

Probing the Starobinsky R^2 inflation with CMB precision cosmology

Yuki Watanabe
NIT, Gunma College

Based on JHEP 02(2018)118 [arXiv:1801.05736] with I. Dalianis;
JHEP 02(2015)105 [arXiv: 1411.6746] with T. Terada, Y. Yamada, J. Yokoyama

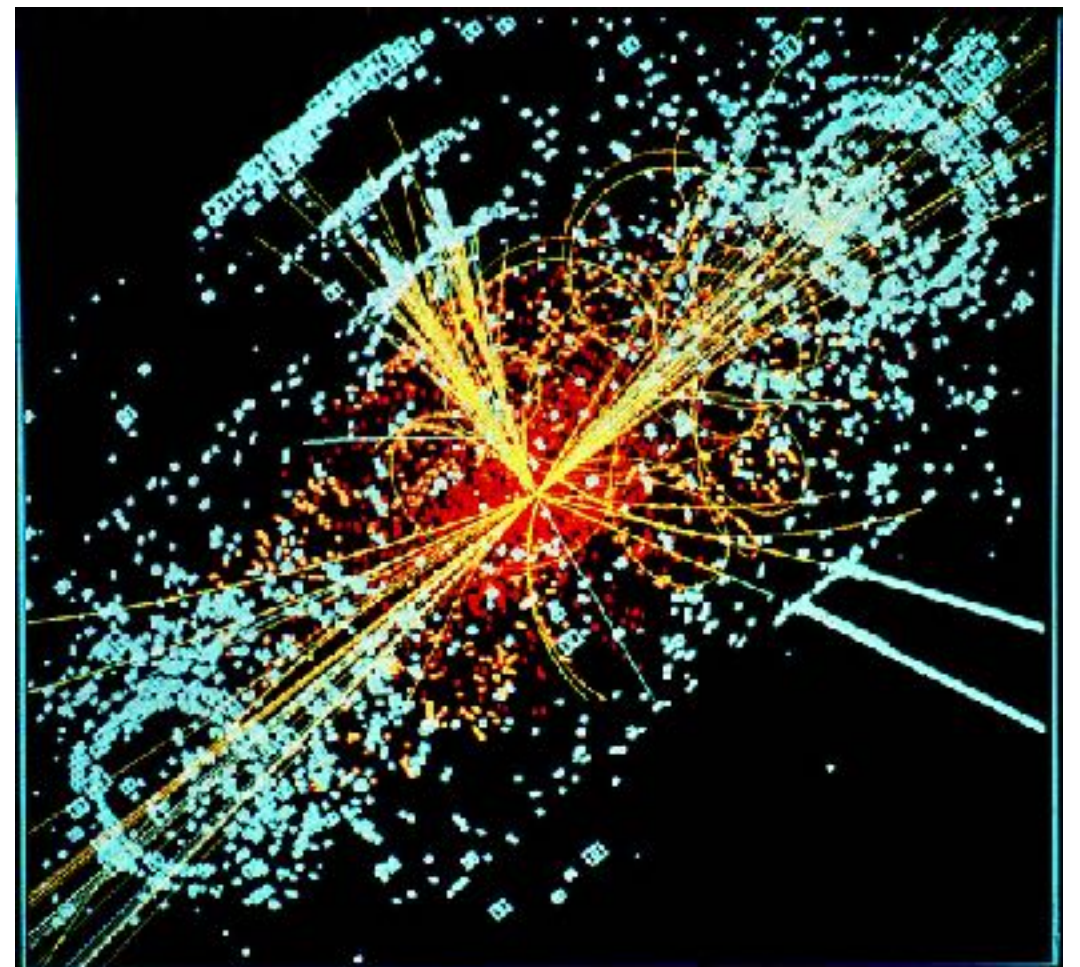
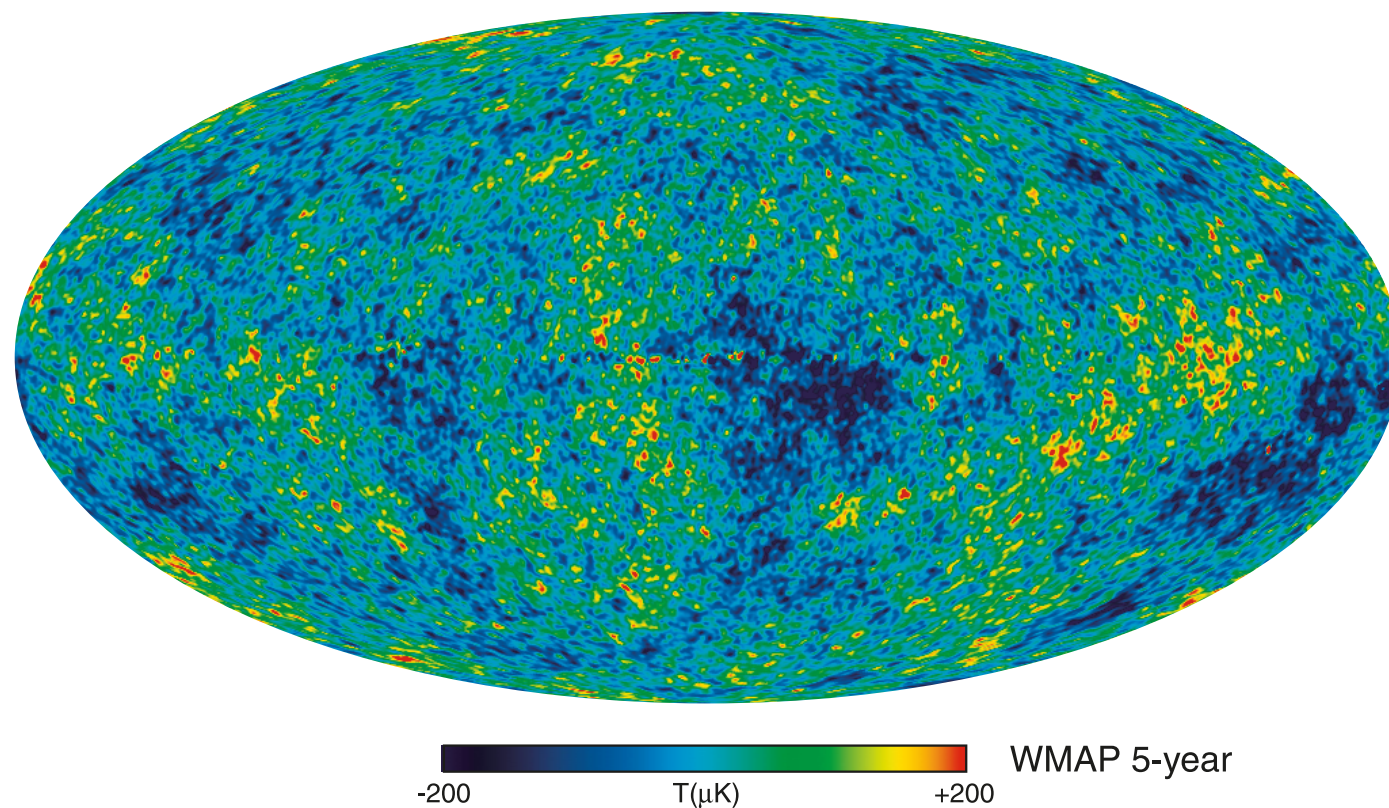


The 22nd Annual International Conference on
Particle Physics and Cosmology
COSMO-18

IBS Science and Culture Center, Daejeon, Korea
August 29, 2018

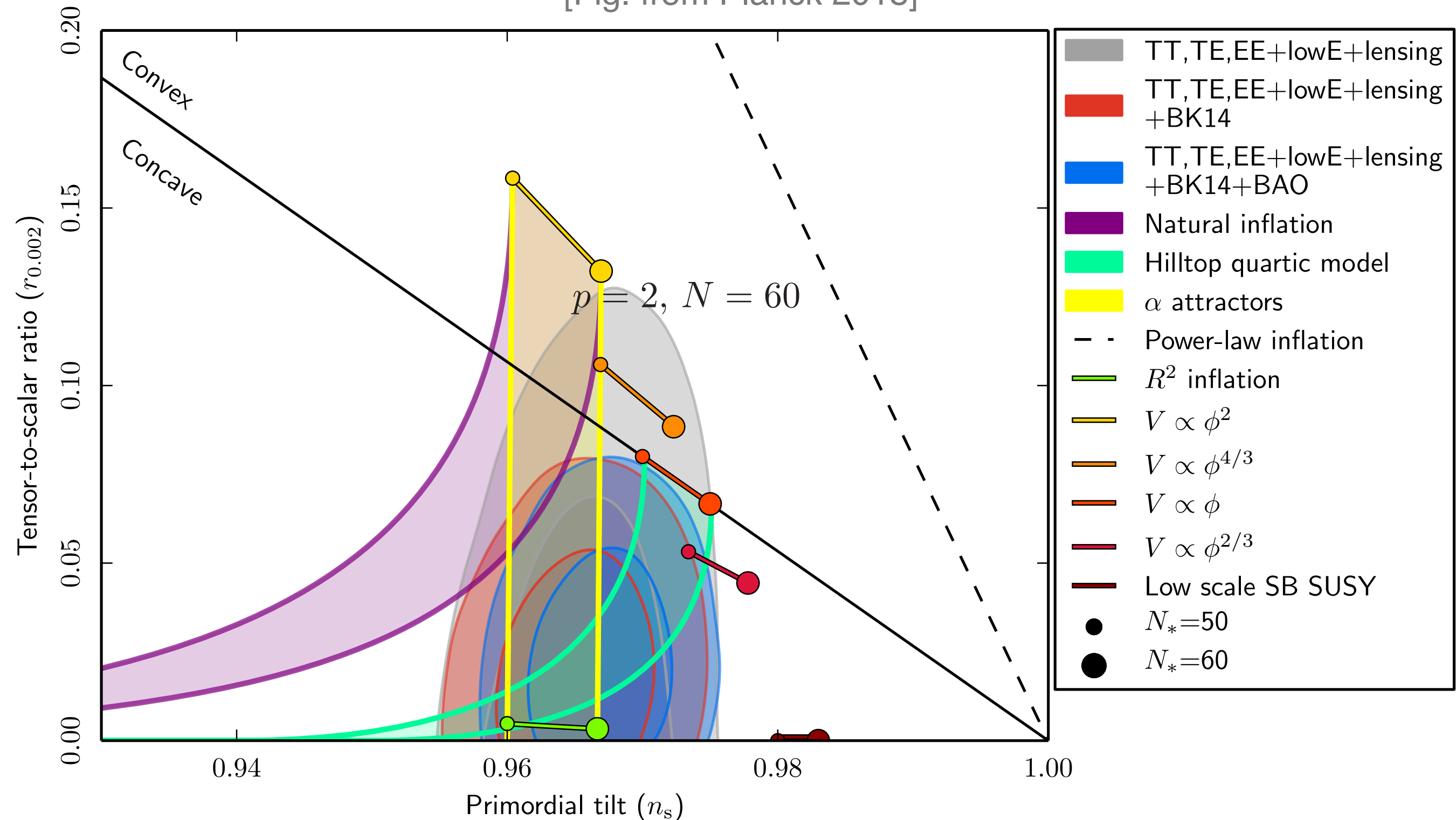
CMB observations and BSM physics

- (n_s, r) precision measurements from CMB
- No signal of physics beyond the Standard Model (BSM) at the LHC



CMB constraint on inflation models

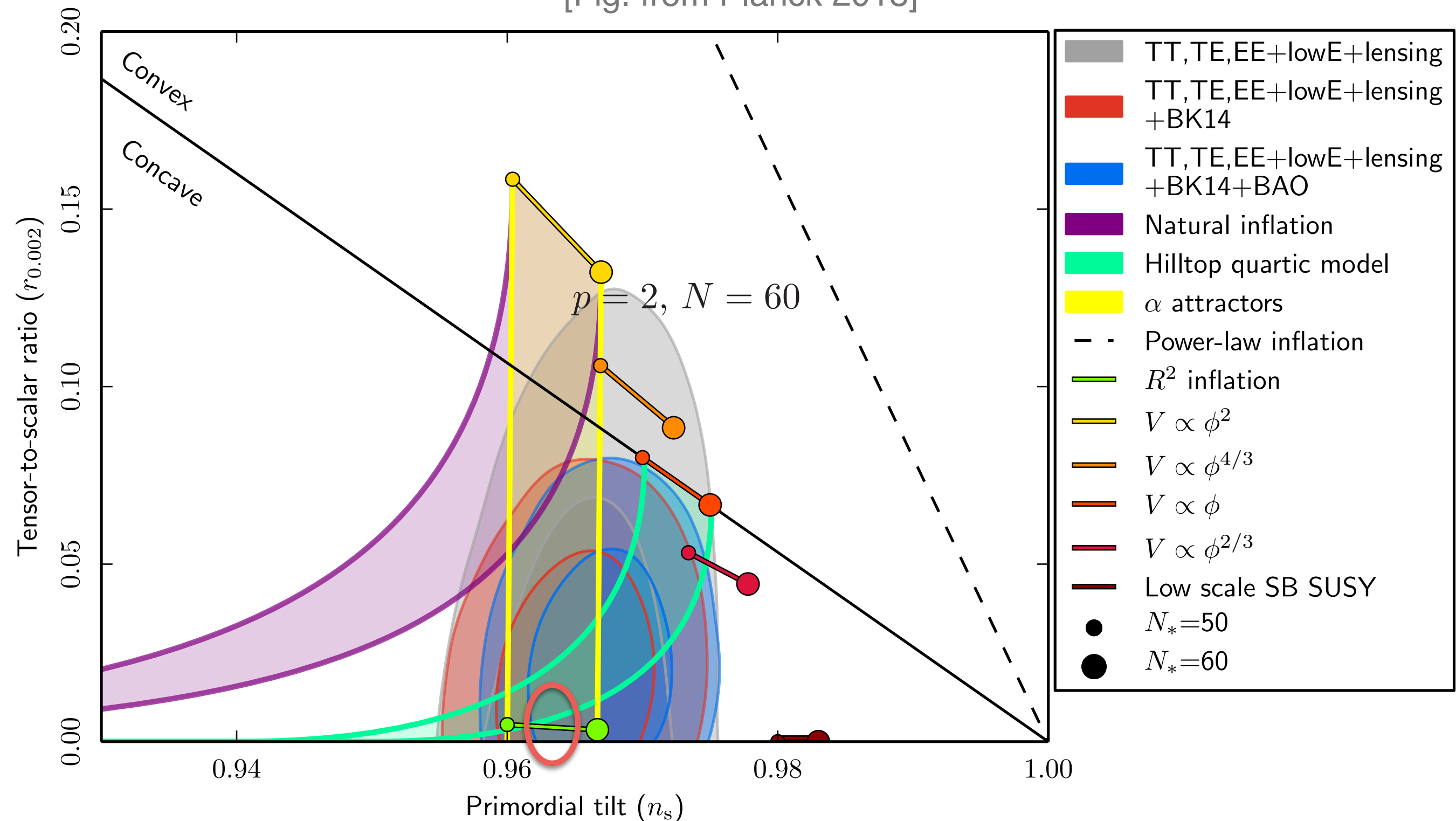
[Fig. from Planck 2018]



- Monomial potentials ($p \geq 2$) in GR are disfavored.

CMB constraint on inflation models

[Fig. from Planck 2018]



- Monomial potentials in GR are disfavored.
- What if we could nail down to further precision?

Starobinsky R^2 Inflation

[Starobinsky 1980; Mukhanov & Chibisov 1981]

$$S = \frac{1}{2\kappa^2} \int d^4x \sqrt{-g} \left(R + \frac{R^2}{6M^2} \right) + S_m$$

$$S_m = \int d^4x \sqrt{-g} \left[-\frac{1}{2} (\nabla \sigma)^2 - V(\sigma) \right] \quad \leftarrow \text{Higgs}$$

+ minimally coupled SM, RHN

+ “*desert*” or BSM

- One of the oldest models of Inflation, before models of Sato and Guth
- A single parameter **M** characterizes the model.

R² Inflation as scalar-tensor theory

[Whitt 1984; Maeda 1988]

$$S_J = \frac{1}{2\kappa^2} \int d^4x \sqrt{-\hat{g}} \left(\hat{R} + \frac{\hat{R}^2}{6M^2} \right) + S_m$$

$$S_m = \int d^4x \sqrt{-\hat{g}} \left[-\frac{1}{2} (\hat{\nabla} \hat{\sigma})^2 - V(\hat{\sigma}) \right]$$

Jordan frame $\hat{g}_{\mu\nu}$
 Einstein frame $g_{\mu\nu}$

$$g_{\mu\nu} = \hat{g}_{\mu\nu} \Omega^2 \quad \Omega^2 = 2\kappa^2 \left| \frac{\partial \mathcal{L}_J}{\partial \hat{R}} \right| = 1 + \frac{\hat{R}}{3M^2} \equiv e^{\sqrt{\frac{2}{3}} \kappa \varphi}$$

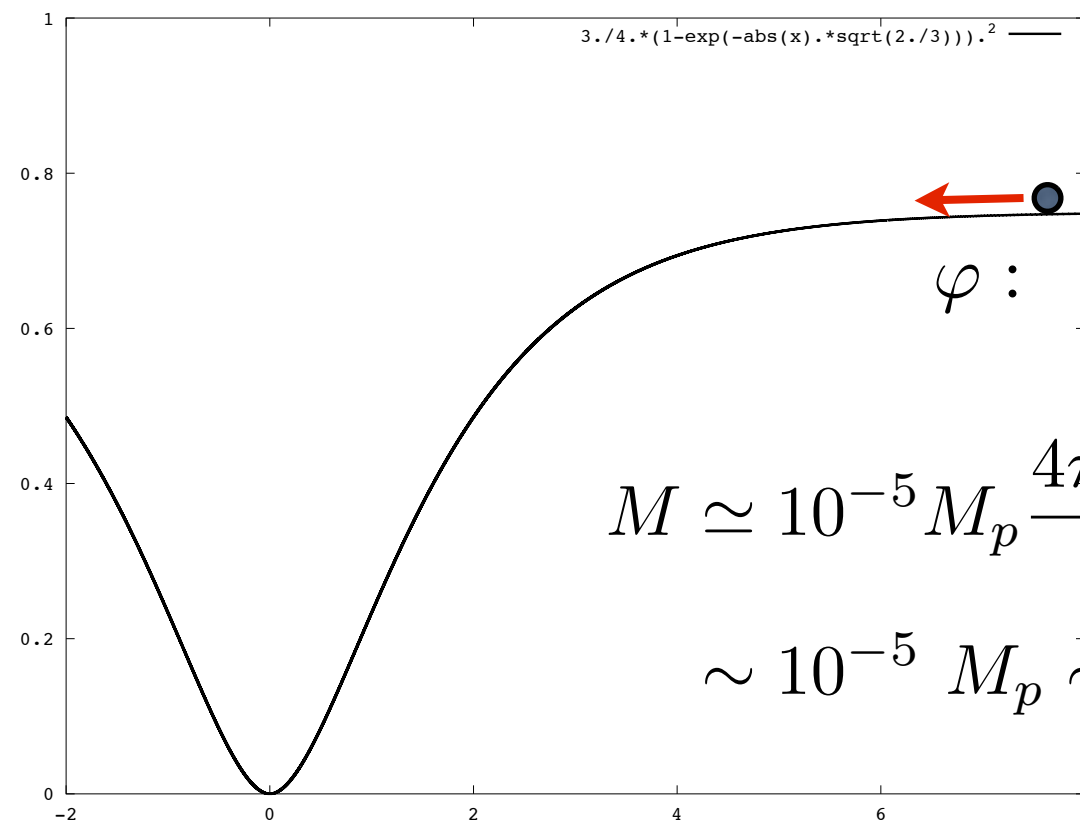
$$\hat{R} = \Omega^2 \left[R + 3\Box(\ln \Omega^2) - \frac{3}{2} g^{\mu\nu} \partial_\mu (\ln \Omega^2) \partial_\nu (\ln \Omega^2) \right]$$

$$S_E = \int d^4x \sqrt{-g} \left[\frac{1}{2\kappa^2} R - \frac{1}{2} (\nabla \varphi)^2 - U(\varphi) - \frac{1}{2} e^{-\sqrt{\frac{2}{3}} \kappa \varphi} (\nabla \hat{\sigma})^2 - e^{-\sqrt{\frac{8}{3}} \kappa \varphi} V(\hat{\sigma}) \right]$$

$$U(\varphi) = \frac{3}{4} M^2 M_p^2 \left(1 - e^{-\sqrt{\frac{2}{3}} \kappa \varphi} \right)^2 = \begin{cases} \frac{3}{4} M^2 M_p^2 & \text{for } \varphi \gg \varphi_f \\ \frac{1}{2} M^2 \varphi^2 & \text{for } \varphi \ll \varphi_f \end{cases}$$

φ : Scalaron = Inflaton

R² Inflation [Starobinsky 1980]



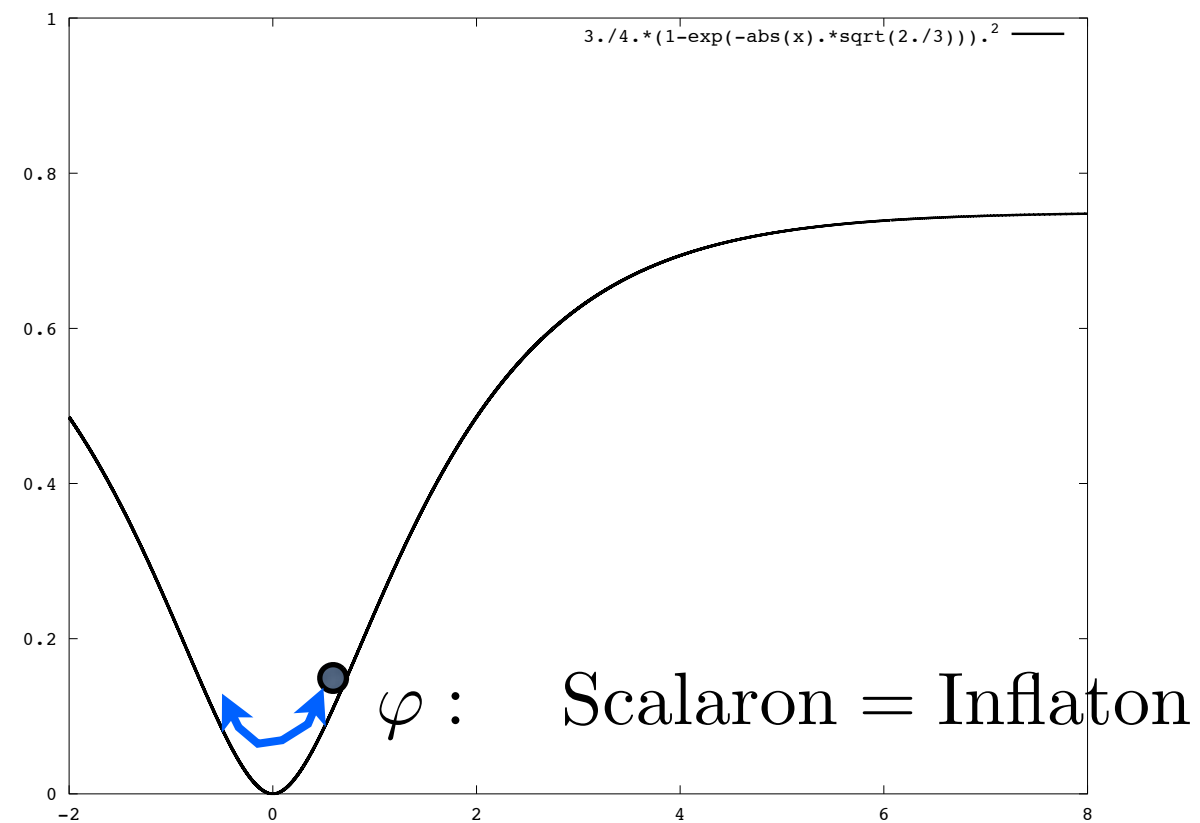
φ : Scalaron = Inflaton

$$M \simeq 10^{-5} M_p \frac{4\pi\sqrt{30}}{N_*} \left(\frac{\mathcal{P}_\zeta(k_*)}{2 \times 10^{-9}} \right)^{1/2}$$

$$\sim 10^{-5} M_p \sim 10^{27} \text{cm}^{-1} \sim 10^{51} \text{Mpc}^{-1},$$

$$U(\varphi) = \frac{3}{4} M^2 M_p^2 \left(1 - e^{-\sqrt{\frac{2}{3}} \kappa \varphi} \right)^2 = \begin{cases} \frac{3}{4} M^2 M_p^2 & \text{for } \varphi \gg \varphi_f \\ \frac{1}{2} M^2 \varphi^2 & \text{for } \varphi \ll \varphi_f \end{cases}$$

R² Inflation [Starobinsky 1980]



$$U(\varphi) = \frac{3}{4} M^2 M_p^2 \left(1 - e^{-\sqrt{\frac{2}{3}} \kappa \varphi} \right)^2 = \begin{cases} \frac{3}{4} M^2 M_p^2 & \text{for } \varphi \gg \varphi_f \\ \frac{1}{2} M^2 \varphi^2 & \text{for } \varphi \ll \varphi_f \end{cases}$$

Gravitational reheating by scalaron decay

[YW & Komatsu gr-qc/0612120; YW 1011.3348; YW & White 1503.08430]

$$\sigma \equiv e^{-\frac{\kappa}{\sqrt{6}}\varphi} \hat{\sigma}$$

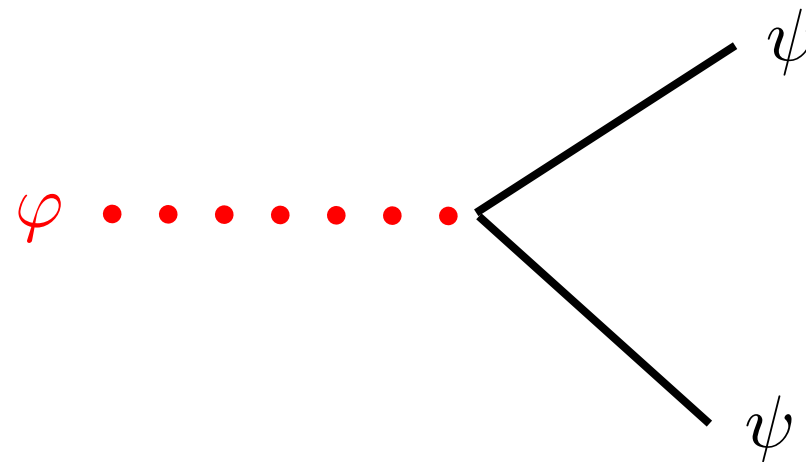
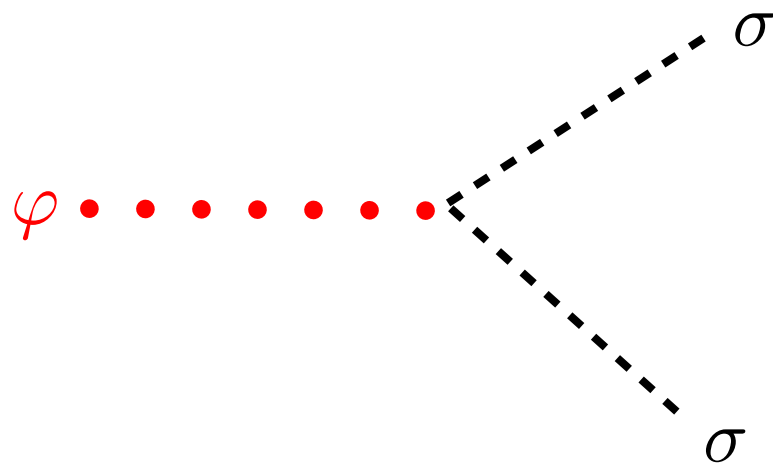
$$\mathcal{L}_{\text{scalar}} = -\frac{1}{2}\partial_\mu\sigma\partial^\mu\sigma - \frac{\kappa\sigma}{\sqrt{6}}\partial_\mu\sigma\partial^\mu\varphi - \frac{\kappa^2\sigma^2}{12}\partial_\mu\varphi\partial^\mu\varphi - \frac{m_\sigma^2}{2}e^{-\frac{2}{\sqrt{6}}\kappa\varphi}\sigma^2$$

$$\psi \equiv e^{-\frac{3\kappa}{2\sqrt{6}}\varphi} \hat{\psi}$$

$$\mathcal{L}_{\text{fermion}} = -\bar{\psi}\not{D}\psi - e^{-\frac{1}{\sqrt{6}}\kappa\varphi}m_\psi\bar{\psi}\psi$$



$$\mathcal{L}_{\text{3leg}} = \frac{1}{\sqrt{6}M_{\text{Pl}}}\varphi\partial^\mu\sigma\partial_\mu\sigma + \frac{2m_\sigma^2}{\sqrt{6}M_{\text{Pl}}}\varphi\sigma^2 + \frac{m_\psi^2}{\sqrt{6}M_{\text{Pl}}}\varphi\bar{\psi}\psi$$



Gravitational reheating by scalaron decay

[YW & Komatsu gr-qc/0612120; YW 1011.3348; YW & White 1503.08430]

$$\Gamma(\varphi \rightarrow \sigma\sigma) = \frac{\mathcal{N}_\sigma (M^2 + 2m_\sigma^2)^2}{192\pi M_{\text{Pl}}^2 M}$$

$$\simeq \frac{\mathcal{N}_\sigma M^3}{192\pi M_{\text{Pl}}^2} + \frac{\mathcal{N}_\sigma m_\sigma^2 M}{48\pi M_{\text{Pl}}^2}$$

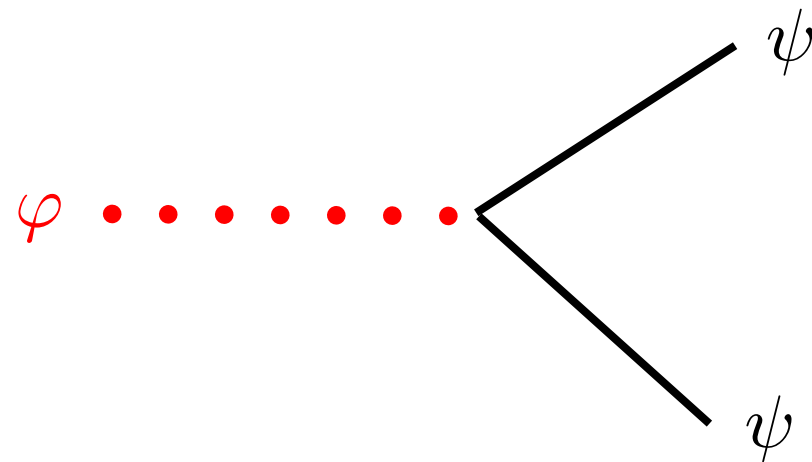
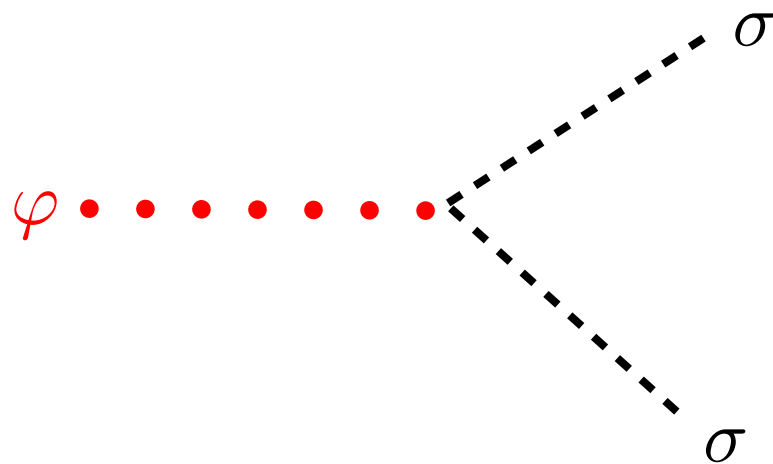
Leading term

$$\Gamma(\varphi \rightarrow \bar{\psi}\psi) = \frac{\mathcal{N}_\psi m_\psi^2 M}{48\pi M_{\text{Pl}}^2}$$



$$H_{\text{rh}} = \Gamma$$

$$T_{\text{rh}} \simeq 0.1 \sqrt{\Gamma_{\text{tot}} M_p} \left(\frac{\mathcal{N}_{\text{tot}}}{100} \right)^{-1/4}$$



Gravitational reheating by scalaron decay

[YW & Komatsu gr-qc/0612120; YW 1011.3348; YW & White 1503.08430]

$$\Gamma(\varphi \rightarrow \sigma\sigma) = \frac{\mathcal{N}_\sigma (M^2 + 2m_\sigma^2)^2}{192\pi M_{\text{Pl}}^2 M}$$

$$\simeq \frac{\mathcal{N}_\sigma M^3}{192\pi M_{\text{Pl}}^2} + \frac{\mathcal{N}_\sigma m_\sigma^2 M}{48\pi M_{\text{Pl}}^2}$$

Leading term

$$\Gamma(\varphi \rightarrow \bar{\psi}\psi) = \frac{\mathcal{N}_\psi m_\psi^2 M}{48\pi M_{\text{Pl}}^2}$$



$$T_{\text{rh}} \simeq 0.1 \sqrt{\Gamma_{\text{tot}} M_p} \left(\frac{\mathcal{N}_{\text{tot}}}{100} \right)^{-1/4} \sim 10^{-9} M_p,$$

$$N_* \simeq 54 + \frac{1}{3} \ln \left(\frac{T_{\text{rh}}}{10^9 \text{ GeV}} \right),$$

If we know the matter sector (e.g. SM minimally coupled to gravity),
inflationary predictions can be made without uncertainty.

Predictions depend on reheating temperature

scalaron mass

$$M \simeq 10^{-5} M_p \frac{4\pi\sqrt{30}}{N_*} \left(\frac{\mathcal{P}_\zeta(k_*)}{2 \times 10^{-9}} \right)^{1/2}$$
$$\sim 10^{-5} M_p \sim 10^{27} \text{cm}^{-1} \sim 10^{51} \text{Mpc}^{-1},$$
$$\sim 10^{13} \text{GeV}$$

e-folds of inflation

$$N_* \simeq 54 + \frac{1}{3} \ln \left(\frac{T_{\text{rh}}}{10^9 \text{GeV}} \right),$$

grav. waves

$$r = \frac{\mathcal{P}_\gamma(k)}{\mathcal{P}_\zeta(k)} \simeq 16\epsilon \simeq \frac{12}{N_*^2}.$$

tilt and running of spectra

$$n_s - 1 = \frac{d \ln \mathcal{P}_\zeta(k)}{d \ln k} \simeq -6\epsilon_V + 2\eta_V \simeq -\frac{2}{N_*},$$

$$n_t = \frac{d \ln \mathcal{P}_\gamma(k)}{d \ln k} \simeq -2\epsilon_V \simeq -\frac{3}{2N_*^2},$$

$$\frac{dn_s}{d \ln k} \simeq 16\epsilon_V \eta_V - 24\epsilon_V^2 - 2\xi_V^2 \simeq -\frac{2}{N_*^2},$$

$$\frac{dn_t}{d \ln k} \simeq 4\epsilon_V \eta_V - 8\epsilon_V^2 \simeq -\frac{3}{N_*^3},$$

Preheating in R² inflation (Minkowski)

[Takeda & YW 1405.3830]

$$\phi(x, t) = \phi_0(t) + \delta\phi(x, t)$$

$$\delta\ddot{\phi}_k + \omega_k^2 \delta\phi_k = 0$$

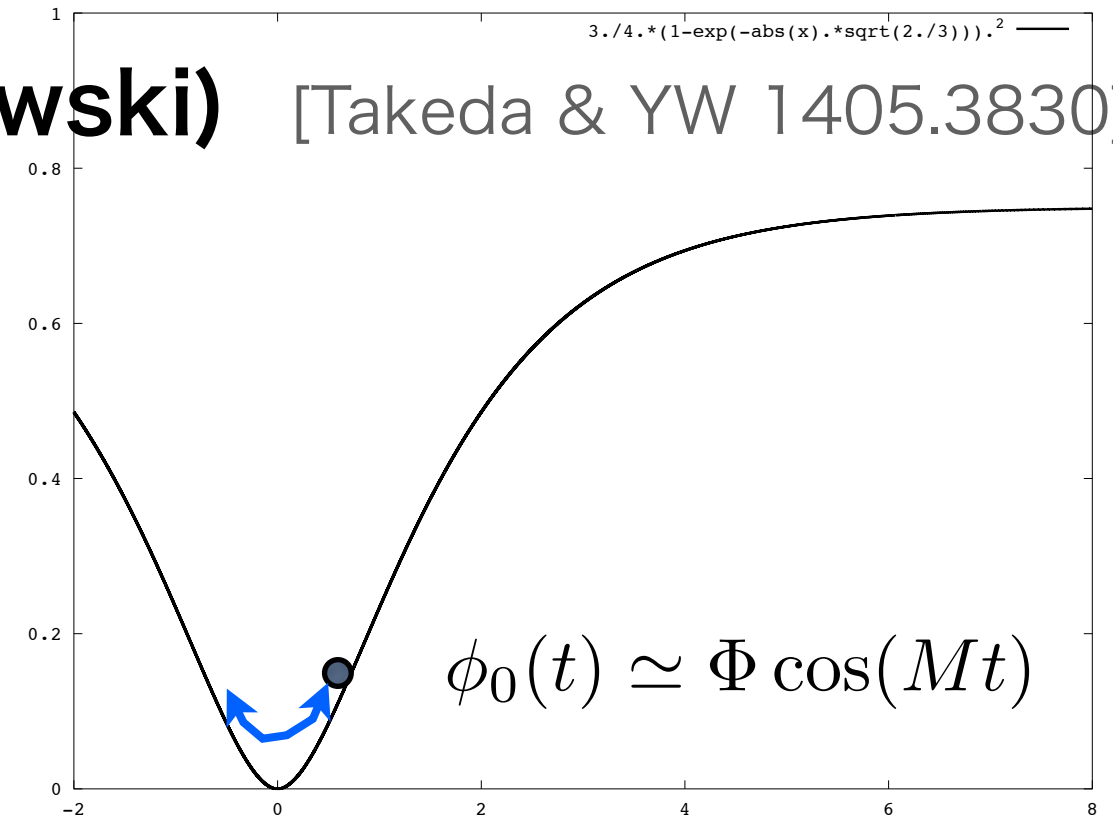
$$\omega_k^2 = k^2 + M^2 \left[1 + \frac{7}{6} \left(\frac{\Phi}{M_p} \right)^2 \right]$$

$$- \sqrt{6} M^2 \frac{\Phi}{M_p} \cos(Mt) + \frac{7}{6} M^2 \left(\frac{\Phi}{M_p} \right)^2 \cos(2Mt)$$

$$\delta\phi_k'' + \left[A_{1k} - 2q_1 \cos(2\hat{T}) \right] \delta\phi_k = 0$$

$$q_1 \equiv 2\sqrt{6} \frac{\Phi}{M_p},$$

$$A_{1k} \equiv 4 + 4 \left(\frac{k}{M} \right)^2 + \frac{7}{36} q_1^2$$



$$\phi_0(t) \simeq \Phi \cos(Mt)$$

2nd narrow resonance:

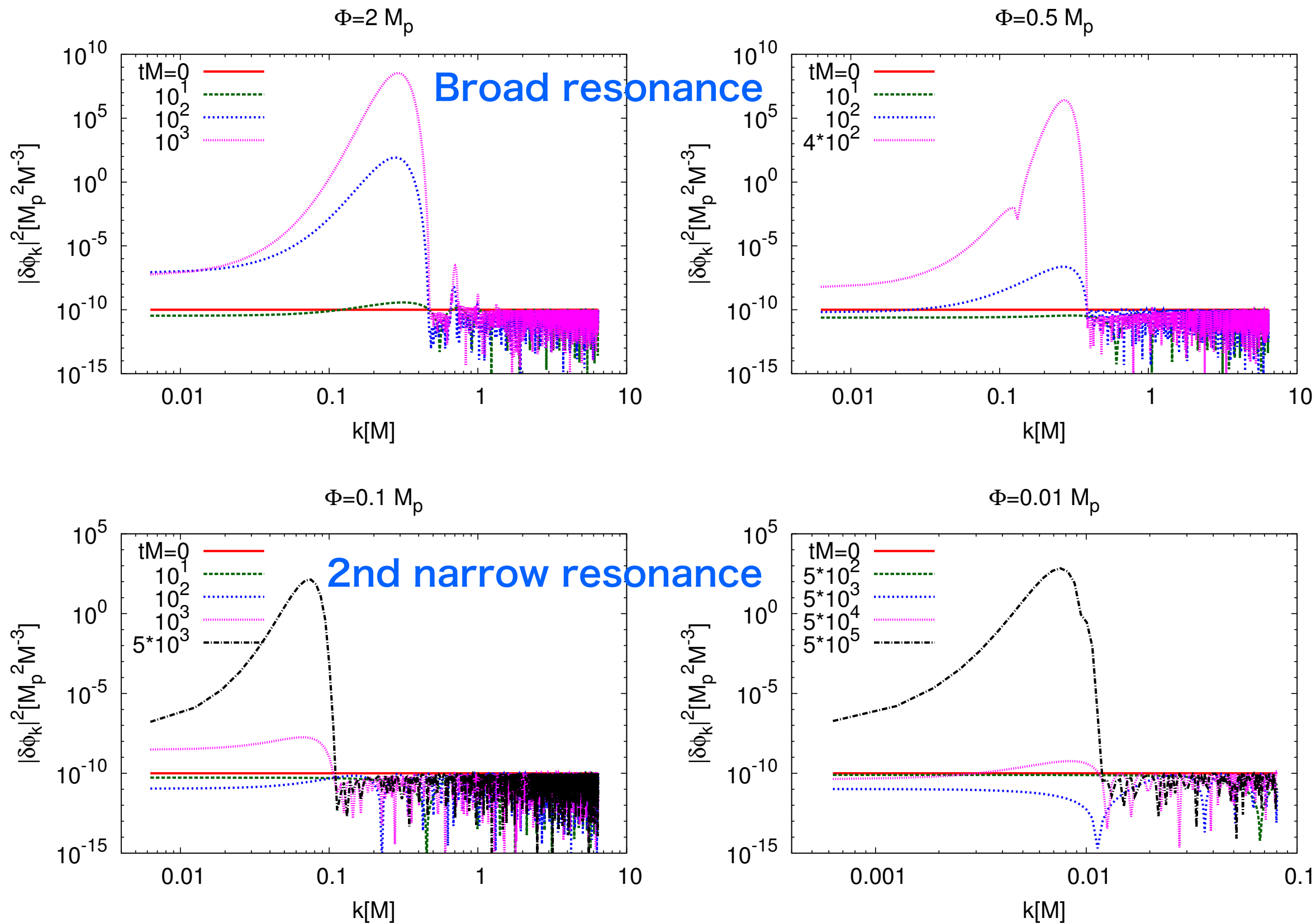
$$0 \leq \frac{k}{M} < \frac{q_1}{3\sqrt{2}} \quad -\frac{q^2}{12} < A_k - 4 < \frac{5q^2}{12}, \quad \Phi < 0.2M_p$$

Broad resonance: $|d\omega/dt|/\omega^2 > 1$ $0.2M_p \lesssim \Phi \lesssim 2M_p$

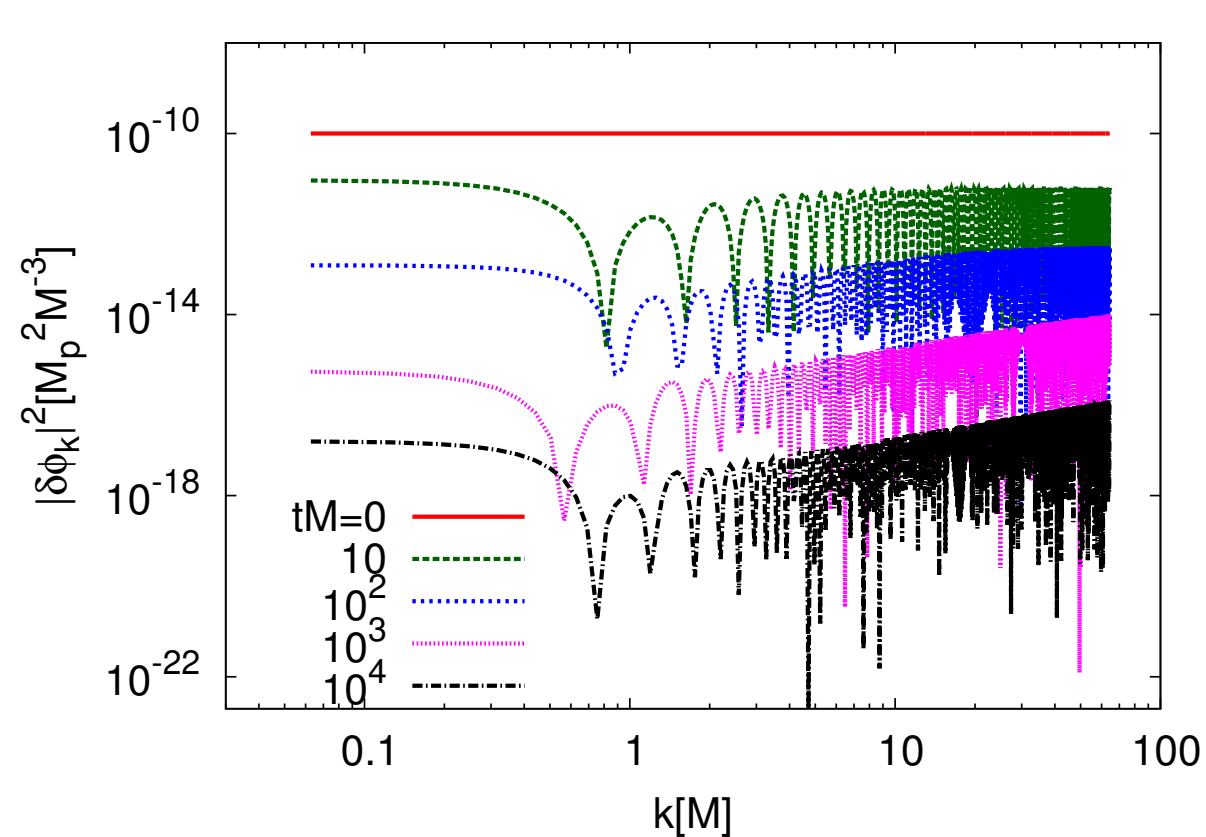
$$\left(\frac{k}{M} \right)^2 < -1 - \frac{7}{6} \left(\frac{\Phi}{M_p} \right)^2 + \sqrt{6} \frac{\Phi}{M_p} \cos(Mt) + \left(\frac{3}{2} \right)^{\frac{1}{3}} \left(\frac{\Phi}{M_p} \right)^{\frac{2}{3}} |\sin(Mt)|^{\frac{2}{3}},$$

Parametric resonant spectrum

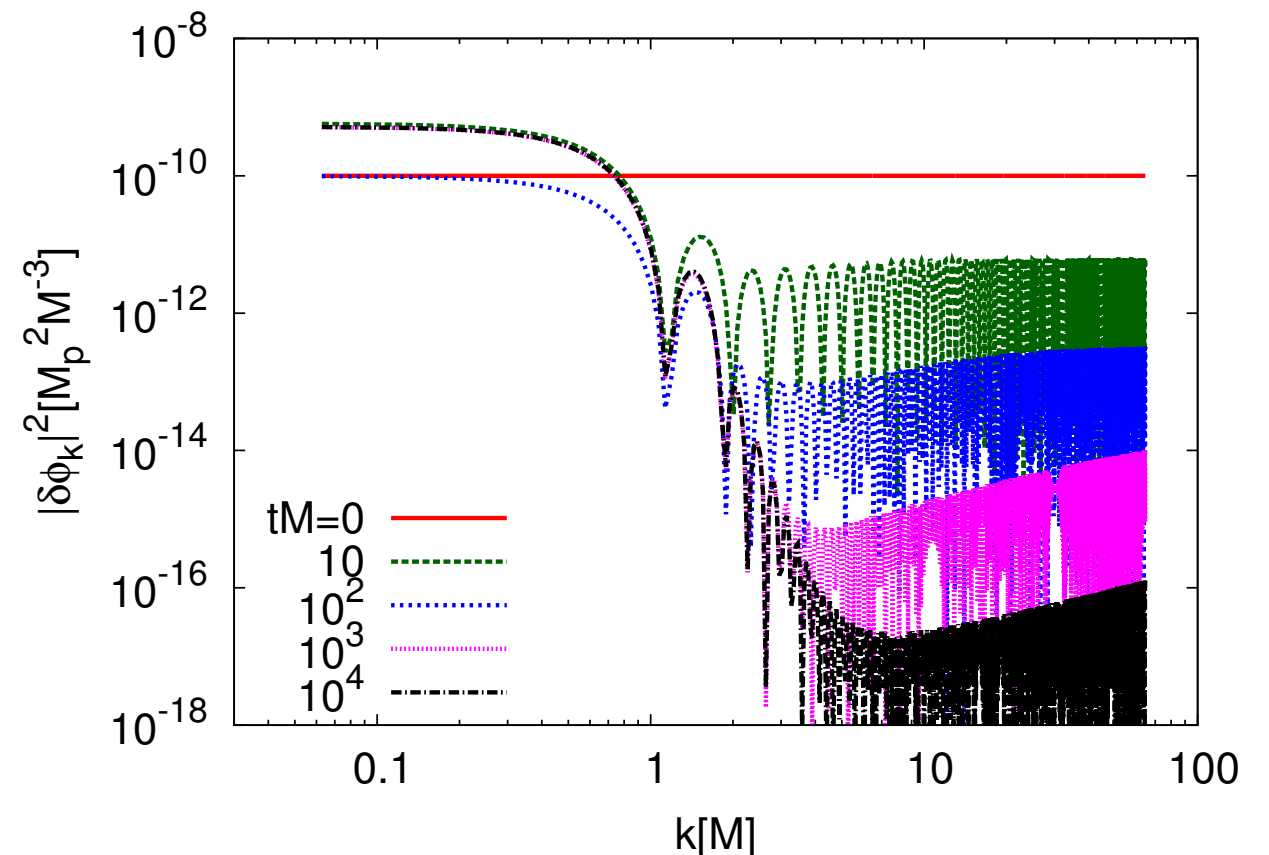
[Takeda & YW 1405.3830]



Preheating in R^2 inflation (Friedmann) [Takeda & YW 1405.3830]



Without back-reaction from metric,
Hubble damping wins over instabilities.



With back-reaction from metric,
preheating is balanced with
Hubble damping.

MS eqn:

$$\delta\ddot{\phi}_k + 3H\delta\dot{\phi}_k + \underbrace{\left[\frac{k^2}{a^2} + V''(\phi_0) + \Delta F \right]}_{\omega_k^2} \delta\phi_k = 0,$$

Back-reaction
from metric:

$$\Delta F \equiv \frac{2\dot{\phi}_0}{M_p^2 H} V'(\phi_0) + \frac{\dot{\phi}_0^2}{M_p^4 H^2} V(\phi_0).$$

Metric preheating in R^2 inflation [Takeda & YW 1405.3830]

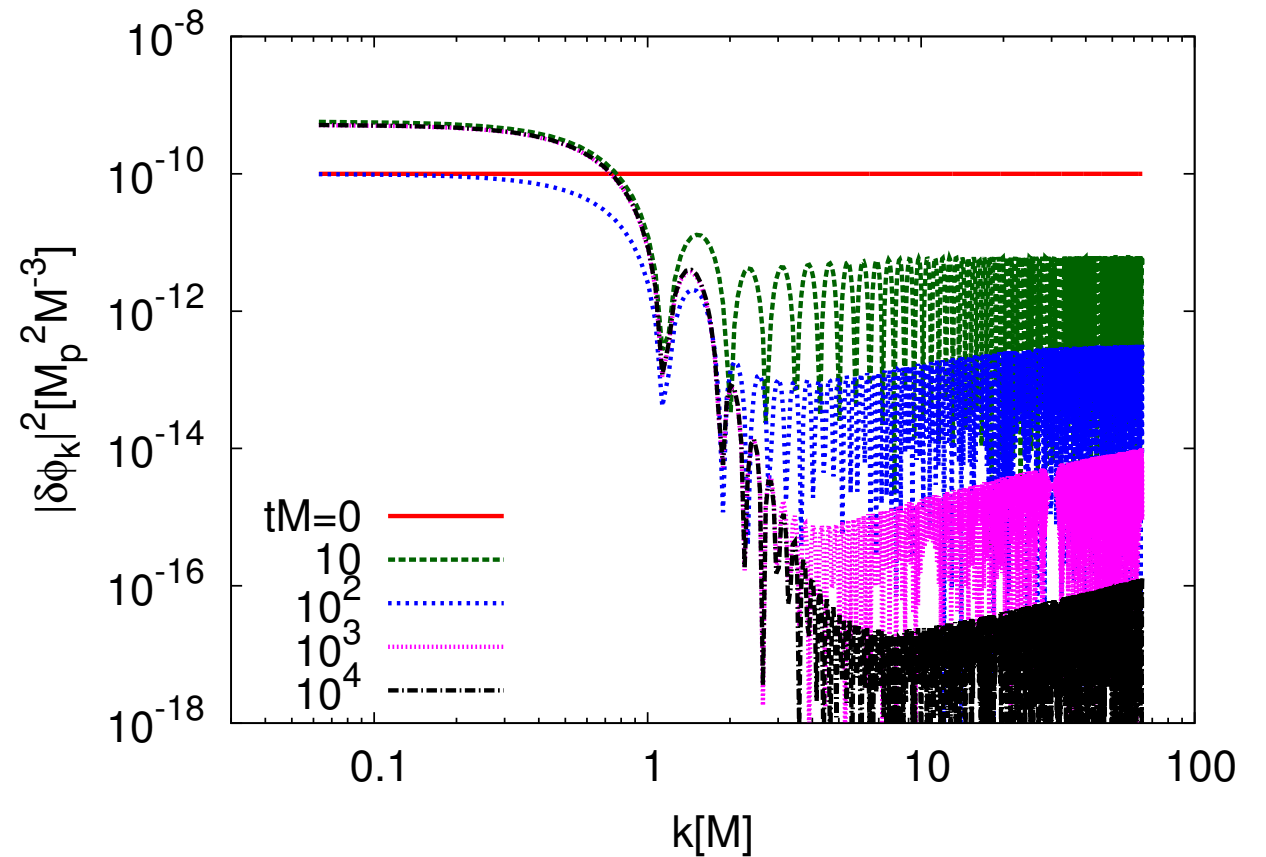
$$\phi_0(t) \simeq \phi_0(t_{\text{ini}}) \left(\frac{a_{\text{ini}}}{a} \right)^{\frac{3}{2}} \sin(Mt)$$

$$\omega_k^2 \simeq \frac{k^2}{a^2} + M^2 \left(1 - \sqrt{6} \frac{\phi_0}{M_p} + \frac{2\dot{\phi}_0\phi_0}{H M_p^2} \right)$$

$$\widetilde{\delta\phi}_k'' + \left[A_{3k} - 2q_3 \cos(2\hat{T}) \right] \widetilde{\delta\phi}_k = 0$$

$$q_3 \equiv \frac{a_{\text{ini}}^3 \phi_0^2(t_{\text{ini}}) M}{2a^3 H M_p^2}, \quad A_{3k} \equiv 1 + \frac{k^2}{a^2 M^2}.$$

$$\widetilde{\delta\phi}_k \equiv a^{3/2} \delta\phi_k$$



1st narrow resonance: $-q^2 < A_k - 1 < q^2$,

$$0 \leq \frac{k}{M} \lesssim a_{\text{ini}} H_{\text{ini}} \sqrt{\frac{3a_{\text{ini}}}{a H M}} \propto a^{1/2}$$

The resonance is not strong enough to form quasi-stable objects!

Higher derivative SUGRA [Cecotti 1987; Ferrara & Porrati 2014]

R is the supercurvature

$$S = \int d^4x d^4\theta E \left(N(\mathcal{R}, \bar{\mathcal{R}}) + J(\phi, \bar{\phi} e^{gV}) \right) \quad \text{\textbf{\(\phi, V\) are the matter sector}}$$
$$+ \left[\int d^4x d^2\Theta 2\mathcal{E} \left(F(\mathcal{R}) + P(\phi) + \frac{1}{4} h_{AB}(\phi) W^A W^B \right) + \text{H.c.} \right]$$

↓ duality trans. by T, S (T is the Lagrange multiplier)

$$S = \int d^4x d^2\Theta 2\mathcal{E} \frac{3}{8} (\bar{\mathcal{D}} \bar{\mathcal{D}} - 8\mathcal{R}) e^{-K/3} + W + \frac{1}{4} h_{AB} W^A W^B + \text{H.c.}$$

Kahler pot: $K = -3 \ln \left(\frac{T + \bar{T} - N(S, \bar{S}) - J(\phi, \bar{\phi} e^{gV})}{3} \right),$

Superpot: $W = 2TS + F(S) + P(\phi).$

Starobinsky SUGRA R² inflation

[Terada, YW, Yamada, Yokoyama 1411.6746; Dalianis & YW 1801.05736]

$$\mathcal{L} = -3M_P^2 \int d^4\theta E \left[1 - \frac{4}{m_\Phi^2} \mathcal{R} \bar{\mathcal{R}} + \frac{\zeta}{3m_\Phi^4} \mathcal{R}^2 \bar{\mathcal{R}}^2 \right]$$

$$N(S, \bar{S}) = -3 + \frac{12}{m_\Phi^2} S \bar{S} - \frac{\zeta}{m_\Phi^4} (S \bar{S})^2$$

↓
S, ImT are stabilized.

$$F(S) = 0,$$

Real part of T becomes the inflaton:

$$V = \frac{3m_\Phi^2}{4} \left(1 - e^{-\sqrt{2/3} \widehat{\text{Re}T}} \right)^2,$$

$$S = \int d^4x d^2\Theta 2\mathcal{E} \frac{3}{8} (\bar{\mathcal{D}} \bar{\mathcal{D}} - 8\mathcal{R}) e^{-K/3} + W + \frac{1}{4} h_{AB} W^A W^B + \text{H.c.}$$

$$K = -3 \ln \left(\frac{T + \bar{T} - N(S, \bar{S}) - J(\phi, \bar{\phi} e^{gV})}{3} \right),$$

$$W = 2TS + F(S) + P(\phi).$$

↓
Grav. coupling to matter

Starobinsky SUGRA R² inflation

[Terada, YW, Yamada, Yokoyama 1411.6746; Dalianis & YW 1801.05736]

$$\mathcal{L} = -3M_P^2 \int d^4\theta E \left[1 - \frac{4}{m_\Phi^2} \mathcal{R} \bar{\mathcal{R}} + \frac{\zeta}{3m_\Phi^4} \mathcal{R}^2 \bar{\mathcal{R}}^2 \right]$$

$$N(S, \bar{S}) = -3 + \frac{12}{m_\Phi^2} S \bar{S} - \frac{\zeta}{m_\Phi^4} (S \bar{S})^2$$

$$F(S) = 0,$$

Real part of T becomes the inflaton:

$$V = \frac{3m_\Phi^2}{4} \left(1 - e^{-\sqrt{2/3} \widehat{\text{Re}T}} \right)^2,$$

SUSY breaking field:

$$J(z, \bar{z}) = |z|^2 - \frac{|z|^4}{\Lambda^2},$$

$$P(z) = \mu^2 z + W_0,$$

Z may dominate after inflation.

Inflaton decay after SUGRA R2 inflation

[Terada, YW, Yamada, Yokoyama 1411.6746; Dalianis & YW 1801.05736]

Scalars:

$$\Gamma(T \rightarrow \phi^i \bar{\phi}^{\bar{i}}) = \frac{3m_i^4}{8\pi M_P^2 m_\Phi}, \quad \Gamma(T \rightarrow \phi^i \phi^j) = \frac{m_\Phi^3}{96\pi M_P^2} |J_{ij}|^2.$$

Fermions:

$$\Gamma(T \rightarrow \chi^i \bar{\chi}^{\bar{i}}) = \frac{m_i^2 m_\Phi}{192\pi M_P^2},$$

Gauge fields
& gauginos:

$$\Gamma(T \rightarrow AA) + \Gamma(T \rightarrow \lambda\lambda) \simeq \frac{3N_g \alpha^2 m_\Phi^3}{128\pi^3 M_P^2} \left(T_G - \frac{1}{3} T_R \right)^2$$

Gravitinos: (Φ is inflaton)

$$\Gamma(\Phi_{R\pm} \rightarrow \psi_{3/2} \psi_{3/2}) \simeq \frac{m_\Phi^3}{48\pi M_P^2} \times \begin{cases} 16 \left(\frac{m_{3/2}}{m_\Phi} \right)^2 & (m_z^2 \ll m_\Phi m_{3/2}) \\ \left(\frac{m_z}{m_\Phi} \right)^4 & (3m_\Phi m_{3/2} \ll m_z^2 \ll m_\Phi^2) \\ 1 & (m_\Phi^2 \ll m_z^2) \end{cases}$$

Constraints from gravitino abundance

[Terada, YW, Yamada, Yokoyama 1411.6746]

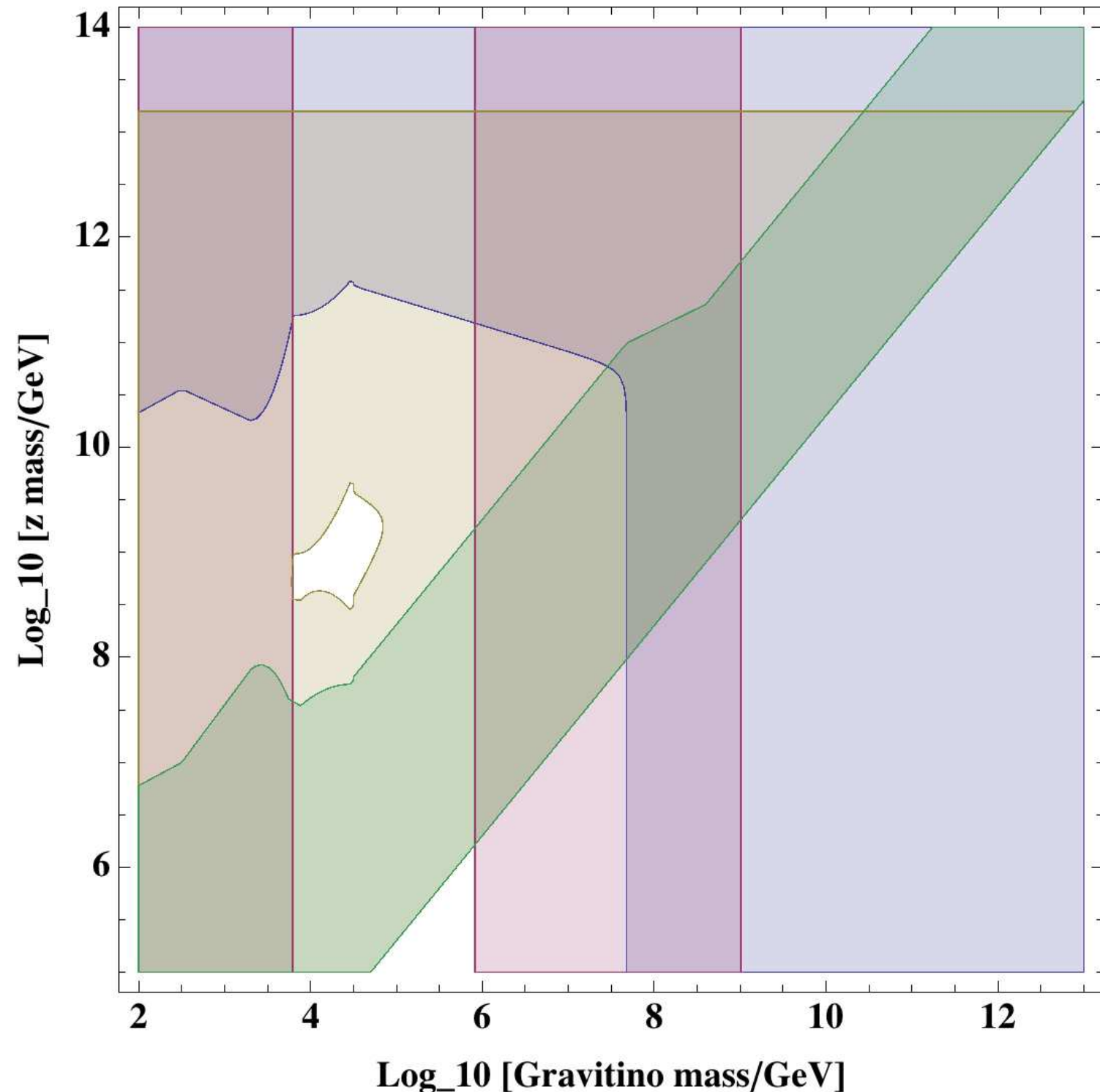
Gravitinos generated from:

- 1) inflaton decay
- 2) thermal scatterings
- 3) decay of particles
- 4) decay of oscillating Z

Wino LSP is assumed for:

gravitino mass $> 10^{4.5}$ GeV
→ anomaly mediation

gravitino mass $< 10^{4.5}$ GeV
→ gravity mediation

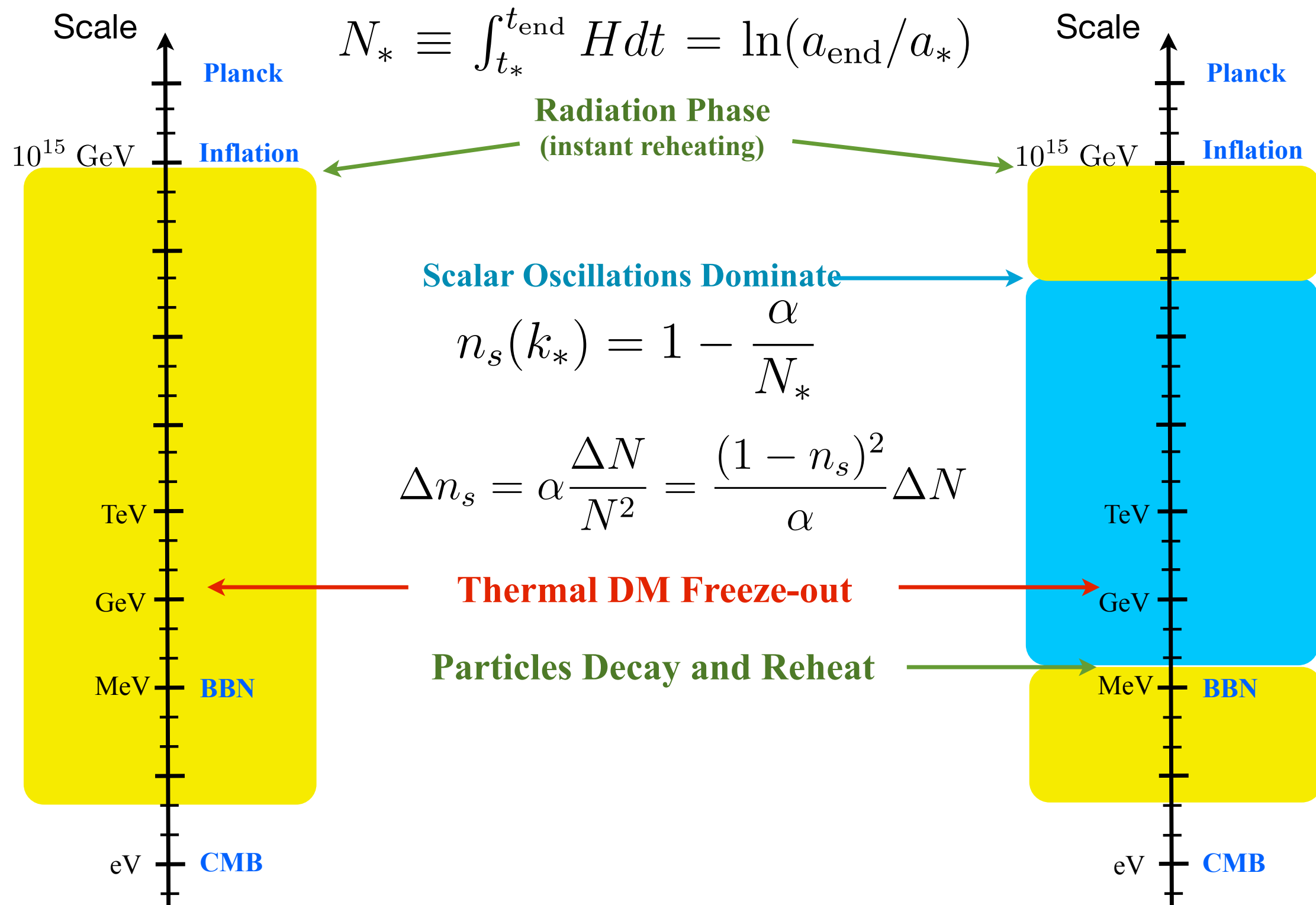


CMB uncertainties from the post-inflationary evolution

[Easter, Galvez, Ozsoy, Watson 2013]

Thermal History

Alternative History



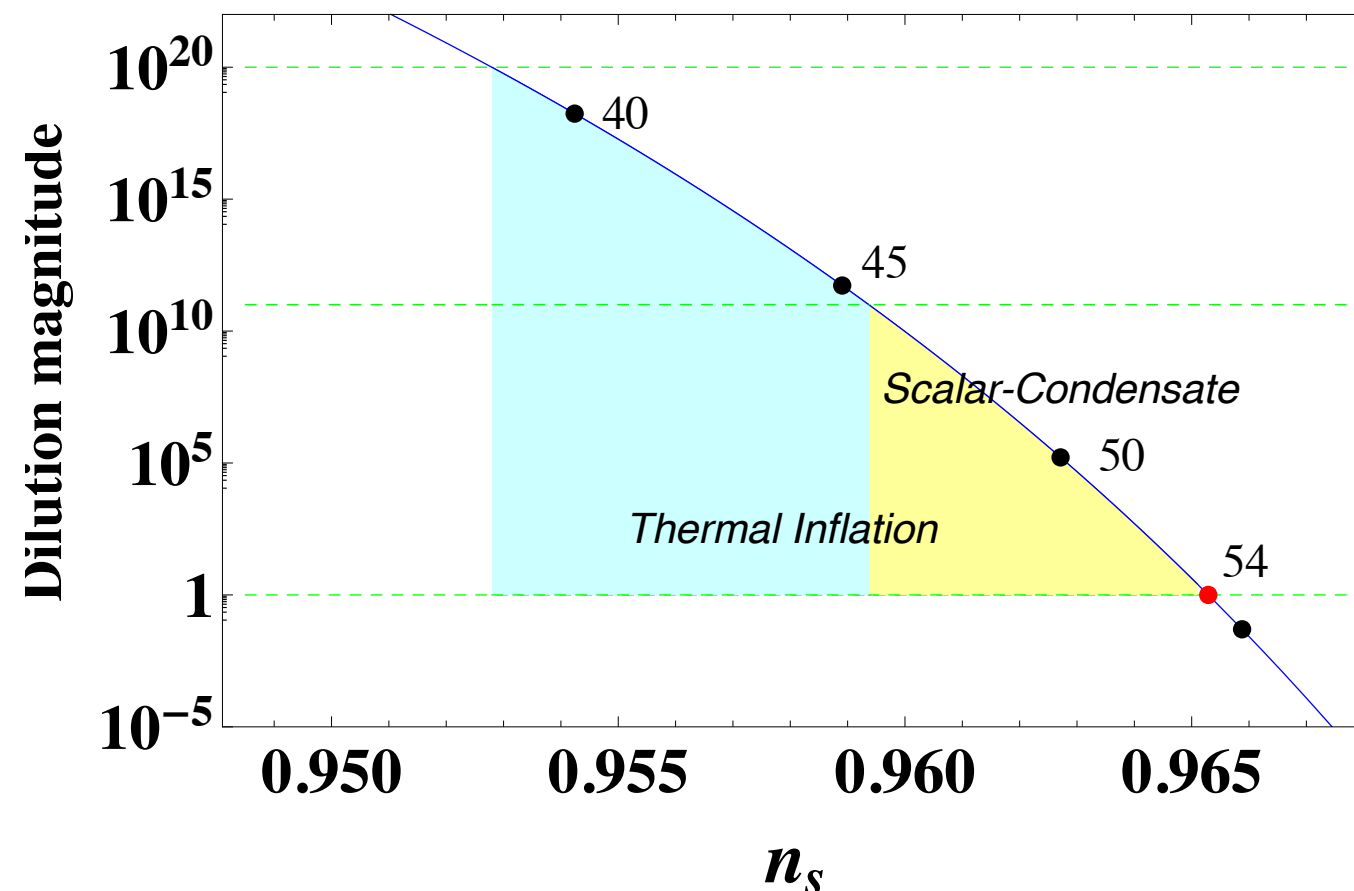
Shift in (ns, r) due to late entropy production

- After inflaton decay, a diluter field X (modulus, flaton) may dominate the universe until BBN. Decays of X produce **entropy**:

$$\Delta N_X = \frac{1}{3} \ln \left[\left(\frac{g_*(T_X^{\text{dom}})}{g_*(T_X^{\text{dec}})} \right)^{1/4} D_X \right] \equiv \frac{1}{3} \ln \tilde{D}_X$$

$$D_X \equiv 1 + \frac{S_{\text{after}}}{S_{\text{before}}} = 1 + \frac{g_s(T_X^{\text{dec}})}{g_*(T_X^{\text{dec}})} \frac{g_*(T_X^{\text{dom}})}{g_s(T_X^{\text{dom}})} \frac{T_X^{\text{dom}}}{T_X^{\text{dec}}} \simeq \frac{T_X^{\text{dom}}}{T_X^{\text{dec}}} \geq 1$$

$$R^2, \quad T_{rh} = 10^9 \text{ GeV}$$



Supersymmetric dark matter cosmology

Merits: Gauge coupling unification, stable dark matter, baryogenesis, stringy UV completion, ...

1. Gravitino LSP

2. Neutralino LSP (WIMP)

- Thermal DM (freeze out): thermal scatterings with the MSSM, messenger fields
- Non-thermal DM (freeze in): decays, thermal scatterings

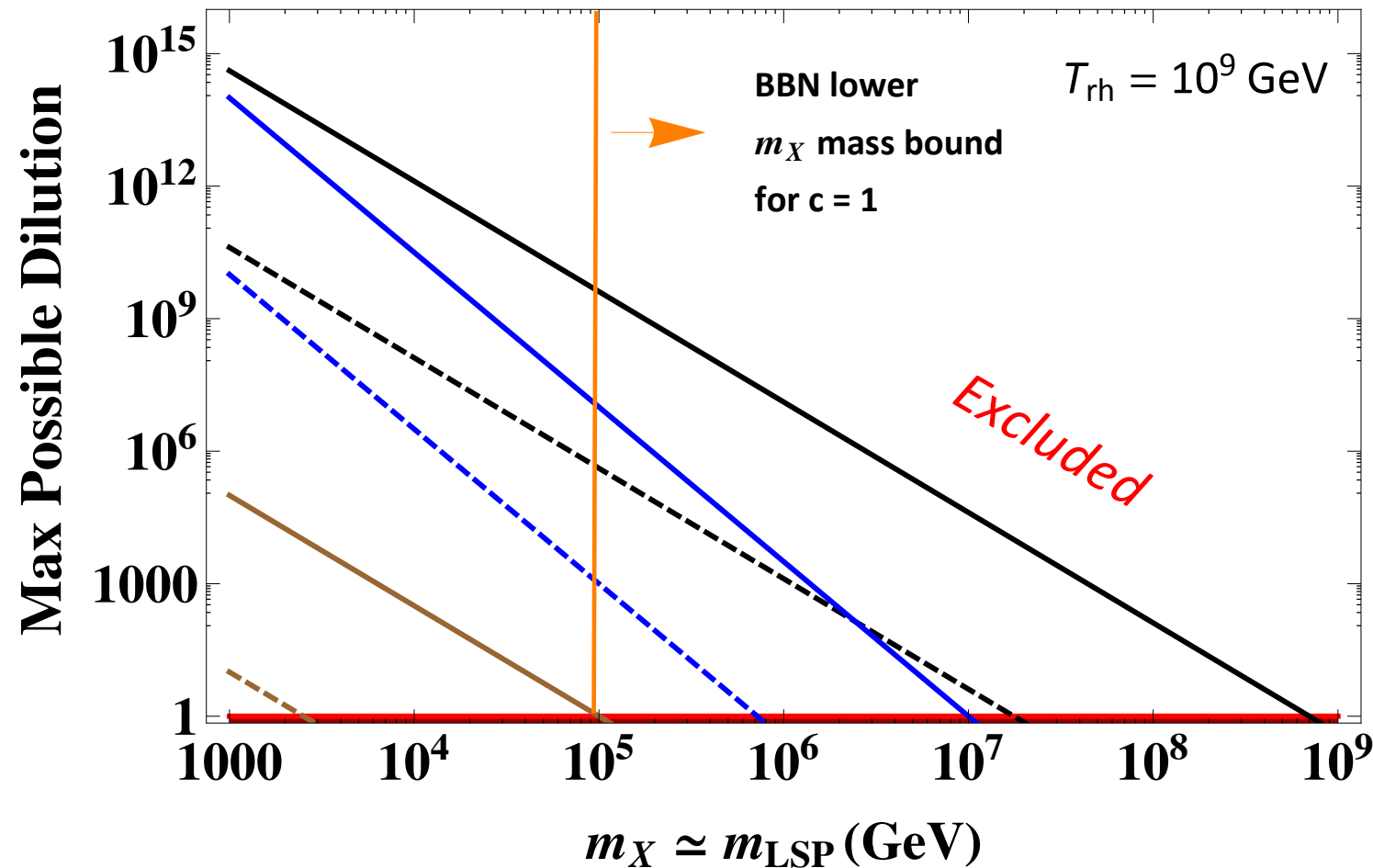
Light WIMP mass is disfavored by the LHC.

$\Omega_{\text{DM}} h^2$ is severely constrained when **sparticle masses increase**:

$$\Omega_{3/2} \propto m_{3/2}^{\alpha} \left(\frac{m_{\tilde{g}}}{m_{3/2}} \right)^{\beta} \left(\frac{m_{\tilde{f}}}{m_{3/2}} \right)^{\gamma} T_{\text{rh}}^{\delta}, \quad m_{3/2} < m_{\tilde{g}}, m_{\tilde{f}},$$

$$\Omega_{\tilde{\chi}^0} \propto m_{\tilde{\chi}^0}^{\tilde{\alpha}} m_{3/2}^{\tilde{\beta}} \left(\frac{m_{\tilde{f}}}{m_{3/2}} \right)^{\tilde{\gamma}} T_{\text{rh}}^{\tilde{\delta}}, \quad m_{\tilde{\chi}^0} < m_{3/2}, m_{\tilde{f}}$$

Alternative cosmic histories and SUSY



—	Dilution Bound
—	$c=1$, Gravitino LSP
- -	$c=10^8$, $\gg \gg$
—	$c=1$, Thermal Neutralino LSP
- -	$c=10^8$, $\gg \gg$
—	$c=1$, Thermal Gravitino LSP
- -	$c=10^8$, $\gg \gg$

$$\Gamma_X = \frac{c}{4\pi} \frac{m_X^3}{M_{\text{Pl}}^2}$$

★ High reheating temp. generally overproduce light LSP

→ Dilution of DM abundance is necessary: **diluter field X**

• If $D_X = 1$ then $T_{\text{rh}} \lesssim \tilde{m}$ or $\tilde{m} \sim \text{TeV}$

• If $\mathcal{O}(\text{TeV}) < (m_{\text{LSP}}, \tilde{m}) < T_{\text{rh}}$ then $D_X \geq D_X^{\text{min}} \equiv \frac{\Omega_{\text{LSP}}^{\leq}}{0.12 h^{-2}}$

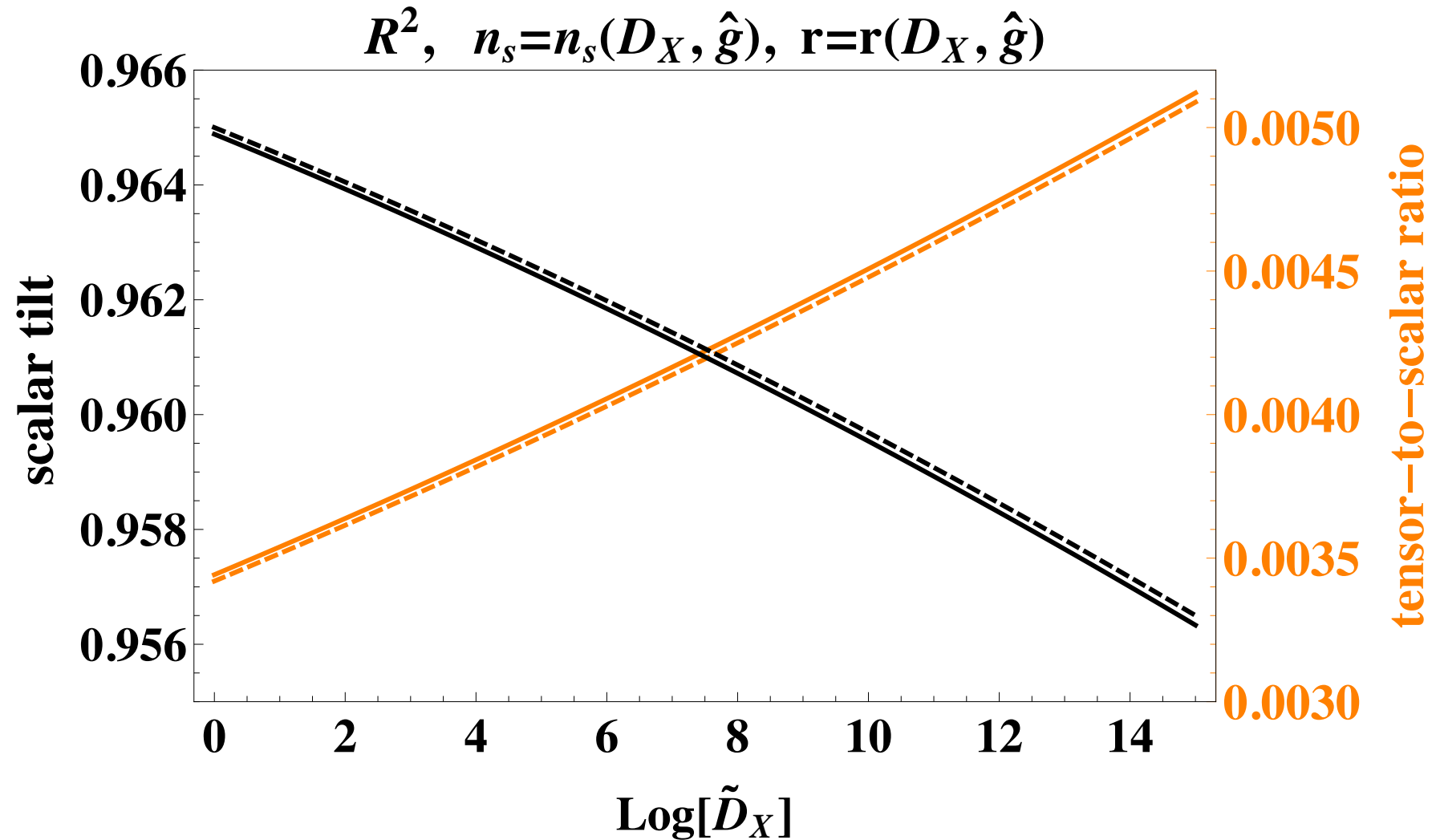
where $\tilde{m}$ the sparticle mass scale.

CMB observables: Starobinsky R2 inflation

$$n_s^{(\text{th})} \Big|_{R^2} = 0.965 ,$$

$$r^{(\text{th})} \Big|_{R^2} = 0.0034$$

$$N^{(\text{th})} = 54$$



$$N_* \Big|_{R^2} = 55.9 + \frac{1}{4} \ln \epsilon_* + \frac{1}{4} \ln \frac{V_*}{\rho_{\text{end}}} + \frac{1}{12} \ln \left(\frac{g_{* \text{rh}}}{100} \right) + \frac{1}{3} \ln \left(\frac{T_{\text{rh}}}{10^9 \text{ GeV}} \right) - \Delta N_X$$

CMB observables: Starobinsky R2 inflation

[Dalianis & YW 1801.05736]

$$\mathcal{L} = -3M_P^2 \int d^4\theta E \left[1 - \frac{4}{m^2} \mathcal{R} \bar{\mathcal{R}} + \frac{\zeta}{3m^4} \mathcal{R}^2 \bar{\mathcal{R}}^2 \right] \quad + \text{MSSM, Z, X, (messengers)}$$

Gravitino DM (in GeV units)

#	m_Z	$m_{\tilde{g}}$	$m_{\tilde{f}}$	$m_{3/2}$ (LSP)	D_X	N_*	n_s	r	Origin
4	10^3	10^3	10^4	10	1	54	0.965	0.0034	Th

Neutralino DM

#	m_Z	$m_{3/2}$	$m_{\tilde{f}}$	$m_{\tilde{\chi}^0}$ (LSP)	$D_{(X)}$	N_*	n_s	r	Origin
4	10^5	10^5	10^5	10^3	1	54	0.965	0.0034	Th

CMB observables: Starobinsky R2 inflation

[Dalianis & YW 1801.05736]

$$\mathcal{L} = -3M_P^2 \int d^4\theta \, E \left[1 - \frac{4}{m^2} \mathcal{R} \bar{\mathcal{R}} + \frac{\zeta}{3m^4} \mathcal{R}^2 \bar{\mathcal{R}}^2 \right] \quad + \text{MSSM, Z, X, (messengers)}$$

Gravitino DM (in GeV units)

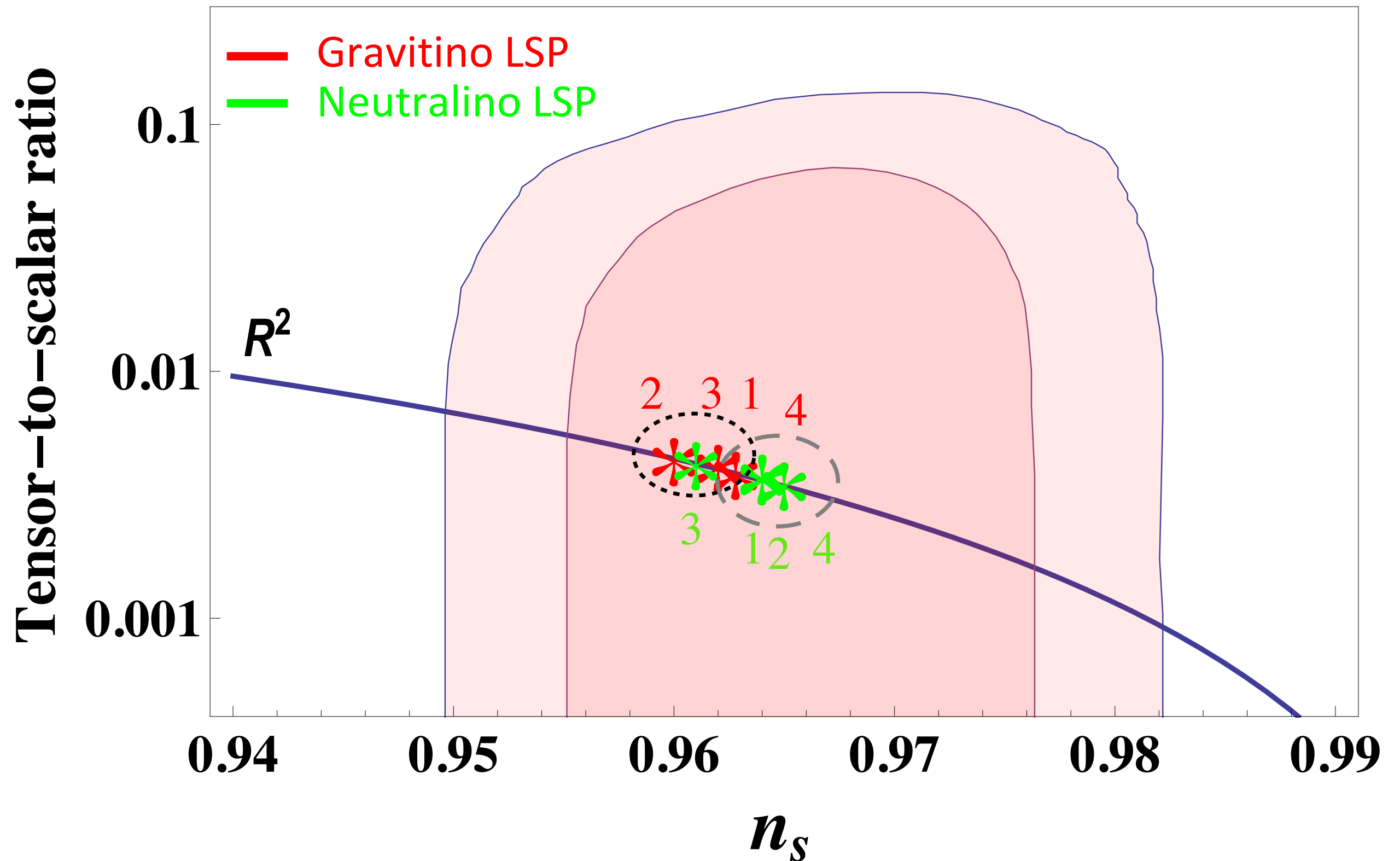
#	m_Z	$m_{\tilde{g}}$	$m_{\tilde{f}}$	$m_{3/2}$ (LSP)	D_X	N_*	n_s	r	Origin
1	10^4	10^4	10^4	10^2	$10^4 _{\text{min}}$	$51 _{\text{max}}$	$0.963 _{\text{max}}$	$0.0038 _{\text{min}}$	Th
2	10^4	10^4	10^5	10^3	$10^{10} _{\text{min}}$	$46 _{\text{max}}$	$0.960 _{\text{max}}$	$0.0044 _{\text{min}}$	Th
3	10^6	10^5	10^6	10^4	$10^6 _{\text{min}}$	$49 _{\text{max}}$	$0.962 _{\text{max}}$	$0.0041 _{\text{min}}$	Non-th
4	10^3	10^3	10^4	10	1	54	0.965	0.0034	Th

Neutralino DM

#	m_Z	$m_{3/2}$	$m_{\tilde{f}}$	$m_{\tilde{\chi}^0}$ (LSP)	$D_{(X)}$	N_*	n_s	r	Origin
1	10^7	10^6	10^6	10^3	$10^2 _{\text{min}}$	$52 _{\text{max}}$	$0.964 _{\text{max}}$	$0.0036 _{\text{min}}$	Non-th
2	10^9	10^8	10^8	10^3	$10^2 _{\text{min}}$	$52 _{\text{max}}$	$0.964 _{\text{max}}$	$0.0036 _{\text{min}}$	Th
3	10^8	10^7	10^7	10^5	$10^8 _{\text{min}}$	$48 _{\text{max}}$	$0.961 _{\text{max}}$	$0.0042 _{\text{min}}$	Non-th
4	10^5	10^5	10^5	10^3	1	54	0.965	0.0034	Th

CMB observables: Starobinsky R^2 inflation

[Dalianis & YW 1801.05736]



Conclusion

- We cannot exclude or verify SUSY by (ns, r) precision measurements even if R2 inflation is verified.
- Nevertheless we can support the presence of BSM physics by ruling out the “BSM-desert” hypothesis for a particular inflation model.
- Hence precision cosmology can offer us complementary constraints to the parameter space of SUSY.