How Potent is Nilpotent Inflation?

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Based on 1601.03397 with E. Dudas, L. Heurtier, M.W. Winkler

Background I

The use of nilpotent or constrained chiral multiplets seems to be in fashion in $\mathcal{N} = 1$ theories describing cosmology

[Achucarro, Antoniadis, Dall'Agata, Dudas, Ferrara, Kallosh, Linde, Quevedo, Roest, CW, Sagnotti, Scalisi, Zwirner,...]

Idea: on goldstino multiplet impose $S^2 = 0$

$$\Rightarrow S = \frac{\psi_S^2}{2F_S} + \sqrt{2}\theta\psi_S + \theta^2 F_S$$

$\longrightarrow$ Great, cosmology becomes simpler

Background II

This is especially useful for inflation with a "stabilizer field":

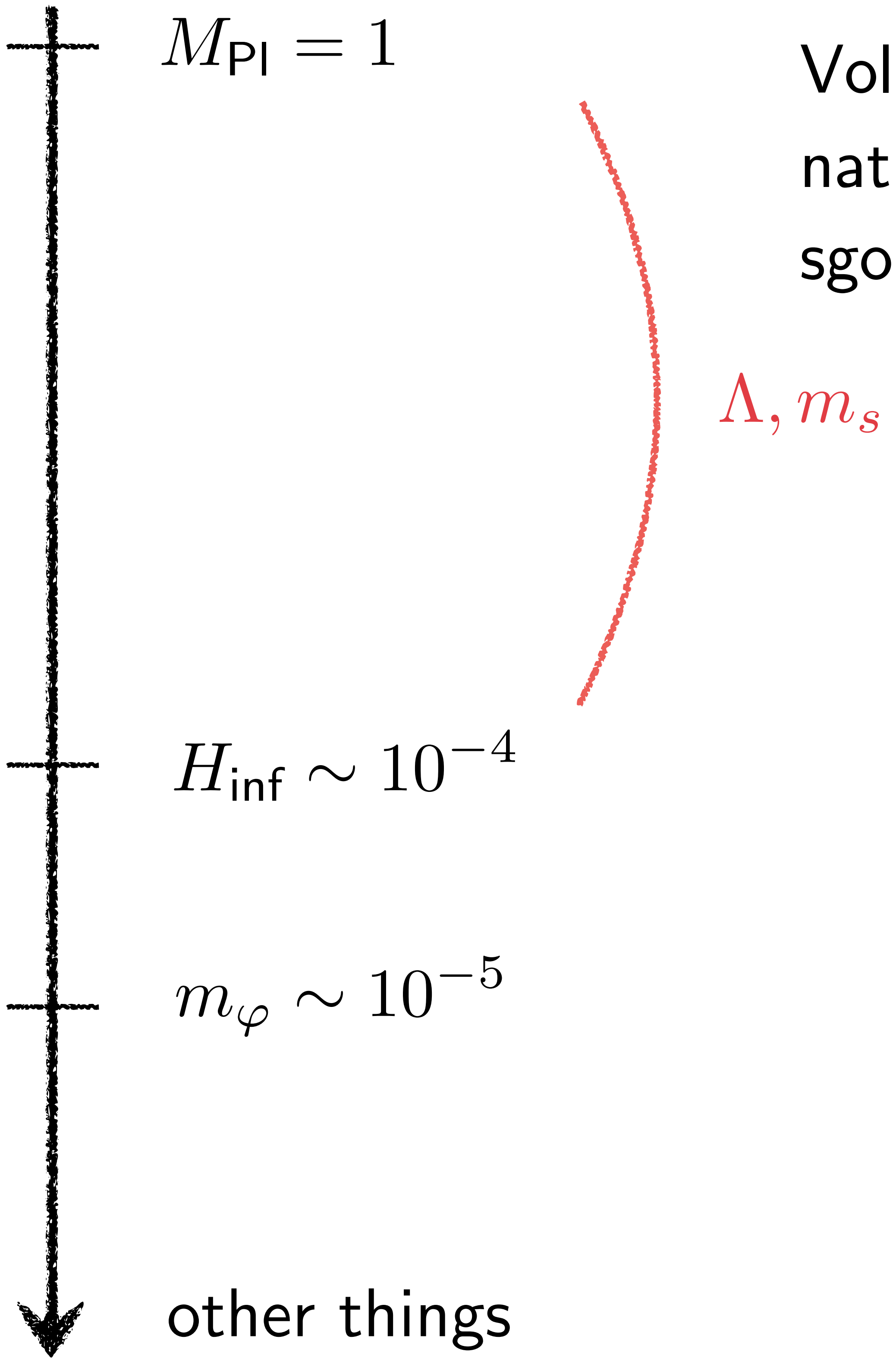
$$K = K(\Phi + \bar{\Phi}, |S|^2)\,, \quad W = S f(\Phi)$$

[Kawasaki et al. '00; Kallosh et al. '11]

When S contains the goldstino, impose nilpotency and get rid of the sgoldstino

[Dall'Agata, Zwirner '14]

Corrections — basics



Volkov-Akulov theories can have a natural cut-off scale, above which the sgoldstino re-enters the theory

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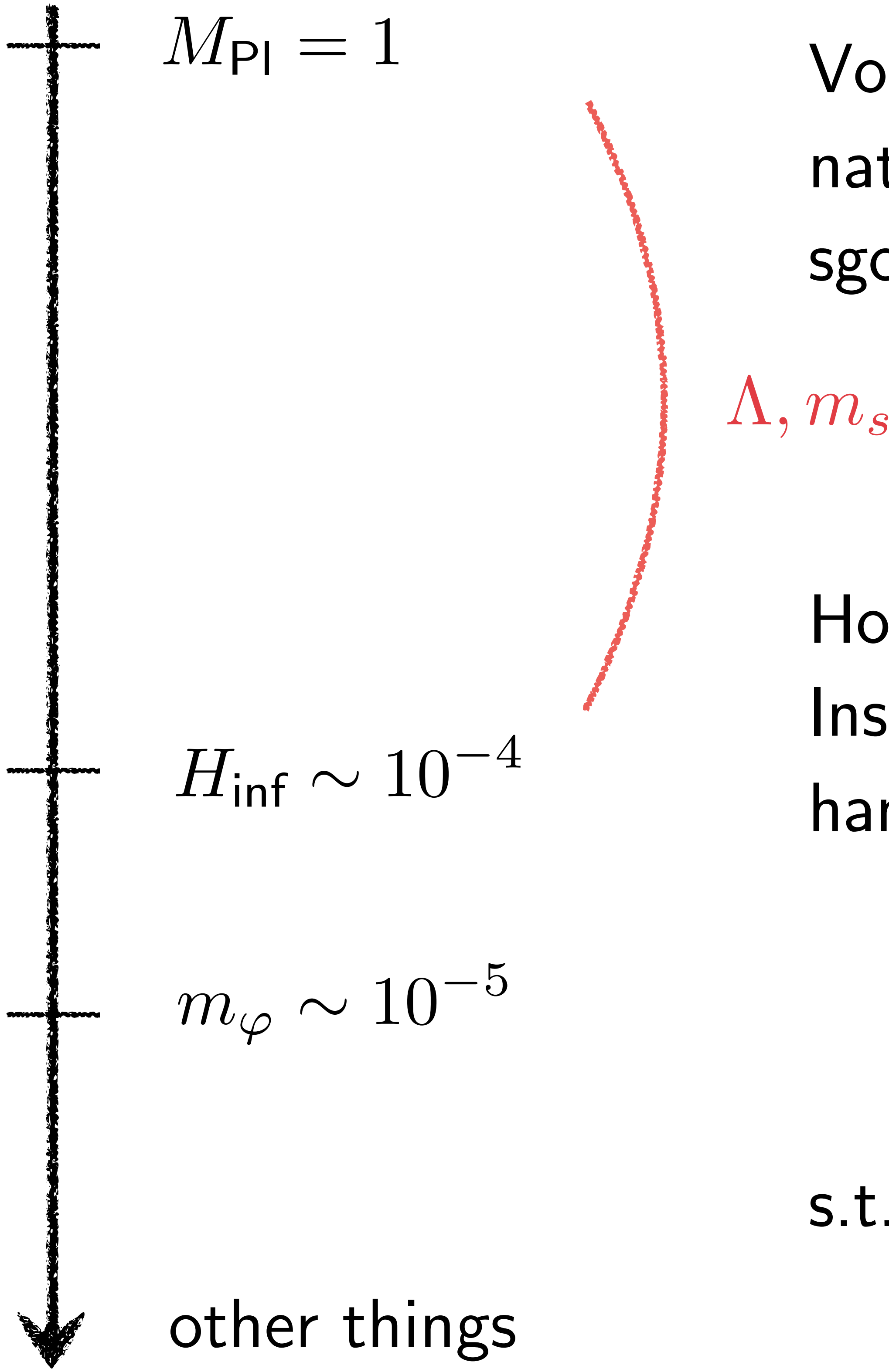

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How to see and quantize such effects? Instead of imposing nilpotency by hand, large mass via operator

$$\boxed{K \supset c\frac{|S|^4}{\Lambda^2}\,,}$$

s.t. $c \to \infty$ corresponds to nilpotency

[Komargodski, Seiberg '09; Kallosh et al. '15]

Corrections — basics

The physics related to the operator

$$\boxed{K \supset c \frac{|S|^4}{\Lambda^2}}$$

correct the inflationary theory in two different ways:

I) The finite-mass sgoldstino s back-reacts on the inflaton potential

II) Heavy fields integrated out at the scale Λ back-react on the inflaton potential

Sgoldstino corrections

Corrections from the sgoldstino scale inversely with its mass

$$m_s^2 = 12\frac{f(\varphi)^2}{\Lambda^2} = 12\frac{m_{3/2}^2}{\Lambda^2}$$

and appear in powers of $m_{3/2}/m_s$ and H/m_s, where $m_{3/2} > H\Lambda$ is a requirement.

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$$V_{\mathsf{eff}}(\varphi) = V_0 + V_0\Lambda^2\left(1 - \frac{V_0}{m_{3/2}^2}\right) + \mathcal{O}(\Lambda^4)$$

(These are actually not too bad when Λ is small enough.)

UV corrections I

Let us not forget about the second type of correction: heavy fields, integrated out at a high scale, generate the mass term in K. They, too, have a finite mass and will back-react.

Example 1: O'Raifeartaigh-type model

$$W = f(\Phi)(1 + \delta S) + \lambda S X^2 + M X Y \,,$$

$$K = \frac{1}{2}(\Phi + \bar{\Phi})^2 + |S|^2 + |X|^2 + |Y|^2$$

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Example 1: O'Raifeartaigh-type model

$$\Lambda = \frac{2\sqrt{3}\pi}{\lambda^2} M$$

$$W = f(\Phi)(1 + \delta S) + \lambda S X^2 + M X Y \,,$$

$$K = \frac{1}{2}(\Phi + \bar{\Phi})^2 + |S|^2 + |X|^2 + |Y|^2$$

$$\boxed{m_X = m_Y = M \,, \quad m_{s,\text{1-loop}} = \frac{\lambda^2 m_{3/2}}{\pi M}}$$

UV corrections II

All is not well during inflation: the inflaton couples to X such that a tachyonic direction arises at large field values,

$$m^2_{\mathsf{Im}\,x} = M^2 - 2\sqrt{3}\lambda m_{3/2}\,,$$

giving rise to a lower bound on M and thus Λ. At the same time, M must be small enough for the sgoldstino to be heavy.

UV corrections III

Example 2: Gauge interactions

$$W = f(\Phi)(1+\delta XS) + \lambda\Psi(XY - v^2)\,,$$
$$K = \frac{1}{2}(\Phi+\bar{\Phi})^2 + |S|^2 + |\Psi|^2 + |X|^2 + |Y|^2$$

After eliminating $\Psi, X,$ and Y this reduces to sgoldstino-less inflation with a mass term

$$m_s^2 = \frac{9m_{3/2}^2}{2v^2}$$

$$\Lambda = \sqrt{\frac{4}{3}}v$$

UV corrections IV

Again, during inflation there is an interaction involving the heavy fields. This time, consistently integrating them out yields an effective inflaton potential shaped like

$$\boxed{V_{\text{eff}}(\varphi) = V_0 - \alpha \frac{m_{3/2}^4}{v^4} + \dots\,,}$$

again, leading to a lower bound on v and Λ. And again, this disagrees with a heavy sgoldstino.

Sgoldstino decoupling?

What have we learned so far about the different EFT limits?

- Sgoldstino corrections: negligible in the limit of small Λ, since

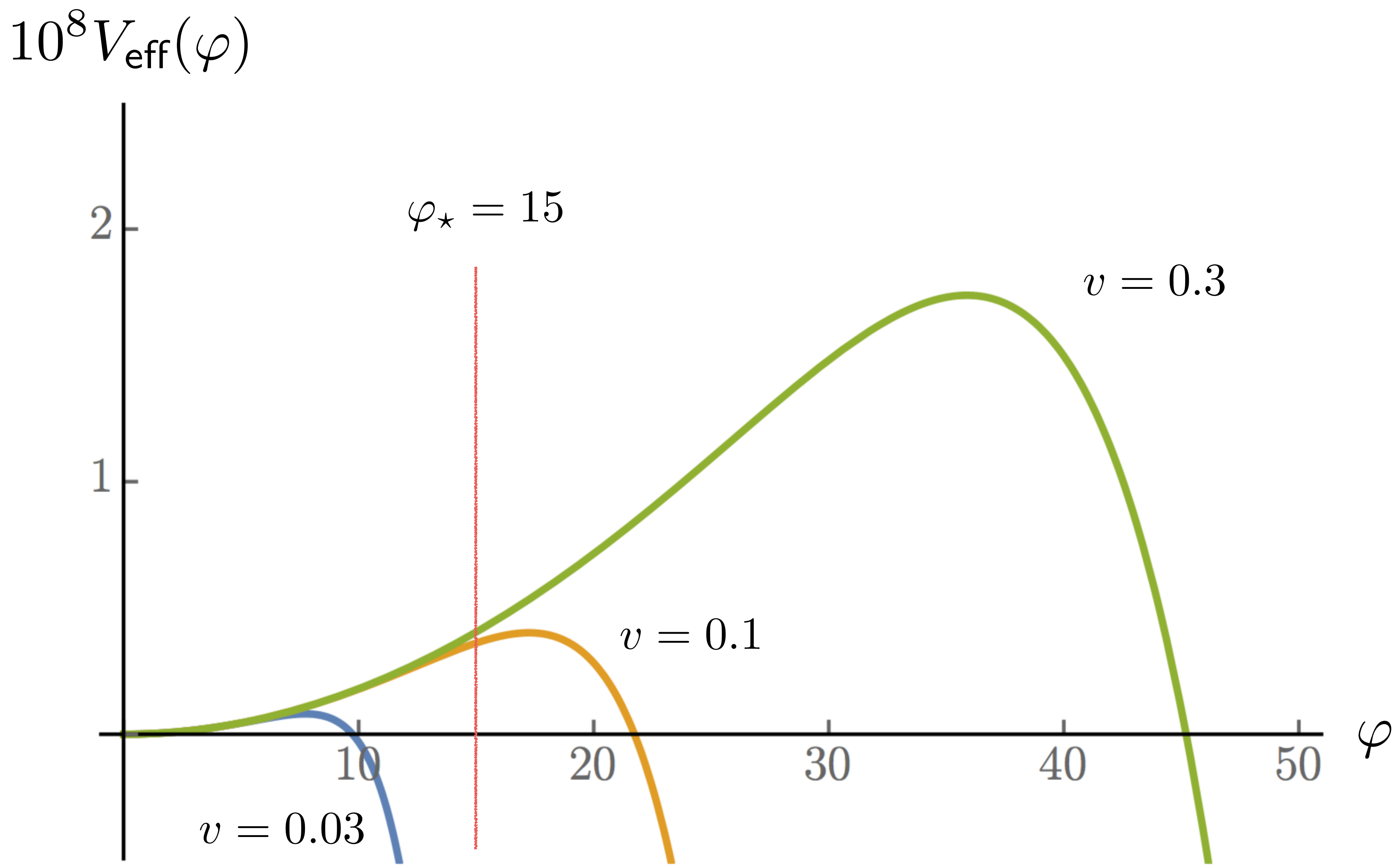
$$\boxed{m_s \propto \Lambda^{-1}}$$

- UV corrections: negligible in the limit of large Λ, since

$$\boxed{m_{X,Y} \propto \Lambda}$$

$\hookrightarrow$ Is there a window in which both are under control?

A numerical example



The back-reaction is under control if $v \gtrsim 0.1$ and flattens the potential. This means Λ is very close to M_{Pl}.

Conclusions

- Decoupling of the sgoldstino scalar in cosmology is nontrivial
- Imposing nilpotency of the goldstino multiplet misses important corrections in inflationary theories

$\longrightarrow$ Non-linear supergravities have a natural cut-off scale above which sgoldstino re-appears

- In UV-complete theory, mass of sgoldstino is generated by interactions with heavy sector
- Corrections can be computed and might be under control in very narrow parameter window