Assisted Hilltop Inflation

[based on arXiv: 1806.04521]

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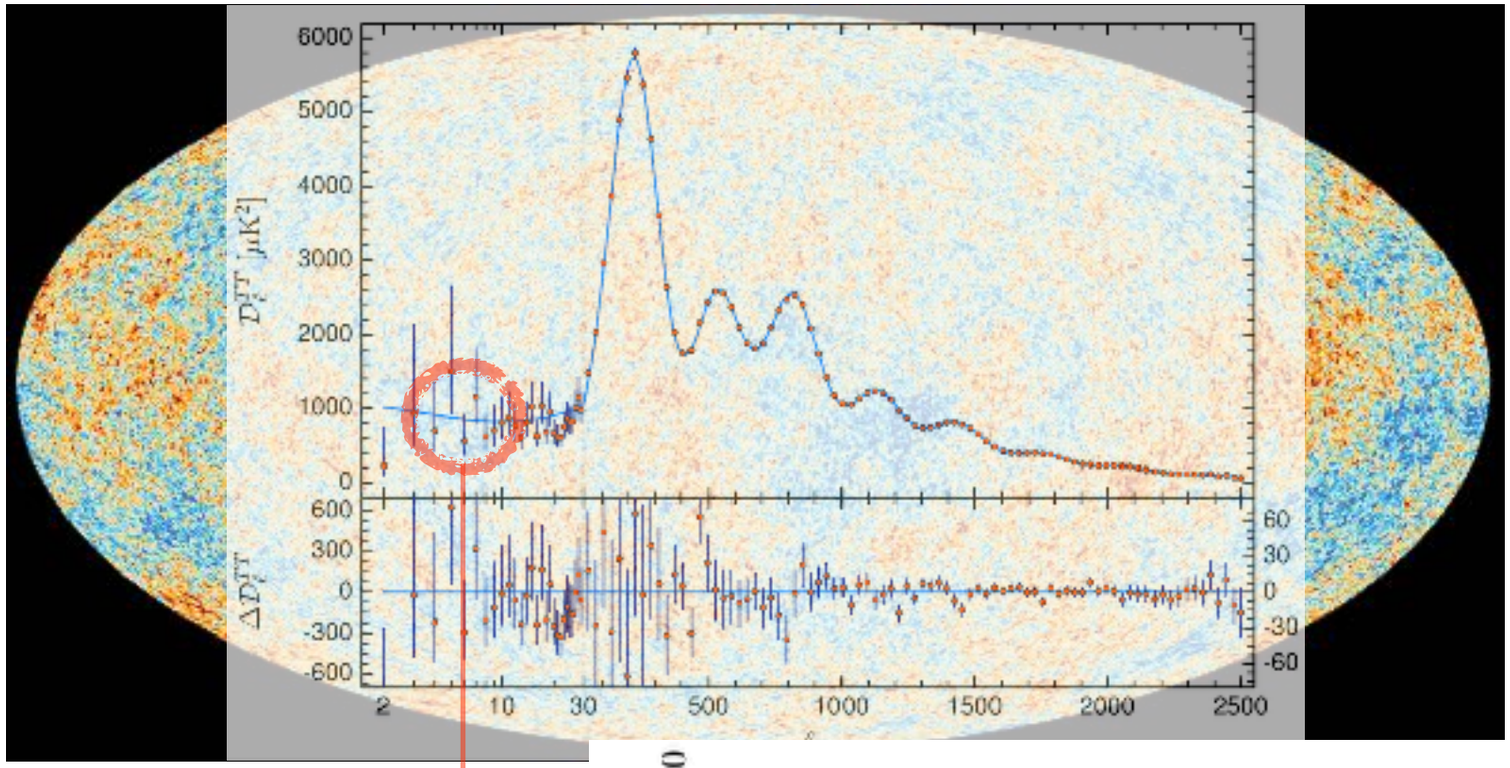
Cosmo 2018, IBS, Daejeon, Aug. 29 (2018)

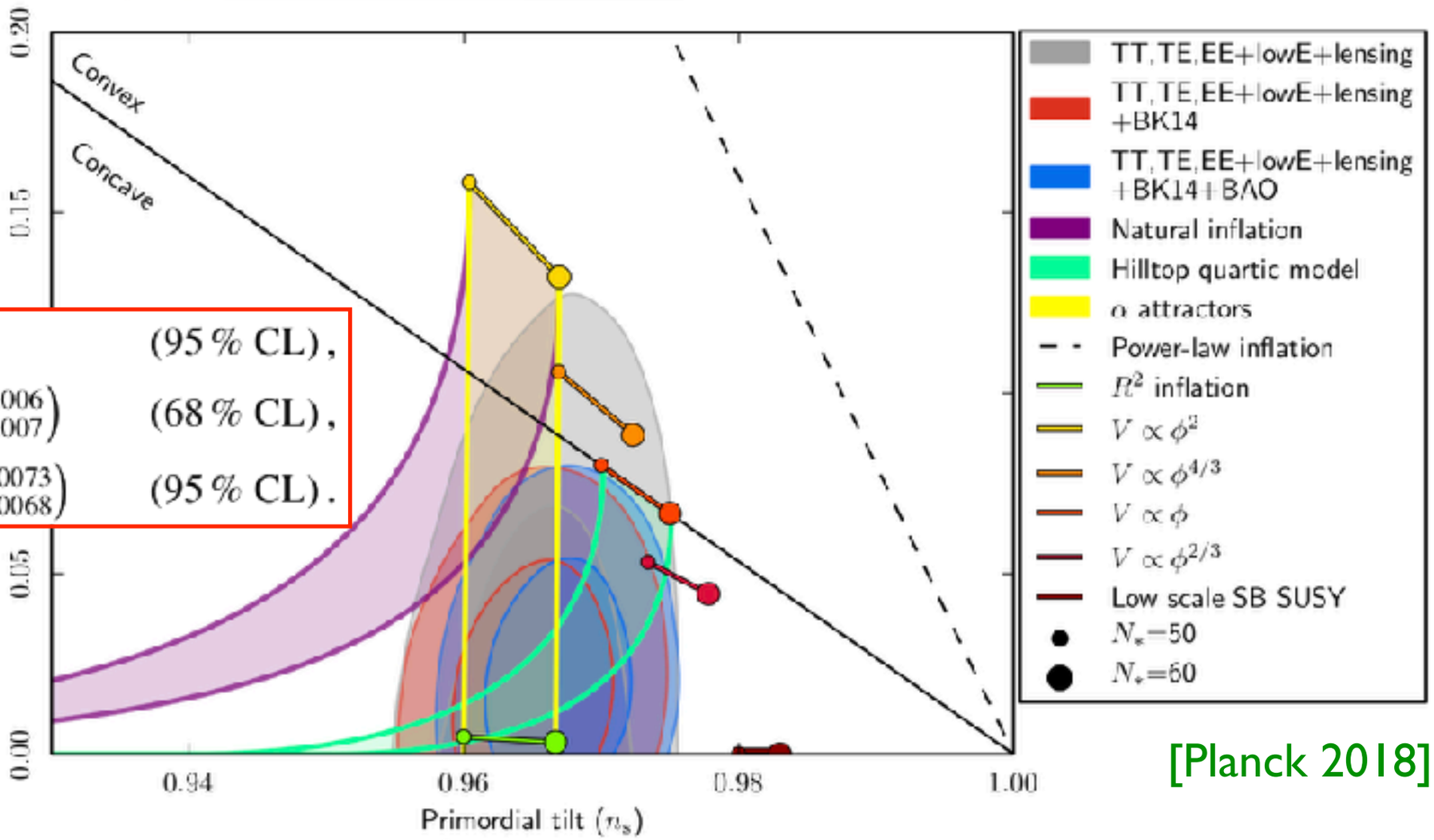
Sorry for many missing references!

Inflation & issues



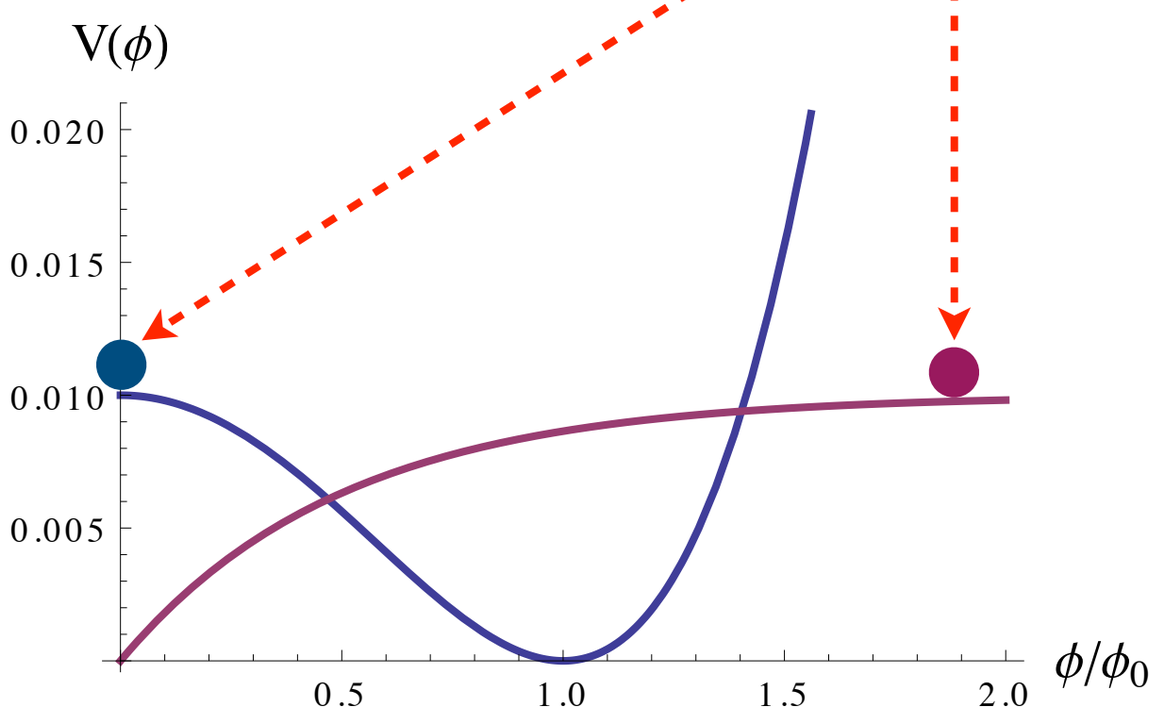
$$n_s - 1 \equiv \frac{d \ln P_R}{d \ln k} \sim -4 \times 10^{-2}$$

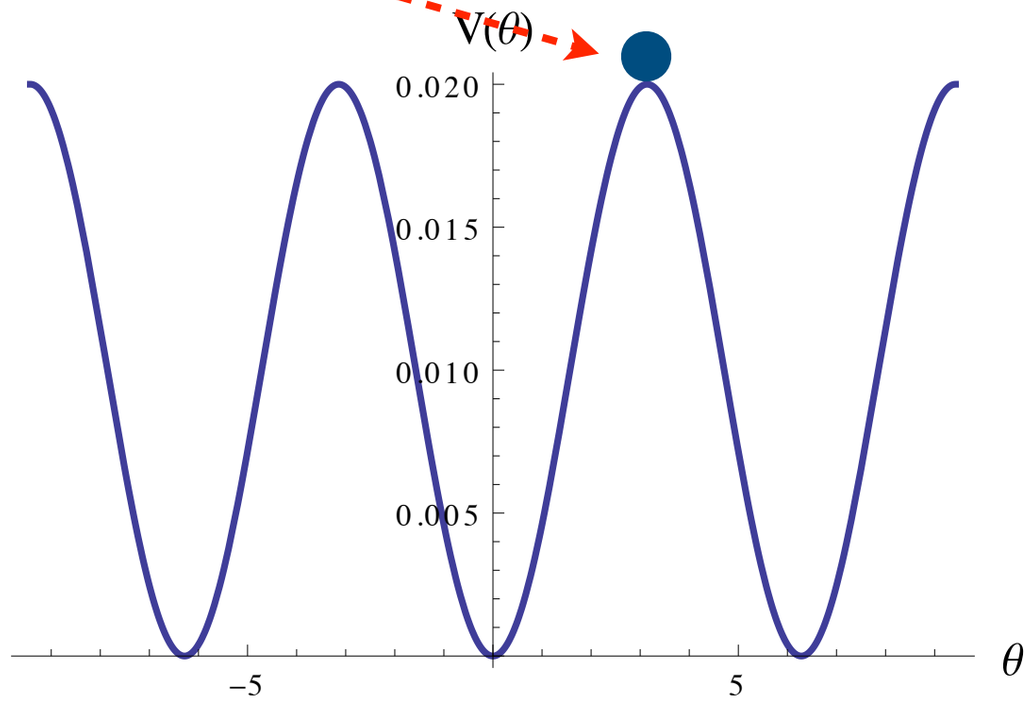
$$\begin{aligned}
&\epsilon_V < 0.0097 && (0.0053) && (95\,\%\ \mathrm{CL}),\\
&\eta_V = -0.010^{+0.007}_{-0.011} && \left(-0.014^{+0.006}_{-0.007}\right) && (68\,\%\ \mathrm{CL}),\\
&\xi^2_V = 0.0035^{+0.0078}_{-0.0072} && \left(0.0023^{+0.0073}_{-0.0068}\right) && (95\,\%\ \mathrm{CL}).
\end{aligned}$$



[Planck 2018]

1. How can it be there initially?
2. How can it be so flat there?





Motivation (1/2)

✦ η-problem of F-term inflation in SUGRA

[Copeland et al. PRD 49, 6410 ('94); Stewart PRD 51, 6847 ('95)]

$$G = -3\ln\left(-\frac{K}{3}\right) + \ln|W|^2$$

$$K = \sum_i \Phi_i^\dagger \Phi_i + b_i\left(\Phi_i^2 + \text{h.c.}\right) + \sum_{ij} c_{ij}\left(\Phi_i^\dagger \Phi_j + \text{h.c.}\right) + \sum_{ij} d_{ij}\Phi_i^\dagger\Phi_i\Phi_j^\dagger\Phi_j + \cdots$$

$$V = e^G\left[G_i\left(G_{i\bar{j}}\right)^{-1}G_{\bar{j}} - 3\right]$$

$$= \left[1 + \delta K + \cdots\right]e^{\langle K\rangle}\left[G_i\left(G_{i\bar{j}}\right)^{-1}G_{\bar{j}} - 3\right]$$

$$\supset c_i H^2|\Phi_i|^2 + \cdots$$

Generically, $|c_i| = \mathcal{O}(1) \Rightarrow |\eta| \equiv \frac{V''}{V} = \mathcal{O}(1)$ during inflation

$$\left(\text{c.f} \quad |\eta^{\text{obs}}| \sim \mathcal{O}(10^{-2})\right)$$

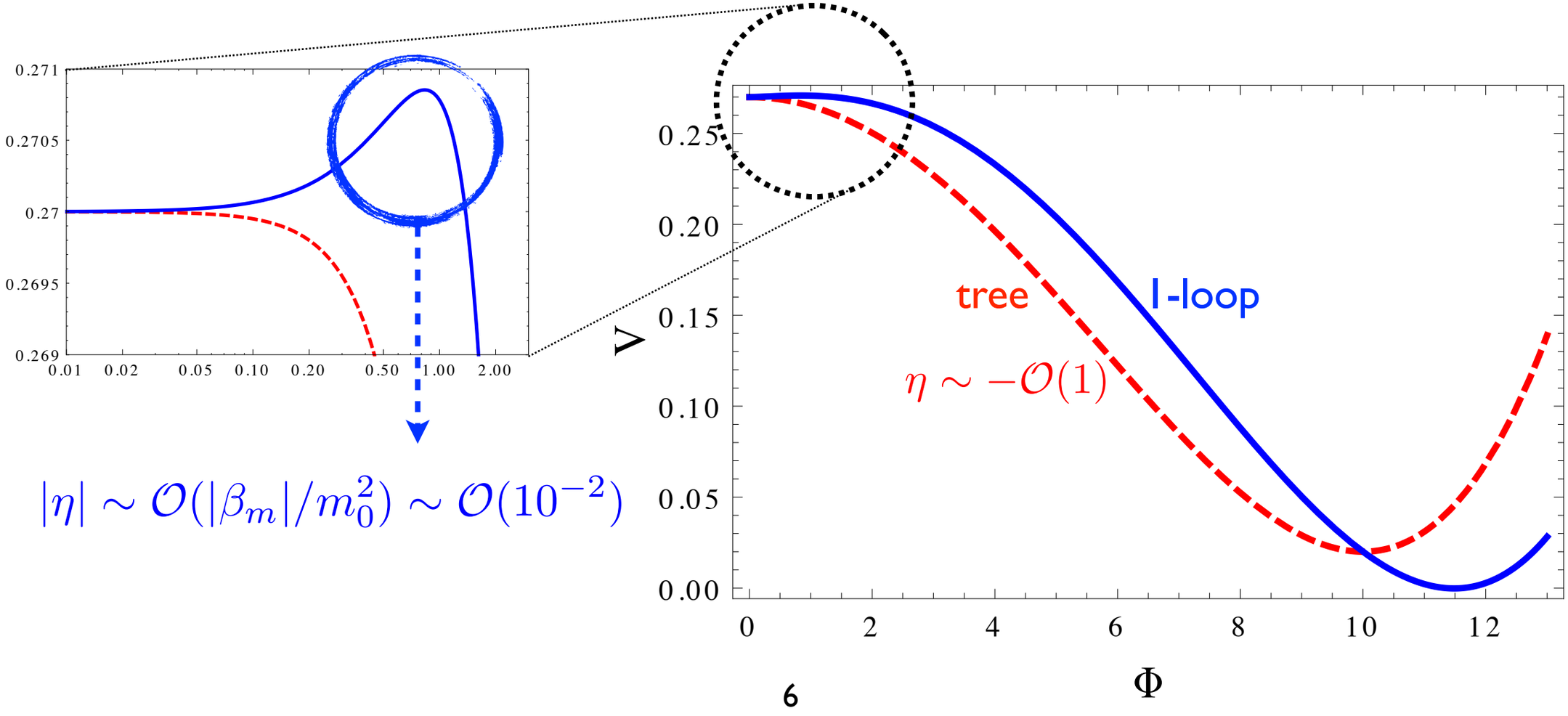
Motivation (2/2)

✦ Running Mass Inflation (as a natural approach)

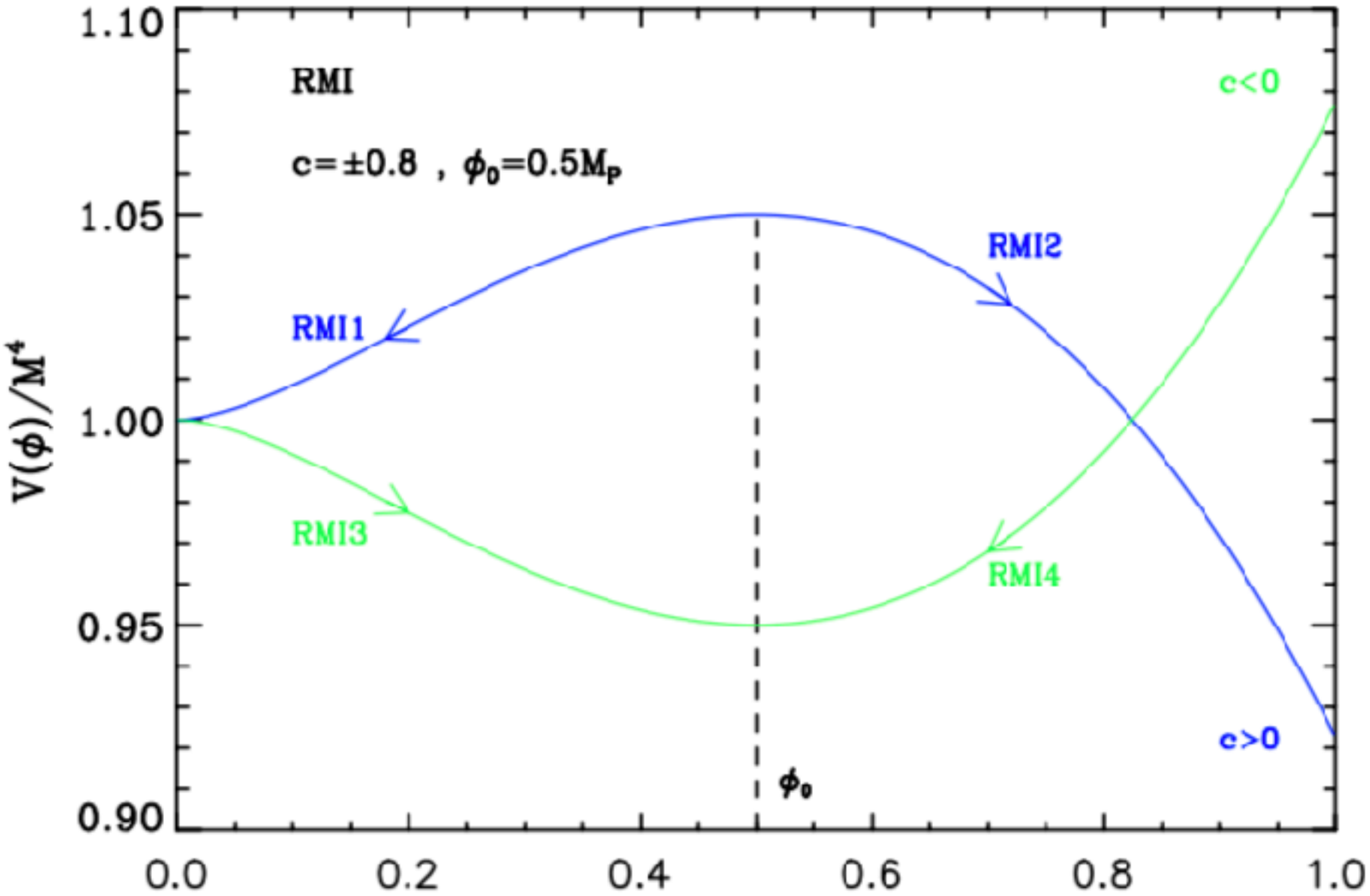
[Stewart PLB 391, 34 ('97)]

$$V = V_0 - m^2(|\Phi|)|\Phi|^2 + \cdots$$

$$m^2(|\Phi|) = m_0^2 + \beta_m \ln|\Phi|$$

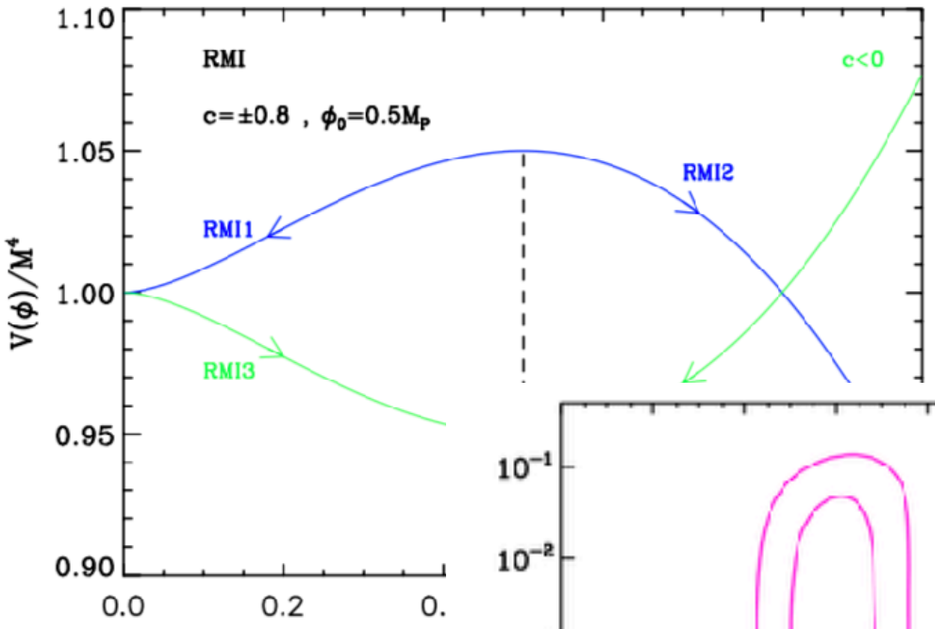


Various possibilities of RMI



Predictions of RMI

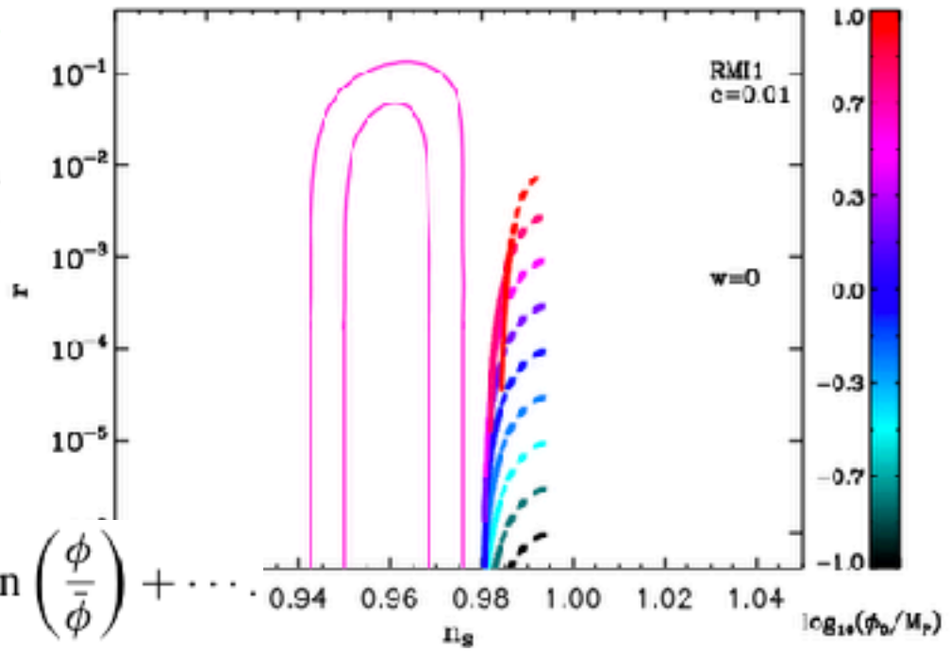
[Martin, Ringeval & Vennin Phys. Dark. Univ. 5-6, 75 ('14)]

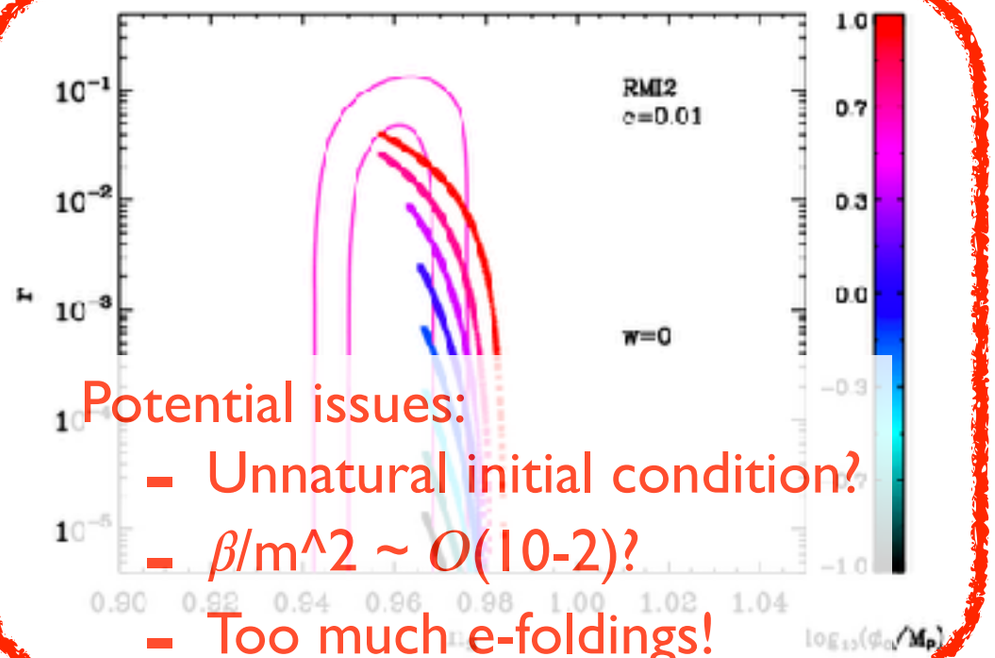


$$\frac{\mathrm{d}m^2}{\mathrm{d}\ln\phi} = \beta_{\mathrm{mat}}$$

$$m^2 = m^2(\bar{\phi}) + \beta_{\mathrm{mat}} \ln\left(\frac{\phi}{\bar{\phi}}\right) + \cdots$$

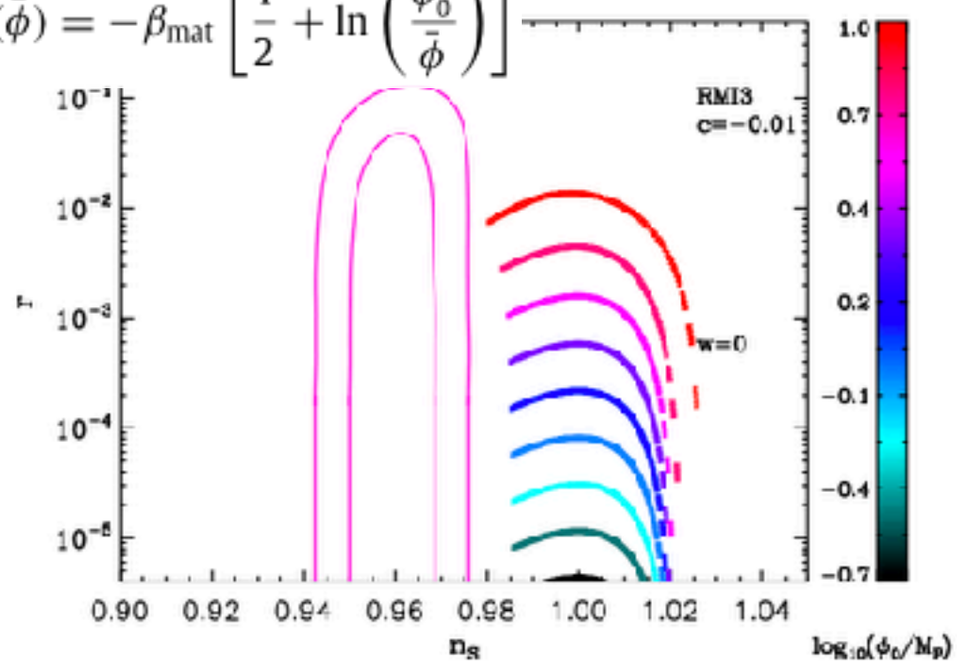
$$c = -\frac{M_{\mathrm{Pl}}^2 \beta_{\mathrm{mat}}}{2V_0}, \quad m^2(\bar{\phi}) = -\beta_{\mathrm{mat}}\left[\frac{1}{2} + \ln\left(\frac{\phi_0}{\bar{\phi}}\right)\right]$$

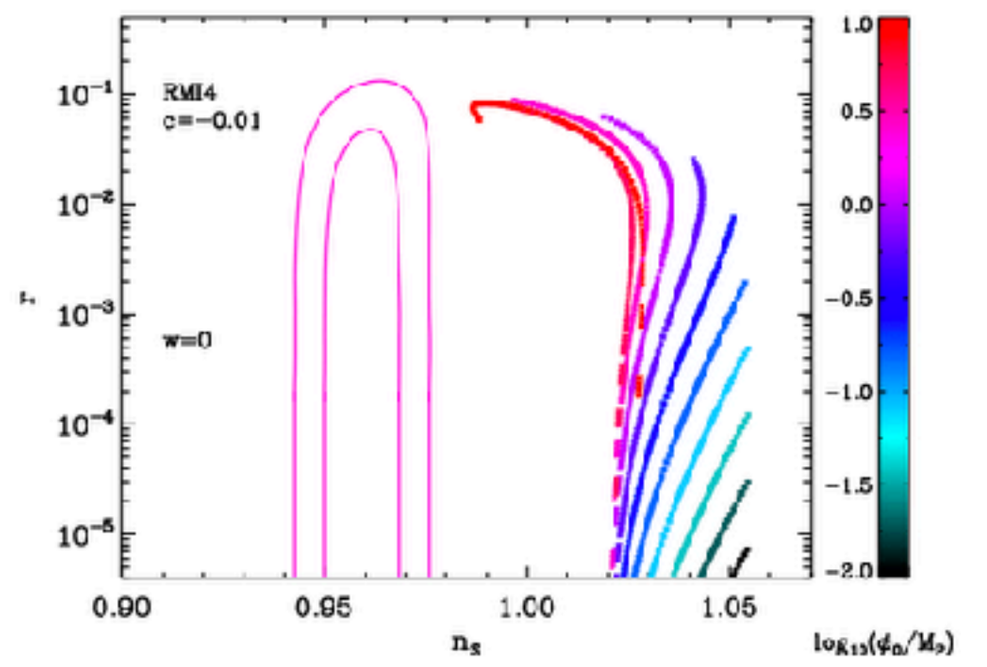




Potential issues:

- Unnatural initial condition?
- β/m^2 ~ O(10-2)?
- Too much e-foldings!





Assisted Hilltop Inflation (1/4)

[WIP, 1806.04521]

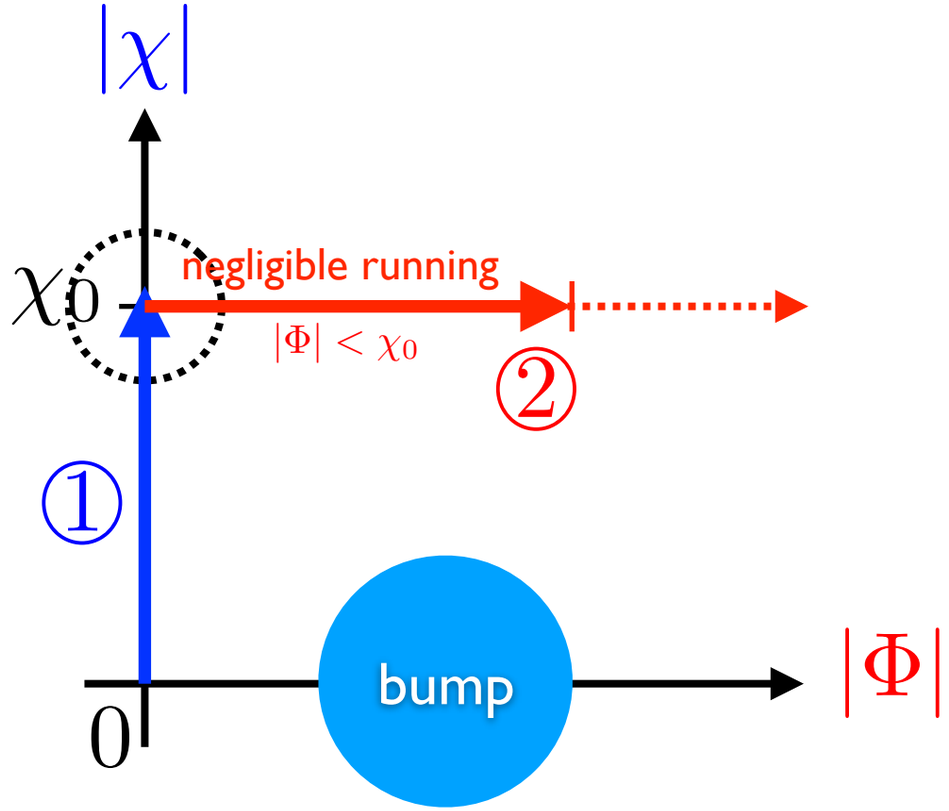
✦ Double running of the inflaton mass-sq. parameter

When particles dominating RG-running of m^2 couple both Φ and χ,

$$m^2(|\Phi|) \to m^2(|\chi|, |\Phi|) = m_0^2 + \frac{1}{2}\beta_m \ln\left(|\chi|^2 + |\Phi|^2\right)$$

In the vicinity of ($\chi_\times$, 0) where $m_\Phi^2=0$,

$$m_\Phi^2 = \beta_m \left[\ln\frac{\chi_0}{\chi_\times} + 3\ln\left(1+\frac{|\Phi|^2}{\chi_0^2}\right)\right]$$



Assisted Hilltop Inflation (2/4)

[WIP, 1806.04521]

✦ A model

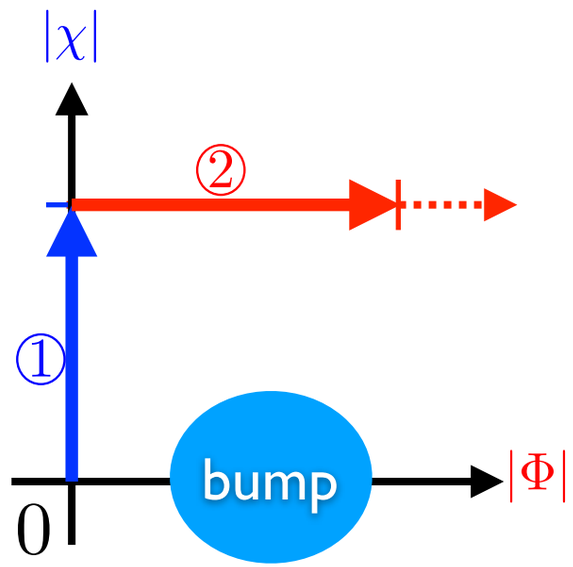
$$V = V(\chi) + V(\chi, \Phi)$$

$$V(\chi) = -m_\chi^2 |\chi|^2 + \left| \frac{\lambda_\chi \chi^{q-1}}{M_*^{q-3}} \right|^2$$

$$V(\chi, \Phi) = -m_0^2 \left[1 + \frac{\beta_m}{2m_0^2} \ln \left(|\chi|^2 + |\Phi|^2 \right) \right] |\Phi|^2 + M^4 \left(1 - \left| \frac{\Phi}{\Phi_0} \right|^n \right)^2$$

Features:

- χ=Φ=0 is a saddle point.
- Thermal mass can hold the field configuration at the origin, setting a natural initial condition for the subsequent inflation.
- A slow-roll inflation takes place along Φ from (χ_0, 0).
- A proper amount of e-foldings is obtained due to the hilltop potential.



Assisted Hilltop Inflation (3/4)

[WIP, 1806.04521]

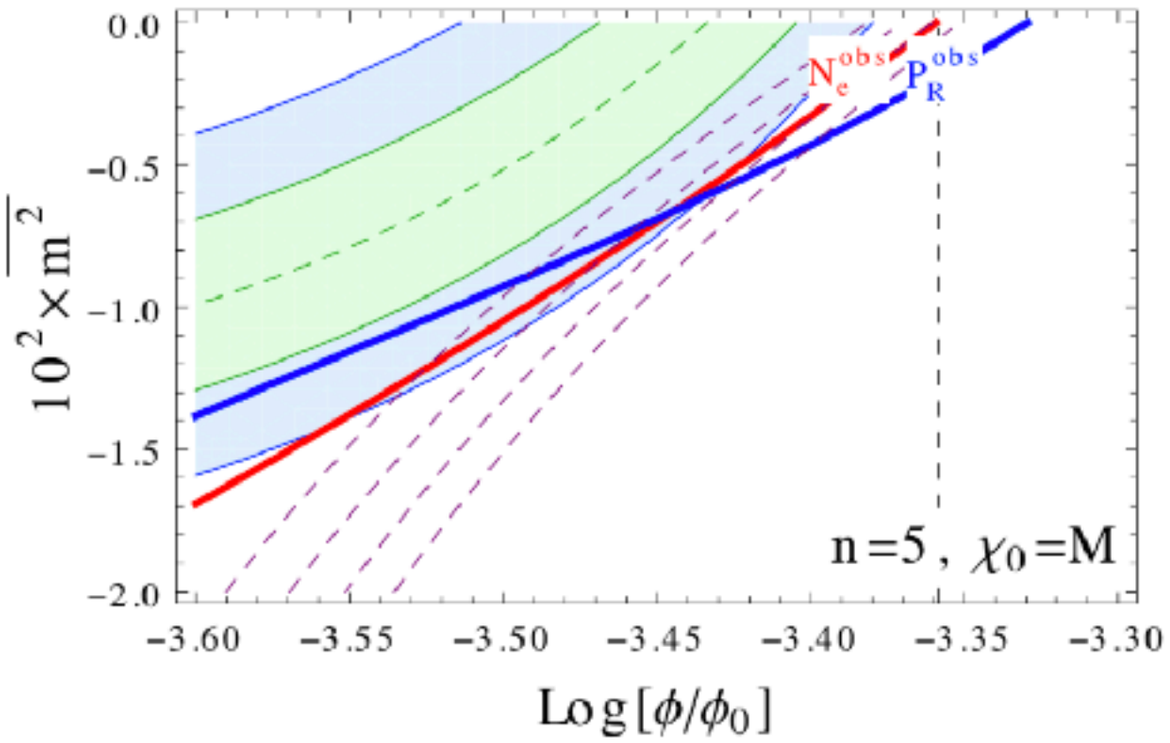
✦ A model

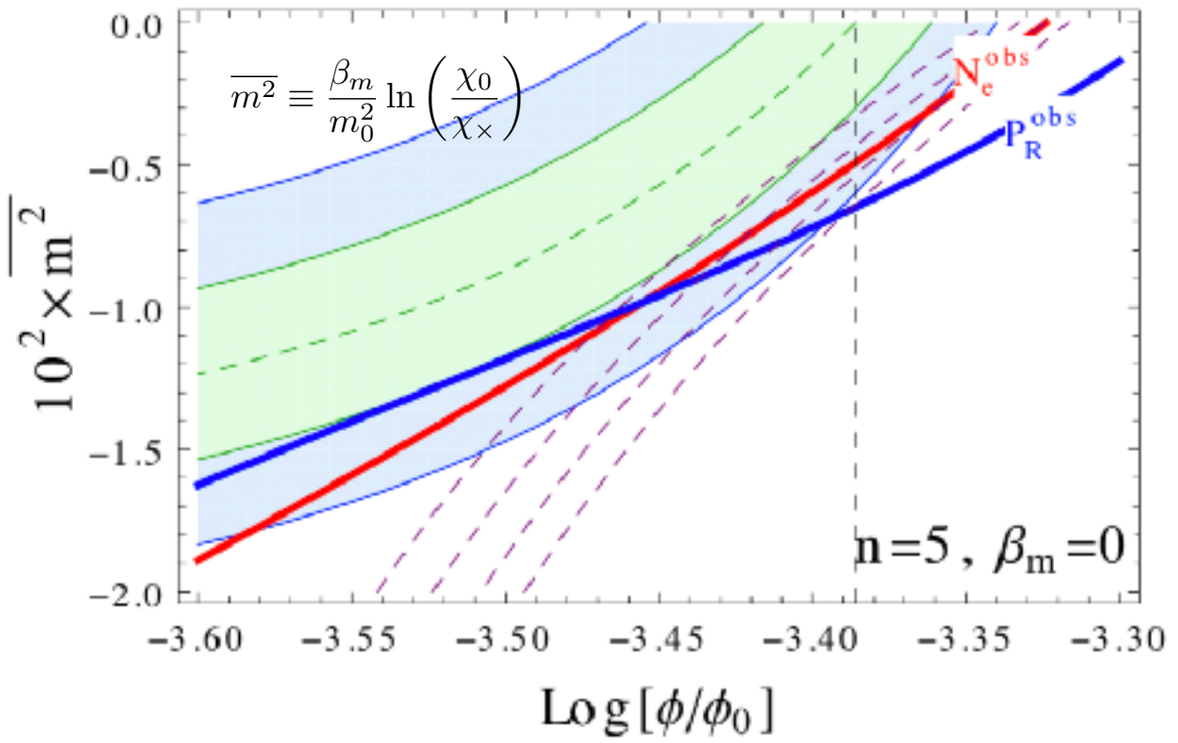
$$V = V(\chi) + V(\chi, \Phi)$$

$$V(\chi) = -m_\chi^2 |\chi|^2 + \left| \frac{\lambda_\chi \chi^{q-1}}{M_*^{q-3}} \right|^2$$

$$V(\chi, \Phi) = -m_0^2 \left[1 + \frac{\beta_m}{2m_0^2} \ln \left(|\chi|^2 + |\Phi|^2 \right) \right] |\Phi|^2 + M^4 \left(1 - \left| \frac{\Phi}{\Phi_0} \right|^n \right)^2$$

Parameter space:





Assisted Hilltop Inflation (4/4)

[WIP, 1806.04521]

✦ A supersymmetric realization

$$W = S\left(M^2 - \frac{\lambda_\phi \phi^n}{n M_*^{n-2}}\right) \equiv M^2 S\left[1 - \left(\frac{\phi}{\phi_0}\right)^n\right]$$

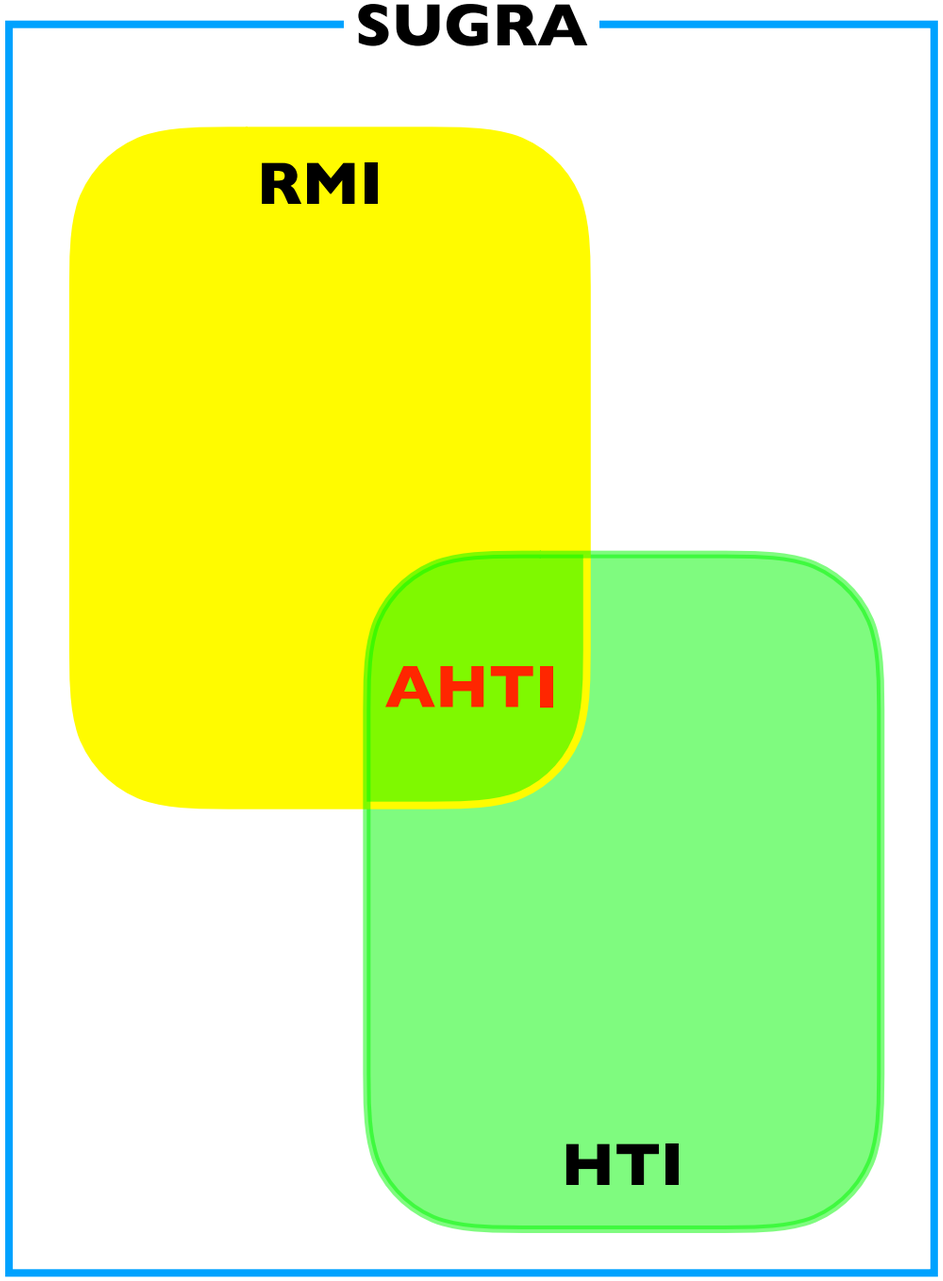
ϕ : a flat direction

Assumptions:

- Low energy SUSY is broken after inflation (to avoid dangerous tadpole)

$\Rightarrow$ may require particular dynamics of moduli or mediation scenario of SUSY-breaking

Conclusions



Assisted Hill-Top Inflation

1. Double-running mass-sq. + Hilltop potential
2. Natural initial condition for small-field slow-roll inflation
3. Small η due to an assisting field
4. Low-energy SUSY-breaking to be checked