Probing the Starobinsky R2 inflation with CMB precision cosmology

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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

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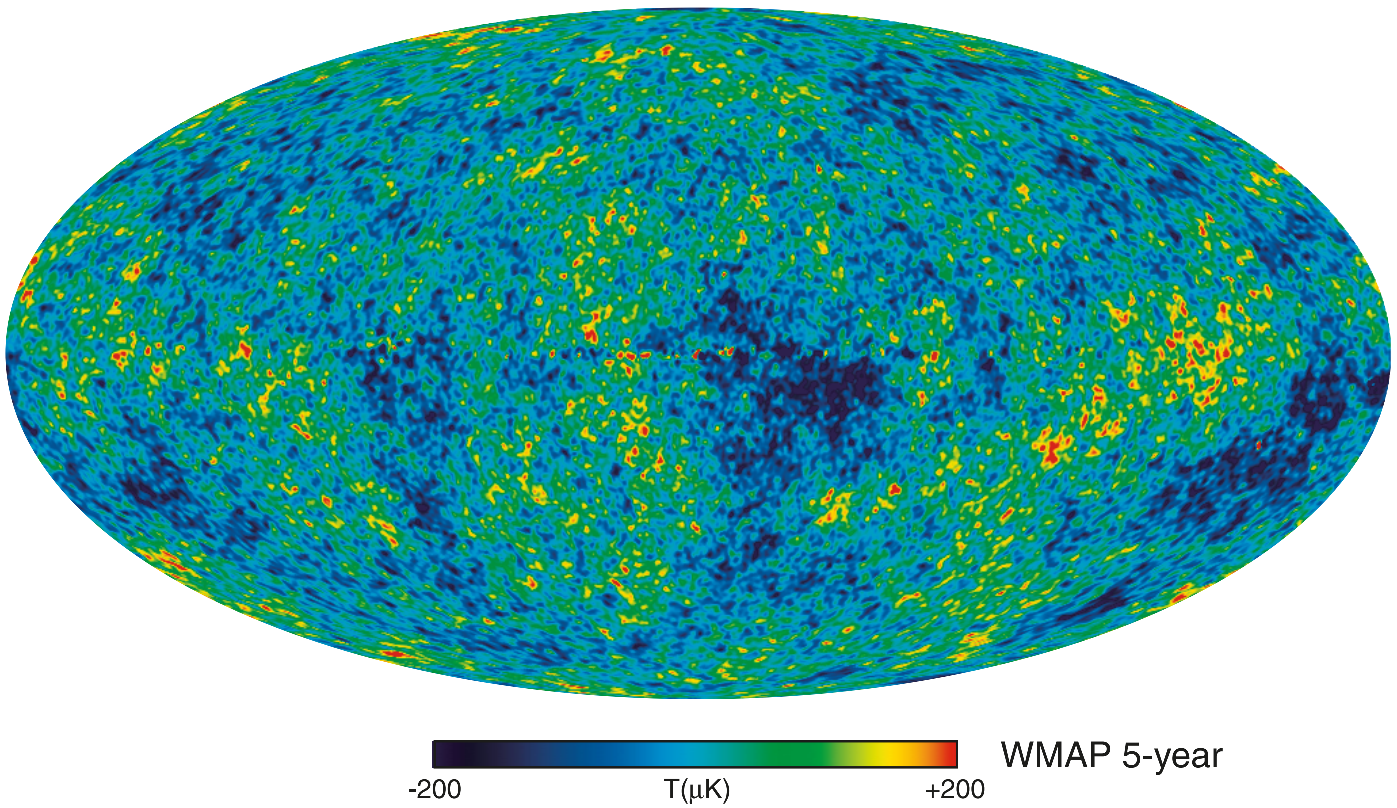
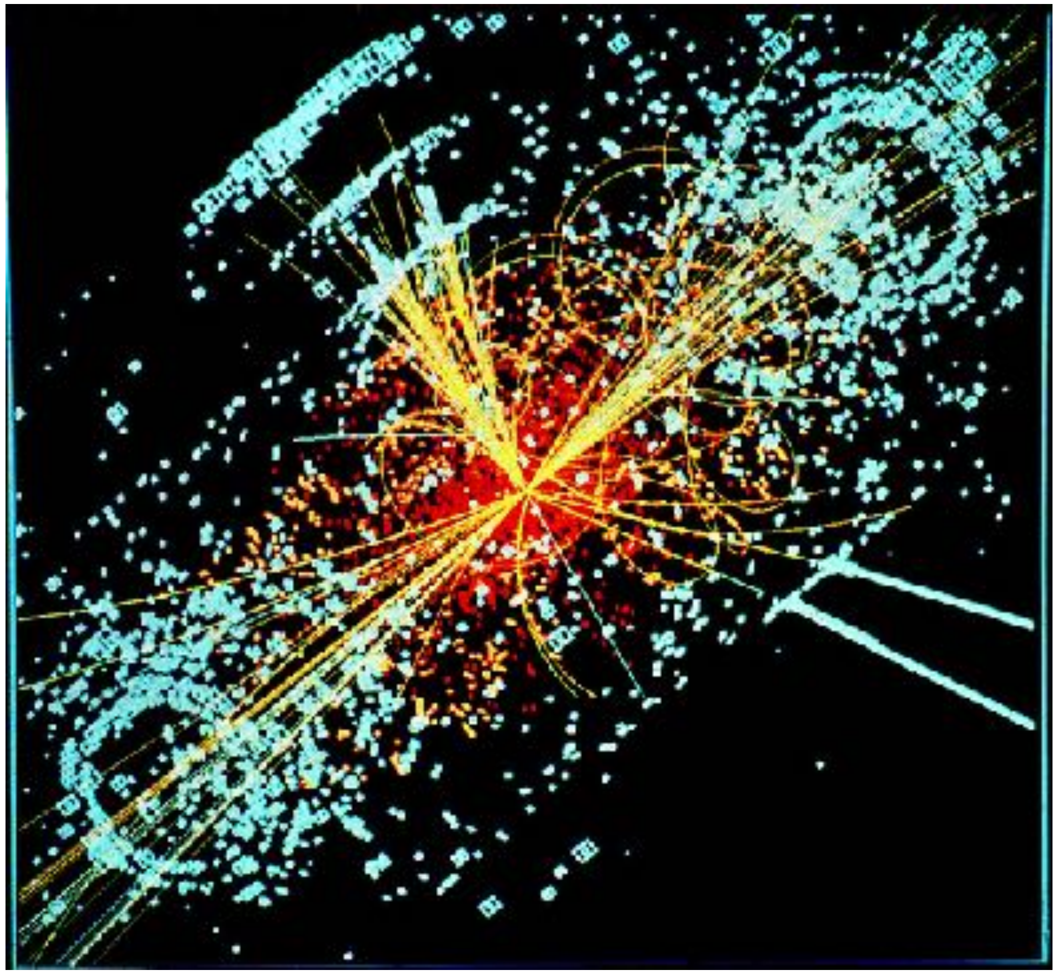
CMB observations and BSM physics

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

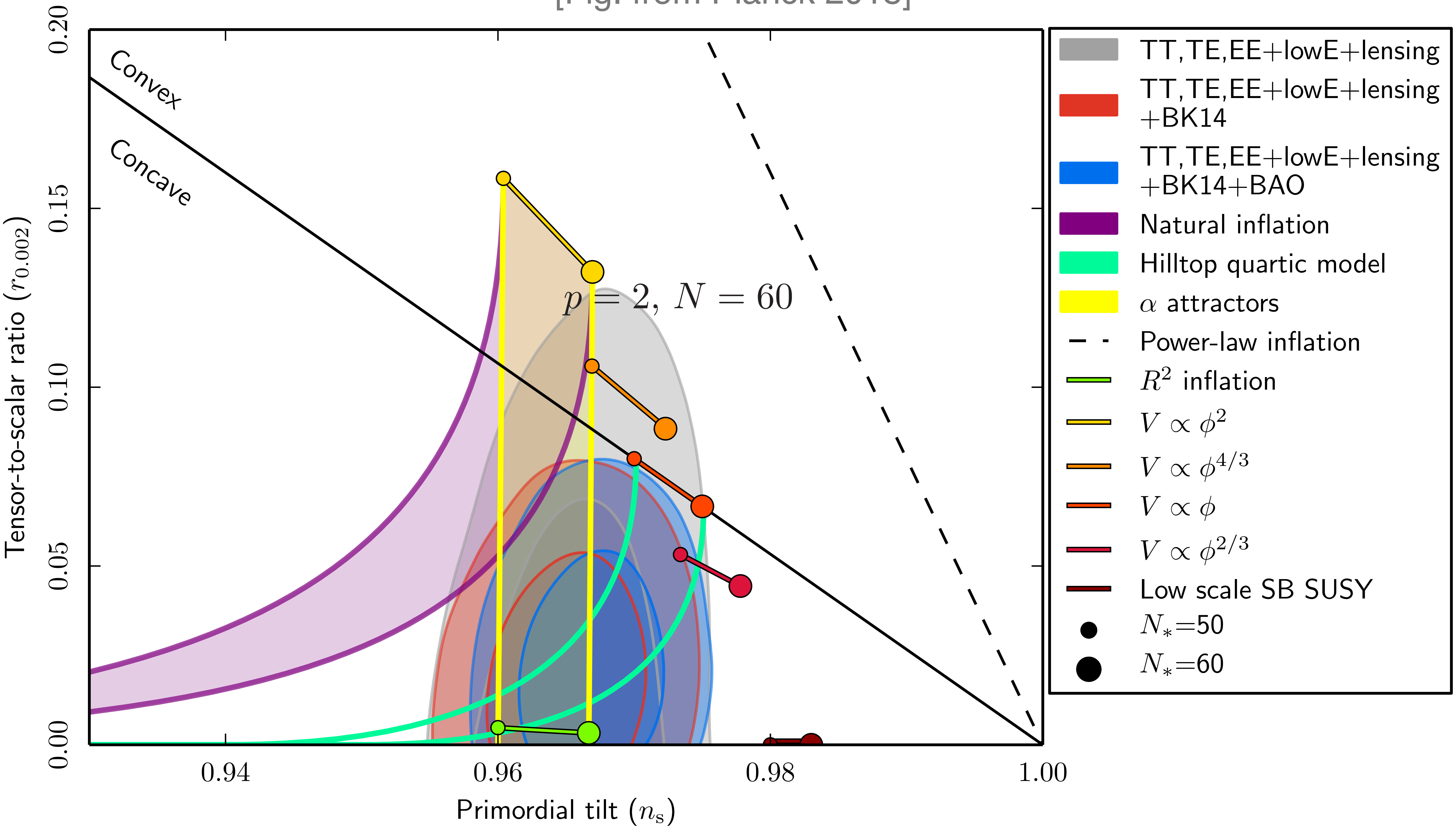




credit: NASA

CMB constraint on inflation models

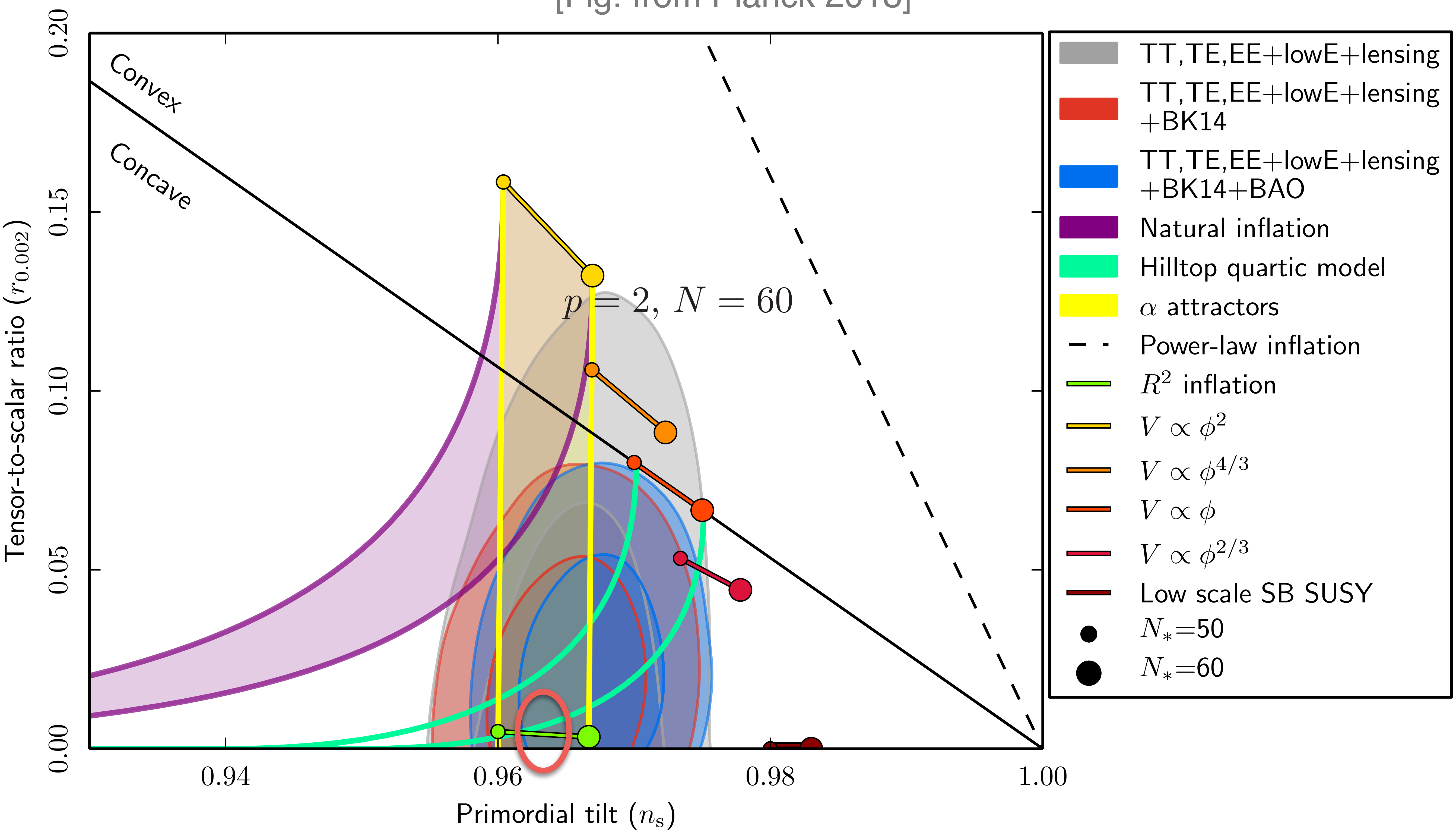
[Fig. from Planck 2018]



- Monomial potentials in GR are almost excluded.

CMB constraint on inflation models

[Fig. from Planck 2018]



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

Starobinsky R^2 Inflation

[Starobinsky 1980; Mukhanov & Chibisov 1981]

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

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

R^2 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 $g_{\mu\nu}$

$$g_{\mu\nu} = \hat{g}_{\mu\nu}\Omega^2$$

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

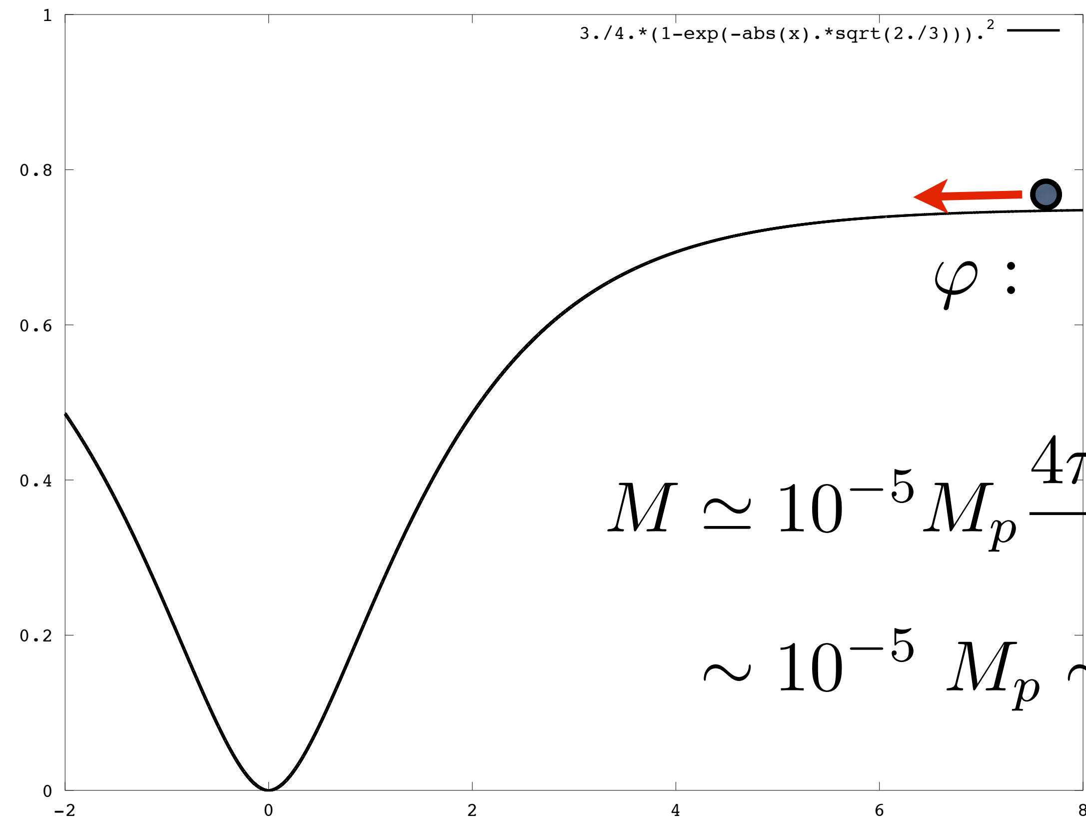
$$\hat{R} = \Omega^2[R + 3\Box(\ln\Omega^2) - \frac{3}{2}g^{\mu\nu}\partial_\mu(\ln\Omega^2)\partial_\nu(\ln\Omega^2)]$$

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

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

$$\varphi: \quad \text{Scalaron} = \text{Inflaton}$$

R^2 Inflation [Starobinsky 1980]



φ : Scalaron = Inflaton

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

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

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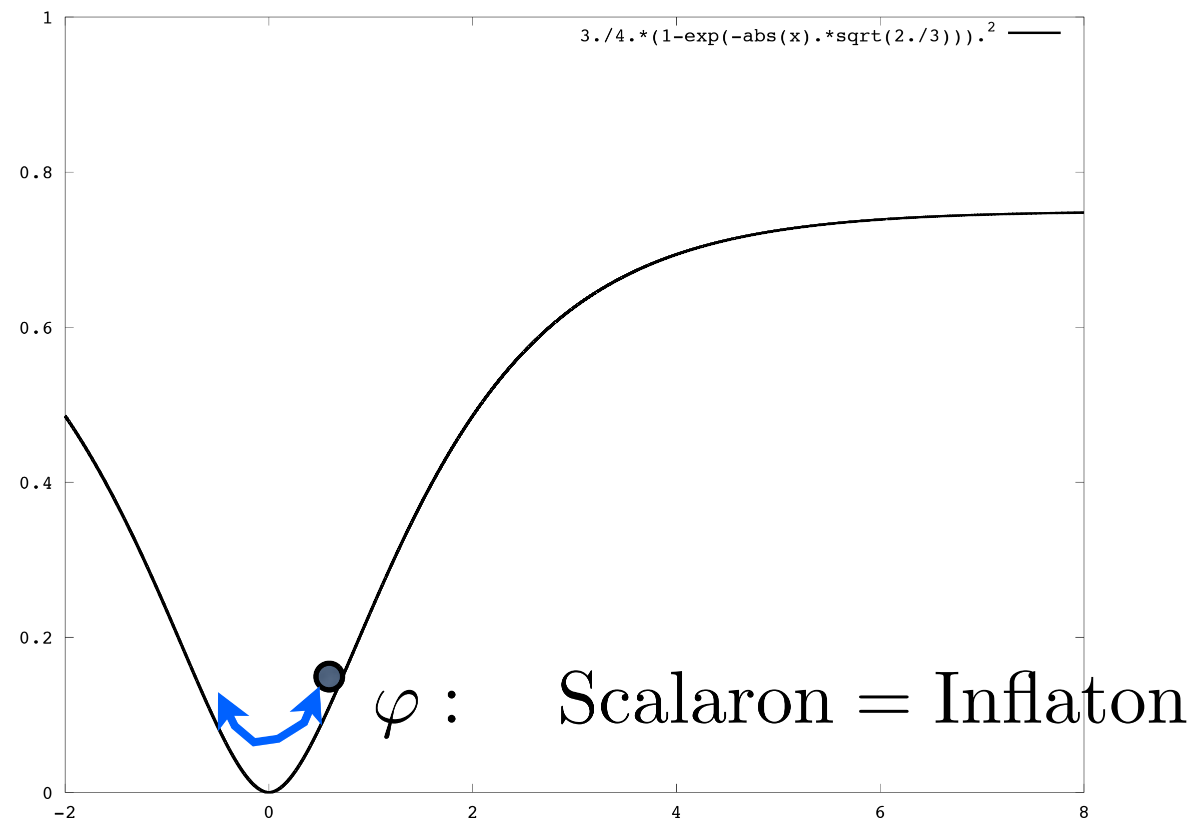
R^2 Inflation [Starobinsky 1980]



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

Gravitational reheating by scalaron decay

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

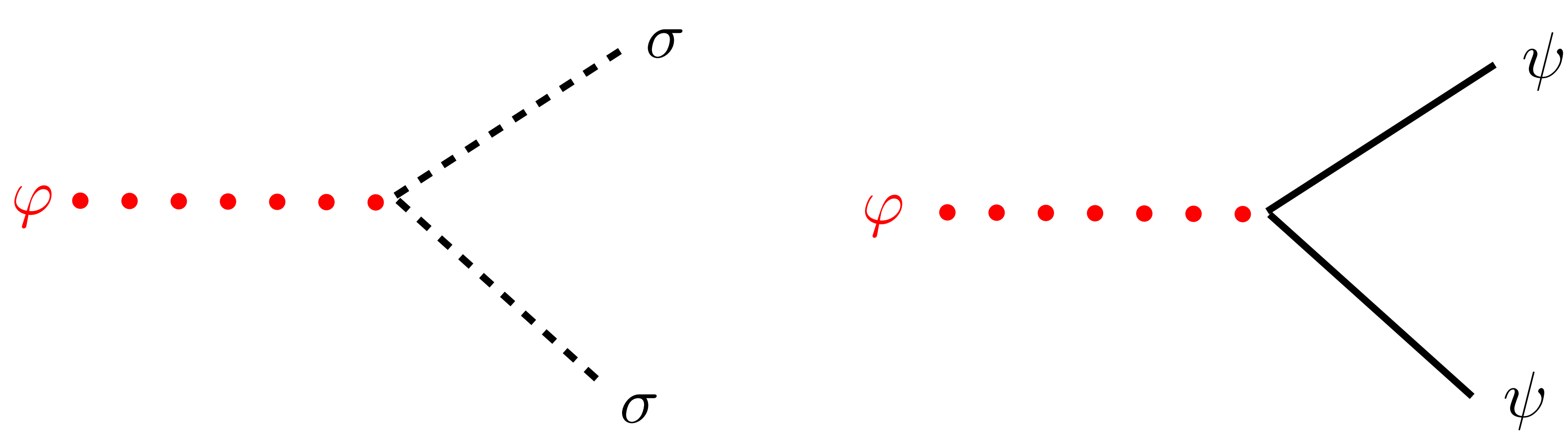
$$\sigma \equiv e^{-\frac{\kappa}{\sqrt{6}}\varphi}\hat{\sigma}$$

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

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

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

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



Gravitational reheating by scalaron decay

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

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

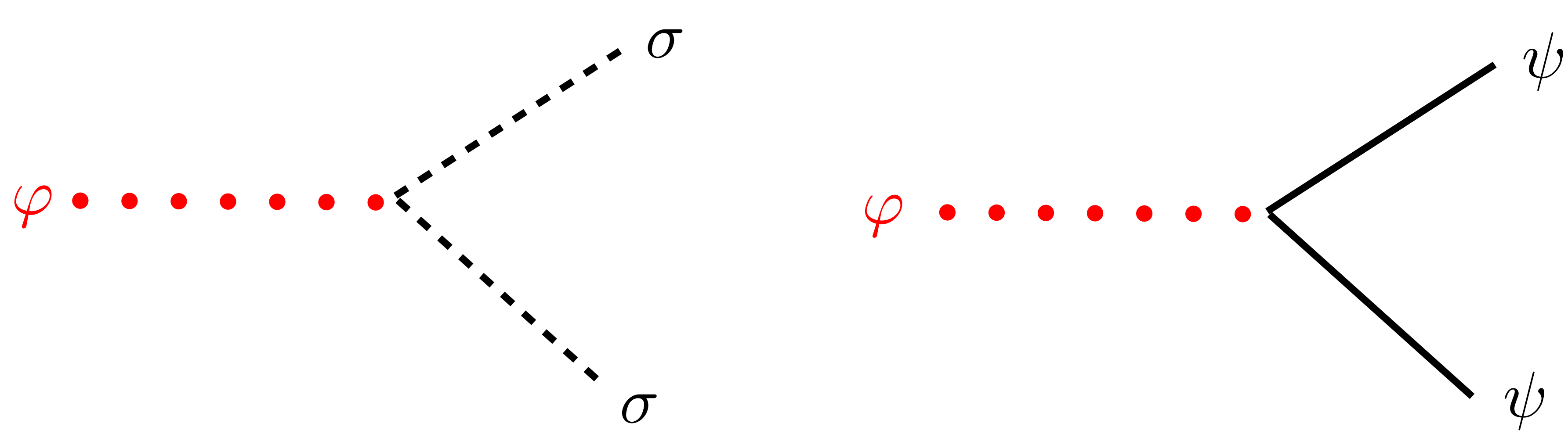
$$\simeq \frac{\mathcal{N}_\sigma M^3}{192\pi M_{\rm Pl}^2} + \frac{\mathcal{N}_\sigma m_\sigma^2 M}{48\pi M_{\rm Pl}^2}$$

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

Leading term

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

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



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

Leading term

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

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

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

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

e-folds of inflation

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

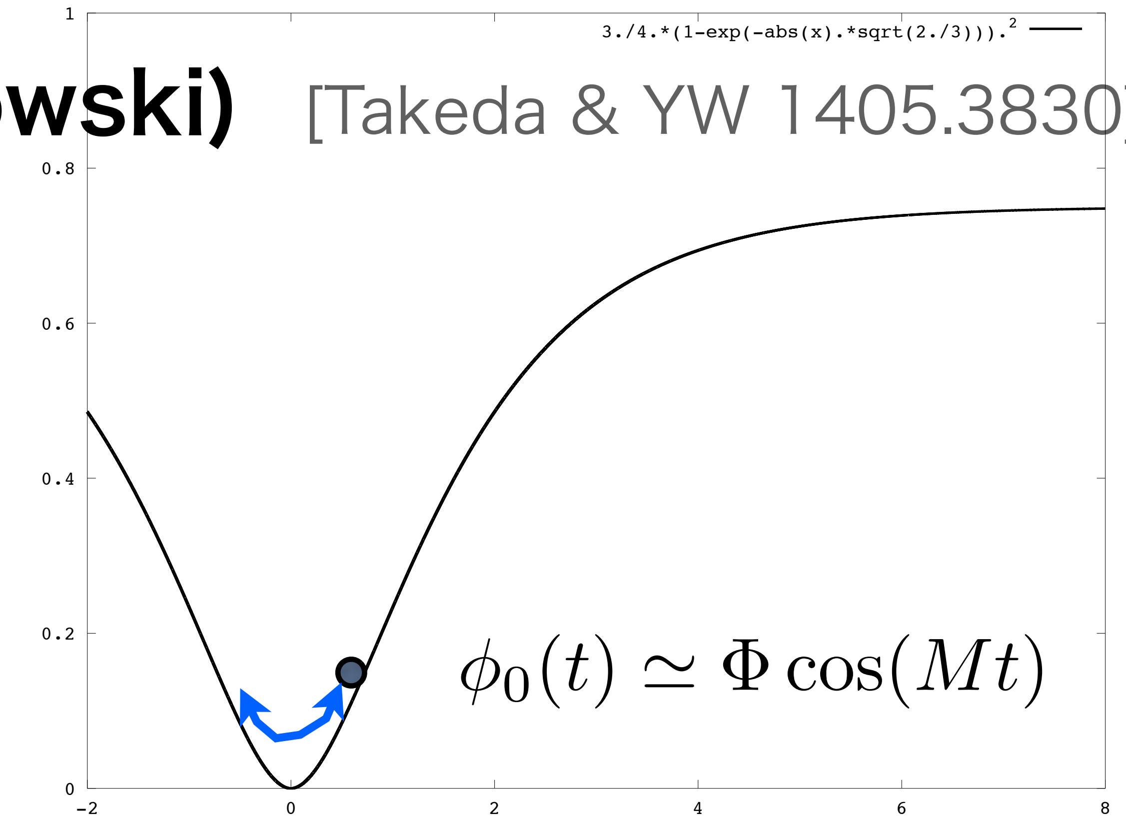
grav. waves

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

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]



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

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

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

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

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

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

2nd narrow resonance: $-\frac{q^2}{12} < A_k - 4 < \frac{5q^2}{12},$ $\Phi < 0.2M_p$

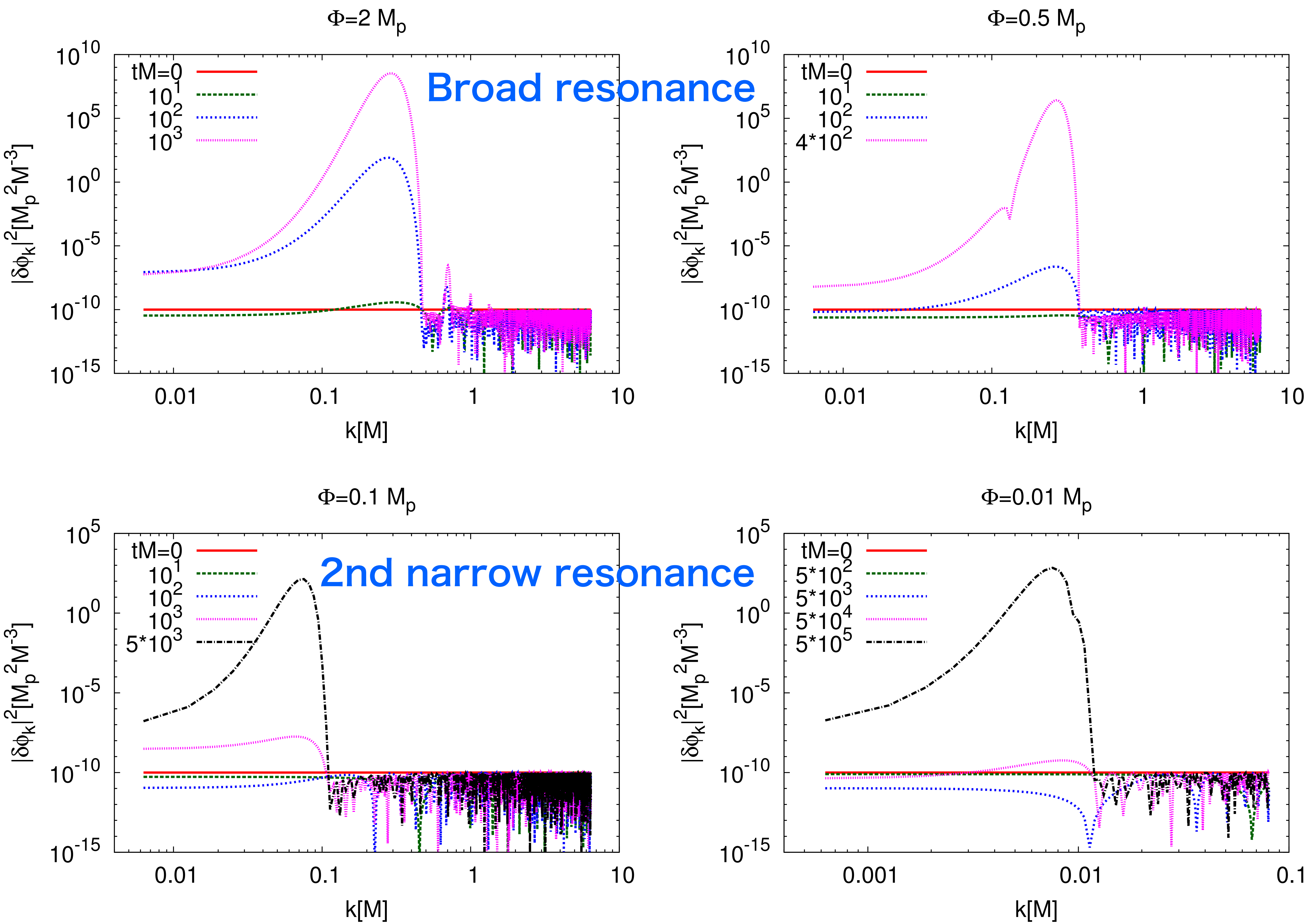
$$0 \leq \frac{k}{M} < \frac{q_1}{3\sqrt{2}}$$

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

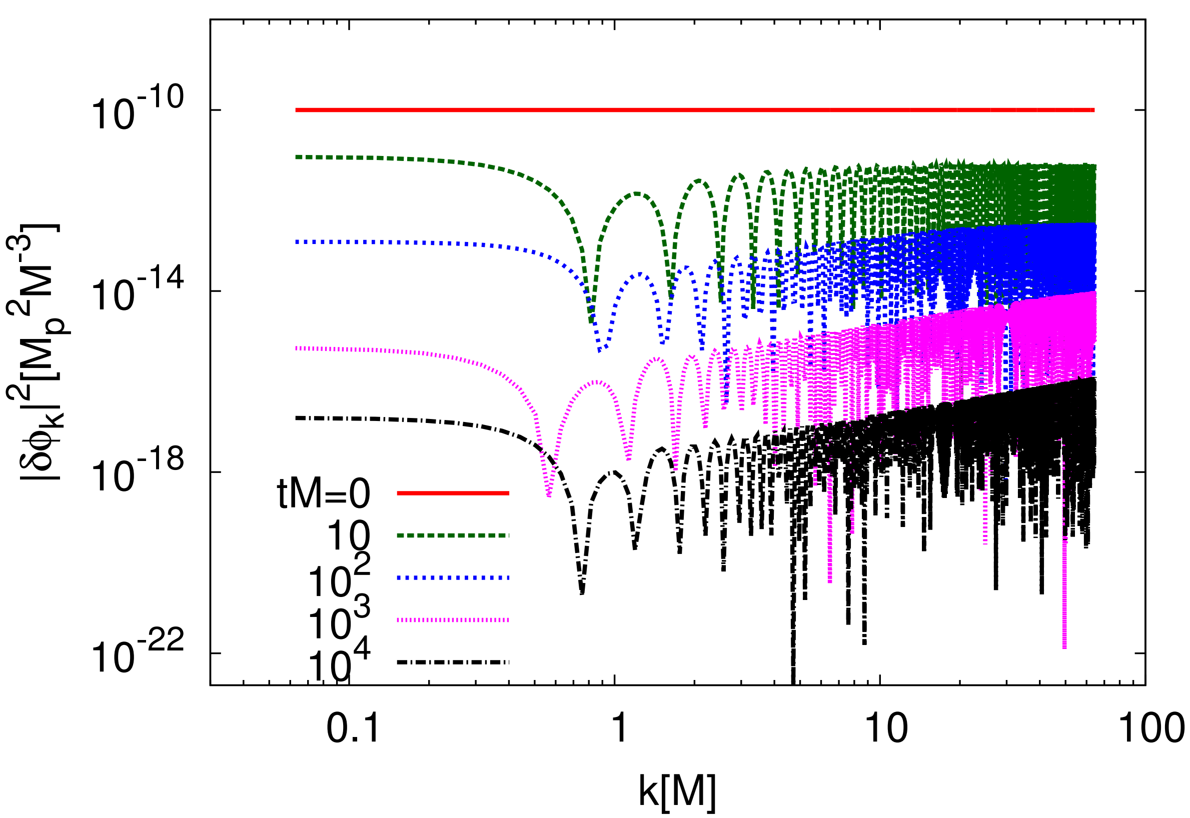
$$\left(\frac{k}{M}\right)^2 < -1 - \frac{7}{6}\left(\frac{\Phi}{M_p}\right)^2 + \sqrt{6}\frac{\Phi}{M_p}\cos(Mt) + \left(\frac{3}{2}\right)^{\frac{1}{3}}\left(\frac{\Phi}{M_p}\right)^{\frac{2}{3}}|\sin(Mt)|^{\frac{2}{3}},$$

Parametric resonant spectrum

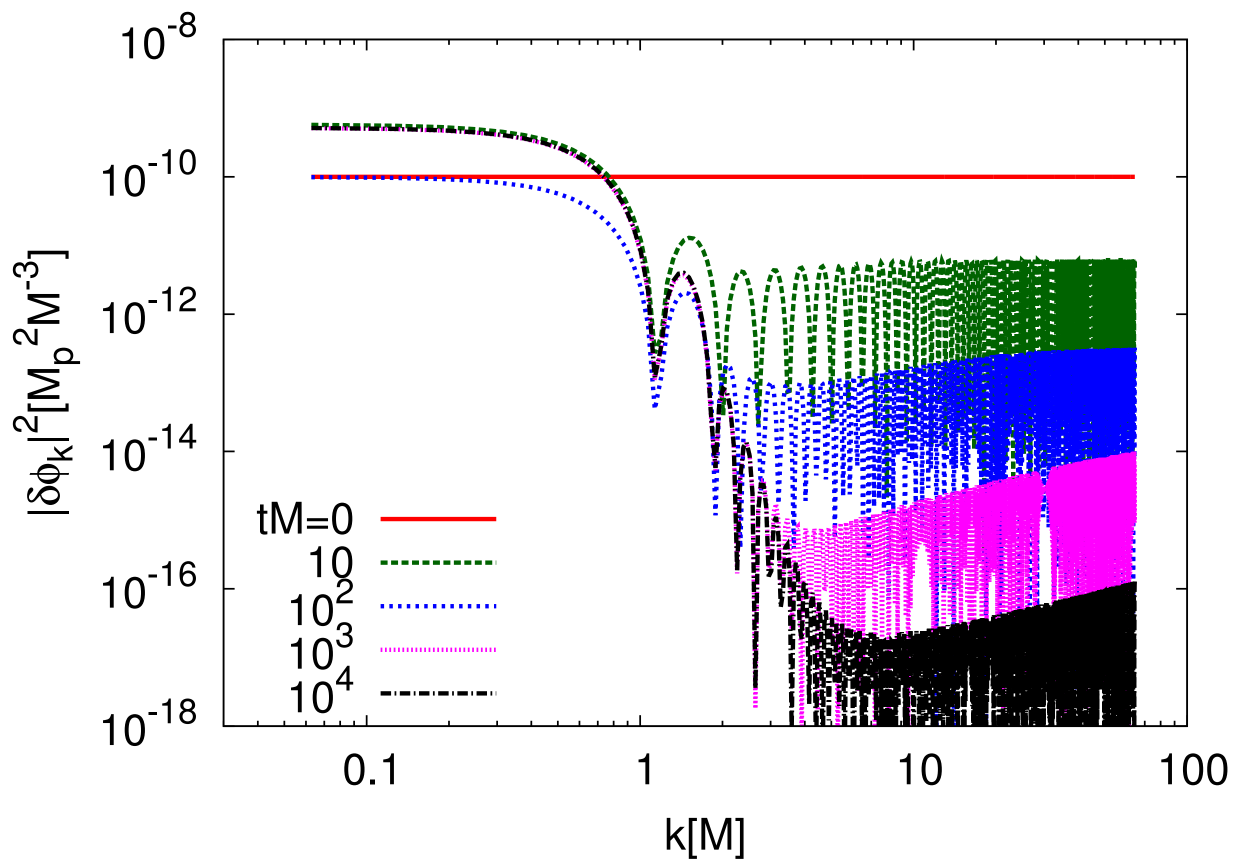
[Takeda & YW 1405.3830]



Preheating in R² 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 R² inflation [Takeda & YW 1405.3830]

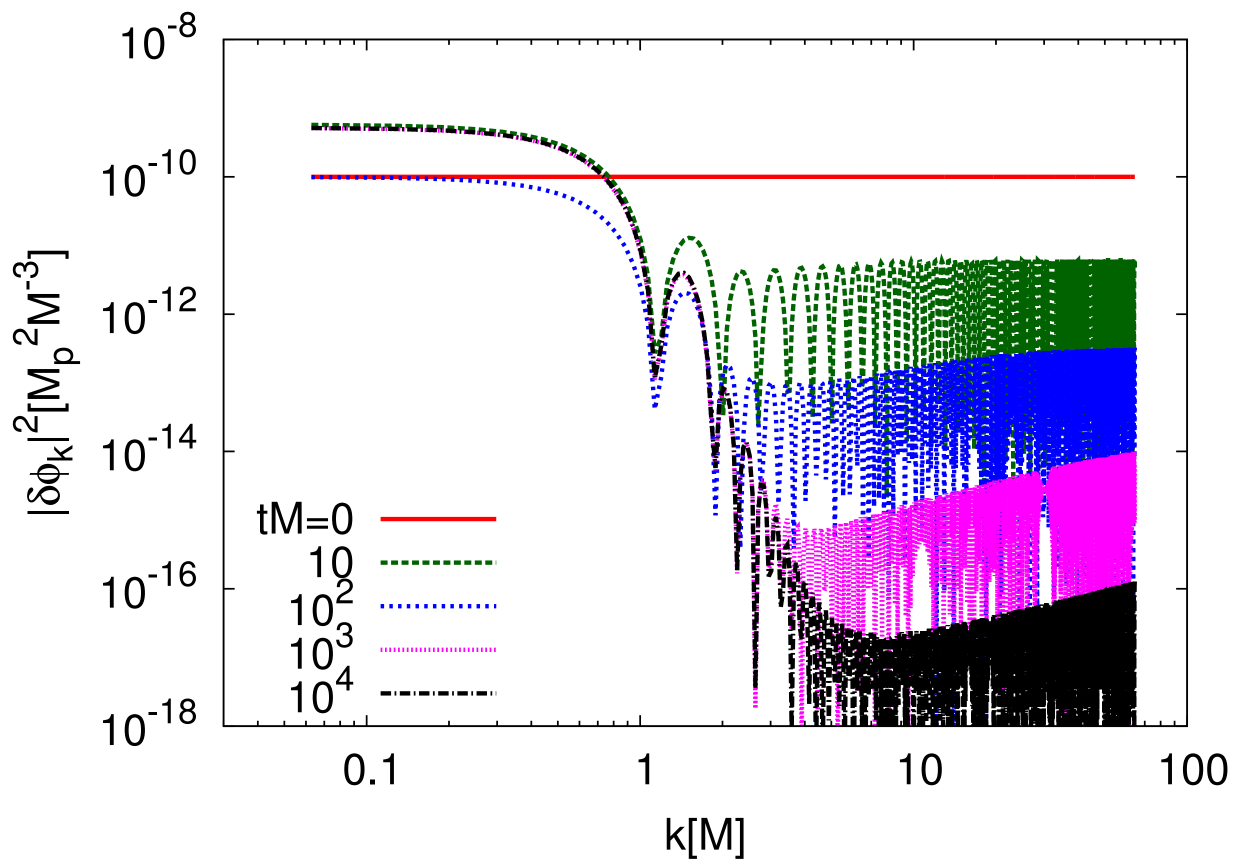
$$\phi_0(t) \simeq \phi_0(t_{\rm ini}) \left(\frac{a_{\rm ini}}{a}\right)^{\frac{3}{2}} \sin(Mt)$$

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

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

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

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



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

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

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

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

R is the supercurvature

ϕ, V are the matter sector

$$S = \int \mathrm{d}^4x\mathrm{d}^4\theta E\left(N(\mathcal{R},\bar{\mathcal{R}}) + J\left(\phi, \bar{\phi}e^{gV}\right)\right)$$
$$+ \left[\int \mathrm{d}^4x\mathrm{d}^2\Theta 2\mathscr{E}\left(F(\mathcal{R}) + P(\phi) + \frac{1}{4}h_{AB}(\phi)W^AW^B\right) + \mathrm{H.c.}\right]$$
$$= \int \mathrm{d}^4x\mathrm{d}^4\theta EN(\mathcal{R},\bar{\mathcal{R}})$$
$$+ \left[\int \mathrm{d}^4x\mathrm{d}^2\Theta 2\mathscr{E}\left(F(\mathcal{R}) + \frac{3}{8}\left(\bar{\mathscr{D}}\bar{\mathscr{D}} - 8\mathcal{R}\right)e^{-K(\phi)/3} + P(\phi) + \frac{1}{4}h_{AB}(\phi)W^AW^B\right) + \mathrm{H.c.}\right]$$

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

$$S = \int d^4xd^2\Theta 2\mathscr{E}\frac{3}{8}\left(\bar{\mathscr{D}}\bar{\mathscr{D}} - 8\mathcal{R}\right)e^{-K/3} + W + \frac{1}{4}h_{AB}W^AW^B + \mathrm{H.c.}$$

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]

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

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

S, ImT are stabilized.

$$F(S) = 0,$$

Real part of T becomes the inflaton: $V = \frac{3m_\Phi^2}{4}\left(1 - e^{-\sqrt{2/3}\widehat{\mathrm{Re}T}}\right)^2$

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

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

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

↓ Grav. coupling to matter

Starobinsky SUGRA R2 inflation

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

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

$$F(S) = 0,$$

Real part of T becomes the inflaton: $V = \frac{3m_\Phi^2}{4}\left(1 - e^{-\sqrt{2/3}\widehat{\mathrm{Re}T}}\right)^2$

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:

$$\Gamma(T \to \phi^i \bar{\phi}^{\bar{i}}) = \frac{3m_i^4}{8\pi M_{\rm G}^2 m_\Phi}, \qquad \Gamma(T \to \phi^i \phi^j) = \frac{m_\Phi^3}{96\pi M_{\rm G}^2} |J_{ij}|^2.$$

Fermions:

$$\Gamma(T \to \chi^i \bar{\chi}^{\bar{i}}) = \frac{m_i^2 m_\Phi}{192\pi M_{\rm G}^2},$$

Gauge fields & gauginos:

$$\Gamma(T \to AA) + \Gamma(T \to \lambda\lambda) \simeq \frac{3N_{\rm g}\alpha^2 m_\Phi^3}{128\pi^3 M_{\rm G}^2}\left(T_G - \frac{1}{3}T_R\right)^2$$

Gravitinos: (Φ is inflaton)

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

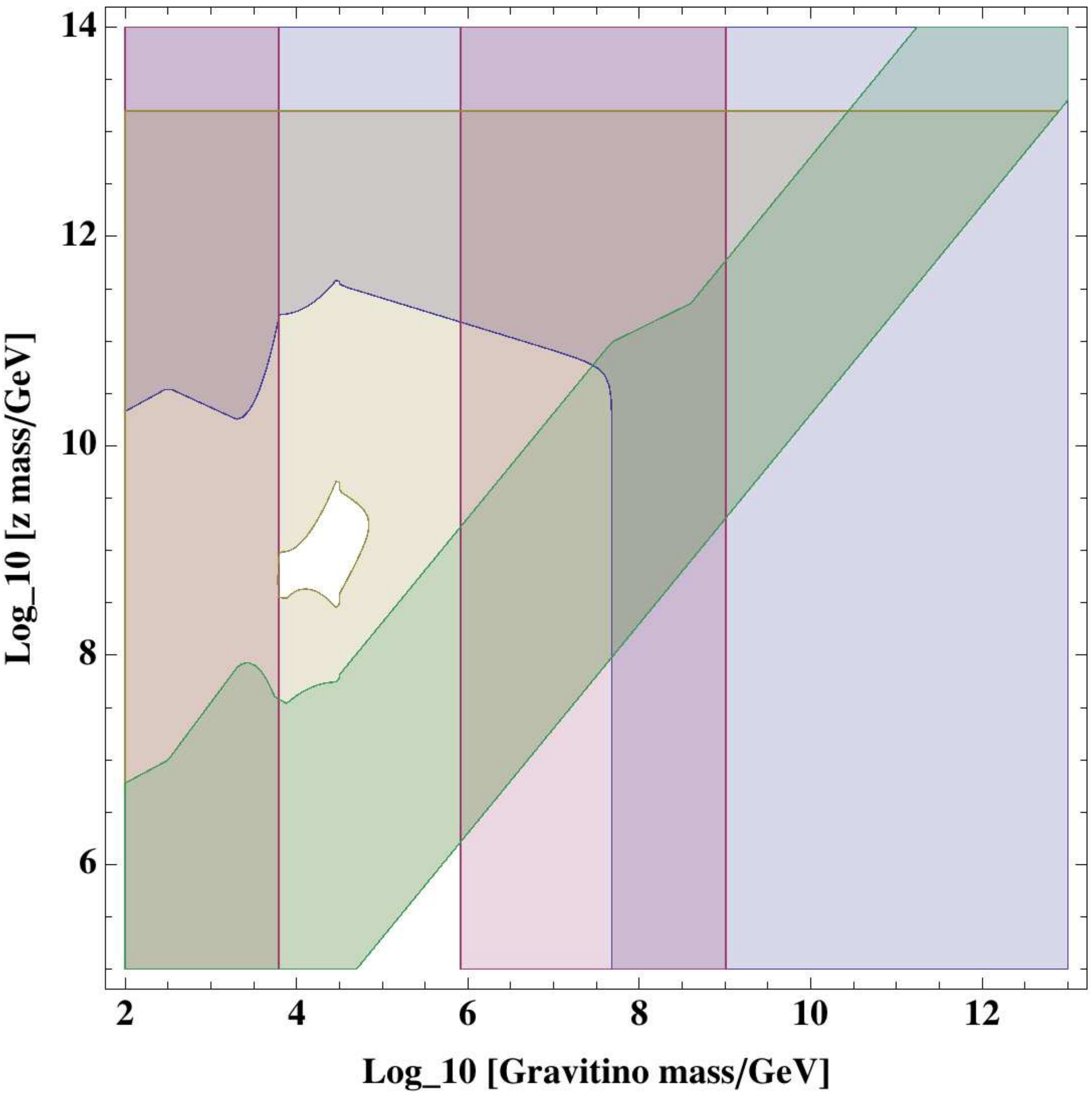
Constraints from gravitino abundance

[Terada, YW, Yamada, Yokoyama 1411.6746]

Gravitinos generated from:

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

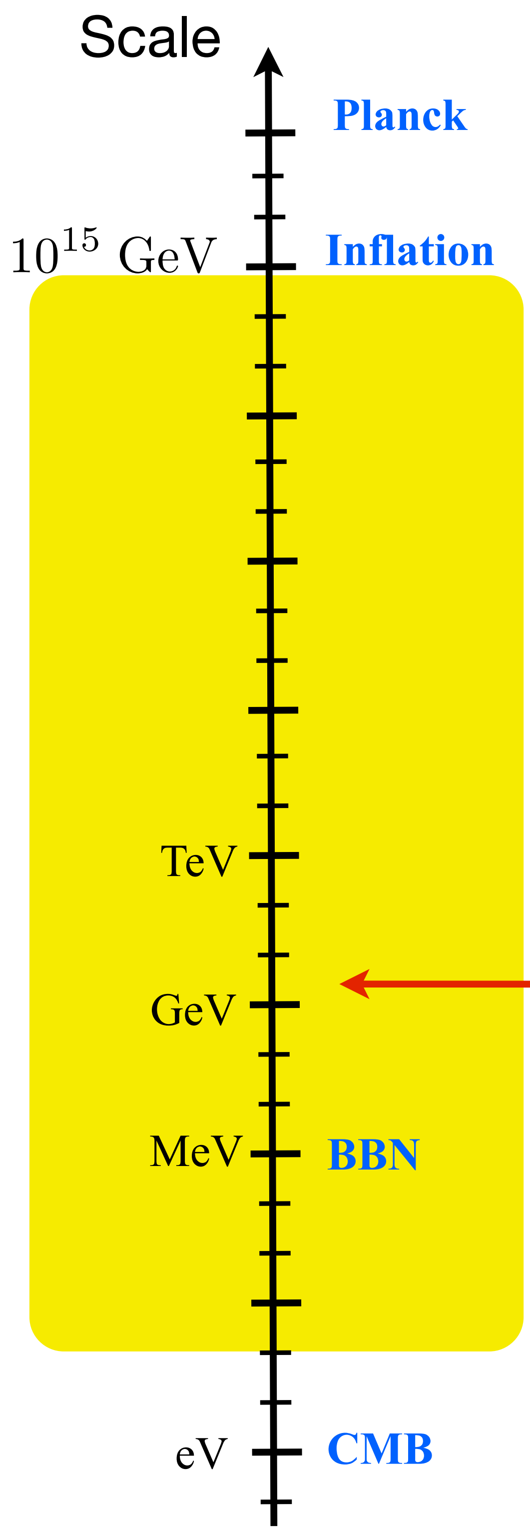
Wino LSP and anomaly mediation are assumed here.



CMB uncertainties from the post-inflationary evolution

[Easther, Galvez, Ozsoy, Watson 2013]

Thermal History



$$N_* \equiv \int_{t_*}^{t_{\rm end}} H dt = \ln(a_{\rm end}/a_*)$$

Radiation Phase (instant reheating)

Scalar Oscillations Dominate

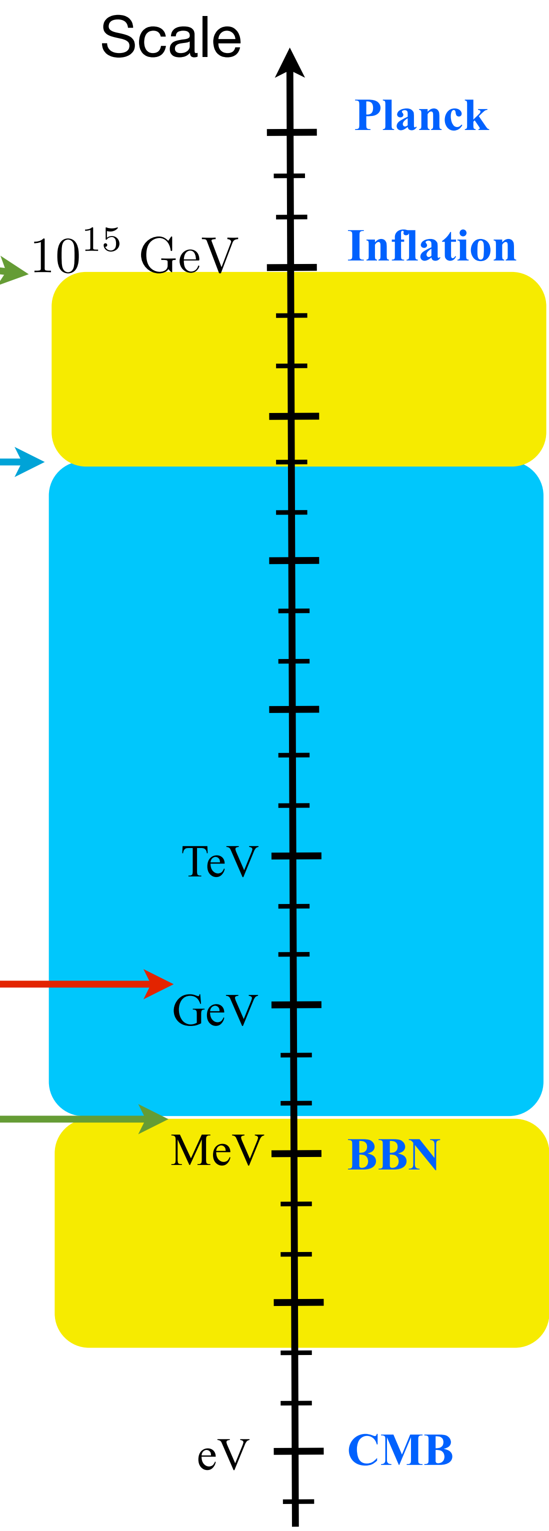
$$n_s(k_*) = 1 - \frac{\alpha}{N_*}$$

$$\Delta n_s = \alpha \frac{\Delta N}{N^2} = \frac{(1-n_s)^2}{\alpha} \Delta N$$

Thermal DM Freeze-out

Particles Decay and Reheat

Alternative History

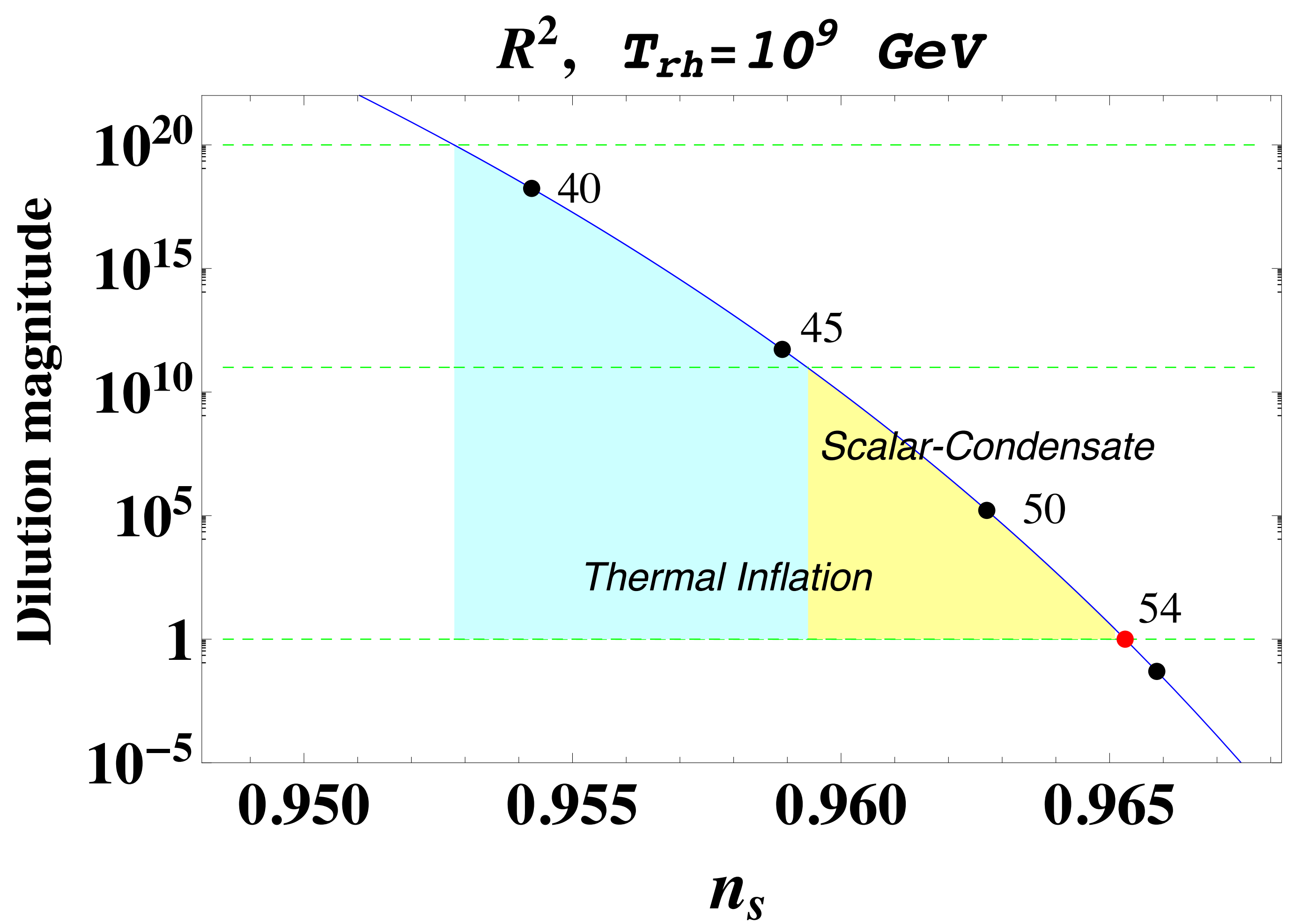


Shift in (ns, r) due to late entropy production

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

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

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



Supersymmetric dark matter cosmology

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

1. Gravitino LSP
2. Neutralino LSP (WIMP)

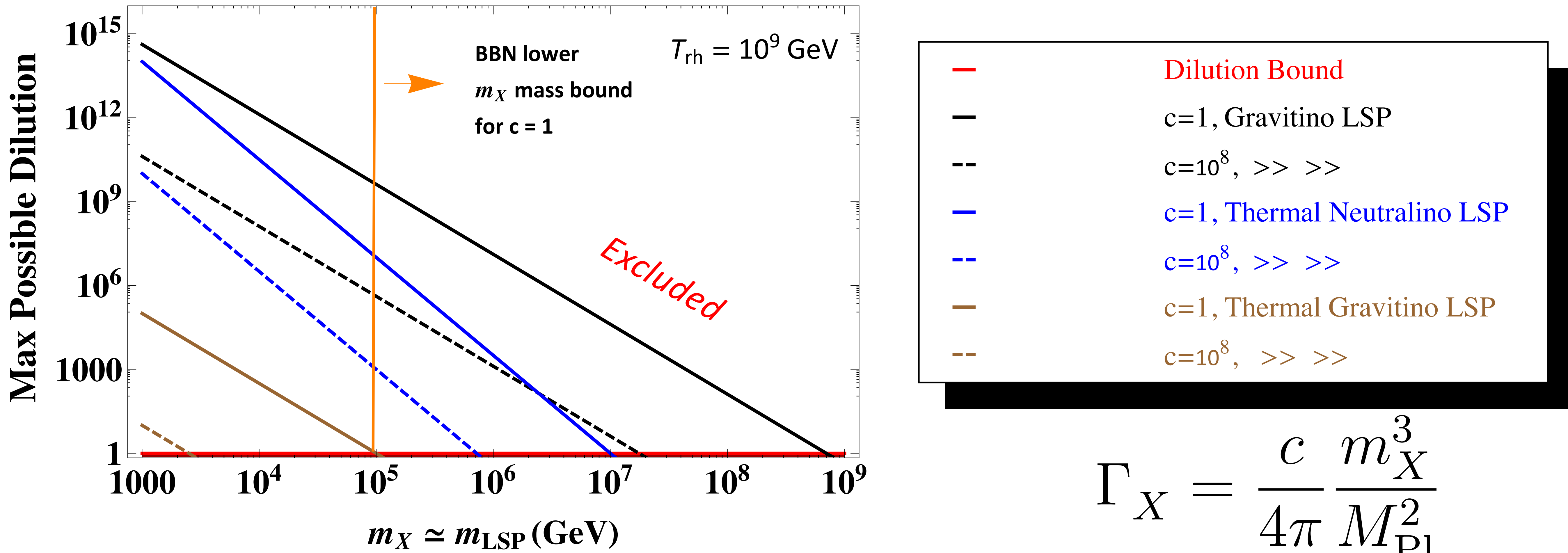
- Thermal DM (freeze out): thermal scatterings with the MSSM, messenger fields
- Non-thermal DM (freeze in): decays, thermal scatterings

Light WIMP mass is disfavored by the LHC.
$\Omega_{DM}h^2$ is severely constrained when **sparticle masses increase**:

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

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

Alternative cosmic histories and SUSY



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

★ High reheating temp. generally overproduce light LSP

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

- If $D_X = 1$ then $T_{\rm rh} \lesssim \tilde{m}$ or $\tilde{m} \sim \text{TeV}$
- If $\mathcal{O}(\text{TeV}) < (m_{\rm LSP}\,, \tilde{m}) < T_{\rm rh}$ then $D_X \geq D_X^{\rm min} \equiv \dfrac{\Omega_{\rm LSP}^{<}}{0.12\, h^{-2}}$

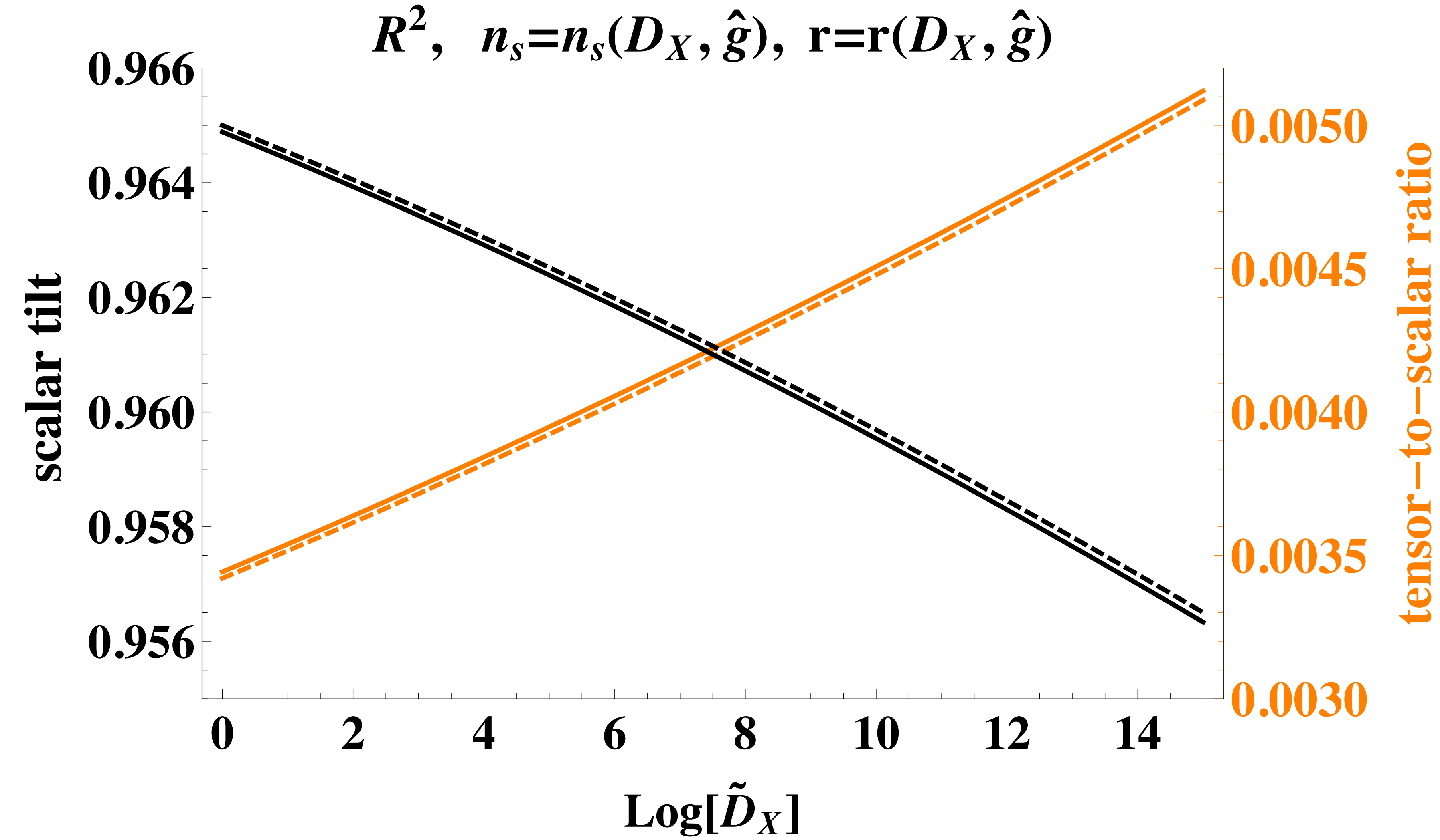
where $\tilde{m}$ the sparticle mass scale.

CMB observables: Starobinsky R2 inflation

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

$$r^{(\mathrm{th})}\big|_{R^2} = 0.0034$$

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



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

CMB observables: Starobinsky R2 inflation

[Dalianis & YW 1801.05736]

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

+ 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

Gaugino 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]

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

+ MSSM, Z, X, (messengers)

Gravitino DM (in GeV units)

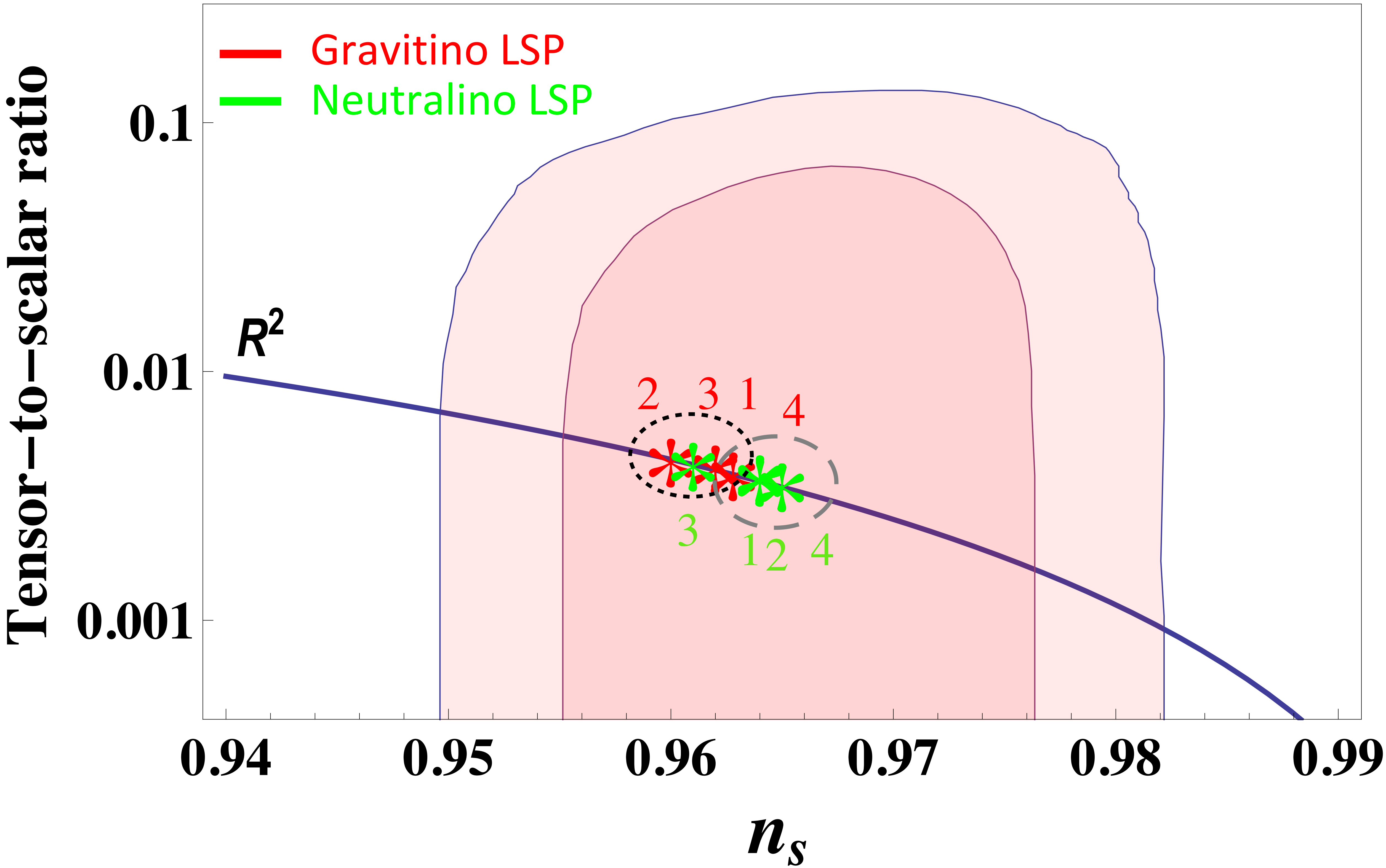
#	m_Z	$m_{\tilde{g}}$	$m_{\tilde{f}}$	$m_{3/2}$ (LSP)	D_X	N_*	n_s	r	Origin
1	10^4	10^4	10^4	10^2	$10^4\|_{\min}$	$51\|_{\max}$	$\mathbf{0.963}\|_{\max}$	$\mathbf{0.0038}\|_{\min}$	Th
2	10^4	10^4	10^5	10^3	$10^{10}\|_{\min}$	$46\|_{\max}$	$\mathbf{0.960}\|_{\max}$	$\mathbf{0.0044}\|_{\min}$	Th
3	10^6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

Gaugino 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	$10^2\|_{\min}$	$52\|_{\max}$	$\mathbf{0.964}\|_{\max}$	$\mathbf{0.0036}\|_{\min}$	Non-th
2	10^9	10^8	10^8	10^3	$10^2\|_{\min}$	$52\|_{\max}$	$\mathbf{0.964}\|_{\max}$	$\mathbf{0.0036}\|_{\min}$	Th
3	10^8	10^7	10^7	10^5	$10^8\|_{\min}$	$48\|_{\max}$	$\mathbf{0.961}\|_{\max}$	$\mathbf{0.0042}\|_{\min}$	Non-th
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]



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 constrains to the parameter space of SUSY.