String Theory, Dark Energy and Varying Couplings

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Based on :

Blåbäck, Danielsson, Junghans, Van Riet, Wrase, MZ (to appear)
1003.0029 (Wrase, MZ)
0912.3287 (Caviezel, Wrase, M.Z.)
0812.3551 (Caviezel, Koerber, Körs, Lüst, Wrase, M.Z.)

Lisbon, September 6, 2010

String theory:

- Unified theory of all interactions & particles
- Quantum theory of gravity

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But: Mathematical consistency requires

10 (or 11) spacetime dimensions

⇒ "Compactification"

Assumption: $\mathcal{M}^{(10)} = \mathcal{M}^{(4)} \times \mathcal{M}^{(6)}$

small & compact

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⇒ Low energy effective field theory:

- Effectively 4D
- Details depend on 6D geometry
  - → Spectrum
  - → Couplings

Moduli

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- $\mathbf{g}_{\mu\nu}$ → 4D metric tensor
- $\mathbf{g}_{\mathbf{mn}}$ → 4D scalar fields

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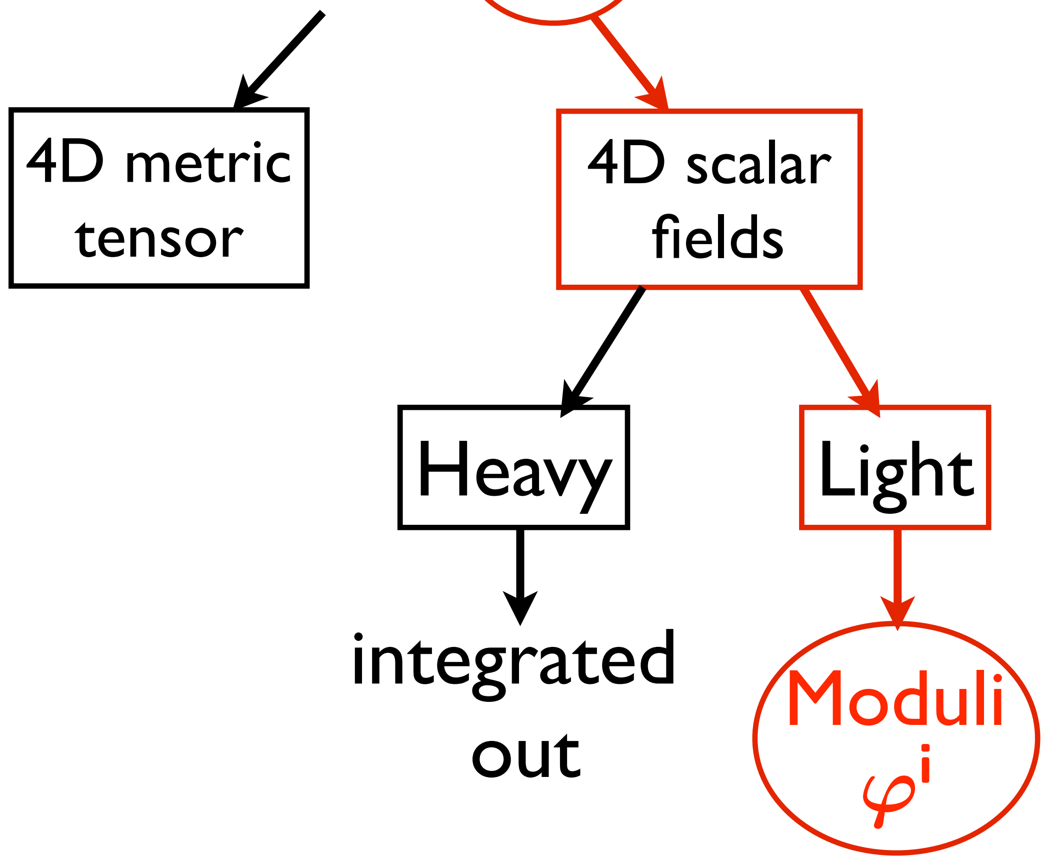

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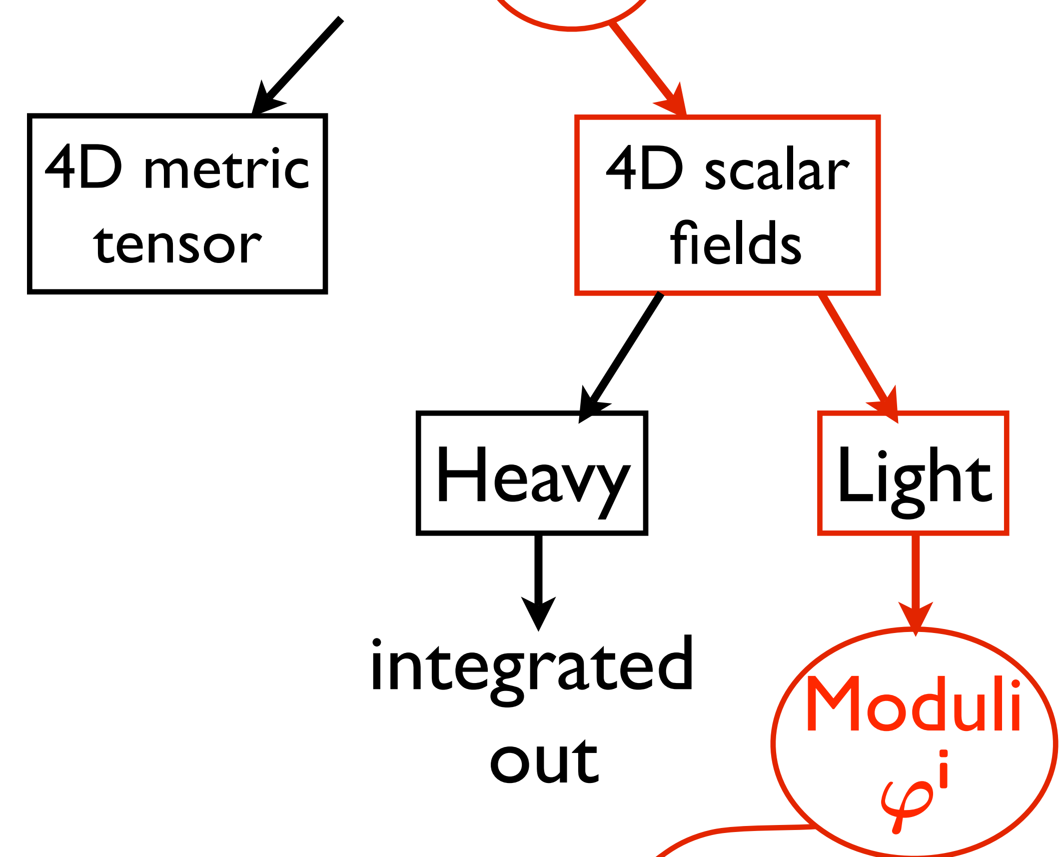
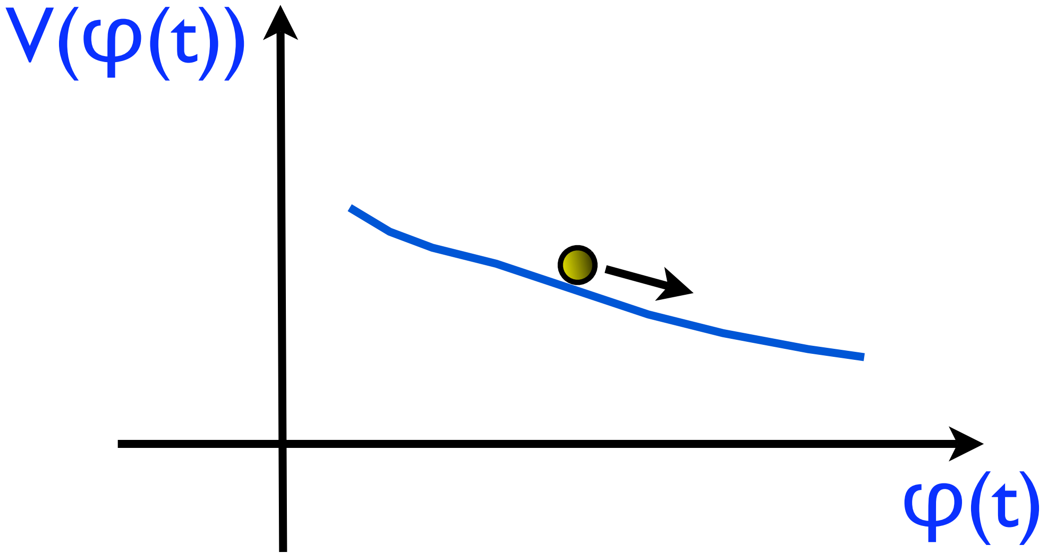


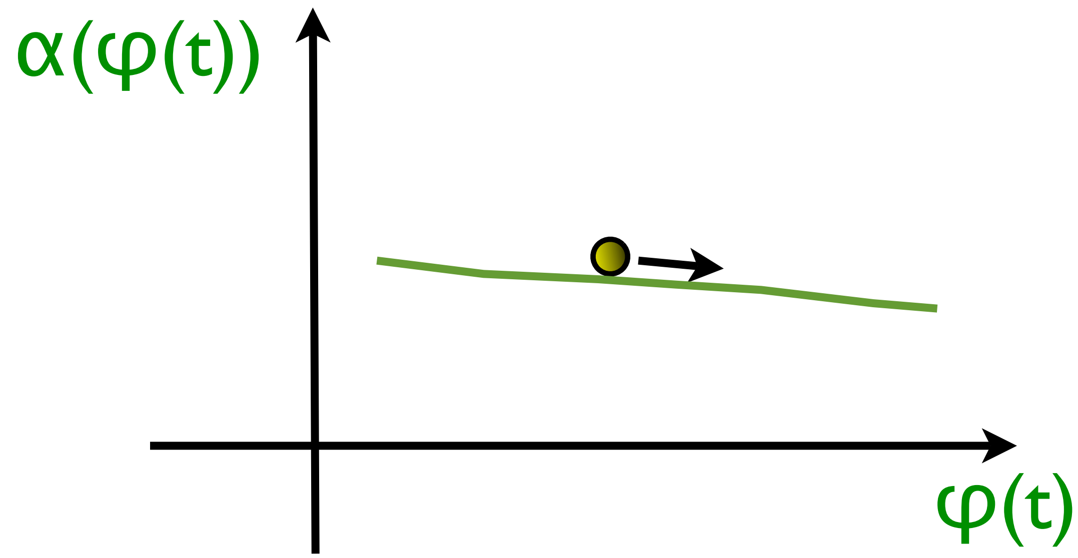
4D "fundamental" couplings: $\alpha = \alpha(\varphi^{\mathbf{i}})$

⇒ Time-dependent couplings

from time-dependent moduli?



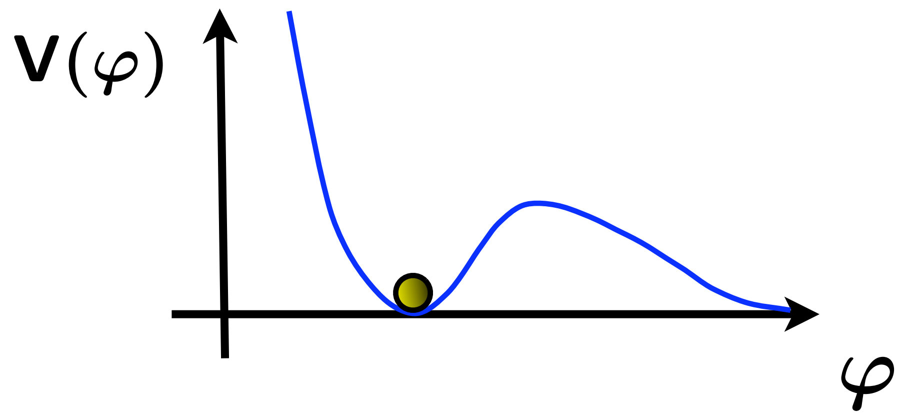
⇒



Phenomenological constraints on light moduli:

- Fifth force experiments
- BBN
- Overclosure bounds

Standard approach: Make moduli sufficiently heavy



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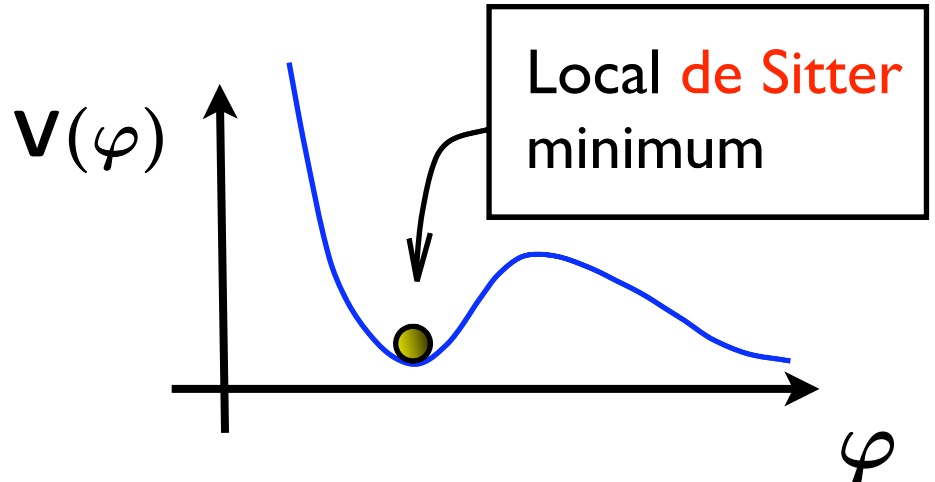

- Accelerated cosmic expansion

A general problem:

Typical scalar potentials receive many contributions and corrections

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Subtle interplay of

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↓ Easy

↓ Hard to compute precisely

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$\Rightarrow$ Field strengths $F_{M_1 \ldots M_p} = \partial_{[M_1} C_{M_2, \ldots, M_p]}$

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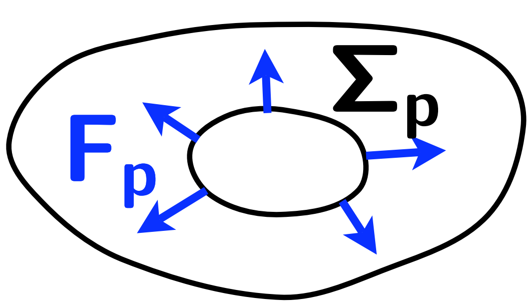

F_p-flux through $\Sigma_p \subset \mathcal{M}^{(6)}$

$\Rightarrow$ Potential for Σ_p-deformation modulus

Simple “no-go” theorems against de Sitter vacua

E.g.: Gibbons (1984);
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A positivity requirement for T_{MN}
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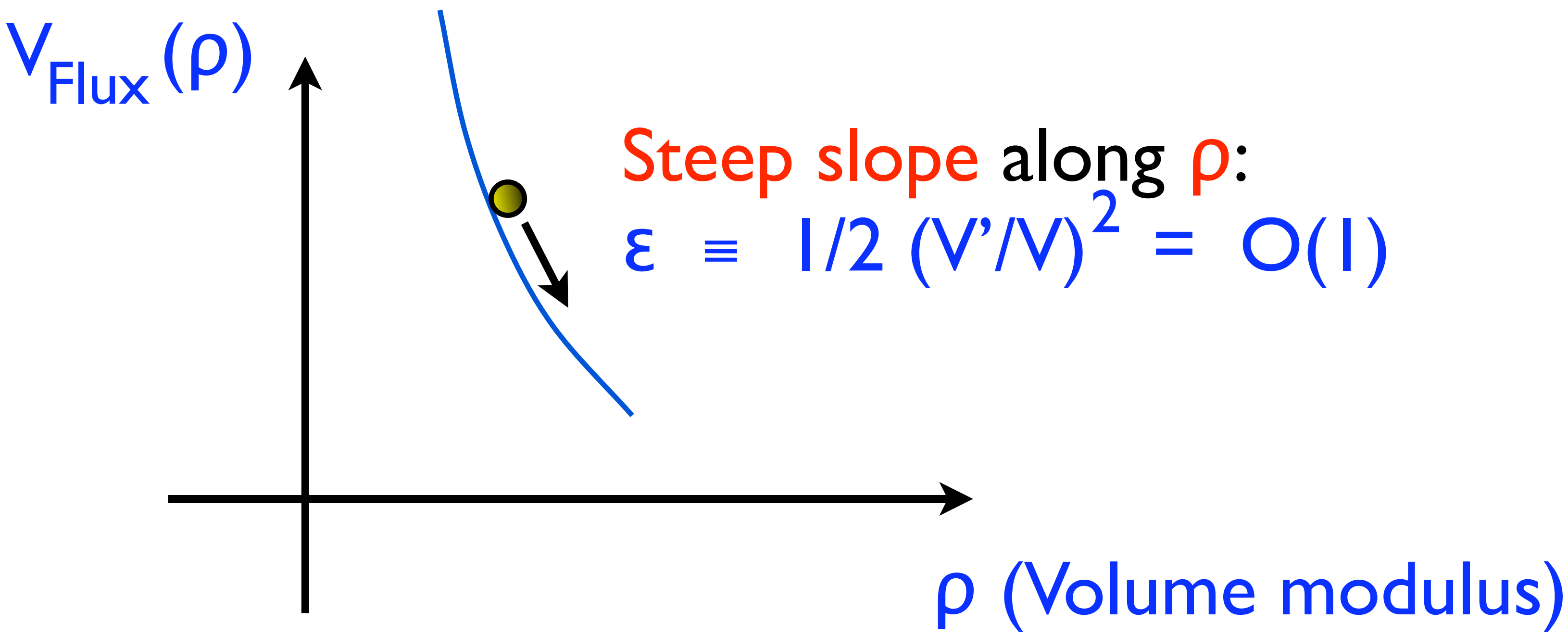
Satisfied for fluxes $\Rightarrow$ No de Sitter!

Manifestation in 4D field theory:



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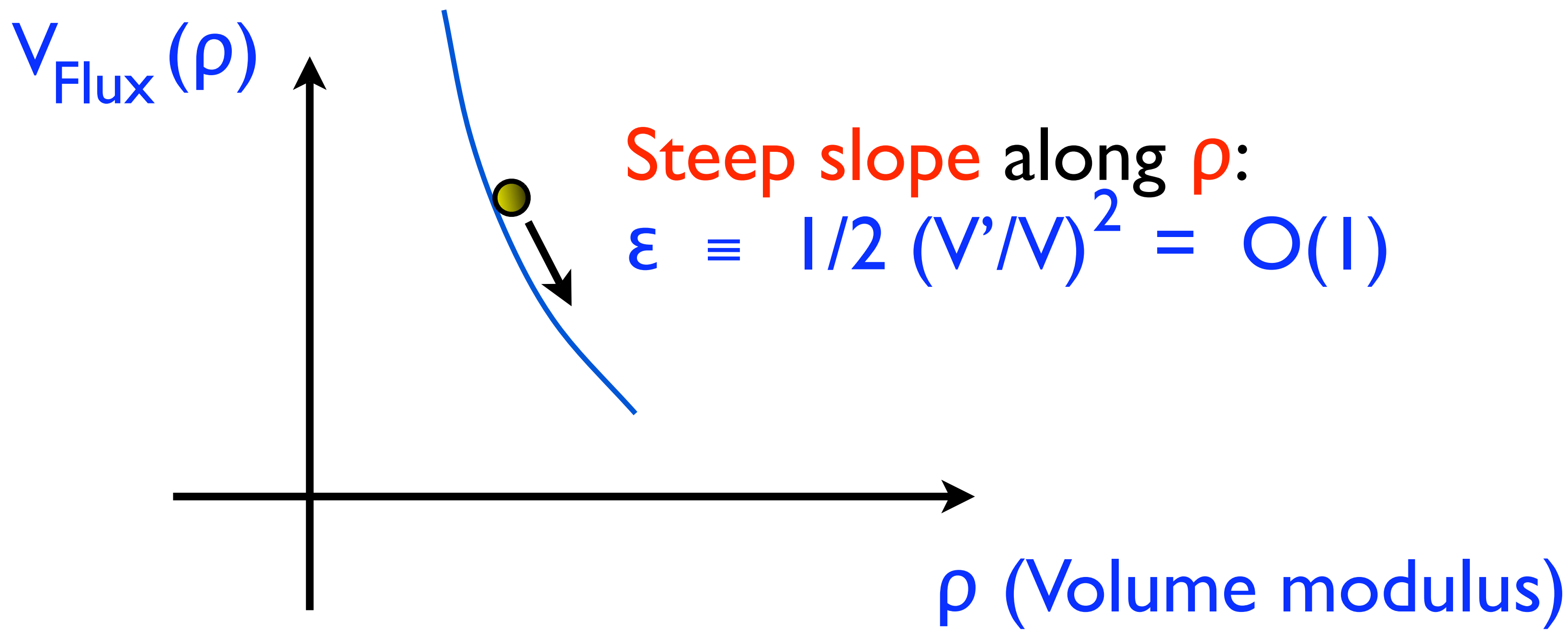

Steep slope along ρ:

$\varepsilon \equiv 1/2\,(V'/V)^2 = O(1)$

At best: Short transient periods of accelerated expansion

Cf. Townsend, Wohlfarth; Steinhardt, Wesley

But:

String theory naturally contains objects that violate the positive energy assumption of the above no-go theorem!

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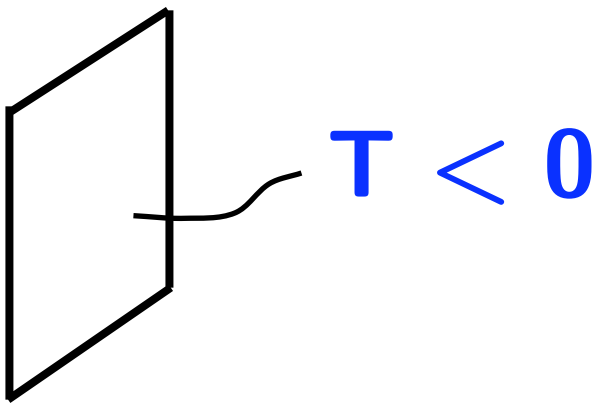
$\Rightarrow$ Orientifold planes ("O-planes")

(=Extended objects with negative tension)



However: Refined no-go theorem for

- Fluxes
- O-planes
- Ricci-flat $\mathcal{M}^{(6)}$

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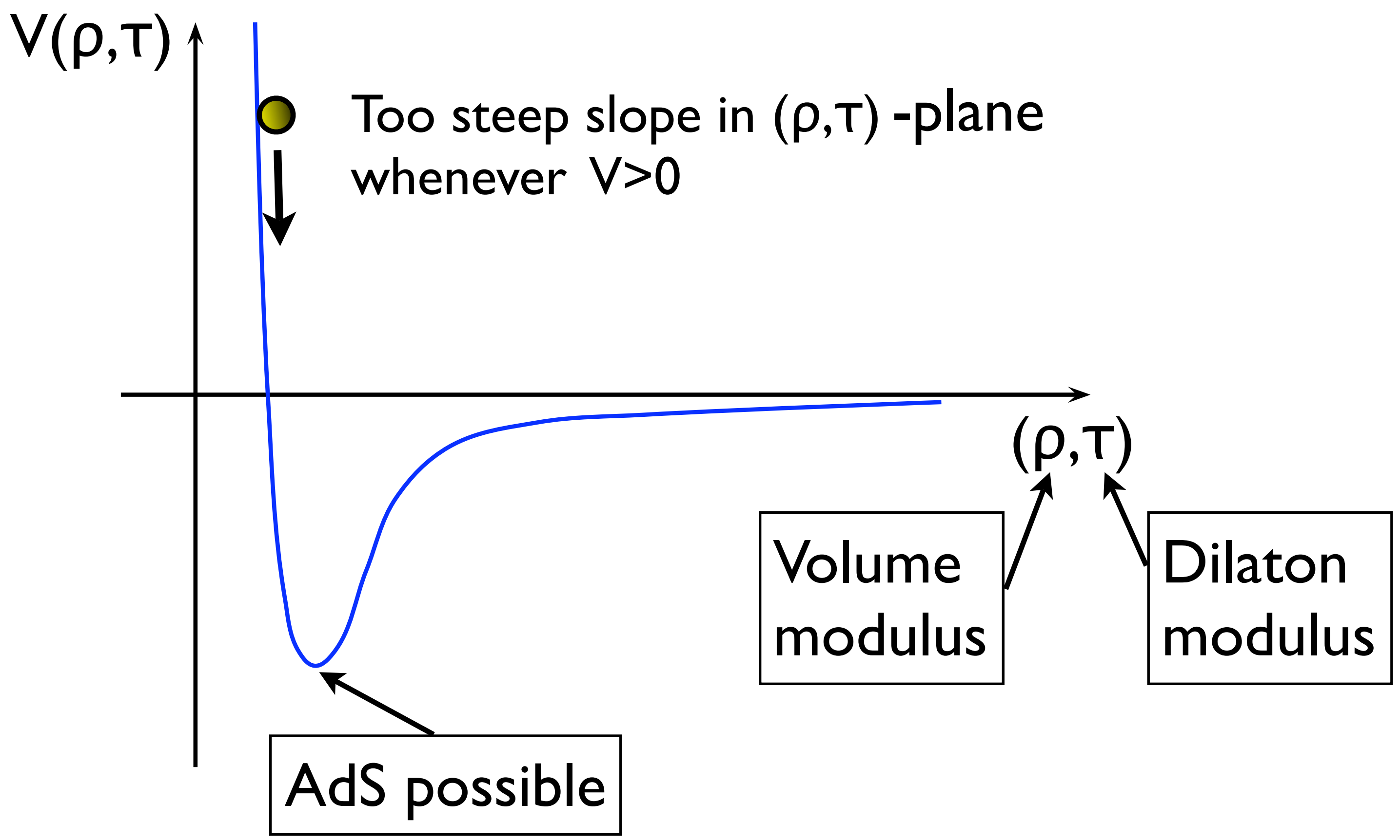

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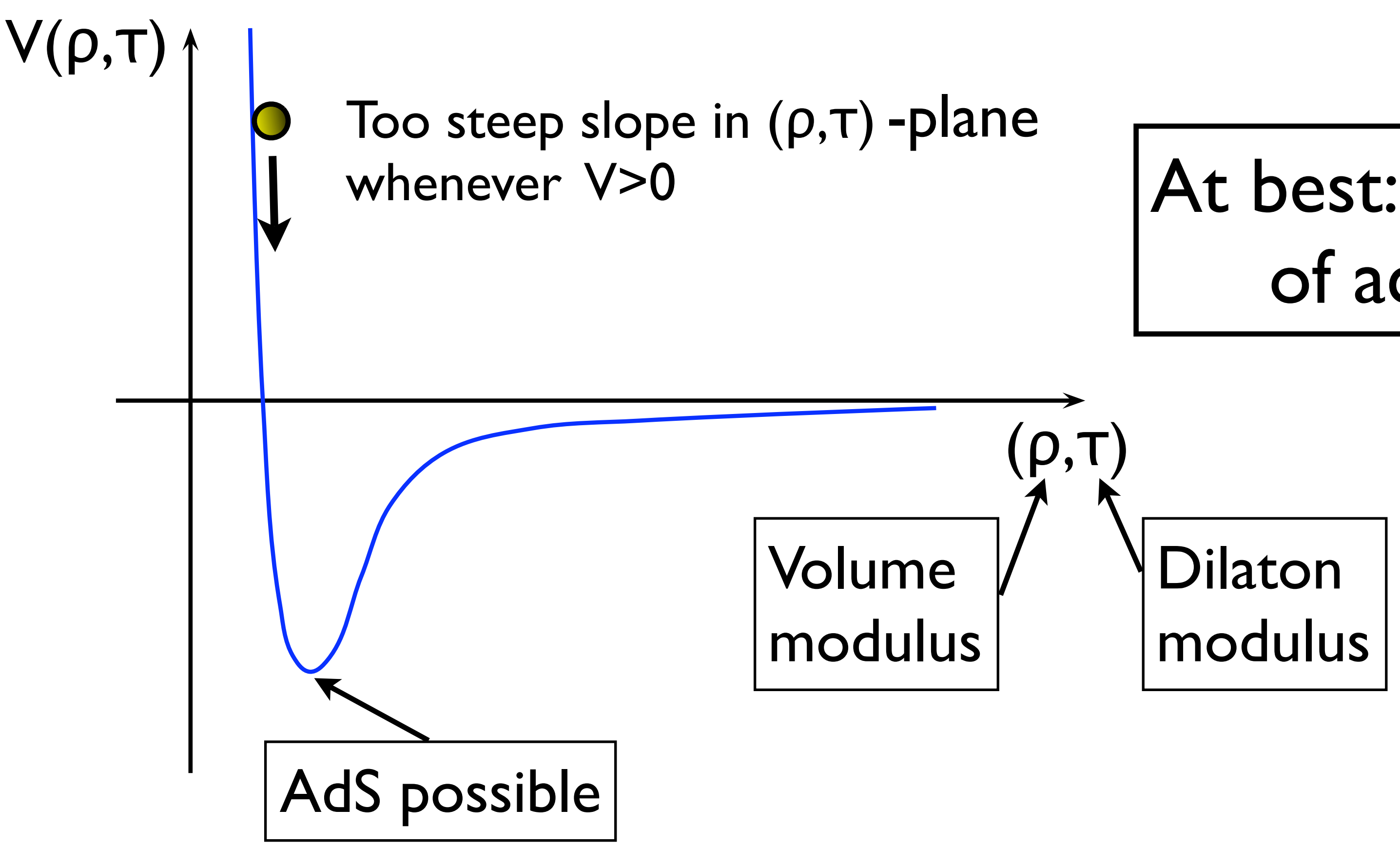

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<u>Promising case</u>: $\mathbf{R}^{(6)} < 0$ (Negative scalar curvature)

Cf. Mimoso's Talk

$$\mathbf{V}_{\mathbf{curv}} \propto -\mathbf{R} \propto \rho^{-1}\tau^{-2}$$

$\Rightarrow$ Effective uplift term for R<0

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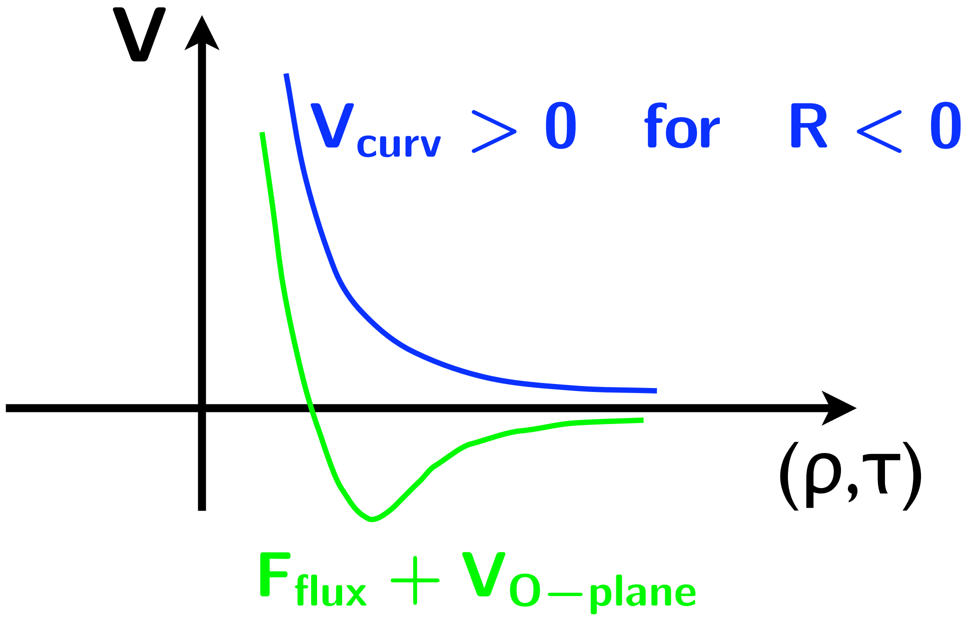

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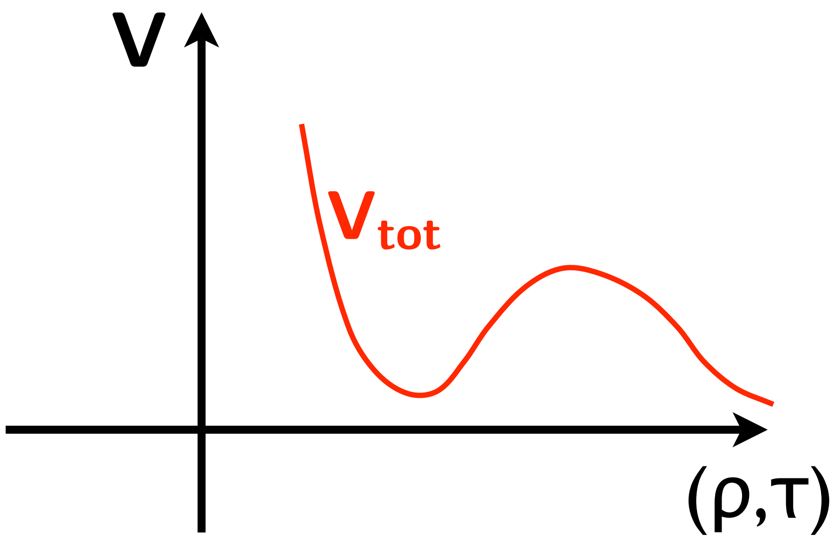

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Effective 4D action hard to compute for $\mathbf{R}^{(6)} \neq \mathbf{0}$

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Found a de Sitter extremum, but with strongly tachyonic direction:

$$\eta \equiv \mathbf{V''/V} = \mathcal{O}(-1)$$

Caviezel, Koerber, Körs, Lüst, Wrase, M.Z. (2008,2009)

However:
Recent studies cast doubts on the validity of the effective 4D theory used here

Douglas, Kallosh (2010)
Blåbäck, Danielsson, Junghans, Van Riet, Wrase, MZ (to appear)

Possibly, this dS extremum does not really exist...

Summary and conclusion:

- Full moduli stabilization in de Sitter minima is quite difficult in purely classical string compactifications

  (Even if one uses O-planes and negative curvature)

- Accelerated expansion in these setups typically only short & transient

- Suggestion (Steinhardt, Wesley (2010): Rule out many of these models based on $\dot{w}$ and $\dot{G}/G$ measurements?

  (E.g. DETF Stage II + 2x improvement in $\dot{G}/G$)

- But what about the other constraints (5th force, BBN, overclosure,...)?

- More realistic scenarios by combination of classical and quantum effects ? ($\rightarrow$ KKLT,...)