Implications of the Gravitino Mass/Distance Conjecture on Inflation

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UV insight into Inflation?

No dS in String Theory?

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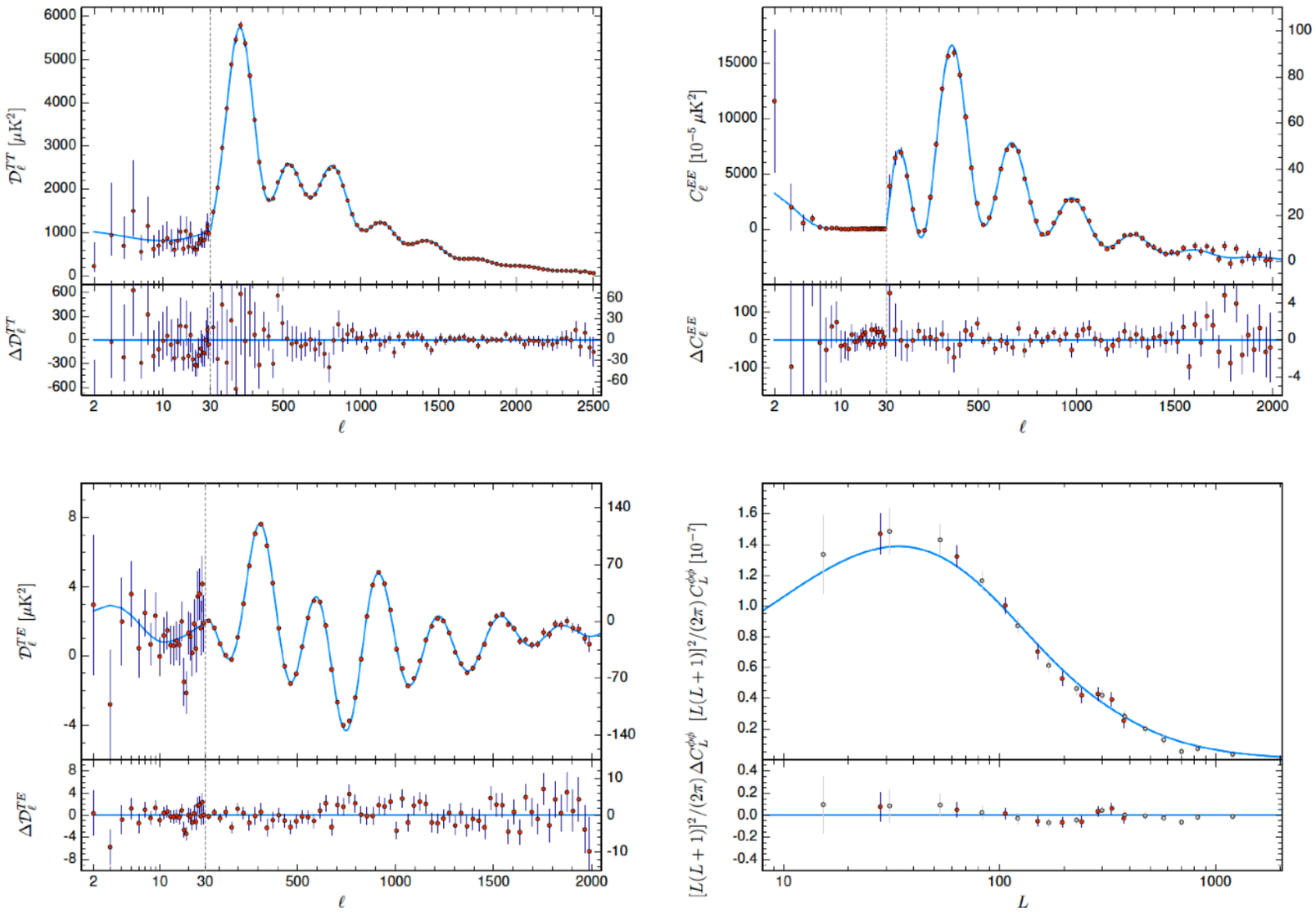

[Planck 2018 results. X. Constraints on inflation]

Precise cosmological data imply inflation (and dark energy).

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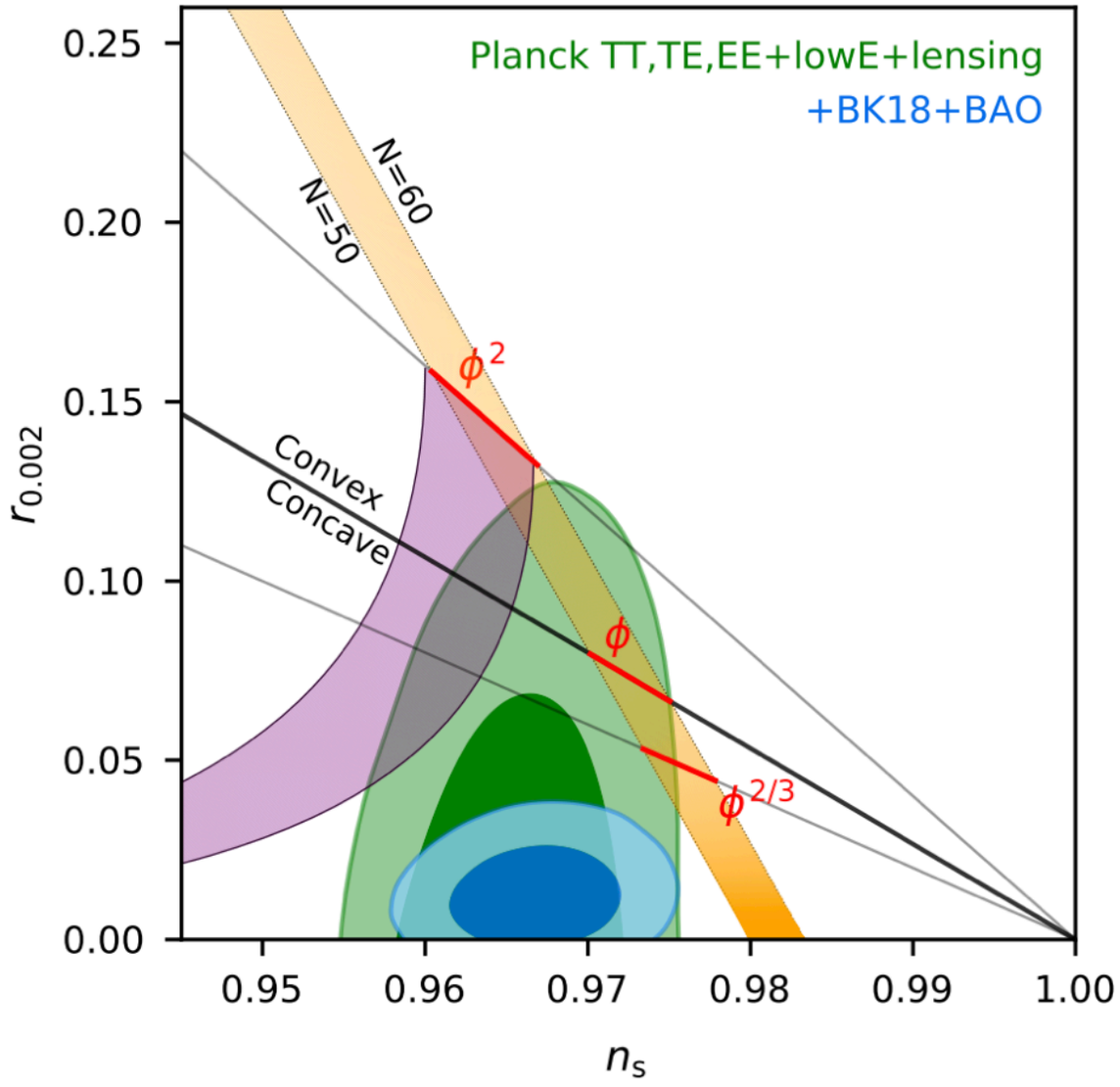
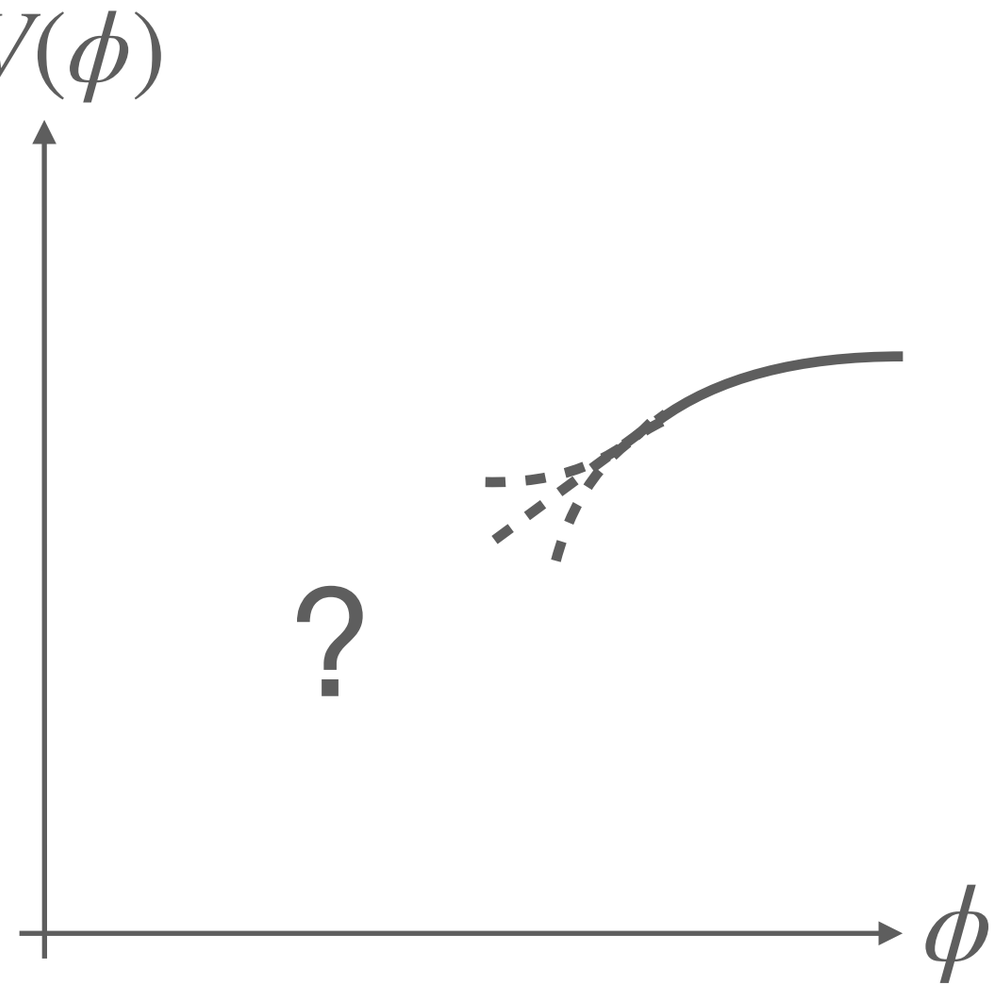


[BICEP/Keck, 2110.00483]



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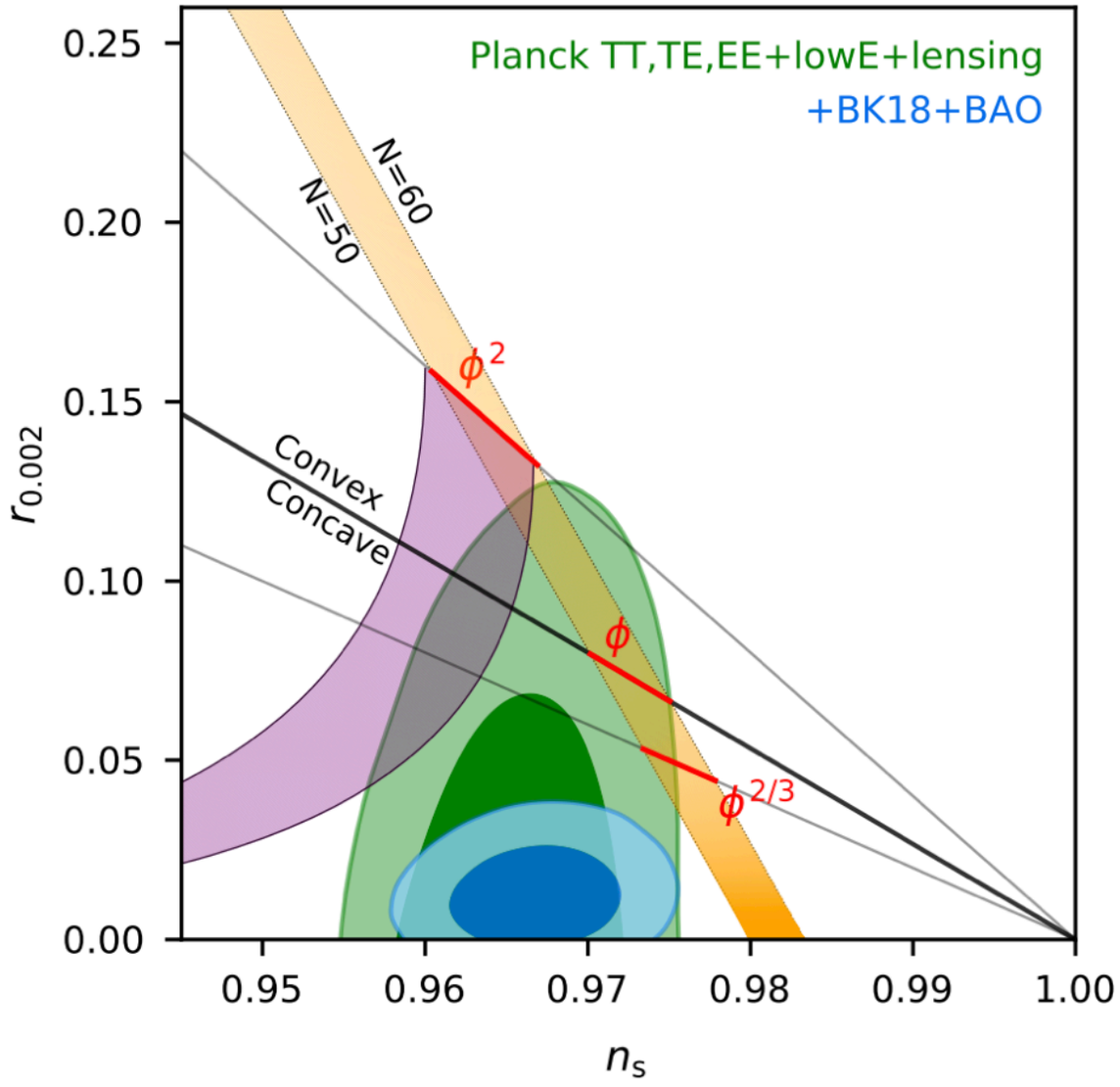

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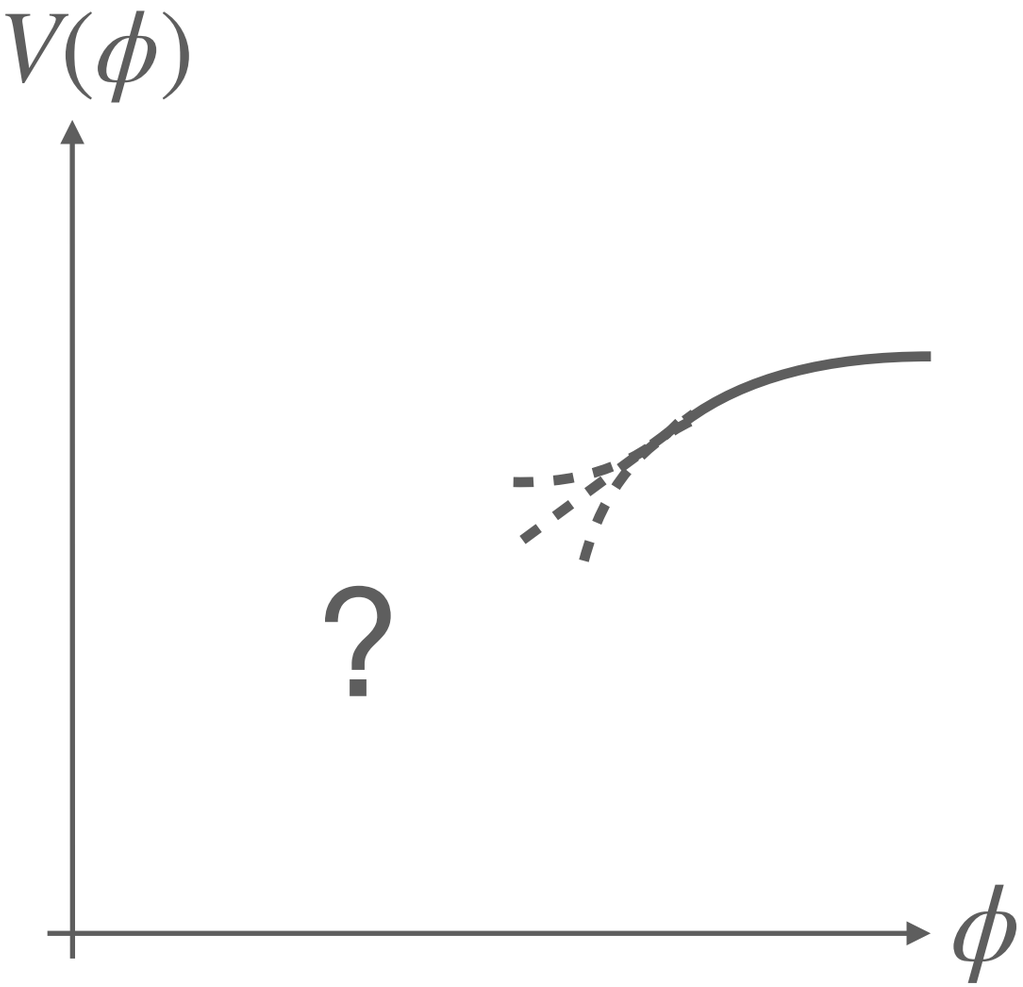

This talk:

Phenomenological description of inflation in $\mathcal{N} = 1$ **supergravity** + **Swampland conjecture**

Swampland Conjectures on Gravitino

- Gravitino sound speed conjecture [Kolb, Long, Mcdonough, 2102.10113; 2103.10437]

  Gravitino sound speed should not vanish.

  Motivated by the catastrophic gravitino production in a special class of SUGRA inflation model
  [Hasegawa et al., 1701.03106] [Ferrara et al., 1512.00545; Carrasco et al., 1512.00546]

  Swampland?? The same thing could happen in non-gravitational theories.
  See also [Talk by Casagrande, Tuesday].

- Gravitino mass conjecture [Cribiori, Lust, Scalisi, 2104.08288]

  Gravitino distance conjecture [Castellano, Font, Herraez, Ibáñez, 2104.10181]

  $m_{3/2} \to 0$ corresponds to an infinite distance limit.

  An infinite tower of light particles invalidating the EFT.

  Note: Magnetic WGC forbids light charged ($\mathcal{N} = 2$) gravitini. [Dall'Agata et al, 2108.04254]

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Gravitino Mass/Distance Conjecture

There are towers of particles (KK particles, winding modes, etc.) in String Theory.

Their masses depend on gravitino mass.

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$$\Lambda_{\rm QG} \sim m_{3/2}^{n/3}$$

(quick derivation)

Number of species below cutoff: $N = \Lambda_{\rm QG}/m_1$

The species scale (conjecture): $\Lambda_{\rm QG} = M_{\rm P}/\sqrt{N}$

[Dvali, 0706.2050; Dvali, Redi, 0710.4344]

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Validity of EFT on quasi de Sitter

Requiring $H < \Lambda_{\rm QG}$ leads to

$$m_{3/2} > H^{3/n}$$

Scalar Potential in Supergravity

$$V = V_+ + V_-$$

$$V_+ = V_F + V_D \qquad\qquad V_- = -3e^K |W|^2$$

$$V_F = e^K K^{\bar{j}i} D_i W \bar{D}_{\bar{j}} \bar{W} \qquad\qquad V_D = \frac{1}{2} h_R^{AB} D_A D_B$$

The positive & negative terms are related to SUSY breaking and gravitino mass, respectively.

$$V_+(\phi^i) = M^4_{\cancel{\text{SUSY}}}(\phi^i) \qquad\qquad V_-(\phi^i) = -3m^2_{3/2}(\phi^i)$$

Friedmann eq. during slow-roll inflation

$$3H^2 \simeq V$$

The gravitino conjecture and quasi de Sitter give us

$$\frac{m^2_{3/2}}{M_P^2} < \frac{M^4_{\cancel{\text{SUSY}}}}{3M_P^4} < \left(\frac{m^2_{3/2}}{M_P^2}\right)^{n/3} + \frac{m^2_{3/2}}{M_P^2}\,.$$

Inflation and *R*-symmetry

- Gravitino mass $m_{3/2} = e^{K/2} \, | \, W \, |$ is an order parameter of R-symmetry breaking, $\langle W \rangle \neq 0$.
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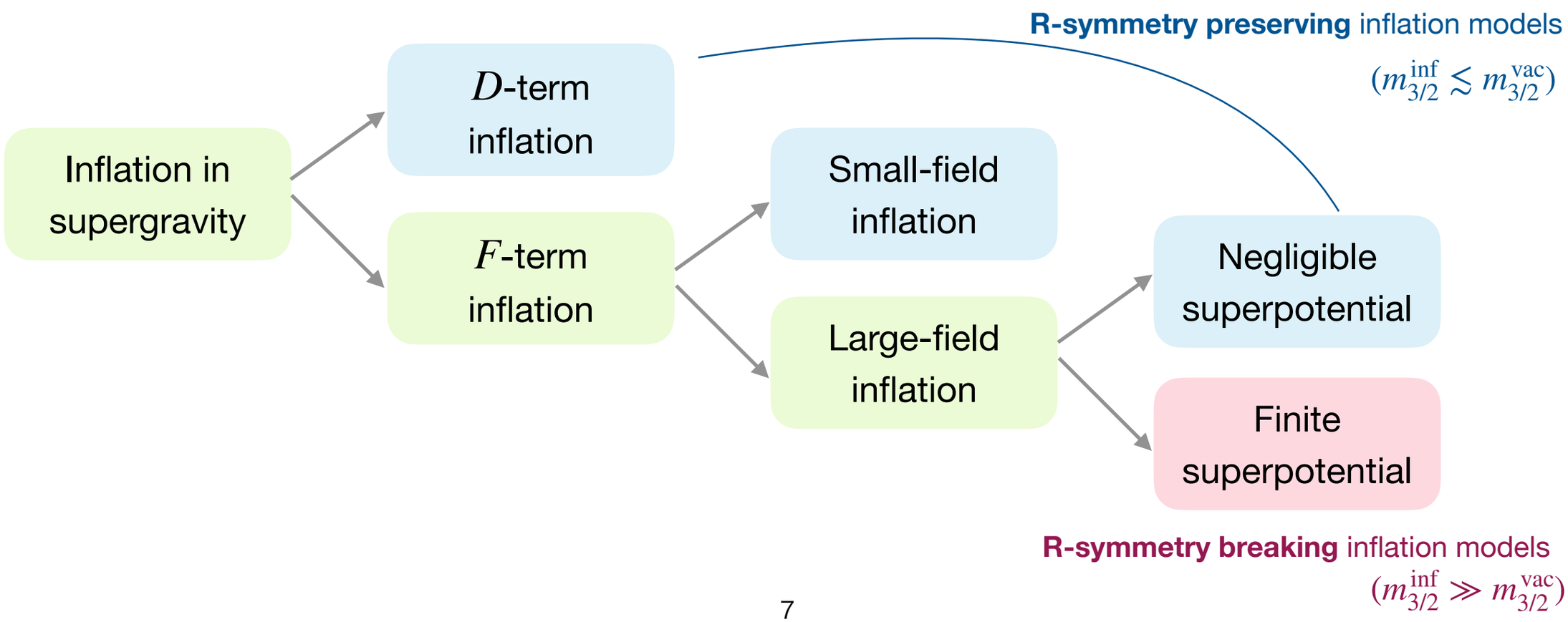

R-Symmetry Preserving Case

$$m_{3/2}^{\text{inf}} \simeq m_{3/2}^{\text{vac}}$$

Reminder:

Tower mass scale $m \sim m_{3/2}^{n}$

$m_{3/2} > H^{3/n}$

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Lower bounds on gravitino mass

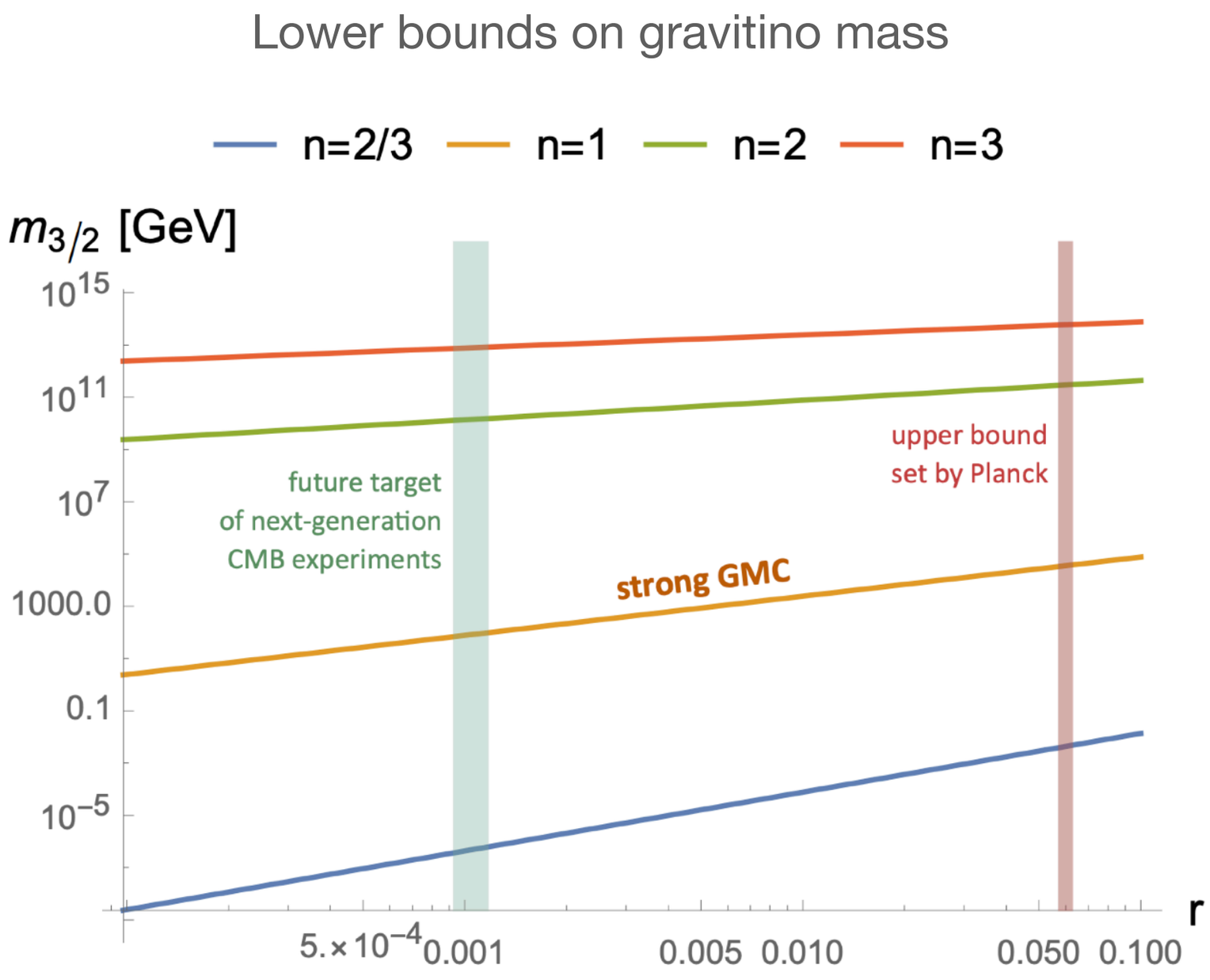

Figure from [Cribiori, Lust, Scalisi, 2104.08288]

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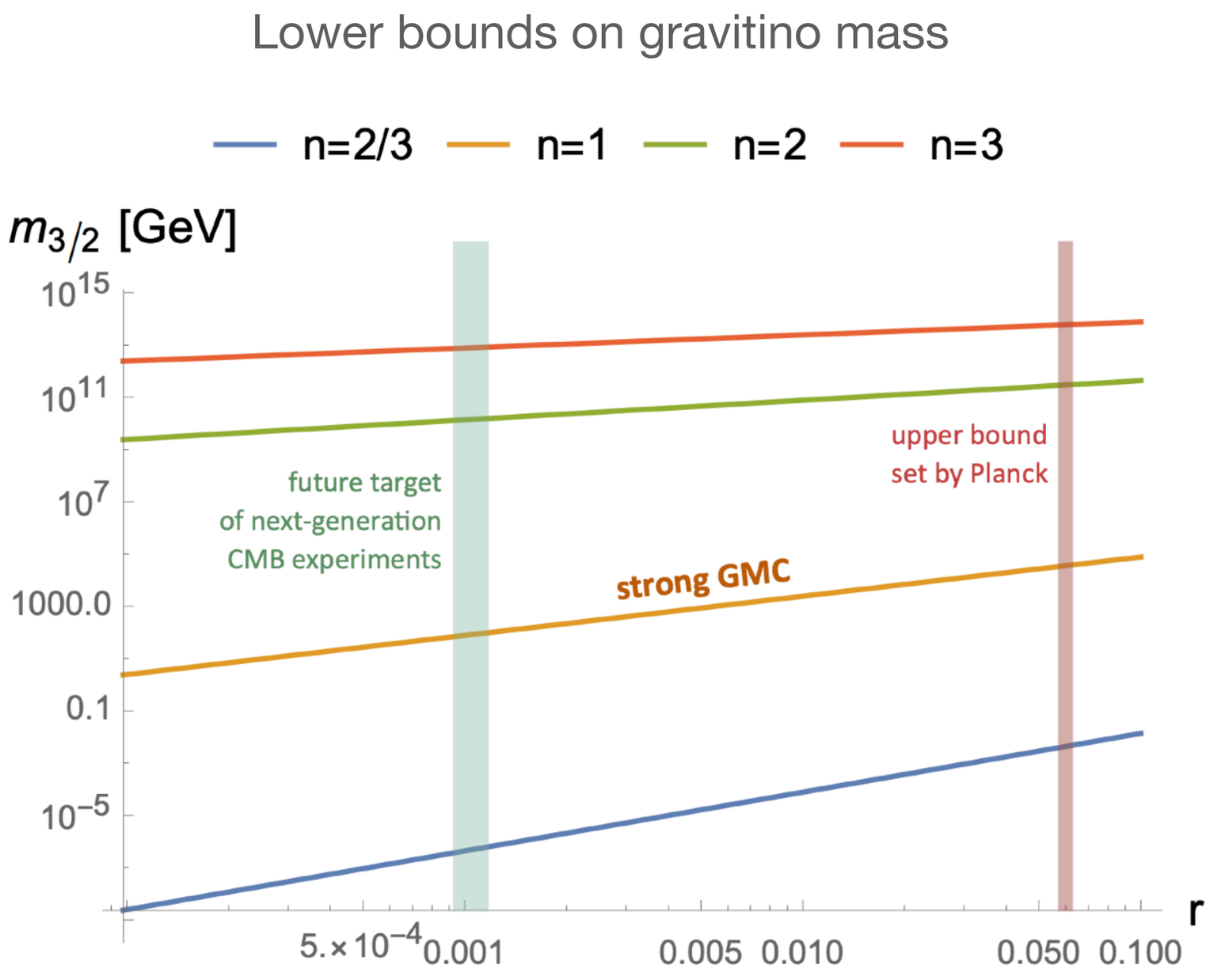

Figure from [Cribiori, Lust, Scalisi, 2104.08288]

This is not the end of the story!

R-Symmetry Preserving Case

Consider a typical inflation setup:

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

$$W = Sf(\phi) + W_0$$

$$V = |f(\phi)|^2 - 3|W_0|^2$$

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Our master formula,

$$\frac{m_{3/2}^2}{M_P^2} < \frac{M_{\cancel{\text{SUSY}}}^4}{3M_P^4} < \left(\frac{m_{3/2}^2}{M_P^2}\right)^{n/3} + \frac{m_{3/2}^2}{M_P^2}$$

implies…

Lowering $\Lambda_{\text{QG}} \sim m_{3/2}^{n/3}$

for $n < 3$	$3|W_0|^2 < |f(\phi)|^2 < 3|W_0|^{6/n}$	nontrivial but tolerable
for $n = 3$	$3|W_0|^2 < |f(\phi)|^2 < 6|W_0|^2$	quite a tight constraint
for $n > 3$	$3|W_0|^2 < |f(\phi)|^2 \lesssim 3|W_0|^2$	inflation impossible (or fine-tuning necessary)

R-Symmetry Breaking Case

$m_{3/2}^{\rm inf} \gg m_{3/2}^{\rm vac}$ In fact, typically $m_{3/2}^{\rm inf} \geq \mathcal{O}(H_{\rm inf})$.

Then, the constraint during inflation becomes $m_{3/2}^{\rm inf} = \mathcal{O}(H_{\rm inf}) > H_{\rm inf}^{3/n}$.

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e.g.) Single-superfield inflation mechanism

[Ketov, Terada, 1406.0252; 1606.02817 (see also 1408.6524; 1509.00953)]

$$K = -\frac{1}{2}(\phi - \bar{\phi})^2 - \frac{1}{12\Lambda^2}(\phi - \bar{\phi})^4 + \cdots,$$
$$W = e^{ic\phi} f(\phi).$$

We obtain bounds on the important parameter c: $3 \lesssim c^2 \lesssim 6$.

Discussions on other inflation mechanisms in supergravity will be in our paper.

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Gravitino conjecture: $m_{3/2} > H^{3/n}$

Quasi-dS: $V > 0$

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Inflation in supergravity

- D-term inflation
- F-term inflation
  - Small-field inflation
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    - Negligible superpotential
    - Finite superpotential

R-symmetry preserving inflation models

$(m_{3/2}^{\text{inf}} \lesssim m_{3/2}^{\text{vac}})$

More constrained.

R-symmetry breaking inflation models

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In both (R-symmetry preserving/breaking) cases, **nontrivial constraints** on inflation model building emerge **as we approach the quantum gravity cutoff**.