

# Constraints on BSM Physics from Quantum Exclusion of de Sitter

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Based on work<sup>1</sup> with Gia Dvali and Cesar Gomez

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<sup>1</sup> *Quantum Break-Time of de Sitter*, JCAP **1706**, arXiv:1701.08776;  
*Quantum Breaking Bound on de Sitter and Swampland*, FP **67**, arXiv:1810.11002;  
*Discrete Symmetries Excluded by Quantum Breaking*, arXiv:1811.03077;  
*A Proof of the Axion?*, arXiv:1811.03079.

# Exclusion of de Sitter?<sup>2</sup>

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## ① Motivation

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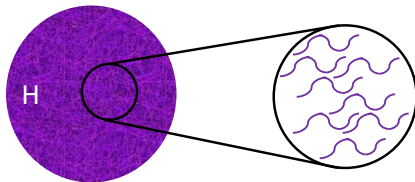
① Motivation

② Implications for BSM physics

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# Quantum Breaking

- ▶ De Sitter as multi-graviton state on top of Minkowski<sup>3</sup>

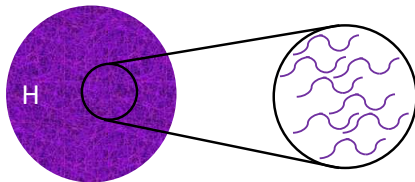


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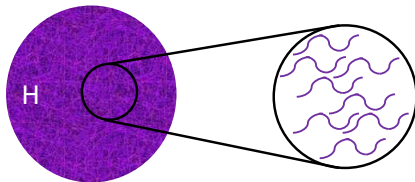
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# Quantum Breaking

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- ▶ Finite quantum break-time
- ▶ Conflict:

Fixed theory parameter  $H$



Evolving quantum state

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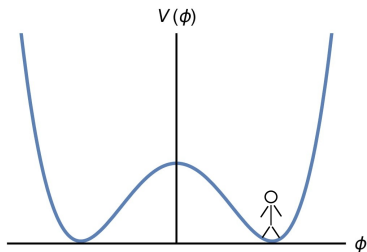
Consistent theory must not have (meta)stable de Sitter state.

- ▶ Also follows from swampland conjecture<sup>4</sup> in string theory

<sup>4</sup>G. Obied, H. Ooguri, L. Spodyneiko, C. Vafa, *De Sitter Space and the Swampland*, arXiv:1806.08362.

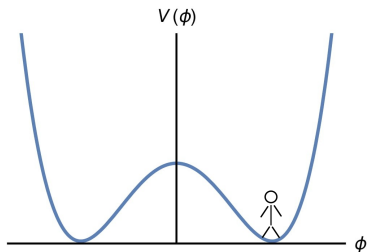
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# Exclusion of Spontaneously-Broken Discrete Symmetries<sup>5</sup>



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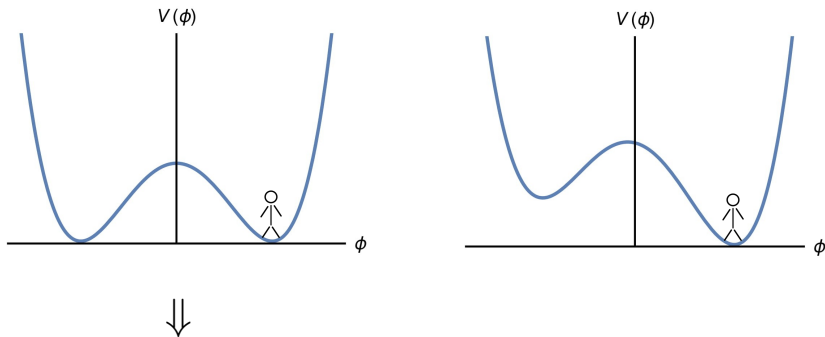


Domain wall problem<sup>6</sup>

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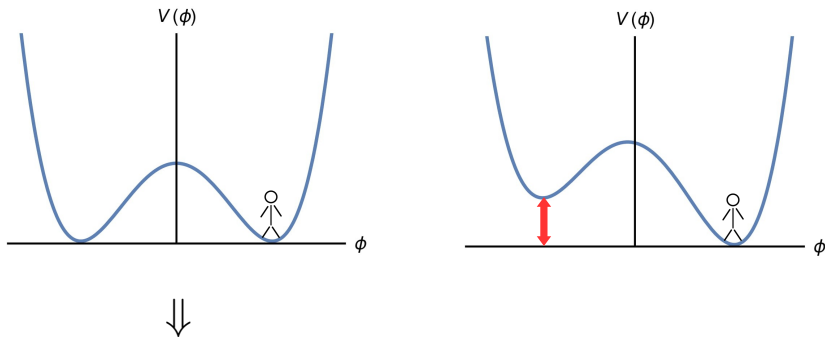


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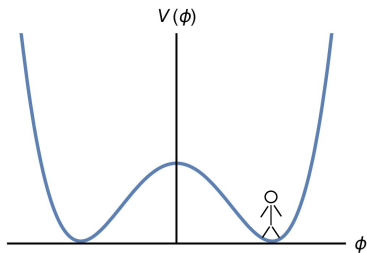


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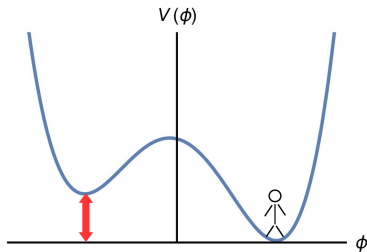
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Inconsistent de Sitter minimum

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# Exclusion of Spontaneously-Broken Discrete Symmetries<sup>5</sup>

- ▶ Need symmetry breaking before inflation  
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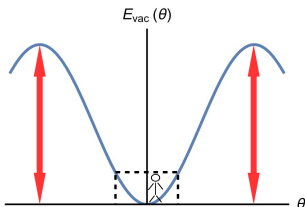
# Exclusion of Spontaneously-Broken Discrete Symmetries<sup>5</sup>

- ▶ Need symmetry breaking before inflation  
(or other solution to domain wall problem)
- ▶ Excludes well-motivated models
  - ▷ NMSSM
  - ▷ Spontaneous CP-violation
  - ▷ Some Peccei-Quinn models
  - ▷ ...

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# Other Systems

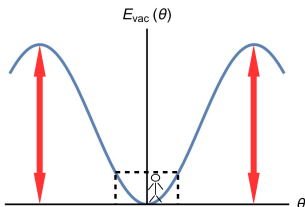
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# Other Systems

- ▶ Existence of axion mandatory<sup>7</sup>



- ▶ Inflation: exclusion of self-reproduction<sup>8</sup>

$$\frac{V'}{\sqrt{GV}} \gtrsim GH^2 \quad \vee \quad \frac{V''}{GV} \lesssim -1$$

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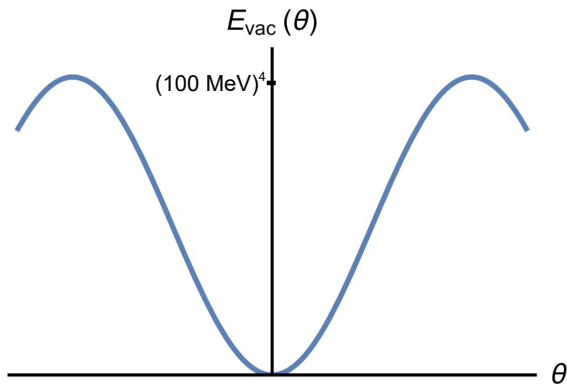
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- ⇒ Consistent theory must avoid de Sitter
- ⇒ Important constraints on BSM physics

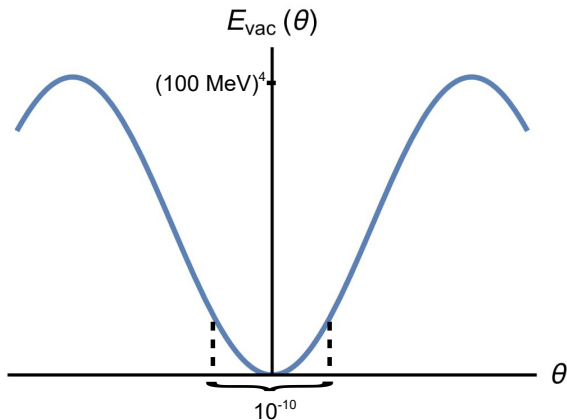
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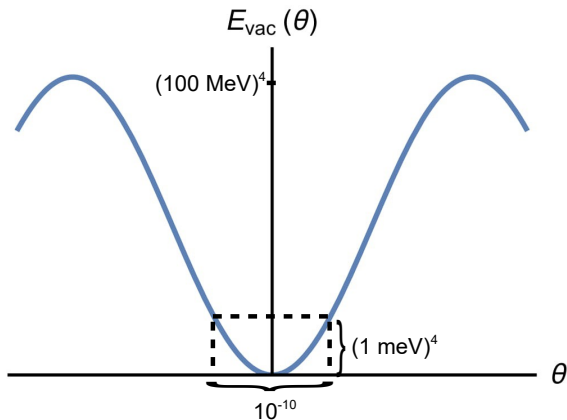


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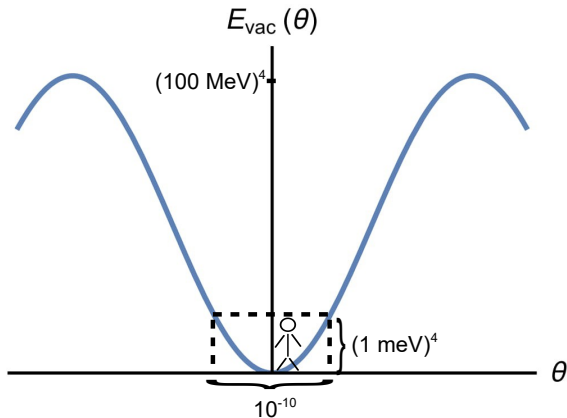


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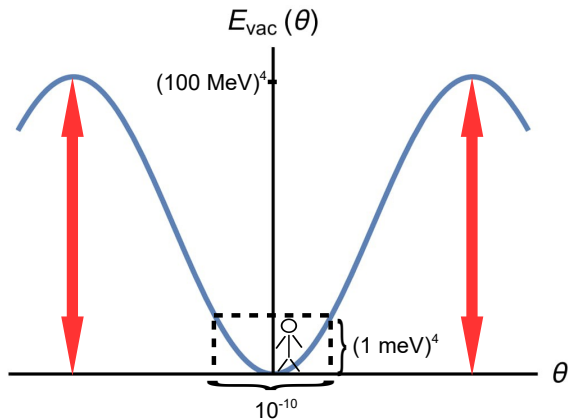
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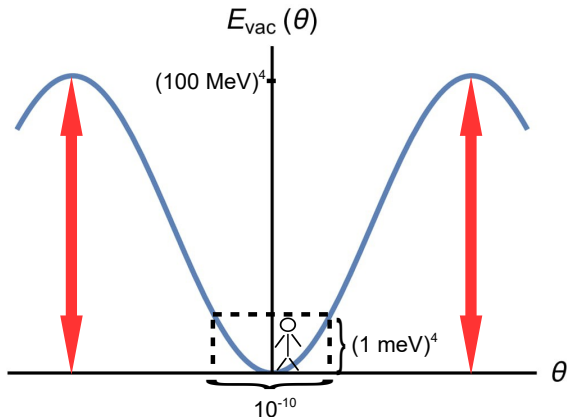
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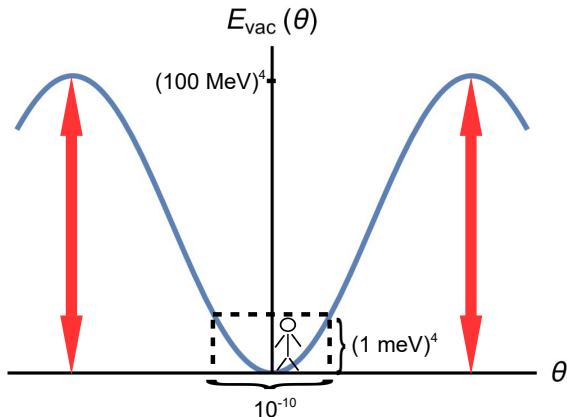
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Existence of Axion Mandatory<sup>9</sup>

- ▶  $\theta$ -vacua: consistency problem instead of naturalness question
- ▶ Only way out: make  $\theta$  unphysical by axion

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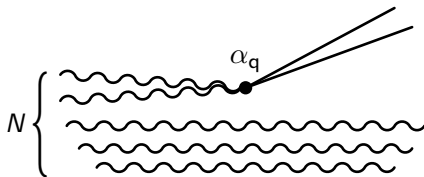
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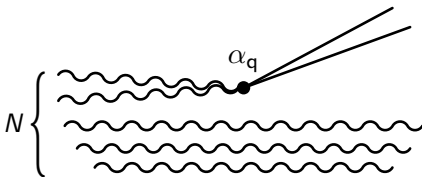
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$$\langle N | \hat{h}_{\mu\nu} | N \rangle = h_{\mu\nu}$$

# Quantum Effect



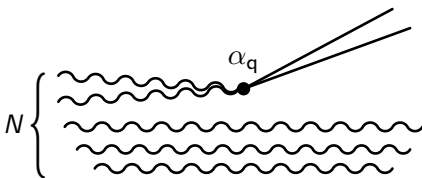
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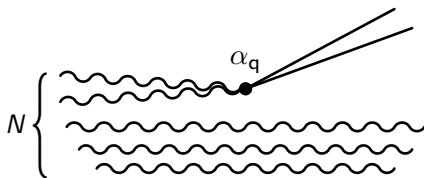
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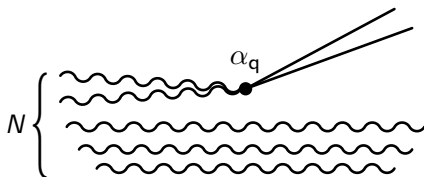
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- ▶ Window beyond last 60 e-foldings of inflation