Messenger inflation in gauge mediation and superWIMP dark matter

Shinsuke Kawai (SKKU, South Korea)

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with Nobuchika Okada (U. Alabama)

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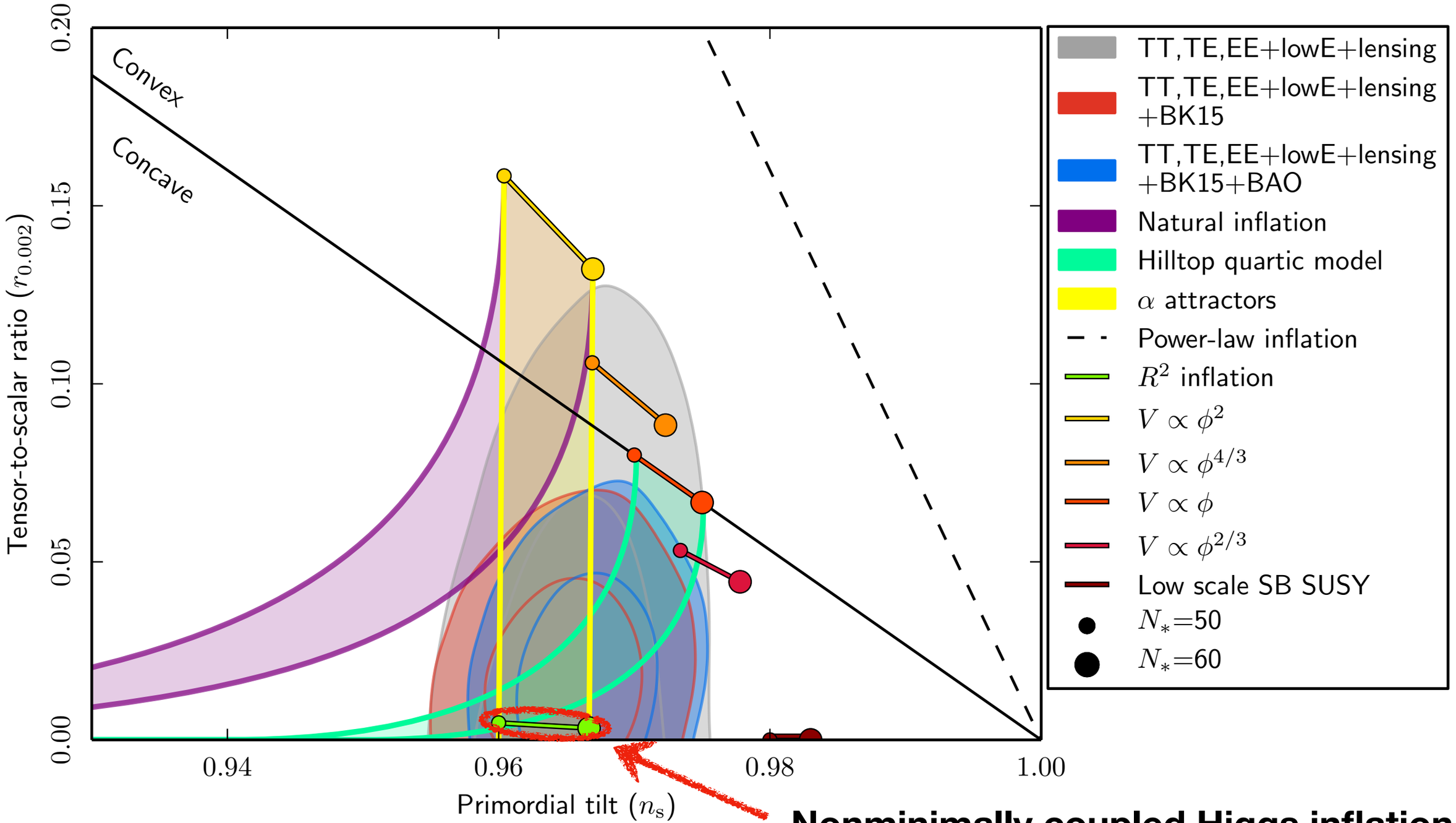
Constraints on inflation



Nonminimally coupled Higgs inflation

SUSY Higgs Inflation

- MSSM no good, NMSSM good [Einhorn & Jones 2009]

- NMSSM model unstable [Ferrara Kallosh Linde Marrani Van Proeyen, 1004.0712]

- Instability removed if appropriate Kähler potential is used [Ferrara Kallosh Linde Marrani Van Proeyen, 1008.2942]

- SU(5) SUSY GUT Higgs inflation [Arai, SK, Okada 1107.4767]

- SUSY seesaw (LHu) inflation [Arai, SK, Okada 1112.2391]

MSSM really cannot accommodate this type of inflation models?

It does!

If SUSY breaking sector is included.

	Gravity mediation	Gauge mediation
Coupling	Planck suppressed ops	MSSM gauge
FCNC	Challenging	Naturally suppressed
μ-problem	Simple	Challenging
DM	Neutralino	Gravitino


Hidden
Sector
mediator
MSSM

Minimal GMSB

$$N_5,\ M,\ \Lambda,\ \tan\beta,\ y,\ \mathrm{sign}\,\mu$$

Superpotential

$$W = (yS + M)\overline{\Phi}\Phi + W_{\rm hid}(S),$$

Messenger field

$$\overline{\Phi} = (D^c, \overline{L}), \quad \Phi = (D, L),$$

$$\times N_5 \text{ sets}$$

	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
D^c	$\mathbf{3}^*$	$\mathbf{1}$	$+1/3$
$\overline{L}$	$\mathbf{1}$	$\mathbf{2}$	$-1/2$
D	$\mathbf{3}$	$\mathbf{1}$	$-1/3$
L	$\mathbf{1}$	$\mathbf{2}$	$+1/2$

$$\langle S\rangle = 0 + \theta^2\ F_S, \qquad \langle\Phi\rangle = \langle\overline{\Phi}\rangle = 0.$$

$$\alpha_a \equiv \frac{g_a^2}{4\pi}\Lambda, \qquad \Lambda \equiv \frac{yF_S}{M}.$$

Gaugino mass

$$M_a = N_5 \frac{\alpha_a}{4\pi}\Lambda,$$

Soft mass

$$m_i^2 = 2N_5\Lambda^2 \sum_{a=1}^{3} C_a(R_i) \left(\frac{\alpha_a}{4\pi}\right)^2.$$

Gravitino mass

$$m_{3/2} = \frac{F_S}{\sqrt{3}M_{\rm P}},$$

Messenger inflation

Superpotential

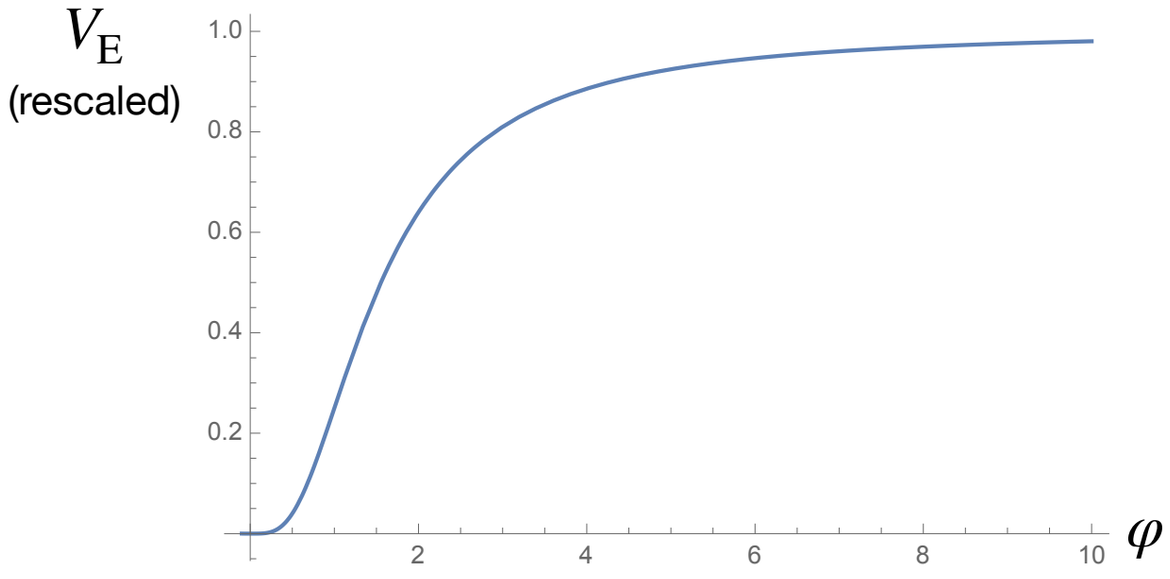
$$W = (yS + M)\overline{\Phi}\Phi + W_{\rm hid}(S),$$

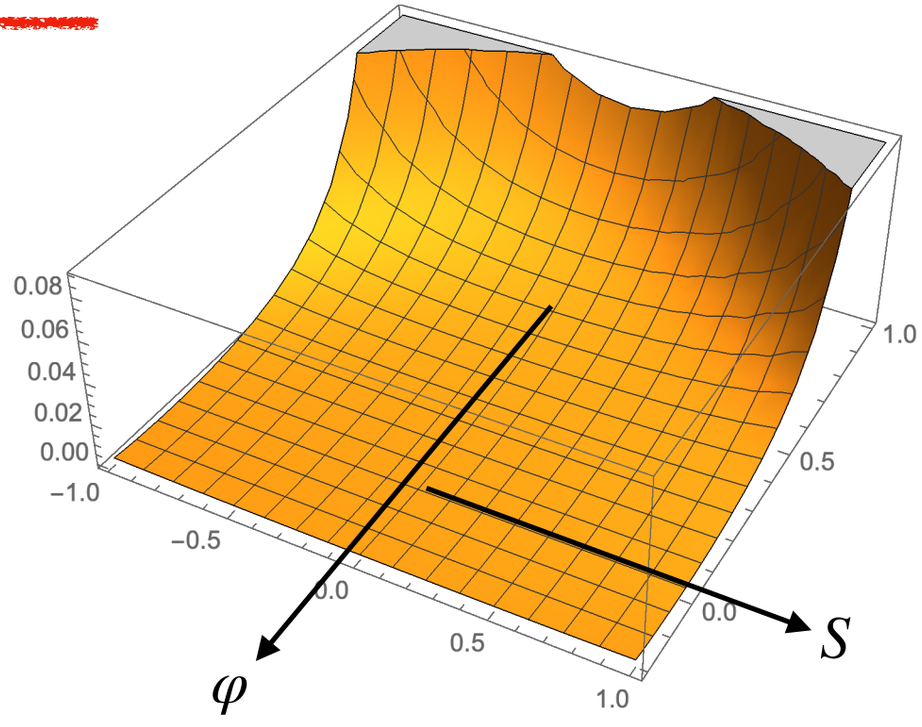
Kähler potential (superconformal framework)

$$\mathcal{K} = -3M_{\rm P}^2 + \left(|\overline{\Phi}|^2 + |\Phi|^2 + |S|^2\right) - \frac{3}{2}\gamma\left(\overline{\Phi}\Phi + \text{h.c.}\right) + \cdots,$$

Scalar potential (Einstein frame)

$$V_{\rm E}(\varphi) = \frac{y^2}{16}\frac{\varphi^4}{(M_{\rm P}^2 + \xi\varphi^2)^2}. \qquad \left(\xi = \frac{\gamma}{4} - \frac{1}{6}\right)$$





($\overline{\Phi}\Phi$ flat direction)

$$\overline{\Phi} = \Phi = \frac{1}{2}\varphi$$

SuperWIMP DM

Neutralino NLSP decay → gravitino DM

$$\Omega_{3/2}h^2 = \Omega_{\tilde{\chi}_1^0}h^2 \times \left(\frac{m_{3/2}}{m_{\tilde{\chi}_1^0}}\right) = 0.120,$$

This constrains the model parameters

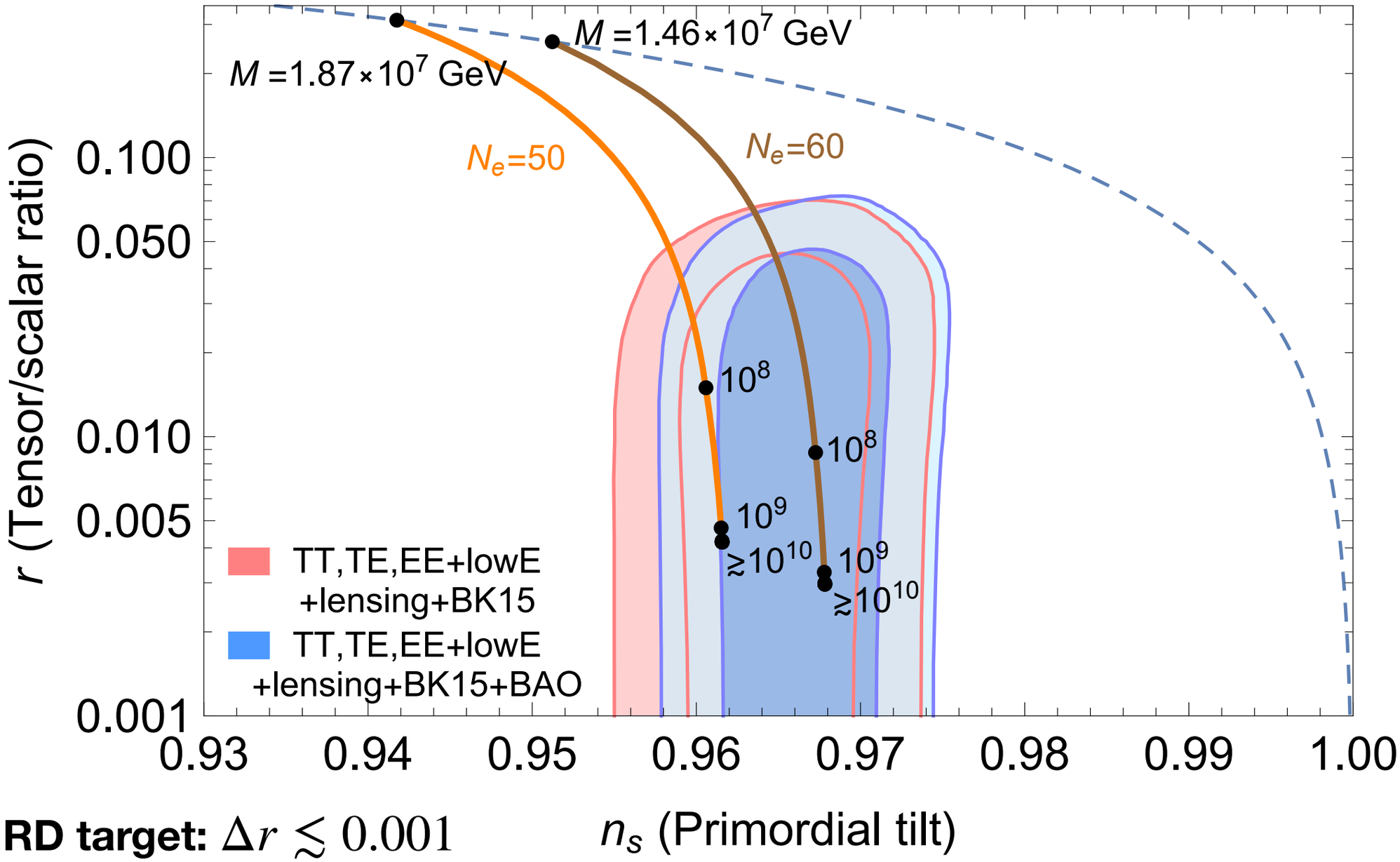
Another requirement is Higgs mass = 125.1 GeV

mGMSB parameters: $N_5,\, M,\, \Lambda,\, \tan\beta,\, y,\, \mathrm{sign}\,\mu$

5 (+1) → 3 (+1)

If $N_5 = 1, \tan\beta = 10$ **are fixed and** $\mu > 0$**, there is only one parameter left (** M **)**

Messenger Inflation: CMB



LiteBIRD target: $\Delta r \lesssim 0.001$

Benchmark model

$N_5 = 1,\ \tan\beta = 10$

Inflaton (messenger) decay via

$$W \supset y_L \overline{L} H_d e^c + y_D D^c H_d Q,$$

Reheating temperature

$$T_{\rm rh} \simeq \frac{y_L}{2\pi}\sqrt{M M_{\rm P}}\left(\frac{45}{2g_*}\right)^{1/4}.$$

$$10^3\ {\rm GeV} \lesssim T_{\rm rh} \lesssim 10^6\ {\rm GeV}$$

neutralino thermal production	no gravitino thermal production

$$y_L \sim 10^{-8}$$

BBN

Lifetime of bino-like neutralino ≲ 1 sec

Gravitino free streaming length

$$\lambda_{\rm FS} \simeq 0.1\ {\rm Mpc}$$

Small scale structure formation

Summary

- Inflation in the flat direction of the messenger fields of minimal GMSB
- Higgs mass and superWIMP DM abundance as constraints
- CMB spectrum $\Longleftrightarrow$ messenger mass *M*
- Energetic gravitino: large free streaming length (warm DM)

$\lambda_{\rm FS} \simeq 0.1\ {\rm Mpc}$ Small scale structure formation