models**



W as arbitrary expansion in both fields

functional freedom between f and g

see Dudas, Wieck 's talks

e.g. $\alpha = \frac{2}{3}$

$$K = -2 \ln (\Phi + \bar{\Phi}) + S \bar{S}$$

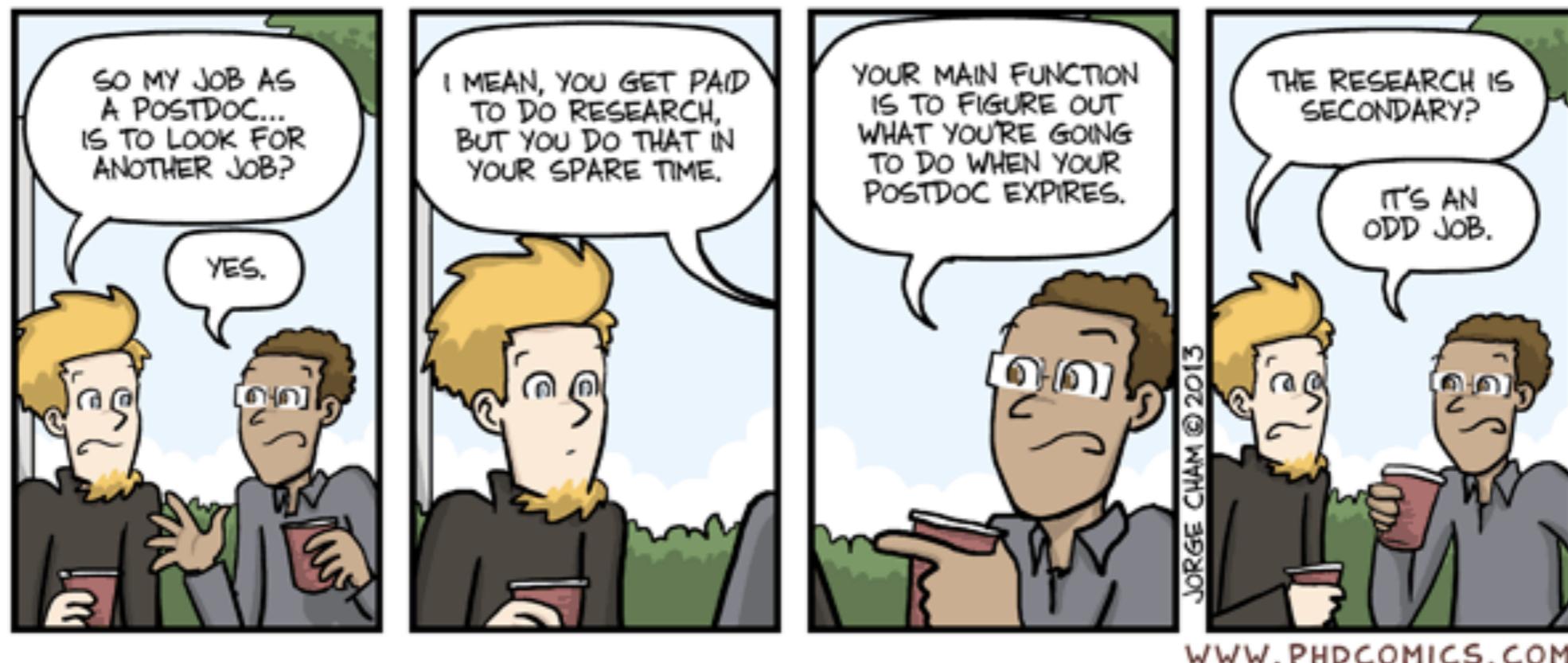
$$W = (a_0 \Phi + a_1 \Phi^2 + \dots) + (b_0 \Phi + b_1 \Phi^2 + \dots) S$$

thank you!

thank you!

and please remember...

...next Fall is “my round”! ;)



Extra slides

α -scale supergravity and stable dS

Roest & MS 2015

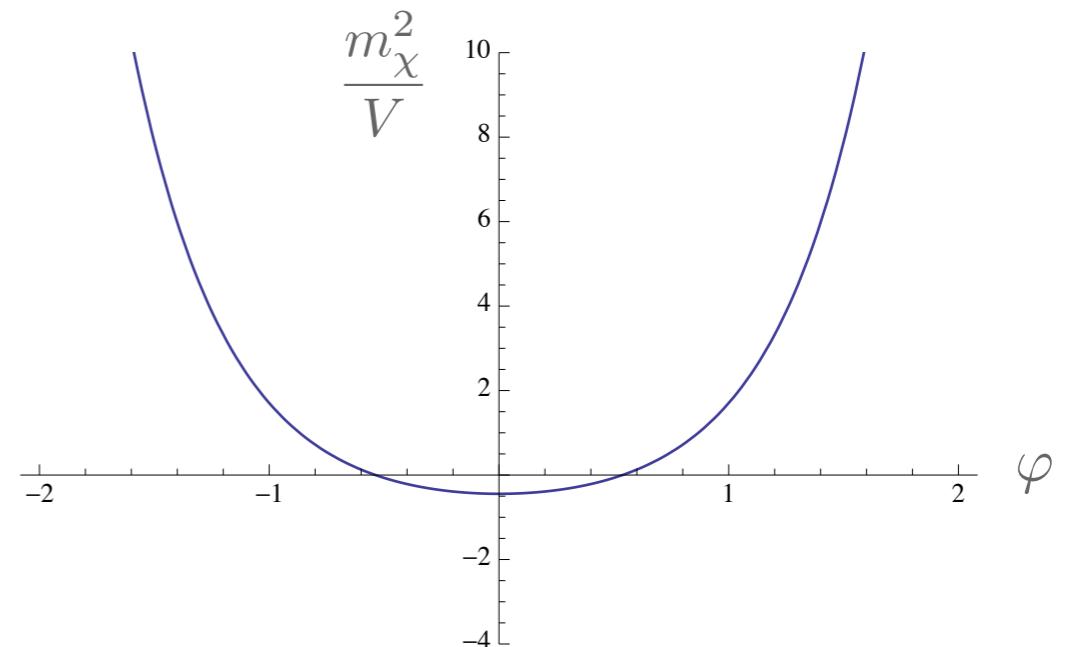
$$K = -3\alpha \ln(\Phi + \bar{\Phi})$$

$$m_\chi^2 = -\frac{4V}{3\alpha} \left[1 - (\alpha - 1) \sinh^2 \left(\sqrt{\frac{3}{2}} \varphi \right) \right]$$

$$W = \Phi^{n_-} - \Phi^{n_+}$$

with

$$n_{\pm} = \frac{3}{2} (\alpha \pm \sqrt{\alpha})$$



$$\alpha > 1$$

α -scale supergravity and stable dS

Roest & MS 2015

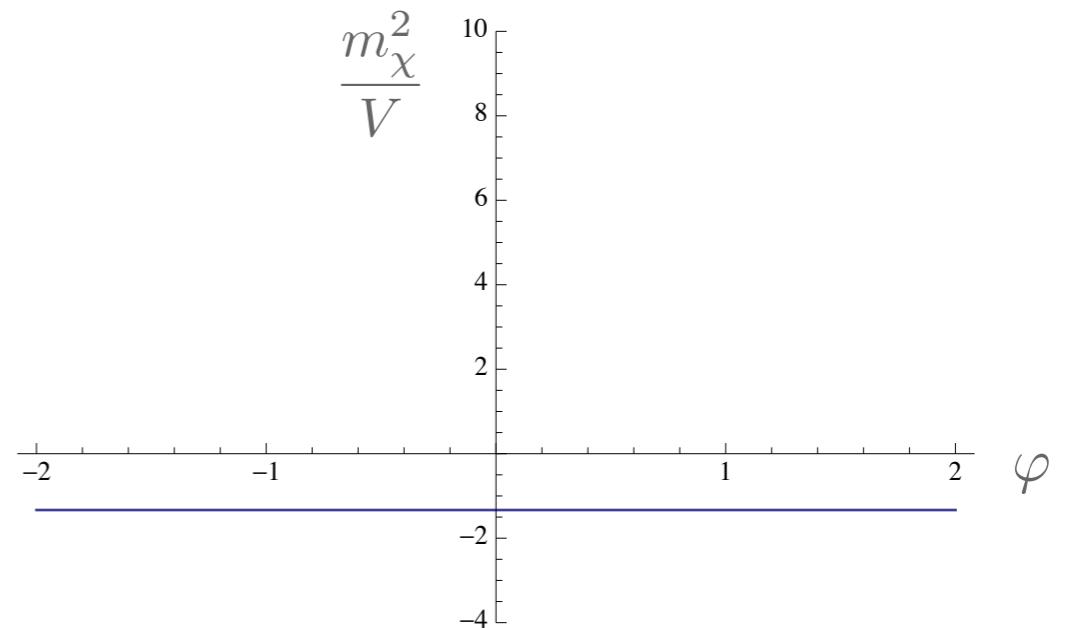
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$$\alpha = 1$$

α -scale supergravity and stable dS

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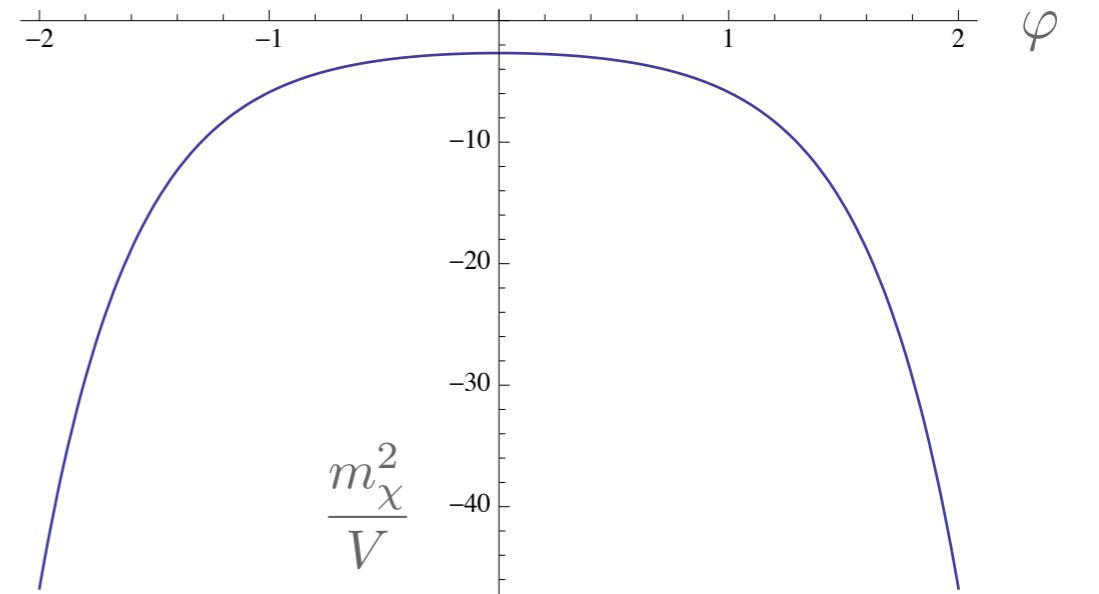
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$$\alpha < 1$$

basics of Supergravity

spin content

0 , 1/2 , 1 , 3/2 , 2



perfect correspondence
between **bosons** and
fermions



the fields Φ_i organize
themselves in a manifold

with metric

$$K_{i\bar{j}} = \partial_{\Phi_i} \partial_{\bar{\Phi}_j} K$$



canonical Kähler

$$K = \Phi_i \bar{\Phi}_j \Rightarrow K_{i\bar{j}} = \delta_{i\bar{j}}$$

$$V = e^K \left(K^{i\bar{j}} \mathcal{D}_i W \mathcal{D}_{\bar{j}} \bar{W} - 3|W|^2 \right)$$

K **Kähler potential**
hermitian function of Φ_i and $\bar{\Phi}_i$

W **Superpotential**
holomorphic function of Φ_i

allowing SUSY to be a
local symmetry