Inflation and Attractors from Nilpotent Kähler Corrections

Marco Scalisi

based on

E. McDonough and MS - JCAP 1611, n.11, 028 (2016) [arXiv:1609.00364]

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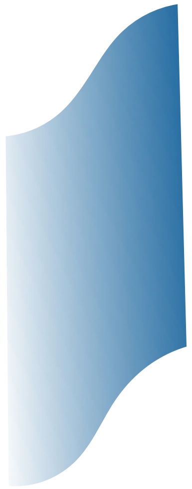
M17 Nebula in Sagittarius - Gianni Benintende (Sicily - Italy)

String Theory

Anti-D3 Brane



de Sitter

$$V > 0$$

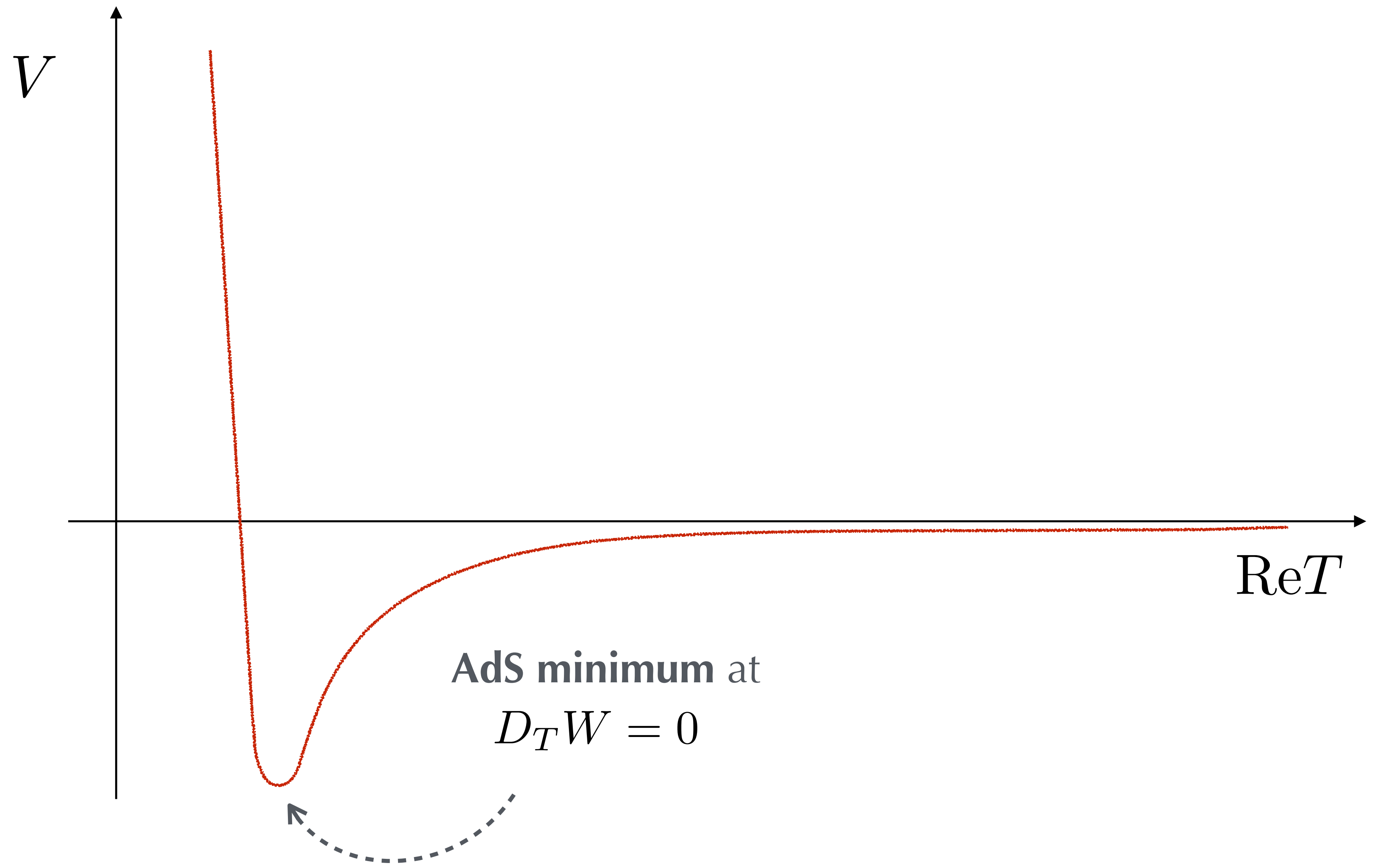
KKLT

Kachru, Kallosh, Linde, Trivedi 2003

$$K = -3\log(T+\bar{T})$$

$$W = W_0 + A\exp(-aT)$$

$$V = V_T$$



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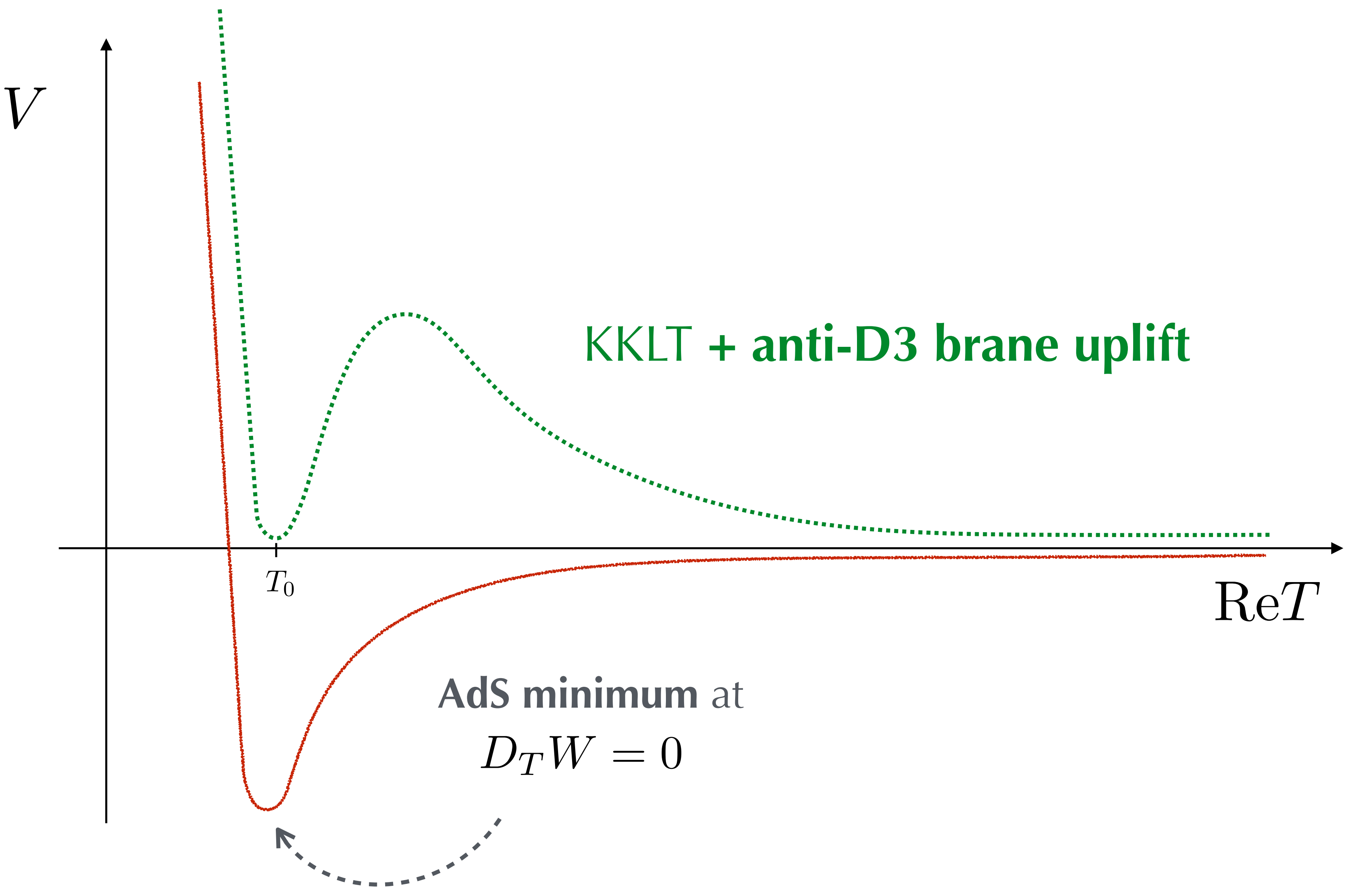

String Theory

Anti-D3 Brane

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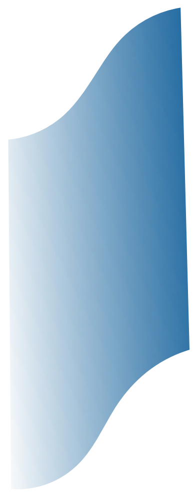
$$V > 0$$

String Theory

Anti-D3 Brane



de Sitter

$V > 0$

Supergravity

Nilpotent Superfield

The nilpotent superfield

$$S(x,\theta) = s(x) + \sqrt{2}\lambda(x)\theta + F(x)\theta^2$$

Volkov, Akulov 1972,1973

Rocek; Ivanov, Kapustnikov 1978

Lindstrom, Rocek 1979

Casalbuoni, De Curtis, Dominici, Feruglio, Gatto 1989

Komargodski, Seiberg 2009

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

$$\Downarrow$$

$$S(x,\theta) = \frac{\lambda\lambda}{2F} + \sqrt{2}\lambda\theta + F\theta^2$$

no scalar! **just fermions!**

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- SUSY **spontaneously broken** $F \neq 0$

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when coupled to SUGRA

de Sitter Supergravity

Bergshoeff, Freedman, Kallosh, Van Proyen 2015
Hasegawa, Yamada 2015

- SUSY **non-linearly** realized
- SUSY **spontaneously broken** $F \neq 0$

de Sitter supergravity

$$K = S\bar{S}$$

$$W = W_0 + MS$$ most general W as $S^2 = 0$

at $S = 0$

$$V = M^2 - 3W_0^2$$

no scalar degrees of freedom!

'de Sitter supergravity'

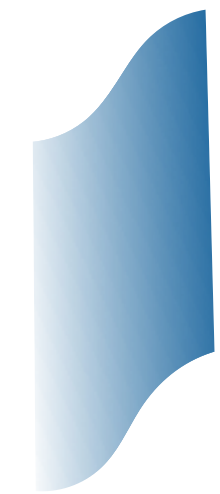
Antoniadis, Dudas, Ferrara, Sagnotti 2014
Bergshoeff, Freedman, Kallosh, Van Proyen 2015
Hasegawa, Yamada 2015

SUSY breaking of *S*

Gravitino mass

String Theory

Anti-D3 Brane



de Sitter

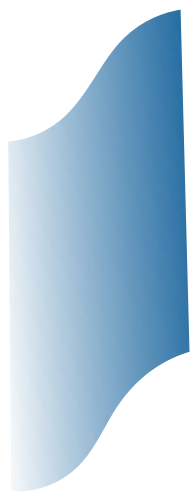
$V > 0$

Supergravity

Nilpotent Superfield

String Theory

Anti-D3 Brane



de Sitter

$V > 0$

Supergravity

Nilpotent Superfield

QUESTION **#1**

Does the Anti-D3 brane break SUSY spontaneously?

McGuirk, Shiu, Ye 2012

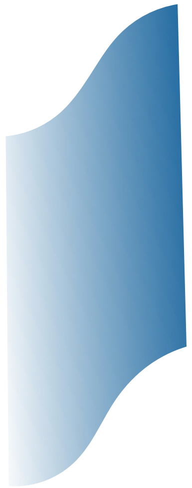
QUESTION **#2**

Can we package the uplifting term into *K* and *W*?

Ferrara, Kallosh, Linde 2014

String Theory

Anti-D3 Brane



Supergravity

Nilpotent Superfield

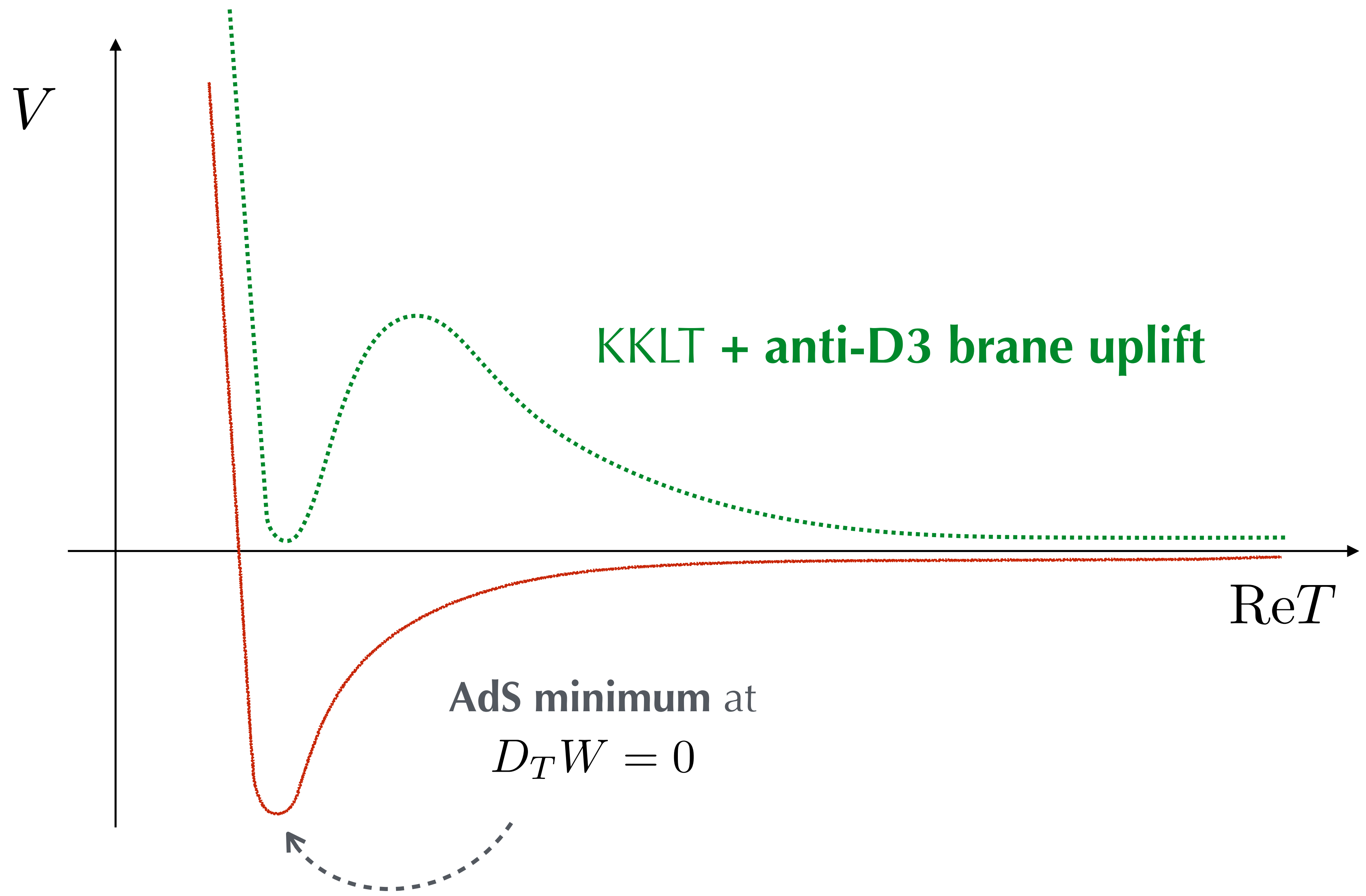
KKLT + Nilpotent Superfield

Ferrara, Kallosh, Linde 2014

$$K = -3\log(T + \bar{T} - S\bar{S})$$

$$W = W_0 + A\exp(-aT) + \mu^2 S$$

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



NILPOTENT SUPERFIELD <—-> D-BRANES

The **four dimensional** description of an **anti-D3 brane** in an N = 1 flux background is a supergravity theory of a **nilpotent superfield**.

Kallosh & Wrase 2014

NILPOTENT SUPERFIELD <—-> D-BRANES

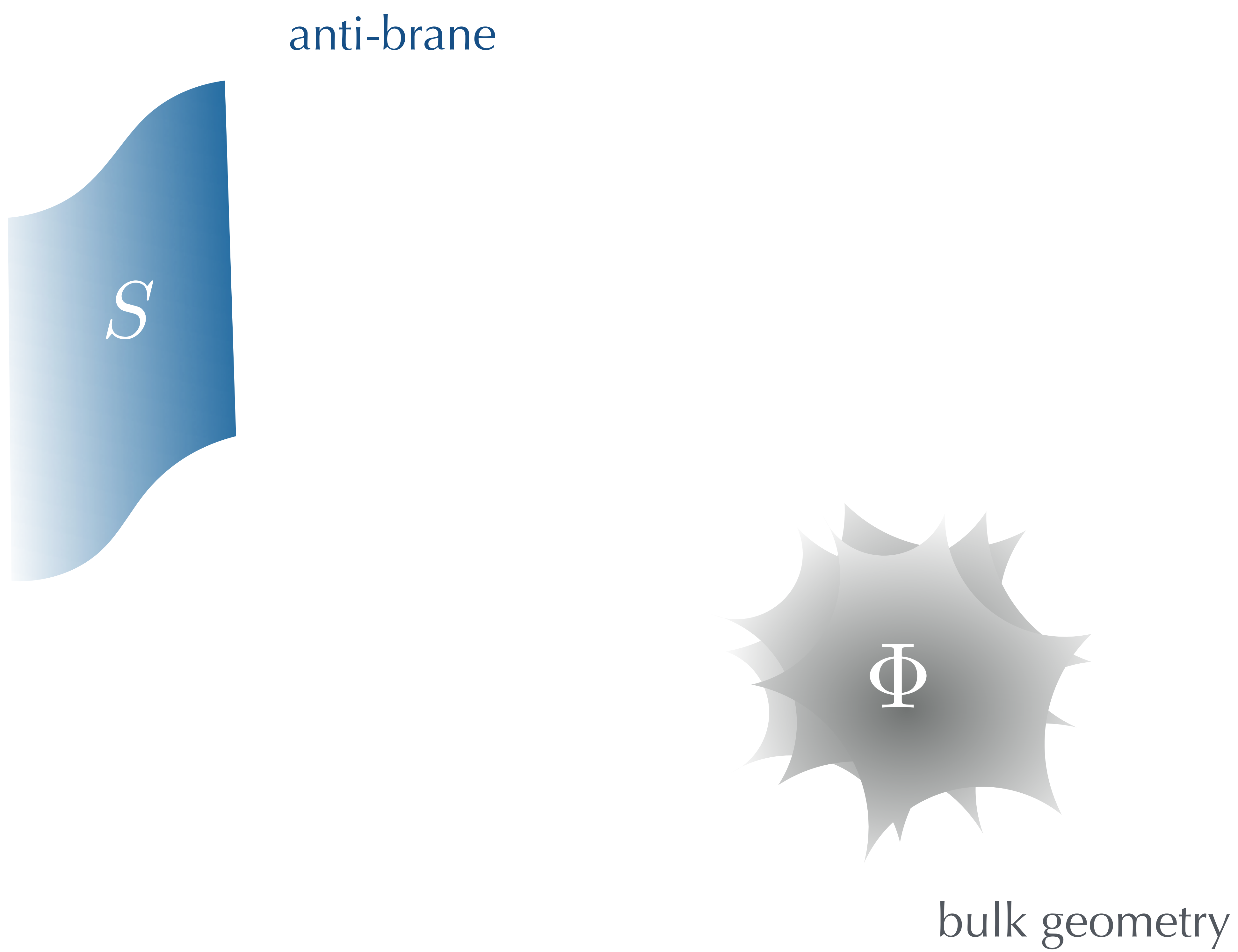
The **fermions** arising when one or more **anti-branes**, placed in certain geometries, break supersymmetry spontaneously can often be packaged into **constrained superfields**.

McGuirk, Shiu, Ye 2012
Kallosh & Wrase 2014
Bergshoeff, Dasgupta, Kallosh, Van Proeyen & Wrase 2014
Kallosh, Quevedo & Uranga 2015
Bertolini, Musso, Papadimitriou & Raj 2015
Aparicio, Quevedo & Valandro 2015
Garca-Etxebarria, Quevedo & Valandro 2015
Dasgupta, Emelin and McDonough 2016
Vercnocke & Wrase 2016
Kallosh, Vercnocke & Wrase 2016
Bandos, Heller, Kuzenko, Martucci and Sorokin 2016

Our Work

McDonough & MS 2016

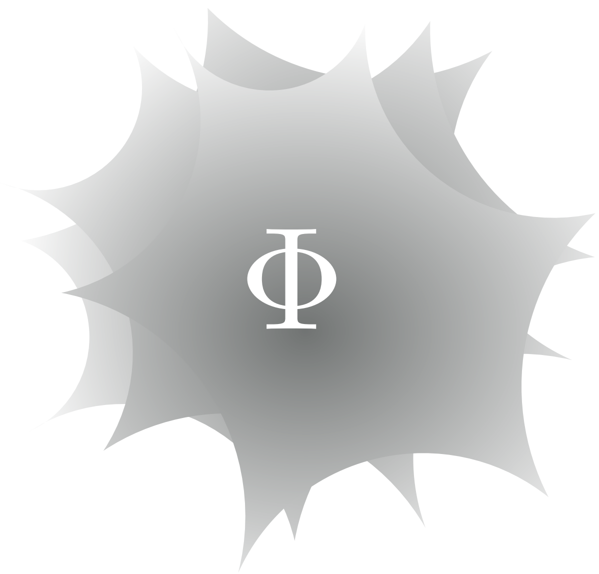
McDonough & MS 2016



McDonough & MS 2016

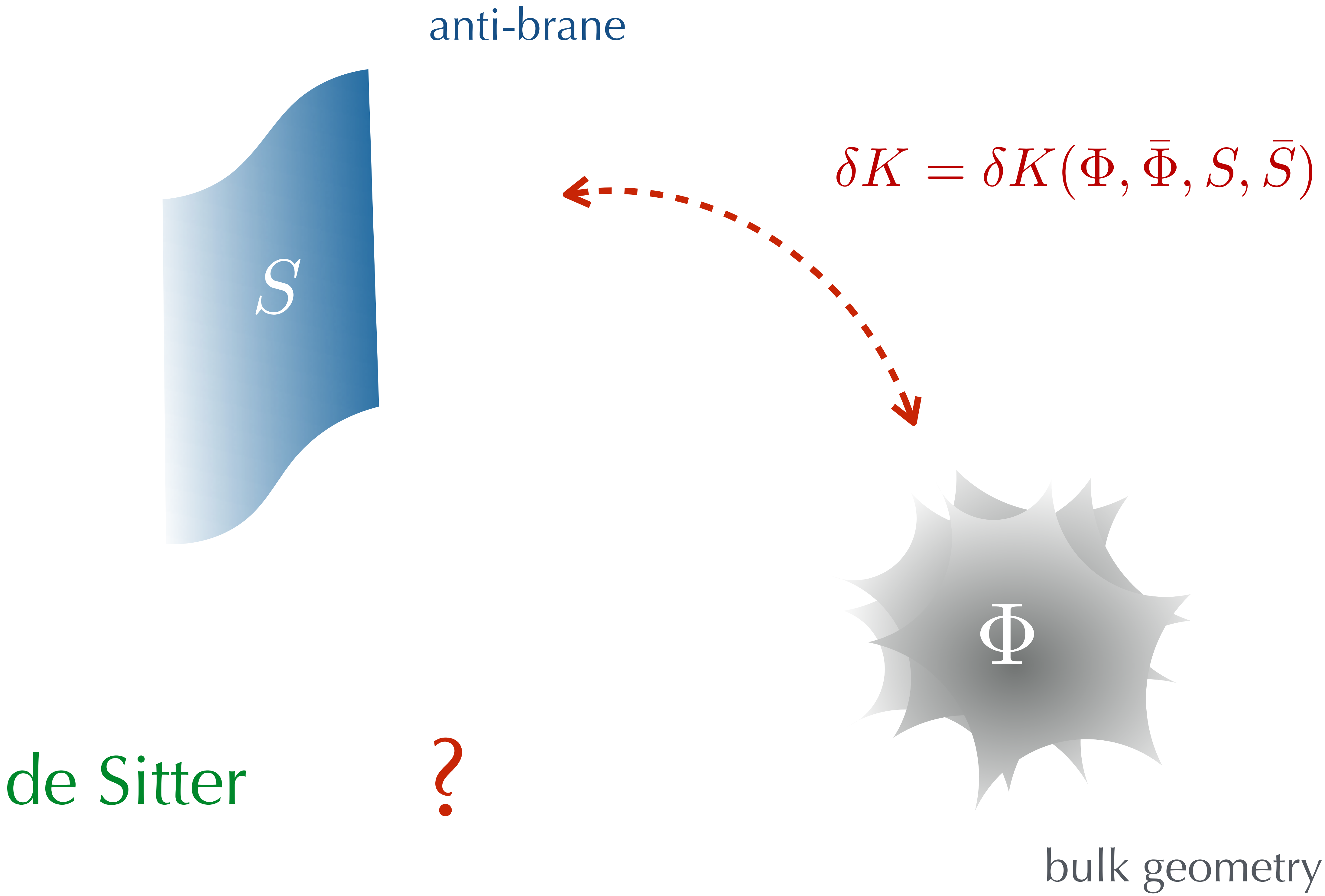
anti-brane

de Sitter



bulk geometry

McDonough & MS 2016



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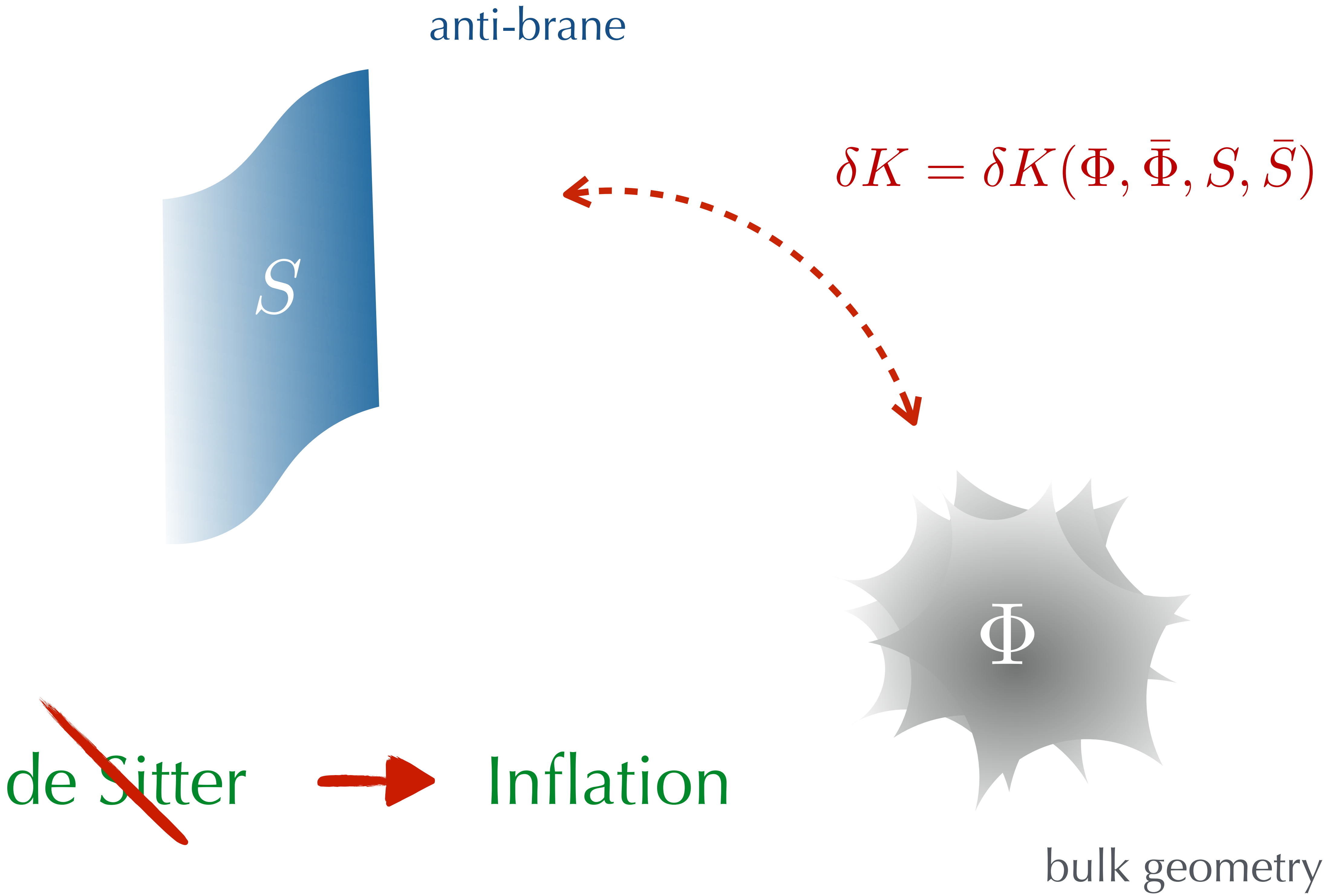

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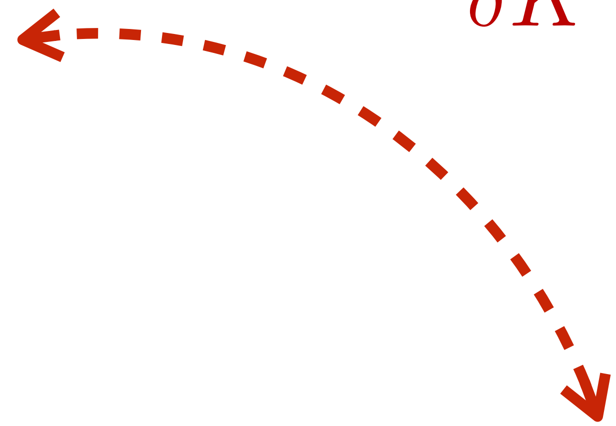

$$\delta K = \delta K(\Phi, \bar{\Phi}, S, \bar{S})$$

!

Renata Kallosh's talk

Kallosh, Linde, Roest, Yamada 2017

"anti-D3 brane induced inflation"

McDonough & MS 2016

$$K = S\bar{S}$$

$$W = W_0 + MS$$

↓ at $S = 0$

$$V = M^2 - 3W_0^2$$

Flat Kähler geometry

McDonough & MS 2016

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

$$W = W_0 + MS$$

↓ at $S = 0$ and at $Im\Phi = 0$

$$V = M^2 - 3W_0^2$$

no inflation! (shift symmetry not broken!)

Flat Kähler geometry

McDonough & MS 2016

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

inflation!

$$W = W_0 + MS$$

$$W = g(\Phi) + f(\Phi)S$$

Kallosh, Linde, MS 2014

at $S = 0$ and at $Im\Phi = 0$

Kallosh, Linde 2014

Dall'Agata,Zwirner 2014

$$V = M^2 - 3W_0^2$$

no inflation! (shift symmetry not broken!)

Flat Kähler geometry

McDonough & MS 2016

$$K = S\bar{S} - \frac{1}{2}\left(\Phi - \Phi\right)^2 + \underbrace{f(\Phi,\bar{\Phi})S\bar{S} + g(\Phi,\bar{\Phi})(S+\bar{S})}_{\delta K}$$

$$W = W_0 + MS$$

Flat Kähler geometry

McDonough & MS 2016

$$K = -\tfrac{1}{2}\left(\Phi - \bar{\Phi}\right)^2 + \left[1 + f\left(\Phi, \bar{\Phi}\right)\right] S\bar{S}$$

$$W = W_0 + MS$$

Flat Kähler geometry

McDonough & MS 2016

$$K = -\frac{1}{2}\left(\Phi - \bar{\Phi}\right)^2 + \left[1 + f\left(\Phi, \bar{\Phi}\right)\right] S\bar{S}$$

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$G_{S\bar{S}}$ *in Kallosh's talk*

Flat Kähler geometry

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$$K = -\frac{1}{2}\left(\Phi - \bar{\Phi}\right)^2 + \left[1 + f\left(\Phi, \bar{\Phi}\right)\right] S\bar{S}$$

$\rightarrow G_{S\bar{S}}$ *in Kallosh's talk*

$$W = W_0 + MS$$

at $S = 0$ and at $Im\Phi = 0$

$$V = M^2 F(\Phi) - 3W_0^2$$

$$F(\Phi) \equiv \frac{1}{1 + f(\Phi, \Phi)}$$

Flat Kähler geometry

McDonough & MS 2016

$$K = -\tfrac{1}{2}\left(\Phi - \bar{\Phi}\right)^2 + \left[1 + f\left(\Phi, \bar{\Phi}\right)\right] S\bar{S}$$

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$\to G_{S\bar{S}}$ *in Kallosh's talk*

at $S = 0$ and at $Im\Phi = 0$

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Phenomenological Flexibility

- Arbitrary **Inflationary Potential**
- Controllable level of **SUSY breaking**
- Tunable level of the **CC**

! ***SUSY broken just in the S direction***

$$D_\Phi W = 0 \qquad D_S W = M$$

Ex. Quadratic Inflation

McDonough & MS 2016

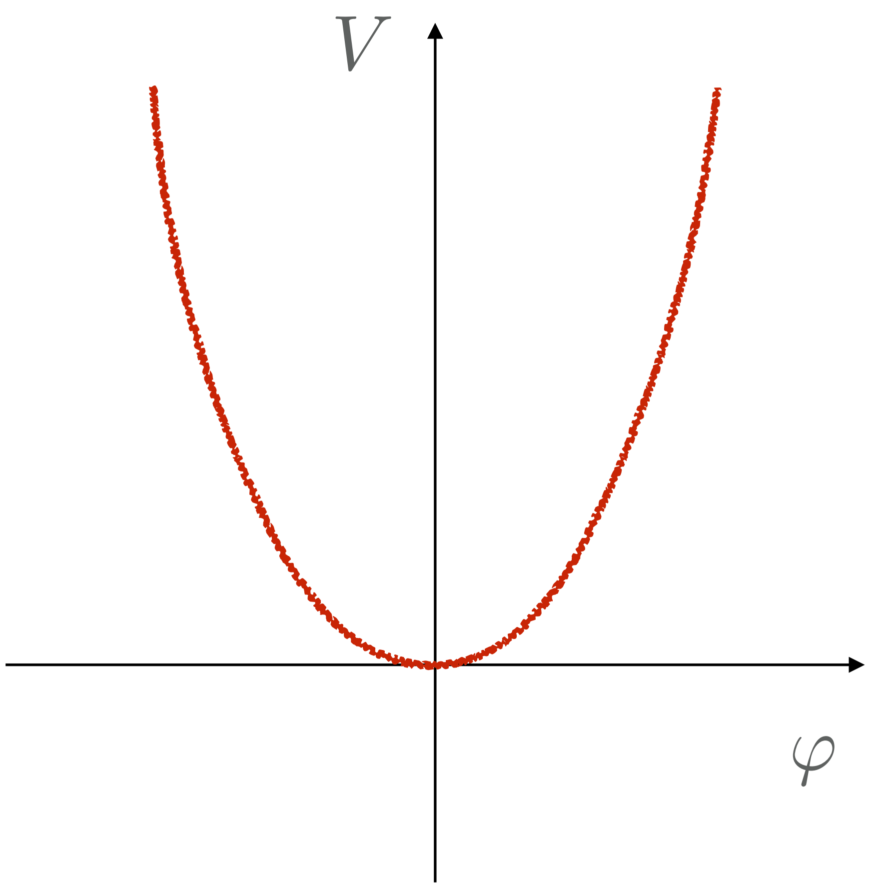
$$K = -\tfrac{1}{2}\left(\Phi - \bar{\Phi}\right)^2 + S\bar{S} - \frac{m^2}{2M^2}\Phi\bar{\Phi}\cdot S\bar{S}$$

$$W = W_0 + MS$$

at $S = 0$ and at $Im\Phi = 0$

$$V = \left(M^2 - 3W_0^2\right) + \frac{1}{2}m^2\varphi^2$$

with $\varphi = \sqrt{2}\mathrm{Re}\Phi$



Hyperbolic Kähler geometry

McDonough & MS 2016

$$K = S\bar{S} - 3\alpha \log\left(\frac{\Phi + \bar{\Phi}}{2|\Phi|}\right)$$

$$W = W_0 + MS$$

at $S = 0$ and at $Im\Phi = 0$

$$V = M^2 - 3W_0^2$$

no inflation! (shift symmetry not broken!)

Hyperbolic Kähler geometry

McDonough & MS 2016

$$K = S\bar{S} - 3\alpha \log\left(\frac{\Phi + \bar{\Phi}}{2|\Phi|}\right) + f(\Phi, \bar{\Phi})S\bar{S} + g(\Phi, \bar{\Phi})(S + \bar{S})$$

δK

$$W = W_0 + MS$$

at $S = 0$ and at $Im\Phi = 0$

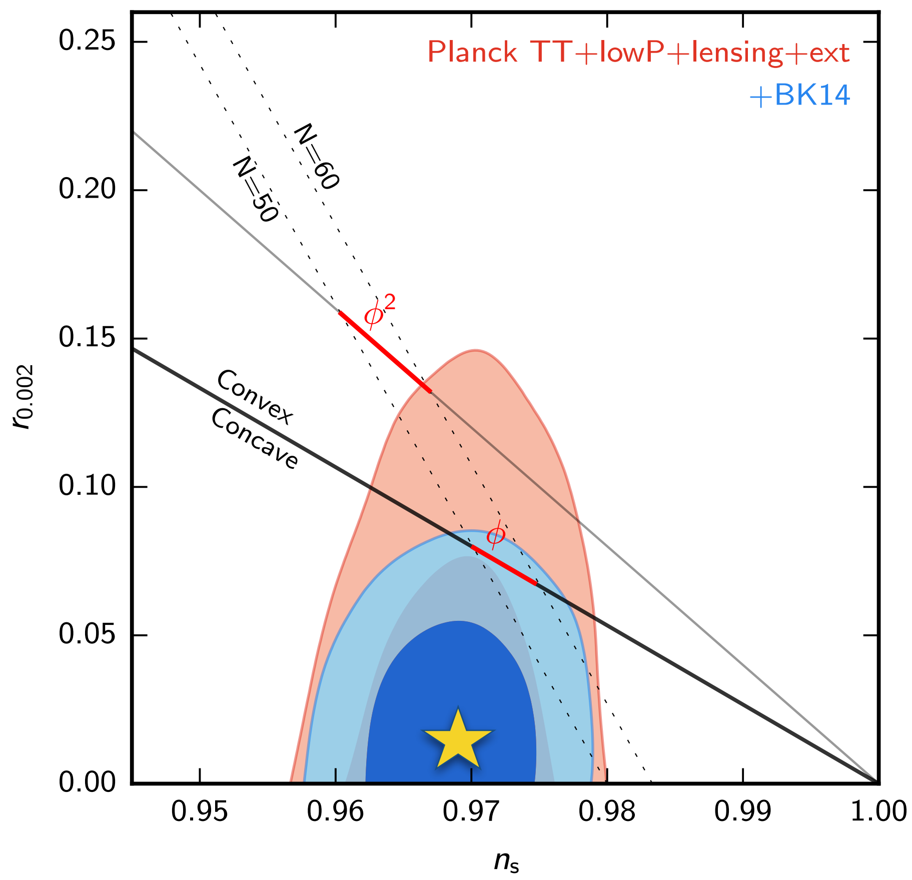
$f = \sum_{n=1}^{\infty} f_n |\Phi|^n \quad g = \sum_{n=1}^{\infty} g_n |\Phi|^n$ small perturbative corrections!

$$V = V_0 + V_1 \exp\left(-\sqrt{2/3\alpha}\,\varphi\right) + \dots$$

$$V_0 = M^2 - 3W_0^2$$

Hyperbolic Kähler geometry

McDonough & MS 2016



α-attractors

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

see Linde's and Yamada's talk

$$V = V_0 + V_1 \exp\left(-\sqrt{2/3\alpha}\ \varphi\right) + \dots$$

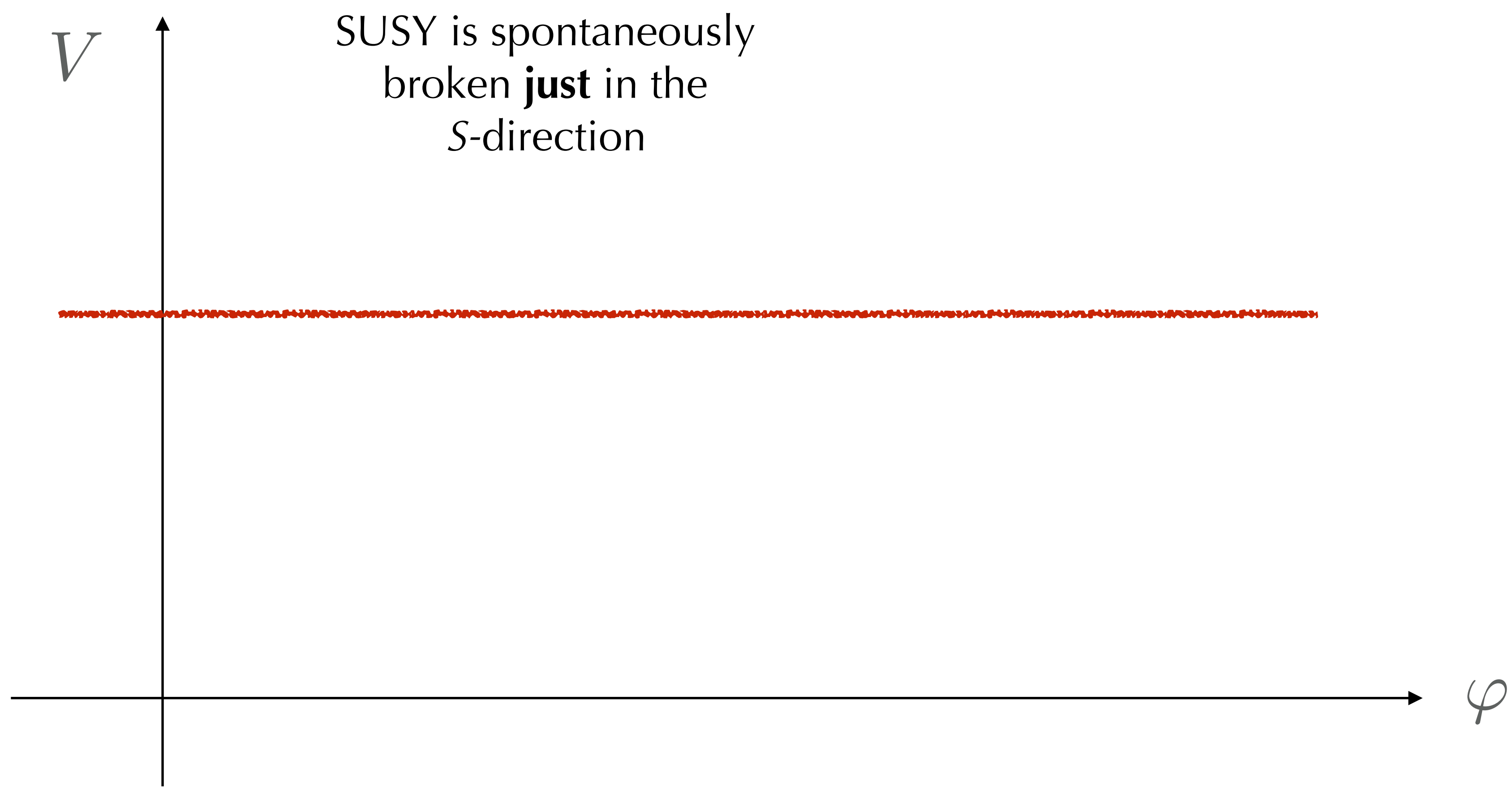
$$V_0 = M^2 - 3W_0^2$$

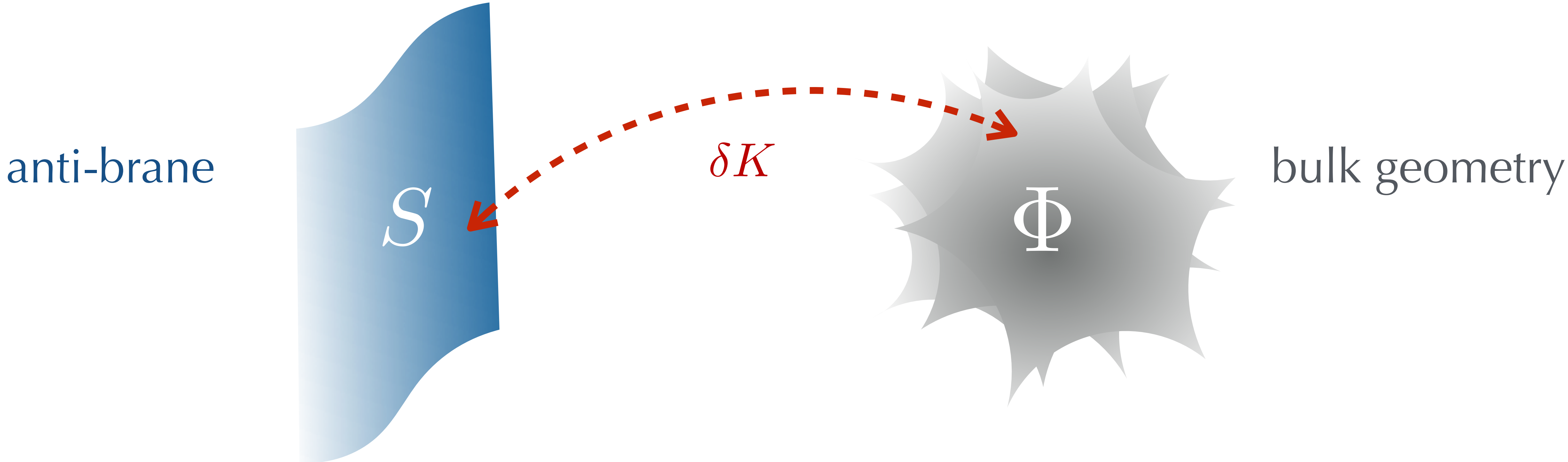
Recap-Cartoon

anti-brane

bulk geometry

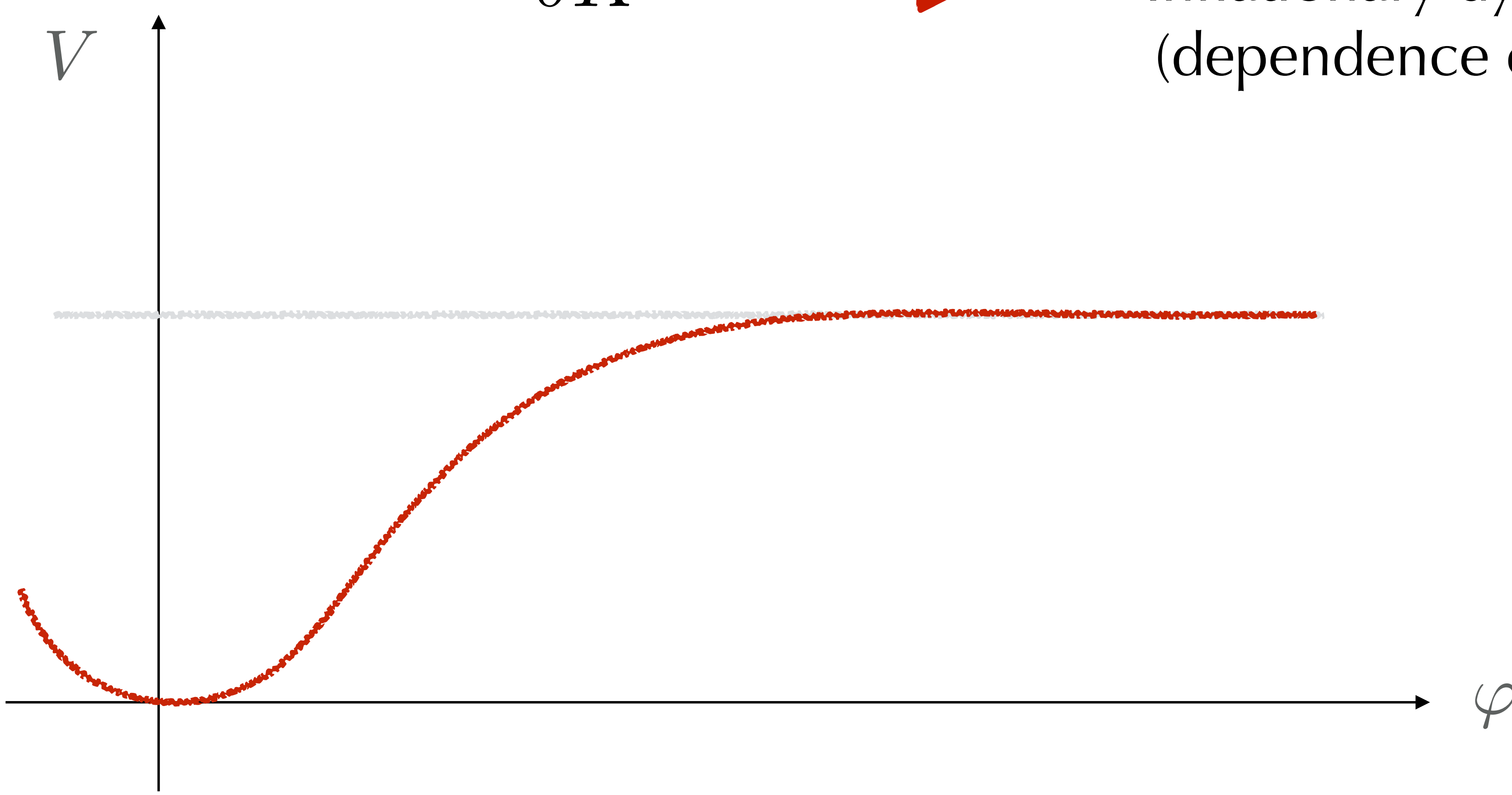
$D_S W \neq 0$ → pure de Sitter

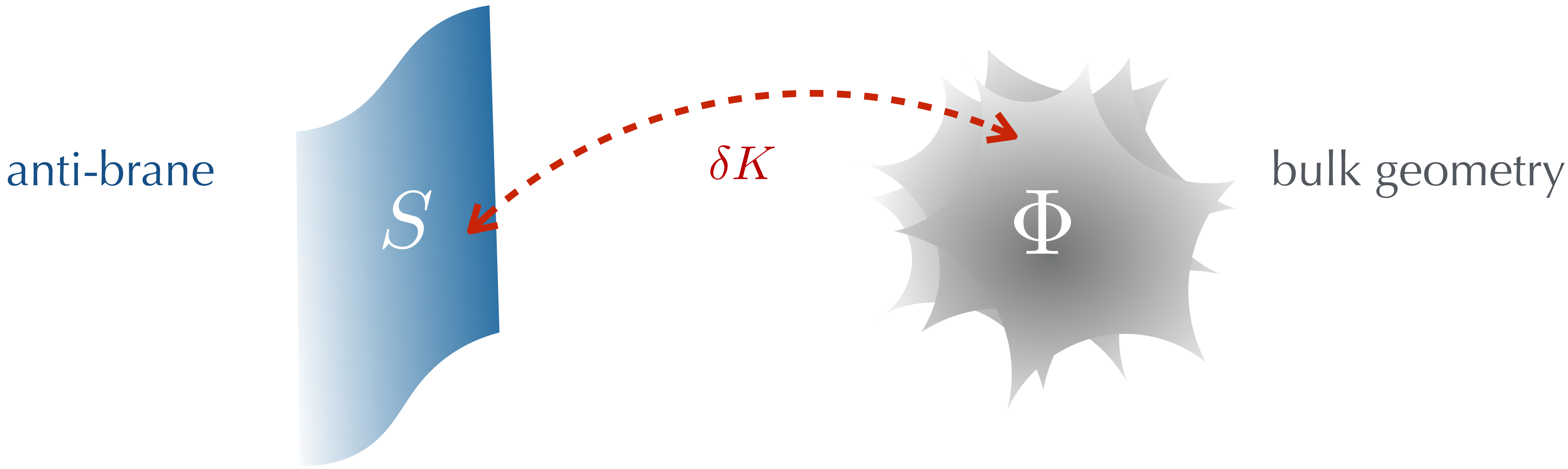




$D_S W \neq 0$ → Hubble inflationary energy

δK → Inflationary dynamics (dependence on Φ)





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