Affleck-Dine baryogenesis and Inhomogeneous reheating scenario

Kohei Kamada (RESCEU,The Univ. of Tokyo)

Baed on: KK, K.Kohri, S.Yokoyama, arXiv: 1008.1450 [astro-ph.CO]

Introduction

Inflation...solves many cosmological problems

strongly supported by WMAP results

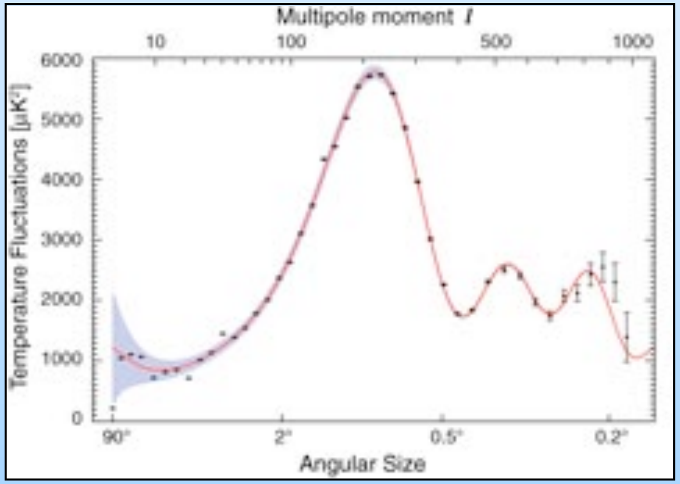
However...

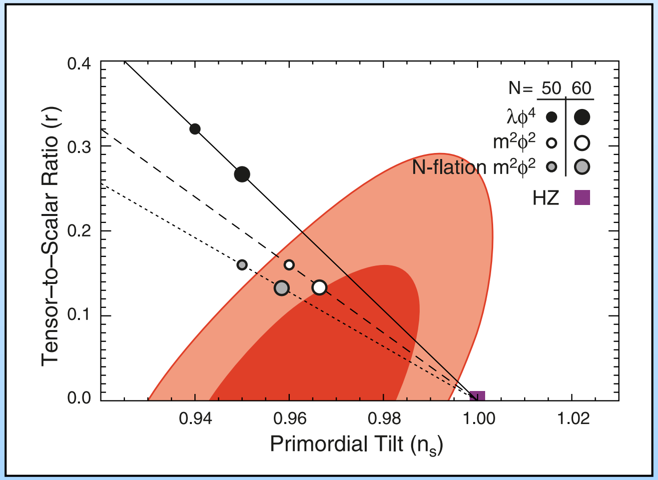
There are many models of inflation.
How do we distinguish them?
Are we really ready for PLANCK
and other future detectors?

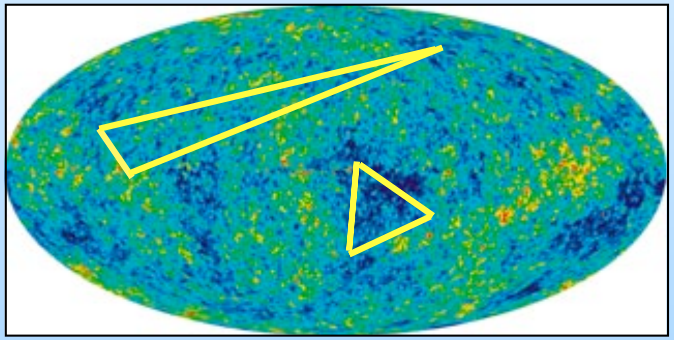
Observables

- Power spectrum of density perturbation (P_ζ)
- Scalar-tensor ratio (r)
- Non-Gaussianity (f_{NL})

Not yet detected !



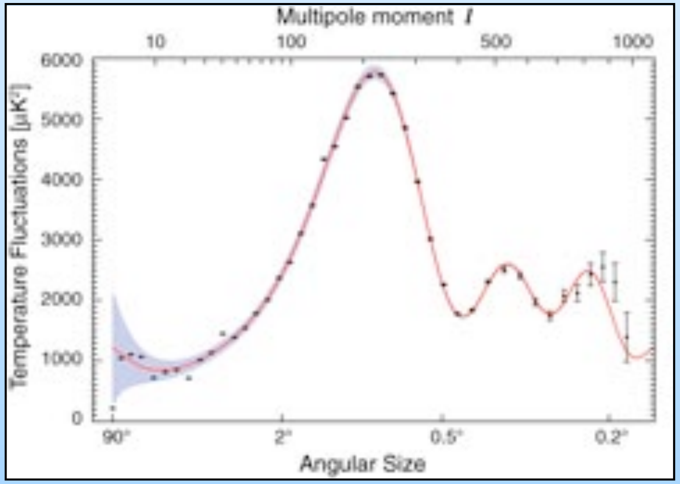


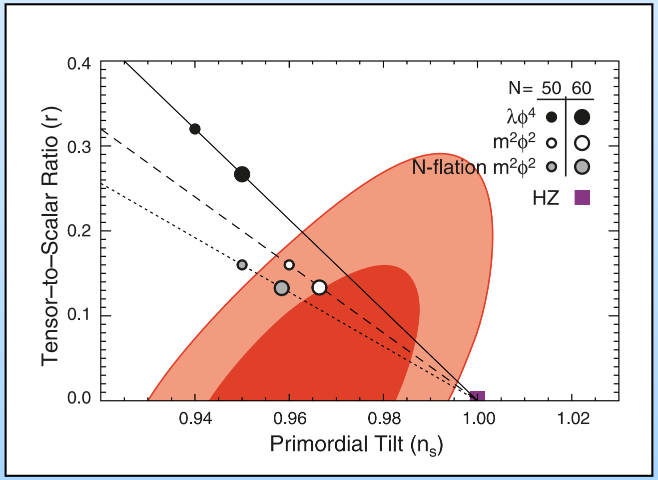


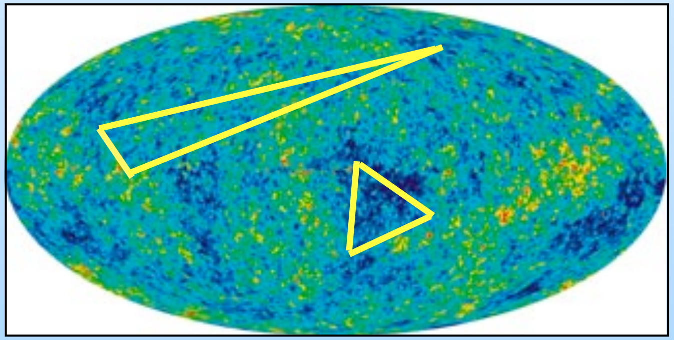
Komatsu('10)

Observables

- Power spectrum of density perturbation (P_ζ)
- Scalar-tensor ratio (r) ⇨ r~0.1(PLANCK) 0.001(LiteBIRD)
- Non-Gaussianity (f_{NL}) ⇨ $\Delta f_{NL} \sim 5$ (PLANCK)







Komatsu('10)

Do we have a scenario that produces both large non-Gaussianity and scalar-tensor ratio?

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YES !

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YES !

Chaotic inflation ($H \sim 10^{13}$ GeV) + modulated reheating can produce large scalar-tensor ratio ($r \sim 0.1$) and large non-Gaussianity ($f_{NL} \sim 10$)

So, do we have a consistent cosmic history in this regime that pass other observational constraints?

Especially, we pay attention the baryogenesis mechanism in supersymmetric theories.

Baryon-to-entropy ratio: $\eta \sim 10^{-10}$

Baryonic isocurvature fluctuation: $|S_B/\zeta| < \mathcal{O}(1) - \mathcal{O}(0.1)$

Kawasaki&Sekiguchi('08), Komatsu et al('10)

Modulated reheating

Dvali, Gruzinov, Zaldarriaga(04), Kofman (04), Zaldarriaga (04)

If the decay rate of inflaton Γ depends on some light scalar σ other than inflaton, $\Gamma = \Gamma(\sigma)$, it affects the number of e-folds after inflation $\mathcal{N}$.

$$\mathcal{N} = -\frac{1}{6}\ln[\Gamma[\sigma]] + \cdots$$

$\delta\mathcal{N}$-formalism

Starobinsky (85), Sasaki Stewart (96), Sasaki Tanaka(98), Lyth Rodriguez (04)

$$\zeta = \delta\mathcal{N} = -\frac{1}{3}\frac{\delta T_R}{T_R}$$

$$f_{\rm NL} = 5\left(1 - \frac{\Gamma\Gamma''}{\Gamma'^2}\right)$$

adiabatic and isocurvature perturbation

Isocurvature perturbation

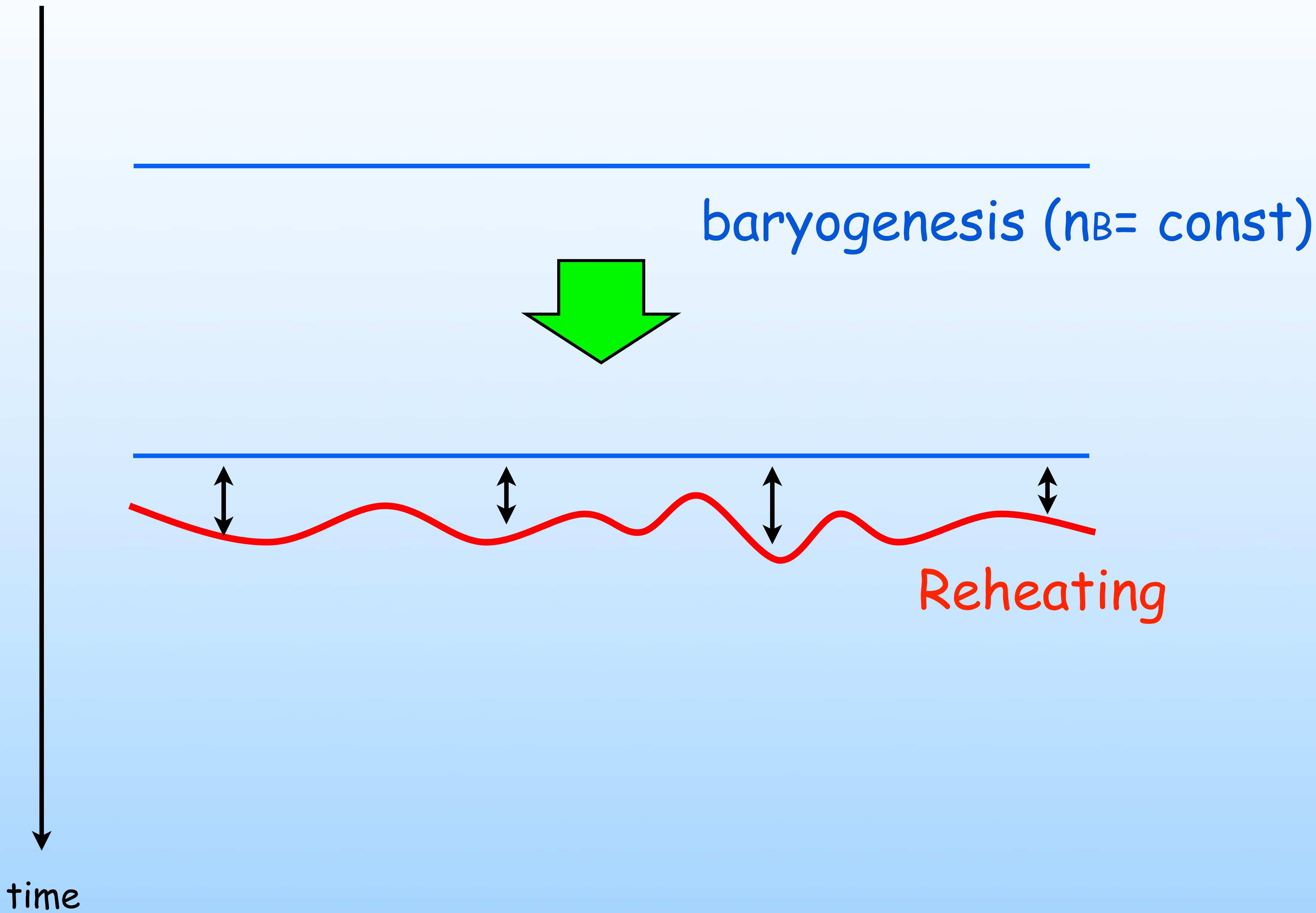
$$S \equiv \frac{\delta n}{n} - \frac{\delta s}{s} = \frac{\delta(n/s)}{n/s}$$

If number-to-entropy ratio depends on the reheating temperature

$$\frac{n}{s} \propto (T_R)^p$$

Relatively large isocurvature perturbation $S \simeq -3p\zeta$ is generated in the modulated reheating scenario.

cf) gravitino DM isocurvature perturbation (Takahashi, Yamaguchi, Yokoyama,Yokoyama ('09))


baryogenesis (n_B= const)
Reheating
time

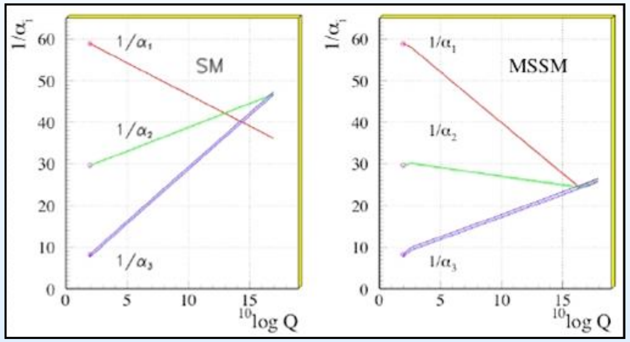
Supersymmetry in cosmology

Supersymmetry...

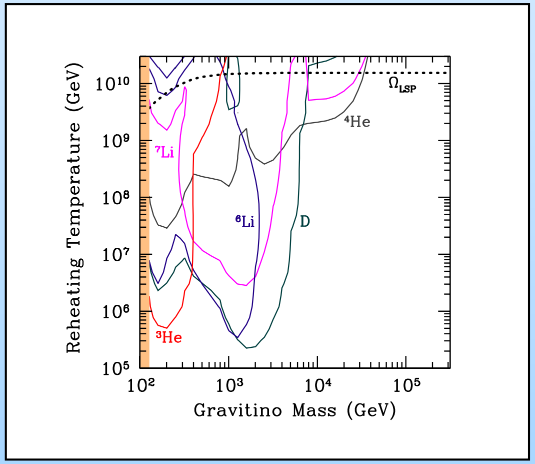
hierarchy problem

gauge coupling unification

DarkMatter candidate



Gravitino problem



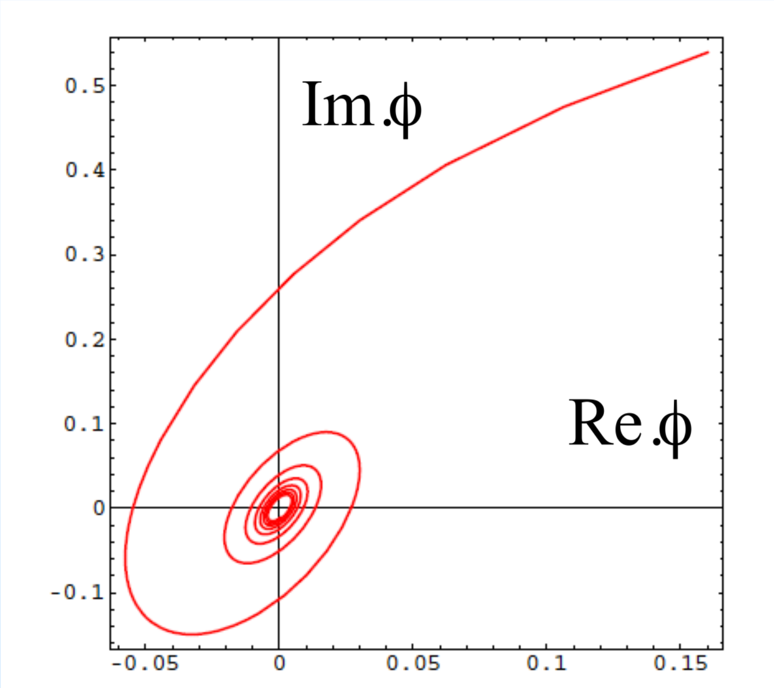
... constraint on the reheating temperature

Affleck-Dine mechanism ?

Kawasaki et al (08)

Affleck Dine mechanism

Affleck & Dine('85), Dine, Randall & Thomas ('96)



rotation of scalar fields with non-zero baryonic charge in the complex space

=baryon number density

$$n_B(t) = iq_B(\dot{\phi}^*\phi - \phi^*\dot{\phi}) = 2|\phi|^2\dot{\theta}$$

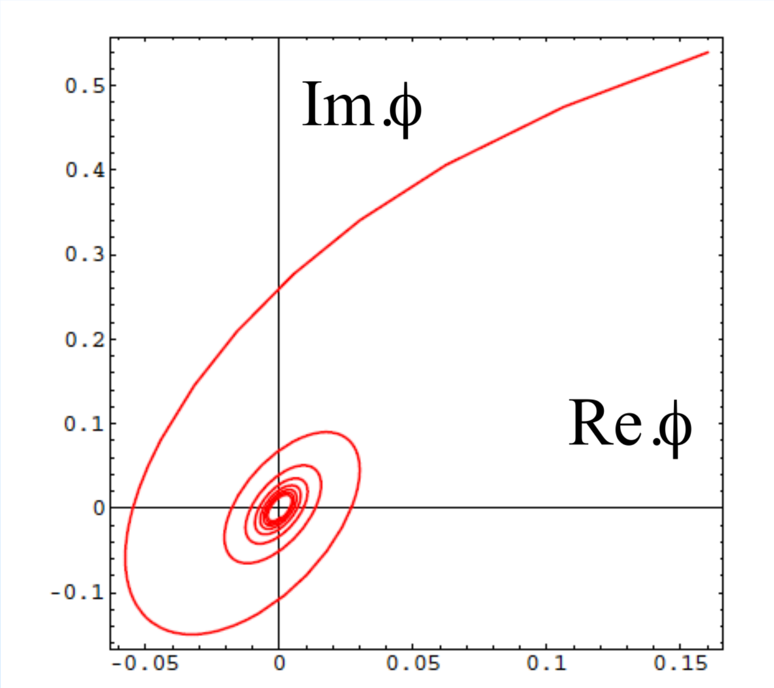
Large field value $|\phi| \to (H_{\rm osc}M^n)^{1/(n+1)}$

Large angular velocity $\dot{\theta} \to m_{3/2}$

Resultant baryon-to-entropy ratio: $\frac{n_B}{s} \simeq \frac{m_{3/2}T_R}{M_G^2 H_{\rm osc}^2}(H_{\rm osc}M^n)^{2/(n+1)}$

Affleck Dine mechanism

Affleck & Dine('85), Dine, Randall & Thomas ('96)



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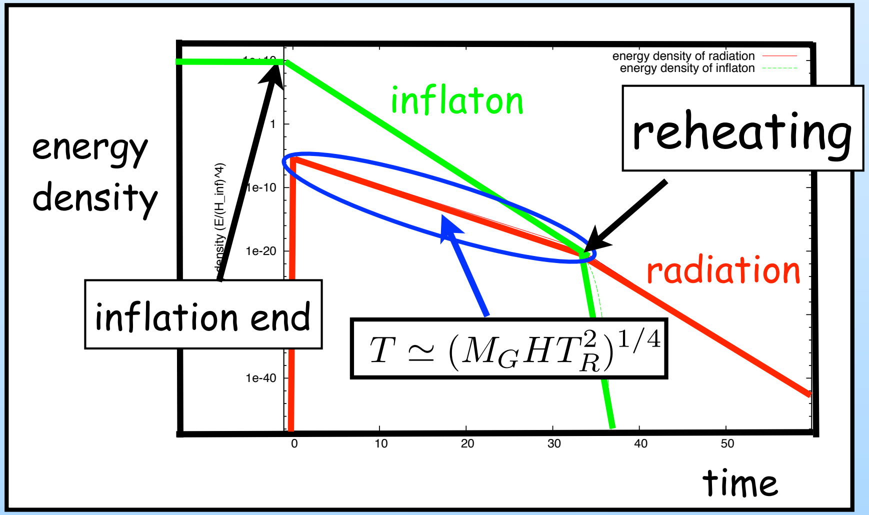
It seems that the AD mechanism and the modulated reheating scenario are incompatible...

However, taking into account the dilute plasma before reheating $T \simeq (T_R^2 H M_G)^{1/4}$, $H_{\rm osc}$ can depend on the reheating temperature.

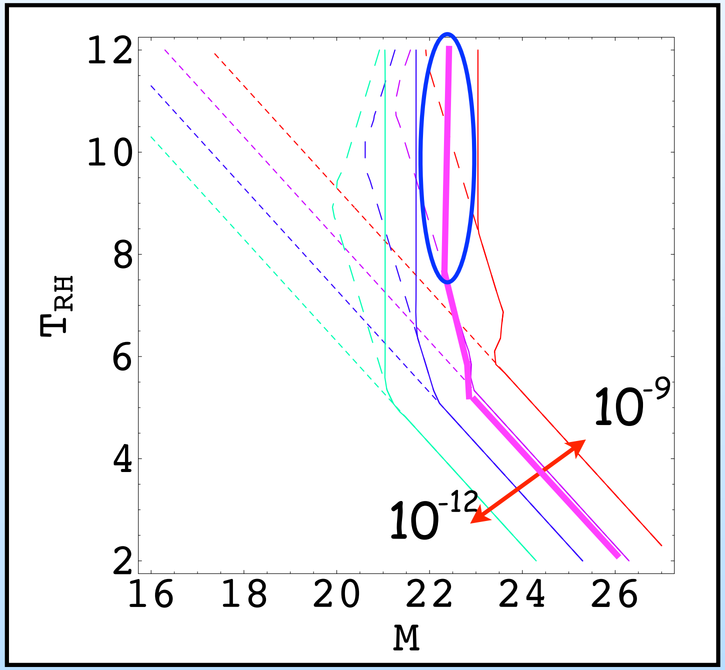


AD field oscillation can be driven by thermal potential

$$V_{\rm thermal} = \begin{cases} h^2 T^2 |\phi|^2 & (|\phi| < hT) \\ T^4 \log\left(\frac{|\phi|^2}{h^2 T^2}\right) & (|\phi| > hT) \end{cases}$$

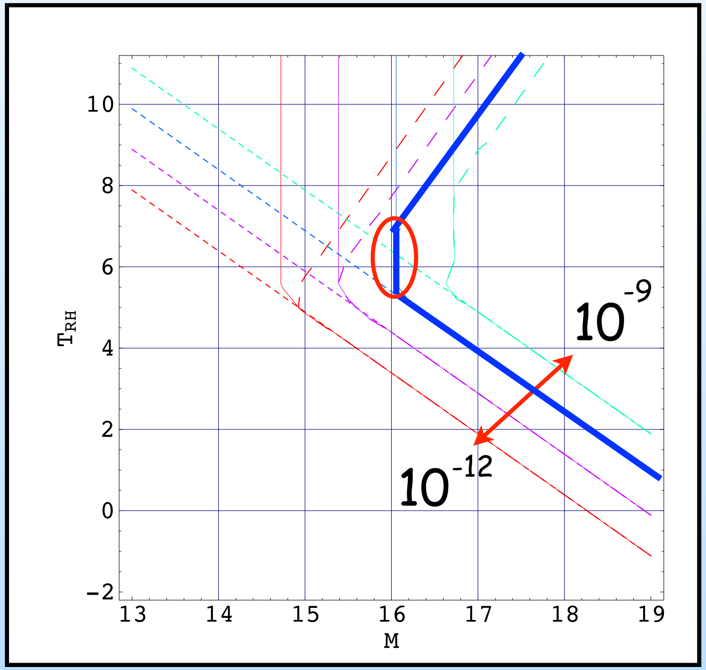
baryon asymmetry and reheating temperature

n=1



thermal log term driven

n=3



thermal mass term driven

M. Fujii (02), master thesis

Example

modulated reheating with

$$\Gamma(\sigma) \simeq \frac{g(\sigma)^2}{8\pi} m_\phi \qquad g(\sigma) = g\left[1 + \lambda\left(\frac{\sigma}{M_{\rm cut}}\right)^2\right]$$

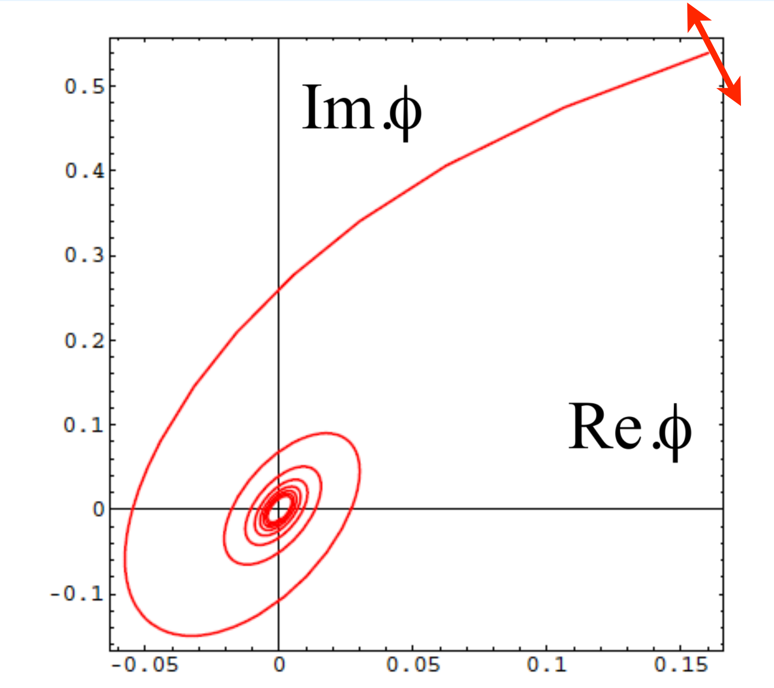
predicts

$$f_{\rm NL} \simeq -10^2 \lambda^{-1} \left(\frac{\sigma/M_{\rm cut}}{0.1}\right)^{-2} \qquad \mathcal{P}(k) \simeq 10^{-10} \times \left(\frac{H_{\rm inf}}{10^{13}{\rm GeV}}\right)^2 \left(\frac{M_{\rm cut}}{10^{16}{\rm GeV}}\right)^{-2} \lambda^2 \left(\frac{\sigma/M_{\rm cut}}{0.1}\right)^2$$

Tensor perturbation:

$$r \sim 0.1 (H_{\rm inf}/10^{13}{\rm GeV})^2$$

Comment on another source of baryonic isocurvature perturbation



Fluctuation of the AD field in the phase direction can be another source of the isocurvature perturbation. (Kasuya, Kawasaki, Takahashi (08))

$$S \simeq \frac{n}{2\pi}\left(\frac{H_{\rm inf}}{M}\right)^{n/(n+1)}$$

n~1, M~10^{22}GeV

$$H_{\rm osc} \lesssim 10^{13}\,{\rm GeV}$$

n~3, M~10^{16}GeV

$$H_{\rm osc} \lesssim 10^{9}\,{\rm GeV}$$

Summary

- Modulated reheating is one of the promising mechanisms that generates a detectable primordial Non-Gaussianity.
- With chaotic inflation, it is possible to generate a detectable tensor perturbation.
- However, modulated reheating and Affleck-Dine baryogenesis are, in general, incompatible.
- Taking into account the thermal correction to the potential, we find a parameter space that generates a proper baryon-to-entropy ratio in this scenario.