On Type IIA Cosmology From Geometric Fluxes

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Based on : 0812.3551 (Caviezel, Koerber, Körs, Lüst, Wrase, M.Z.)
0806.3458 (Caviezel, Koerber, Körs, Lüst, Tsimpis, M.Z.)
(0812.3886 (Flauger, Paban, Robbins, Wrase))

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An important problem in string phenomenology:

Moduli stabilization

$\Rightarrow \mathbf{V}(\varphi^{\mathbf{i}})$

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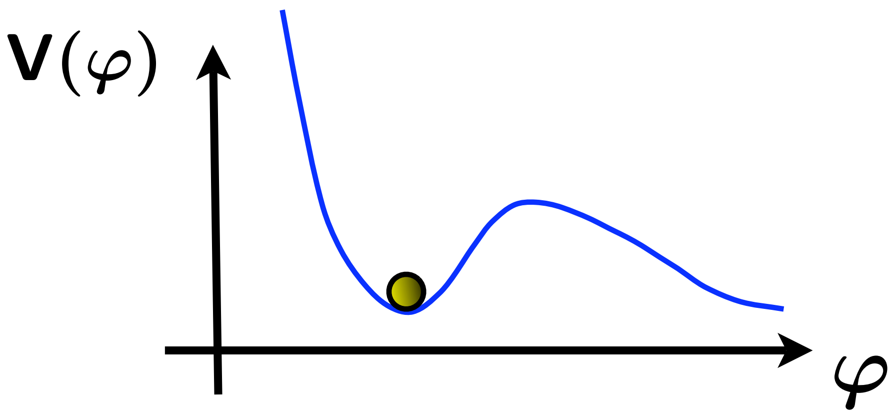
Particularly interesting:

$\mathbf{V}(\varphi^{\mathbf{i}}) > \mathbf{0}$

Positive potential energy for:

(i) de Sitter vacua

($\Lambda > 0 \Rightarrow$ Today's accelerated expansion)



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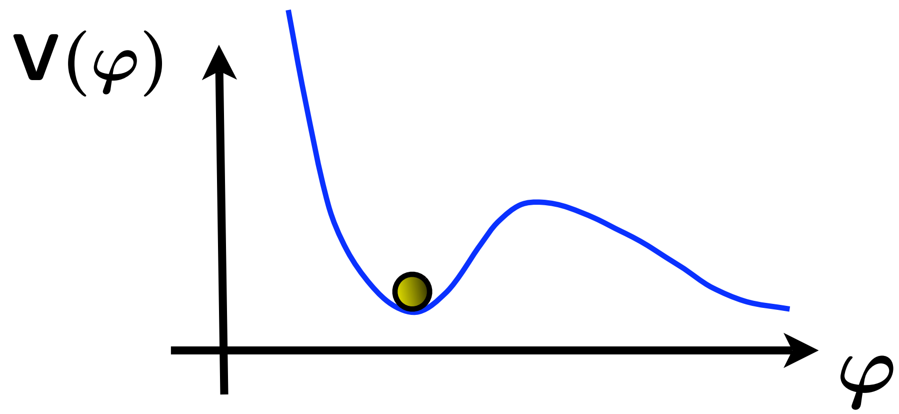
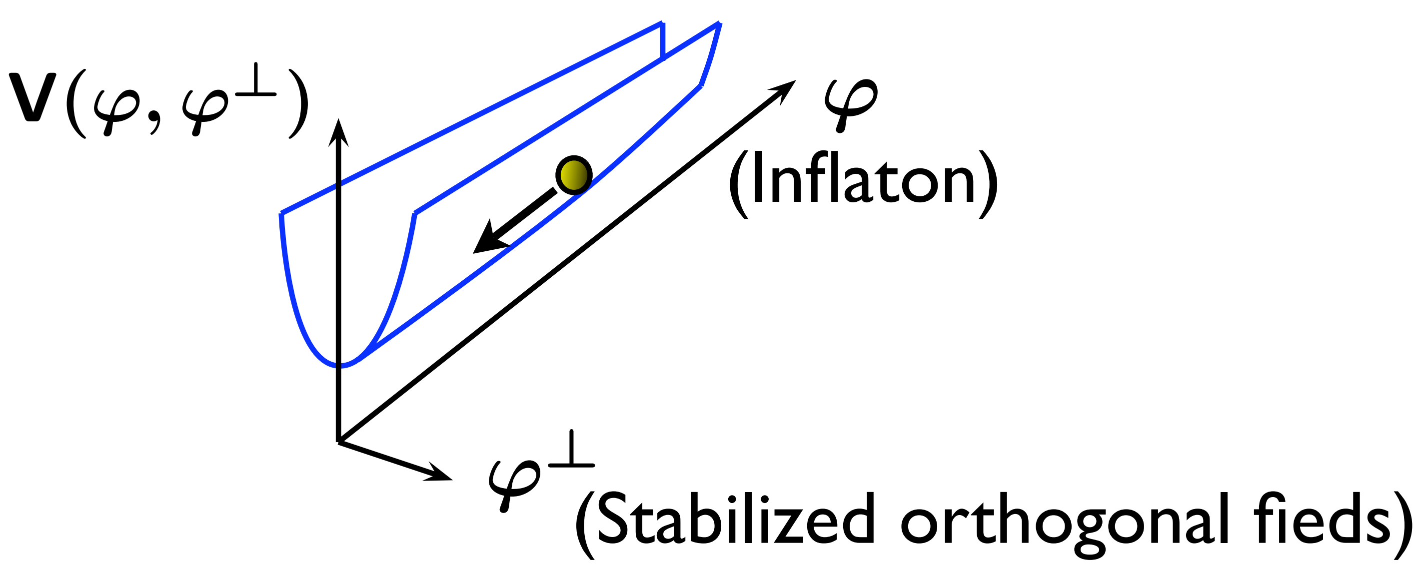


(ii) Slow-roll inflation



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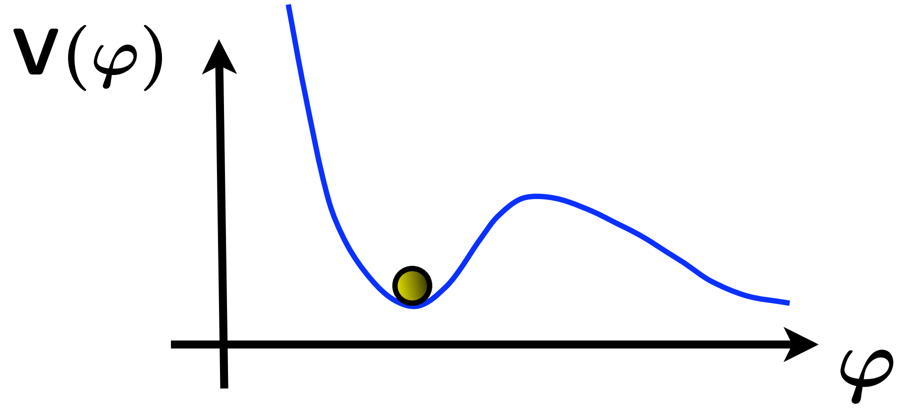

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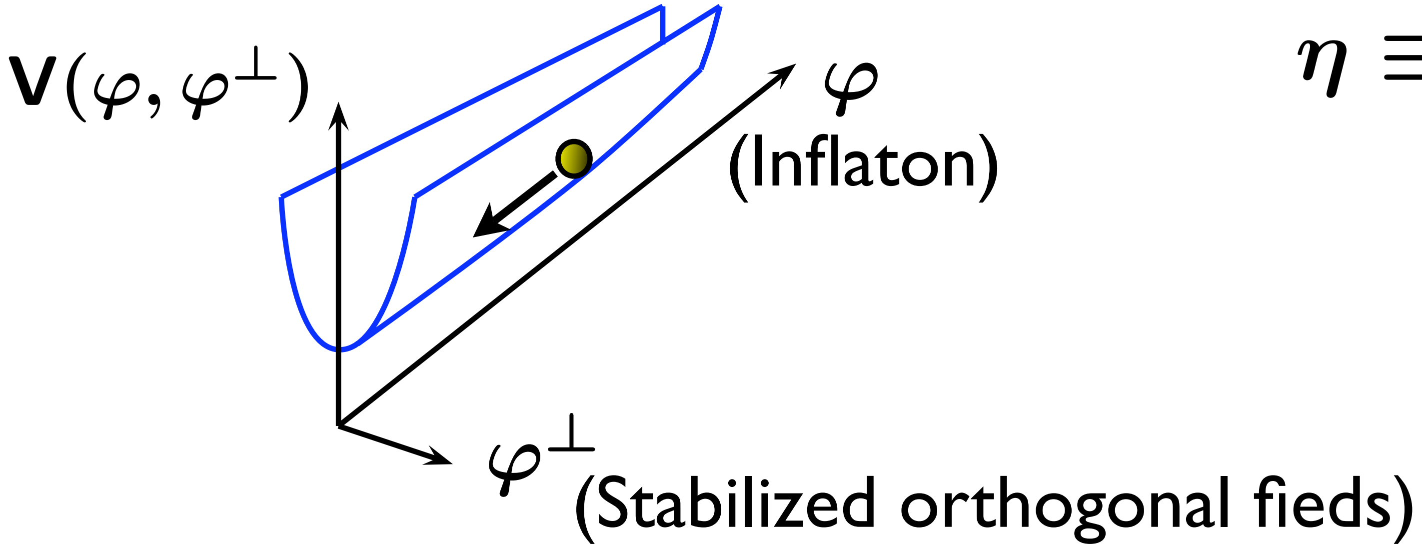

$$\epsilon \equiv \frac{1}{2} g^{ij} \frac{(\partial_{\varphi^i} V)\,(\partial_{\varphi^j} V)}{V^2}$$

$$\eta \equiv \text{Min. eig.val.} \left(\frac{\nabla^i \partial_j V}{V} \right)$$

$$\epsilon, |\eta| \ll 1$$

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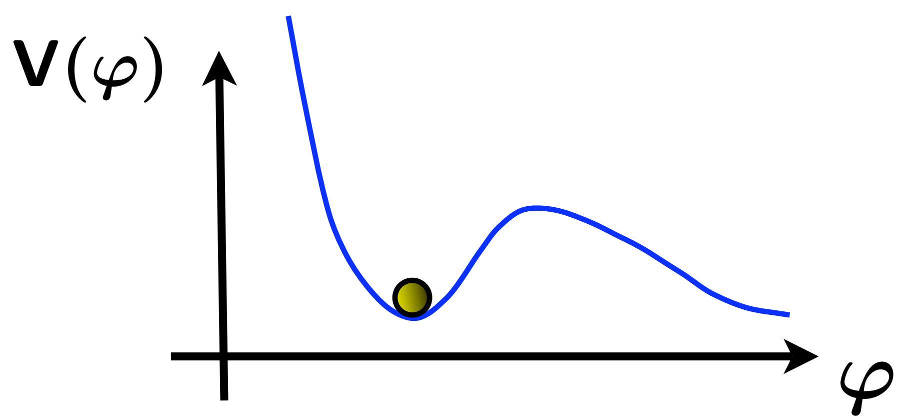

$$\epsilon = 0, \quad \eta > 0$$

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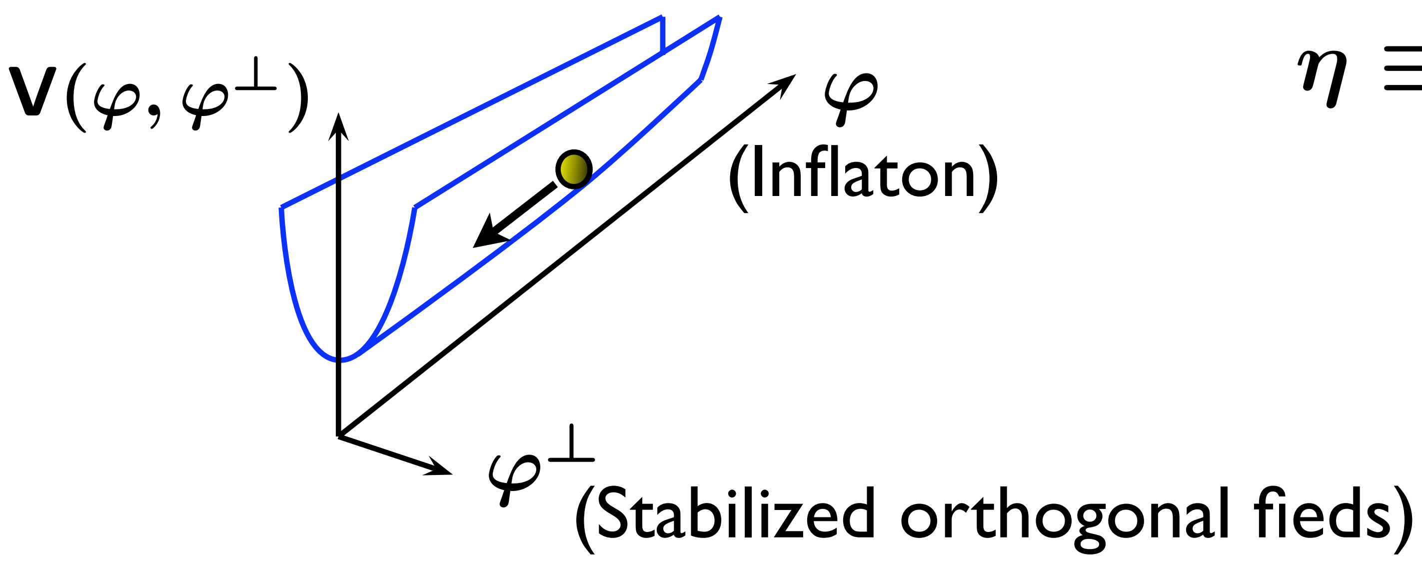

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A general problem:

Typical scalar potentials receive many contributions and corrections

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Often:

Subtle interplay of

classical and quantum effects

E.g. KKLT; Conlon, Quevedo, ...

classical → Easy

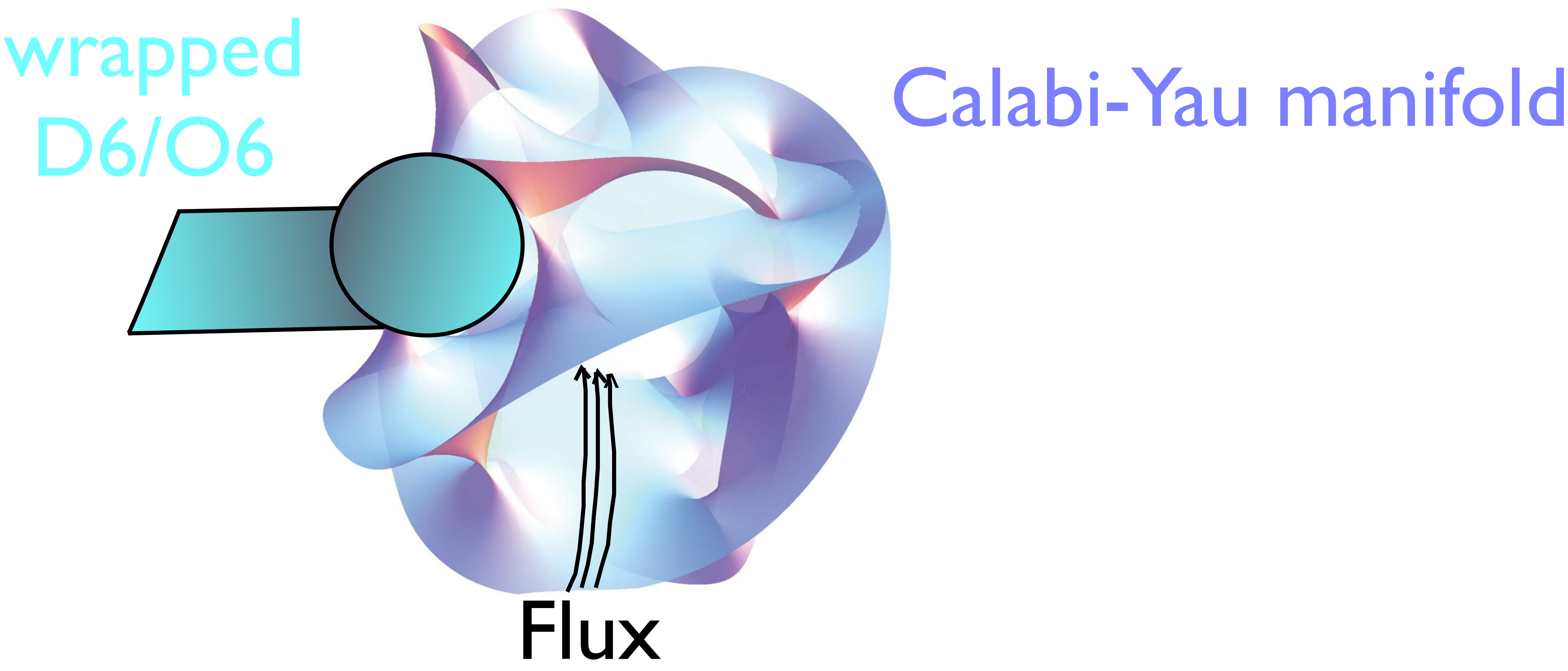
quantum effects → Hard to compute precisely

Cf. McAllister's talk

A nice laboratory:

Type IIA on Calabi-Yau spaces with

- Magnetic fluxes of p-form field strengths
- D6-branes/O6-planes



Observation:

All geometric moduli can be stabilized at tree-level

Grimm, Louis (2004); Kachru, Kashani-Poor (2004)

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In special cases:

- All moduli stabilized
- Parameterically controlled classical regime

$\Rightarrow$ Quantum corrections small

Derendinger, Kounnas, Petropoulos, Zwirner (2004, 2005)
Villadoro, Zwirner (2005)
de Wolfe, Giryavets, Kachru, Taylor (2005)

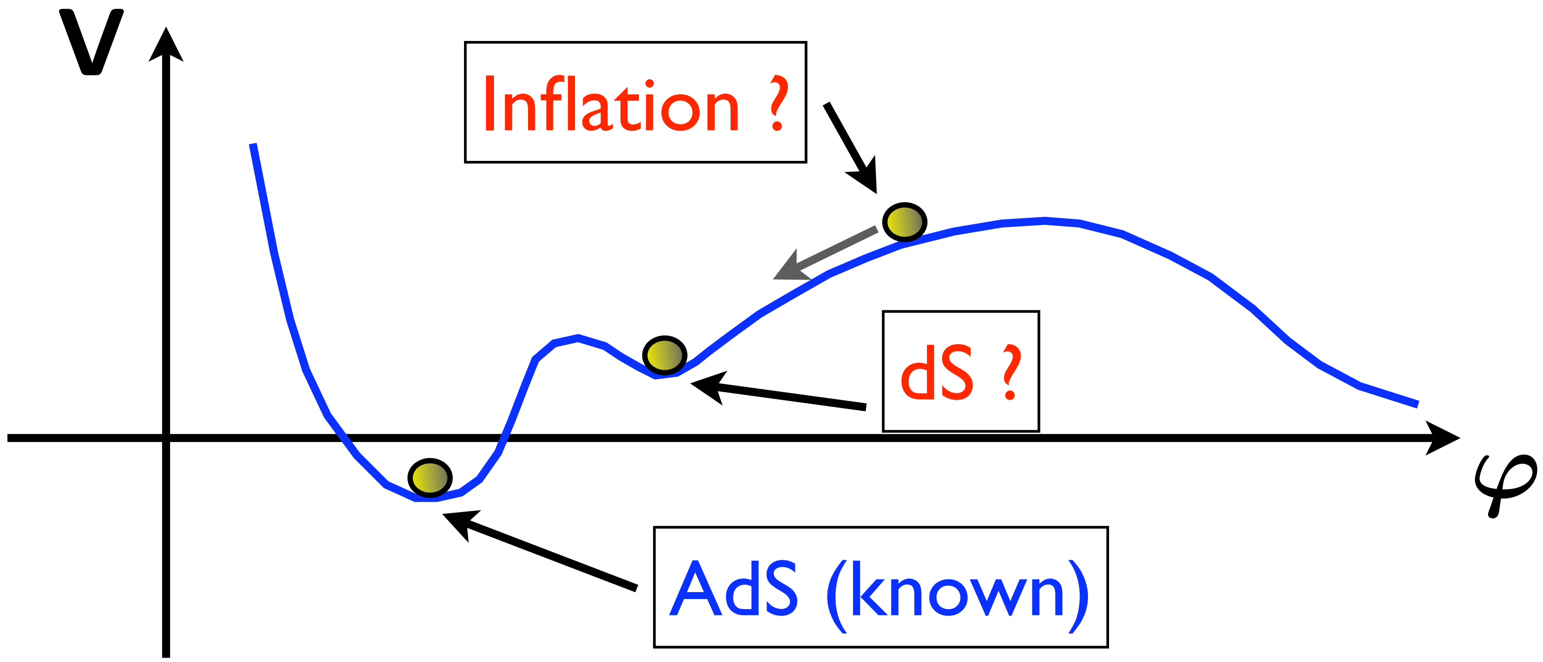
Unfortunately...

All these stabilized vacua have

$\Lambda<0$ ($\Rightarrow$AdS)

Two possibilities:

(i) Search for dS/inflation away from AdS vacuum



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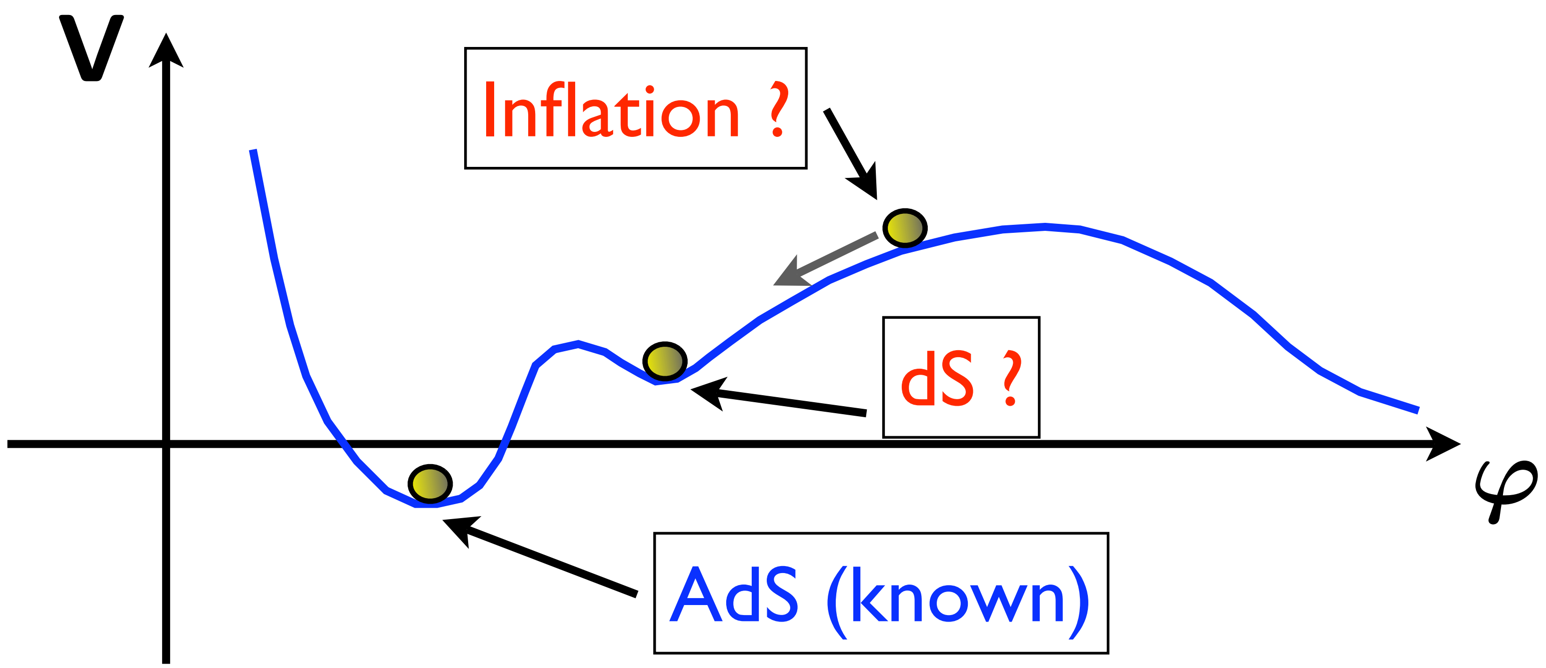
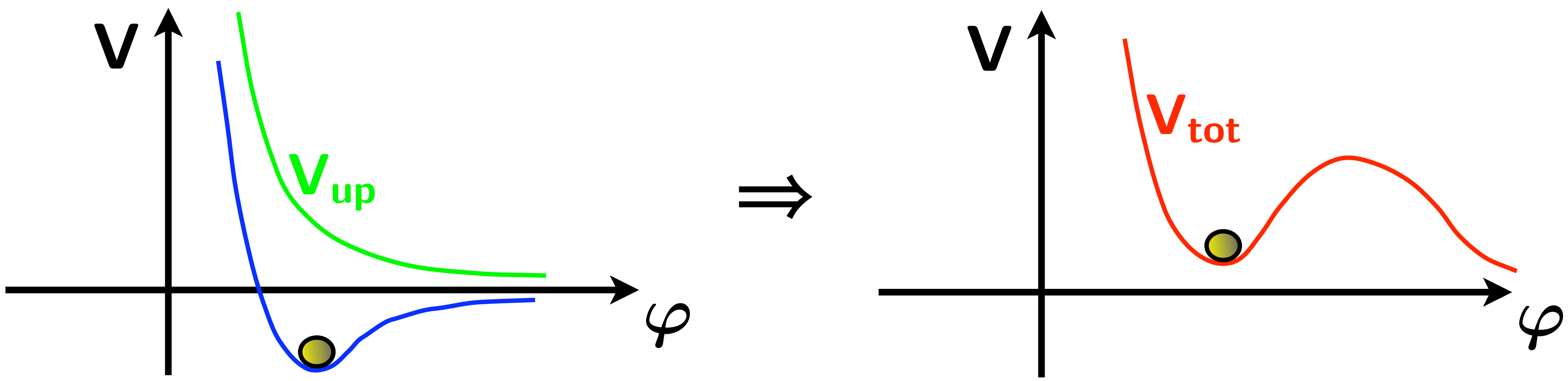
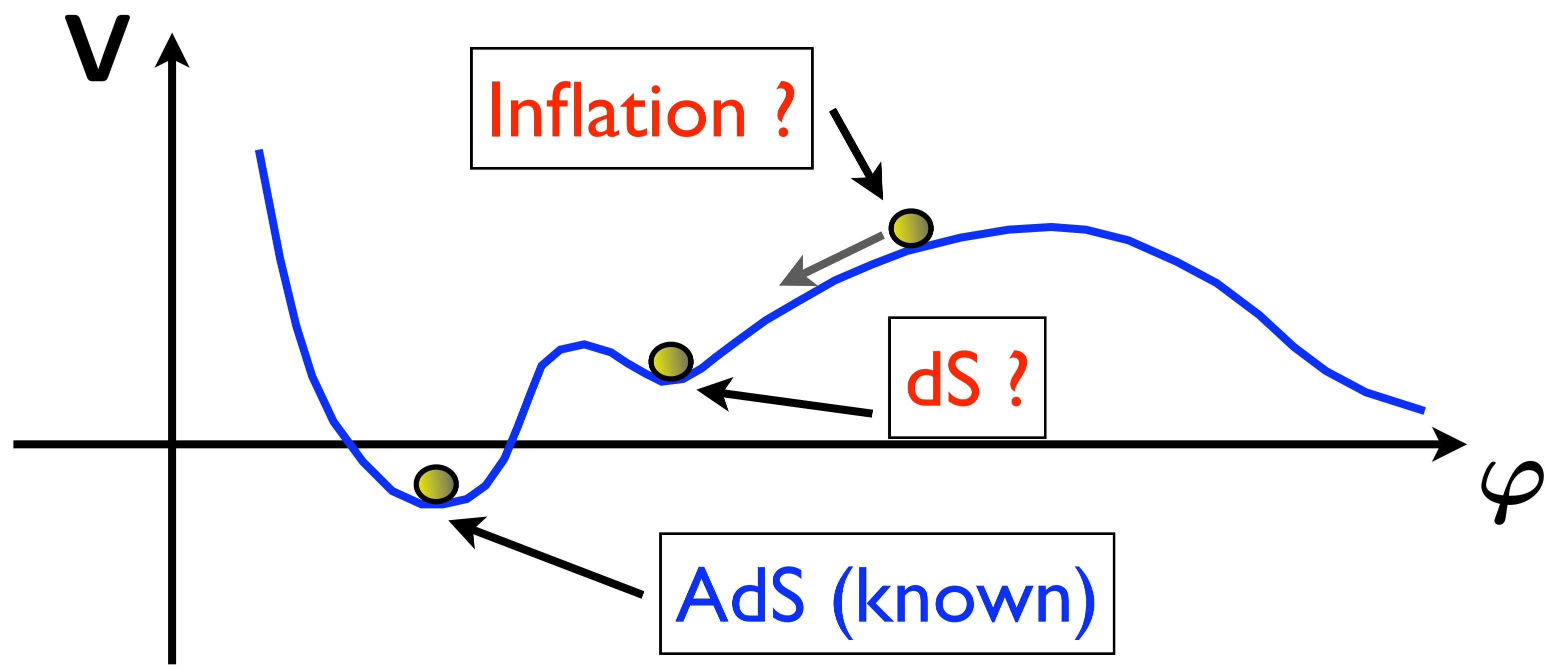


(ii) Add additional ingredients ⇒ “Uplift potentials”



(i) dS or inflation away from AdS vacuum?



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No-go theorem:

Classical IIA compactifications with

- $\mathcal{M}^{(6)} =$ Calabi-Yau ($\rightarrow$Ricci-flatness)
- O6/D6 sources
- p-form fluxes (incl. Romans' mass)

$\Rightarrow$No de Sitter vacua and no slow-roll inflation !

Hertzberg, Kachru, Taylor, Tegmark (2007)

Note: Due to the O6-planes ($\rightarrow$ negative tension), this goes beyond no-go theorem by Maldacena-Nuñez (2000)

Cf. also Wesley, Steinhardt (2008)

Sketch of proof:

Consider scaling of potential w.r.t.

$$\rho \equiv (\mathbf{Vol})^{1/3}$$

$$\tau \equiv \mathbf{e}^{-\phi}\sqrt{\mathbf{Vol}} \qquad (\phi = \text{10D Dilaton})$$

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$$V(\rho, \tau, \ldots) = V_3 + \sum_{p=0,2,4,6} V_p + V_{O6/D6}$$

H_3 → V_3; F_p → V_p

$V_3 \propto \rho^{-3}\tau^{-2}$

$V_p \propto \rho^{3-p}\tau^{-4}$

$V_{O6/D6} \propto \pm\tau^{-3}$

$$\Rightarrow \quad \mathbf{DV} \equiv (-\rho\partial_\rho - 3\tau\partial_\tau)\mathbf{V} \geq 9\mathbf{V}$$

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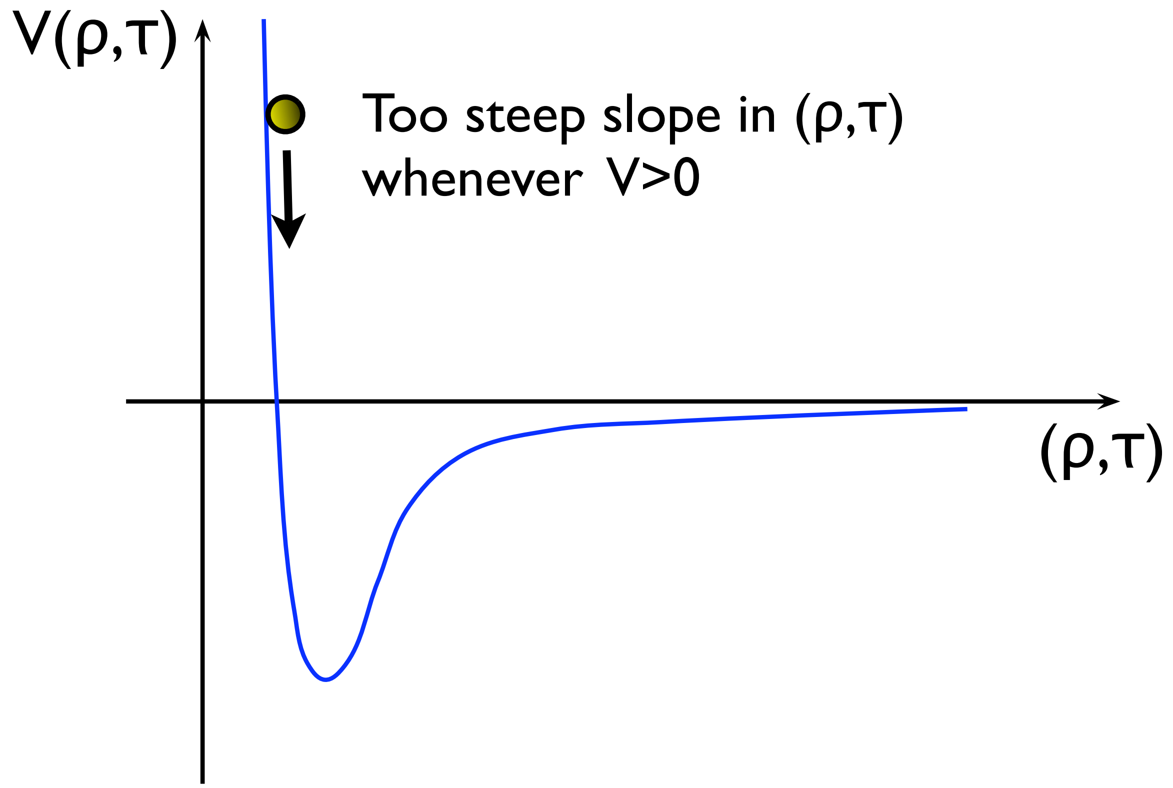

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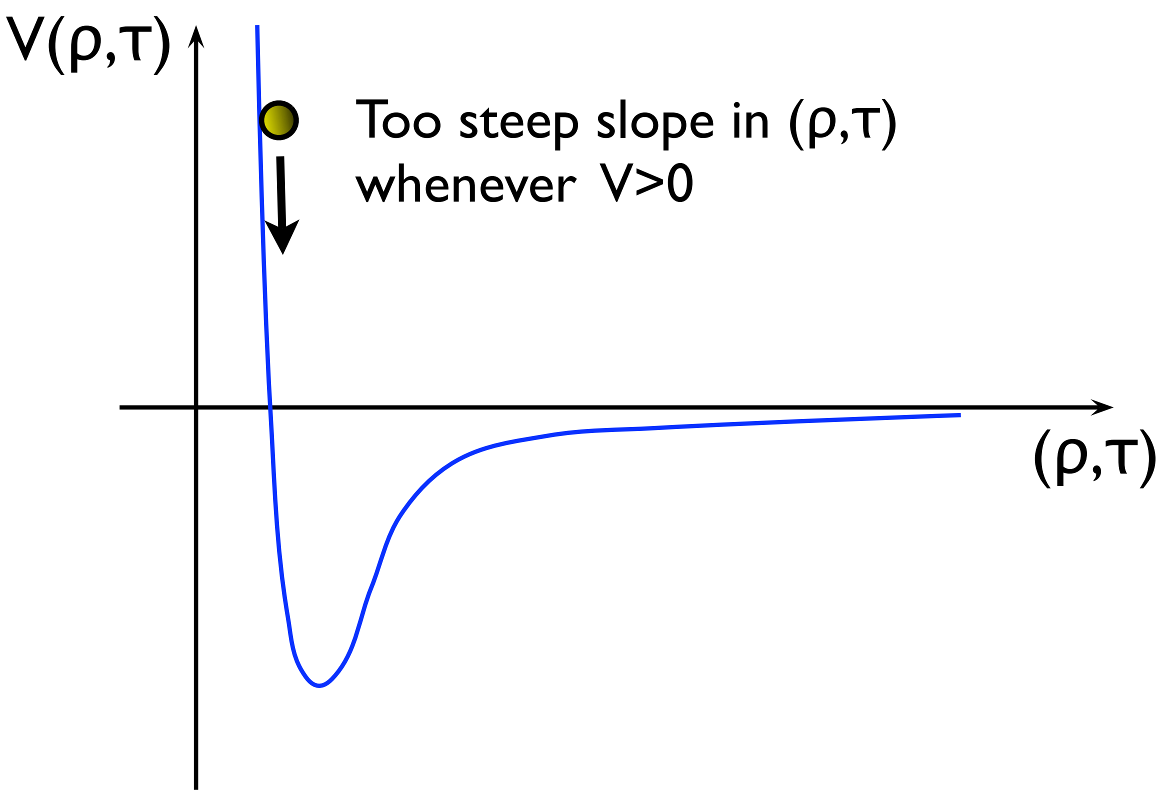

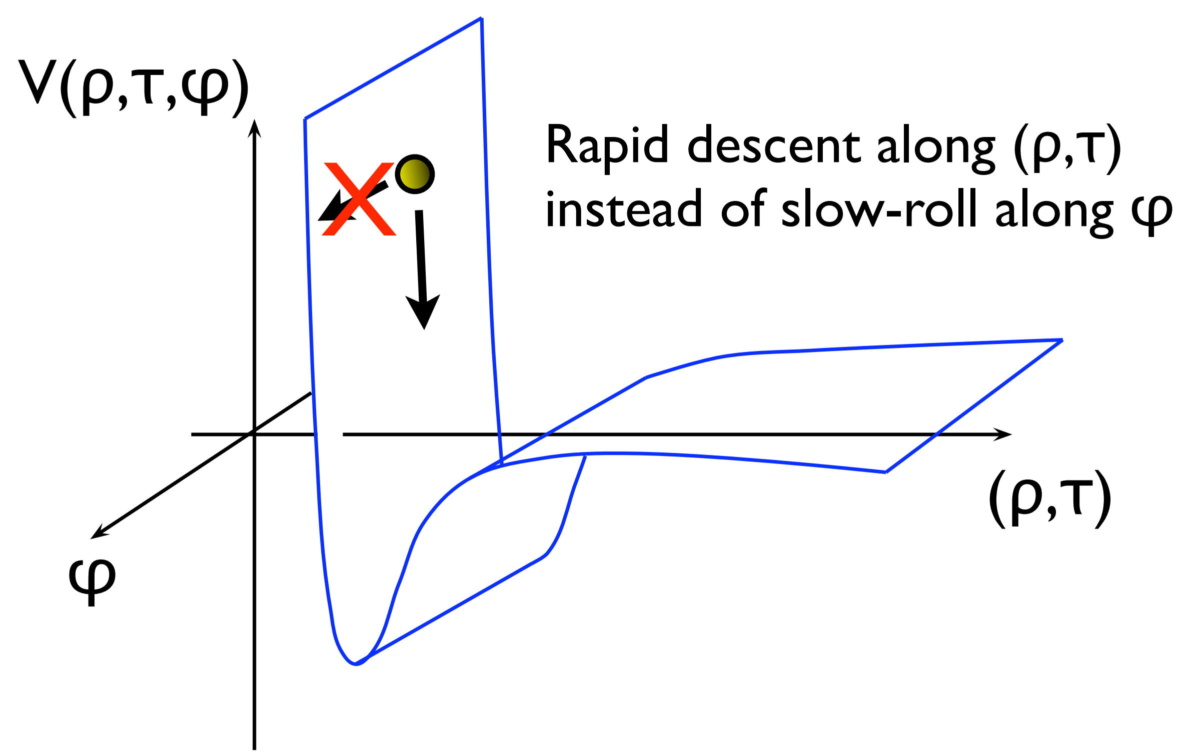

Possible caveats:

- Quantum corrections — E.g. Saueressig, Theis, Vandoren (2005); Palti, Tasinato, Ward (2008)

- Additional classical ingredients
  - "Geometric fluxes" ("Torsion")
    (= geometric twisting away from CY $\Rightarrow R_{mn} \neq 0$)
  - O4-planes
  - D8-branes
  - NS5-branes
  - KK5-monopoles
  - "Nongeometric fluxes"

  ⋮

Silverstein (2007):

For classical de Sitter vacua add, e.g.:

- Geometric fluxes
  (Particular twisted torus)
- KK5-monopoles
- Fractional Chern-Simons invariants

Some issues to keep in mind:

- High SUSY breaking scale
- No large mass gap to KK modes
- Backreaction under control?

What is the minimal controllable setup?

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Best understood extra ingredient:

Geometric fluxes

$\Rightarrow$ Are they sufficient ?

Three recent works:

(i) Haque, Shiu, Underwood, Van Riet (2008)

$$\mathcal{M}^{(6)} = (\mathrm{Nil}_3 \times \mathrm{Nil}_3')/\mathcal{O}$$

(ii) Caviezel, Koerber, Körs, Lüst, Wrase, M.Z. (2008)

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Geometric fluxes

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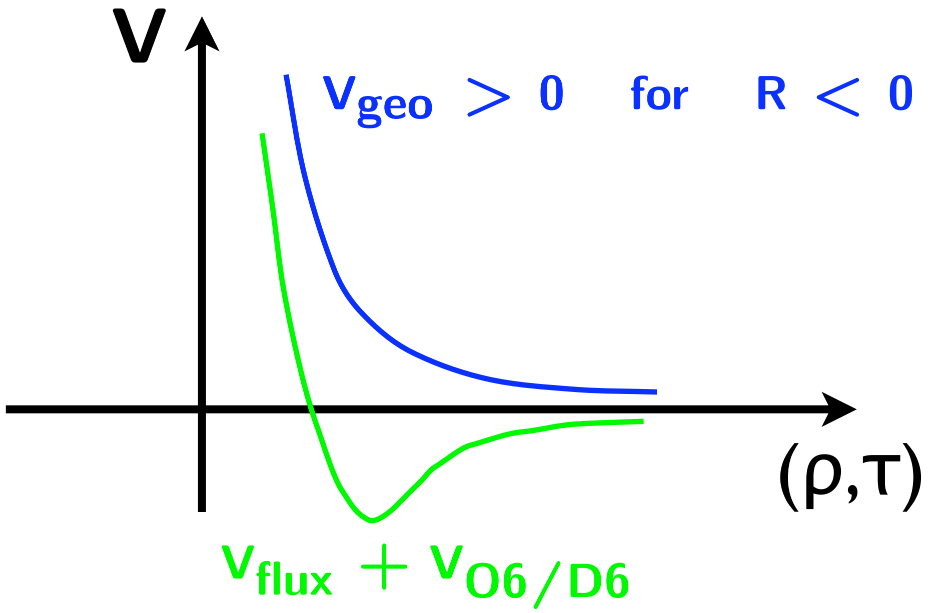
⇒ Effective uplift term for R<0



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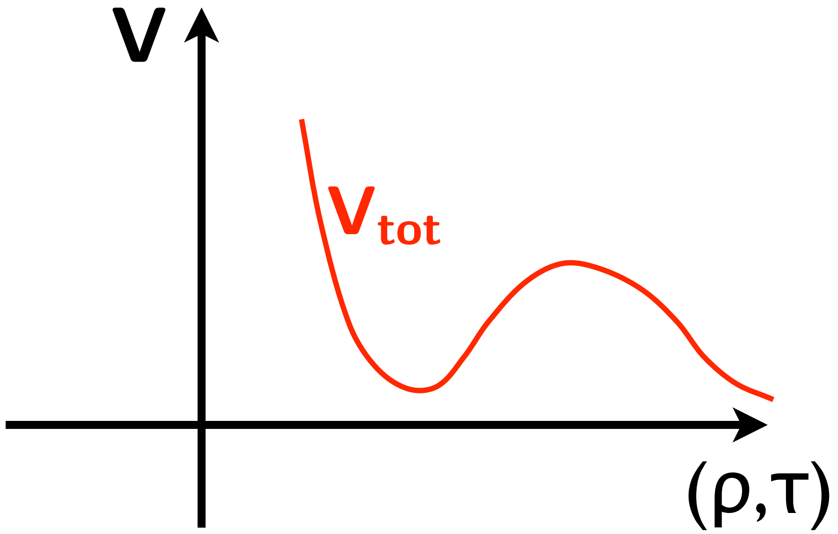

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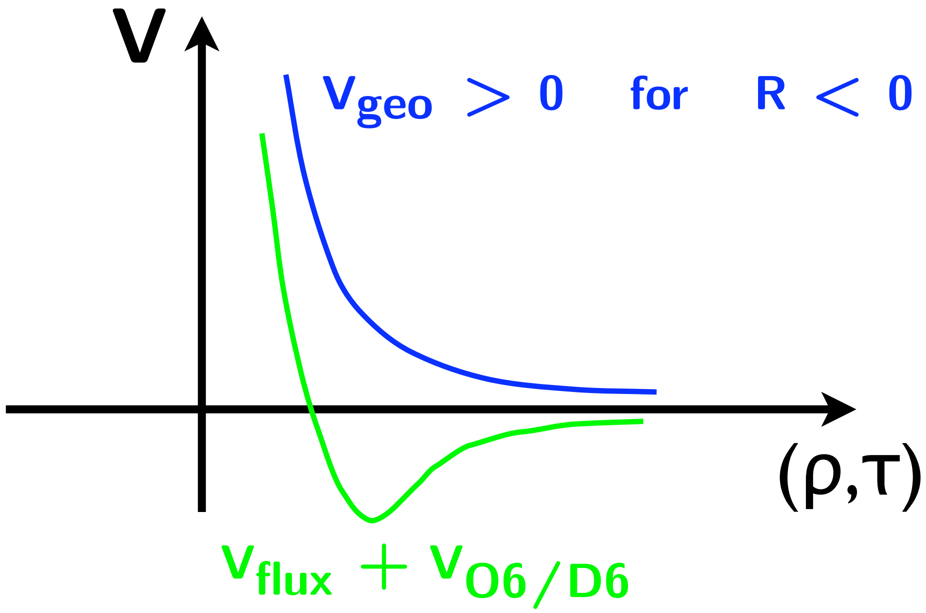

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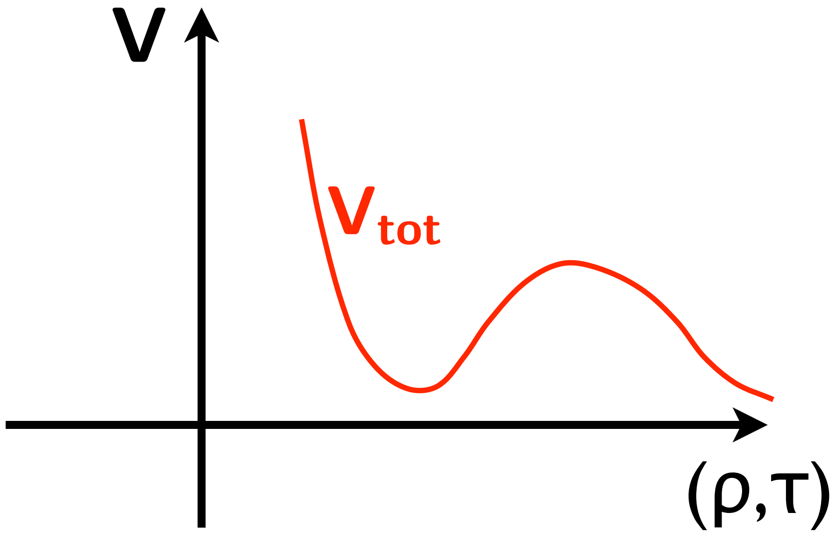

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But: Are all <u>orthogonal</u> field directions also ok?

$\Rightarrow$ Need a setup in which

$$\mathbf{V} = \mathbf{V}(\rho, \tau, \varphi^{\perp})$$

is well understood

A well-controlled setup:

Caviezel, Koerber, Körs, Lüst, Tsimpis, M.Z. (2008)

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SU(3)-structure:

$\Rightarrow$ $\mathcal{M}^{(6)}$ admits globally well-defined spinor η

$\Rightarrow$ 4D, N=1 supergravity action

$\Rightarrow$ For $\nabla\eta\neq0$: No CY $\Rightarrow$ $\mathbf{R_{mn} \neq 0}$ $\Rightarrow$ $\mathbf{V_{geo} \neq 0}$

Cf. Marchesano's talk

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Early work: Gurrieri, Louis, Micu, Waldram;
Dall'Agata, Prezas; Lüst, Tsimpis; Behrndt, Cvetič;
Gauntlett, Martelli, Waldram;
Graña, Minasian, Petrini, Tomasiello;...

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Problem:

$$\mathbf{J_{mn}} \equiv \mathbf{i}\eta_+^\dagger \gamma_{\mathbf{mn}} \eta_+ \qquad \mathbf{\Omega_{mnp}} \equiv \eta_-^\dagger \gamma_{\mathbf{mnp}} \eta_+$$

∇η≠0 $\Rightarrow$ dJ, dΩ≠0 $\Rightarrow$Expansion basis, moduli?

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Coset space structure:

⇒ Natural expansion basis: G-invariant forms

⇒ Explicit 4D action (consistent truncation)

Cassani, Kashani-Poor (2009)

Restriction to semisimple and Abelian group factors

$\Rightarrow$ **7 Models:** Koerber, Lüst, Tsimpis (2008)

$$\frac{G_2}{SU(3)}, \quad \frac{Sp(2)}{S(U(2)\times U(1))}, \quad \frac{SU(3)}{U(1)\times U(1)}, \quad \frac{SU(3)\times U(1)}{SU(2)}, \quad \frac{SU(2)^2}{U(1)} \times U(1)$$

$$SU(2) \times U(1)^3, \quad SU(2) \times SU(2)$$

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R < 0 possible $\Rightarrow$ Evade old no-go!

$\Rightarrow$ de Sitter or inflation?

Or are there new no-go's?

A refined no-go theorem

Cf. Flauger, Paban, Robbins, Wrase (2008)

Old no-go: $\mathbf{V_{geo} = 0,} \qquad \mathbf{V = V(\tau, \rho, \ldots)}$

$\Rightarrow \varepsilon \geq 27/13$

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Violates old no-go

Different Kähler modulus

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If:

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(ii) $-\sigma \partial_\sigma \left[2\tau^2 \rho^3 \mathbf{V_{geo}} \right] \geq 0$

$\Rightarrow \quad \boxed{\epsilon \geq 2}$ for $\boxed{V > 0}$

Our cosets:

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Only remaining candidate.
(The others have $\varepsilon \geq 2$)

$SU(2) \times SU(2)$

Numerically: $\varepsilon \approx 0$ with $V > 0$

But:

$$\eta \leq -2.4$$

(Large tachyonic direction)

Interestingly:

- Tachyon is combination of all moduli
- Not the tachyon of

Covi, Gomez-Reino, Gross, Louis, Palma, Scrucca (2008)

Also:

- NS5, D4, D8 can not be added in these models

- No F-term uplifting à la "O'KKLT" possible

  Cf. Kallosh, Linde (2006), Kallosh, Soroush (2006)

- KK5-Monopole ? ⇒ Drastic modification of geometry

  See also Villadoro, Zwirner (2007)

⇒ So far nothing really worked...

Conclusions

Type IIA on CY + p-form fluxes + D6/O6:

- Tree-level moduli stabilization in AdS
- No-go against dS and inflation (HKKT)

→ $V > 0$ is too steep in (ρ,τ)

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Type IIA on CY + p-form fluxes + D6/O6:

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→ $V > 0$ is too steep in (ρ, τ)

⇒ Quantum effects or/and additional classical ingredients

- Best understood: Geometric fluxes (deviation from CY)

Studied cosets with SU(3)-structure

⇒ Refined no-go in (σ, τ): $\varepsilon \geq 2$ except for $SU(2)\times SU(2)$

$SU(2)\times SU(2)$: $\varepsilon \approx 0$, but $\eta \leq -2.4$

Consistent with other works:

Haque, Shiu, Underwood, Van Riet (2008)

Flauger, Paban, Robbins, Wrase (2008)

⇒ Geometric fluxes may help in (ρ,τ)-plane, but certainly do not automatically take care of all moduli ⇒ Many dangerous directions

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$\Rightarrow$ de Sitter and inflation in IIA?

- More general manifolds? cf. Dall'Agata, Villadoro, Zwirner (2009)
- More general classical ingredients (e.g. Silverstein) ?
- Quantum effects (e.g. Saueressig, Theis, Vandoren; Palti, Tasinato, Ward) ?

Cf. Talks by Villadoro, de Carlos?