Moduli Inflating Curvaton

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This talk is based on the following paper:

Affleck-Dine baryogenesis in inflating curvaton scenario with O(10-10^2TeV) mass moduli curvaton

Kazuyuki Furuuchi and Chia-Min Lin
arXiv:1111.6411 JCAP 1203 (2012) 024

CML and Kazuyuki Furuuchi

Moduli (Polonyi) Problem

$$\Gamma \sim \frac{1}{4\pi}\frac{m_\phi^3}{M_P^2}$$

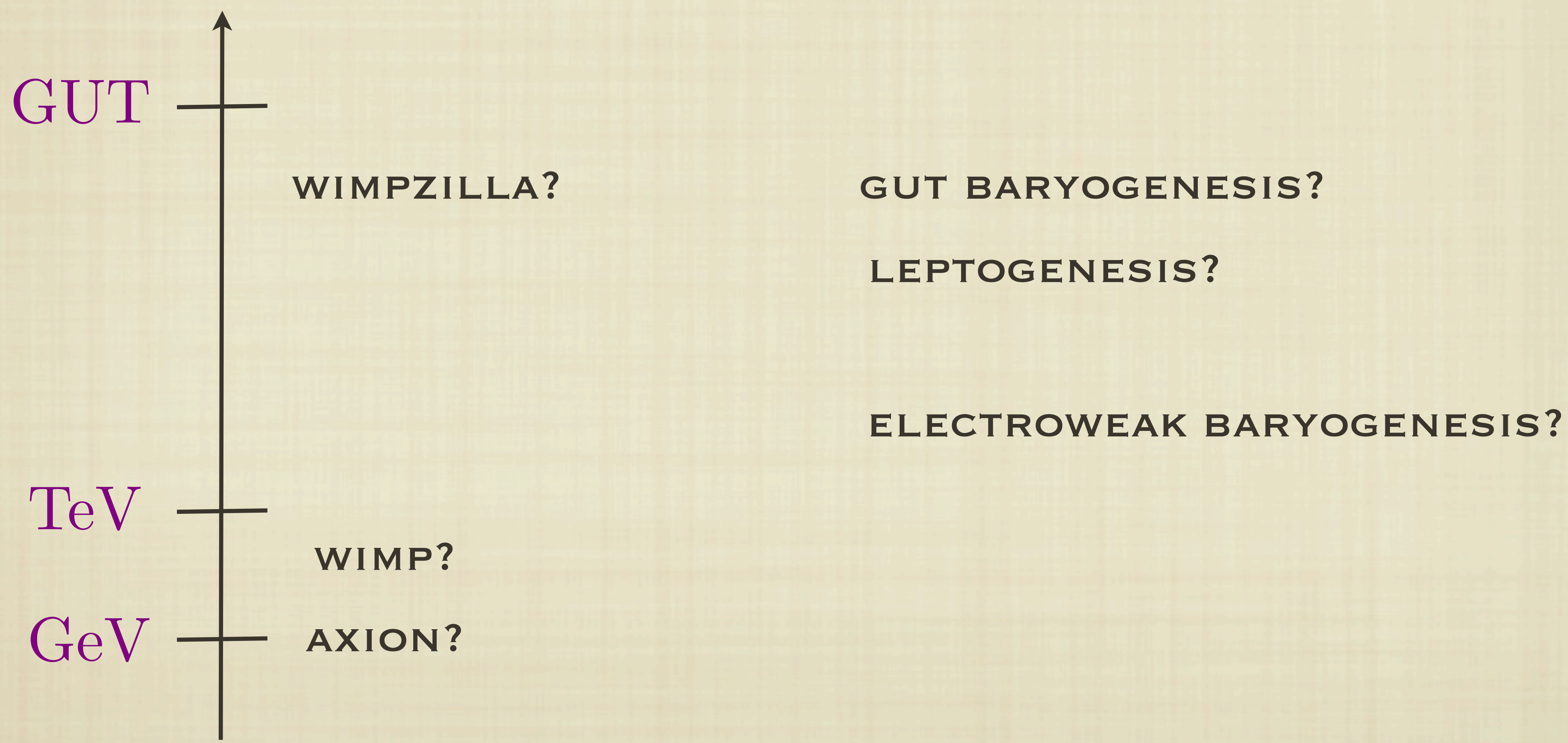
$$T_R \sim 1.2 g_*^{-1/4}\sqrt{M_P \Gamma_\phi} \sim 1.2 \times 10^{-7}\mathrm{GeV} \times \left(\frac{m_\phi}{1000\mathrm{GeV}}\right)^{3/2}$$

$T_R > 1\mathrm{MeV}$ ⇒ $m_\phi > 10\mathrm{TeV}$

We do not really know the thermal history of the universe before BBN.

IT IS POSSIBLE THAT BEFORE BBN THE UNIVERSE IS COLD AND DOMINATED BY MODULI MATTER

IF SO, THE QUESTION IS HOW CAN WE HAVE DARK MATTER AND BARYOGENESIS THEN?



WE CONSIDER:

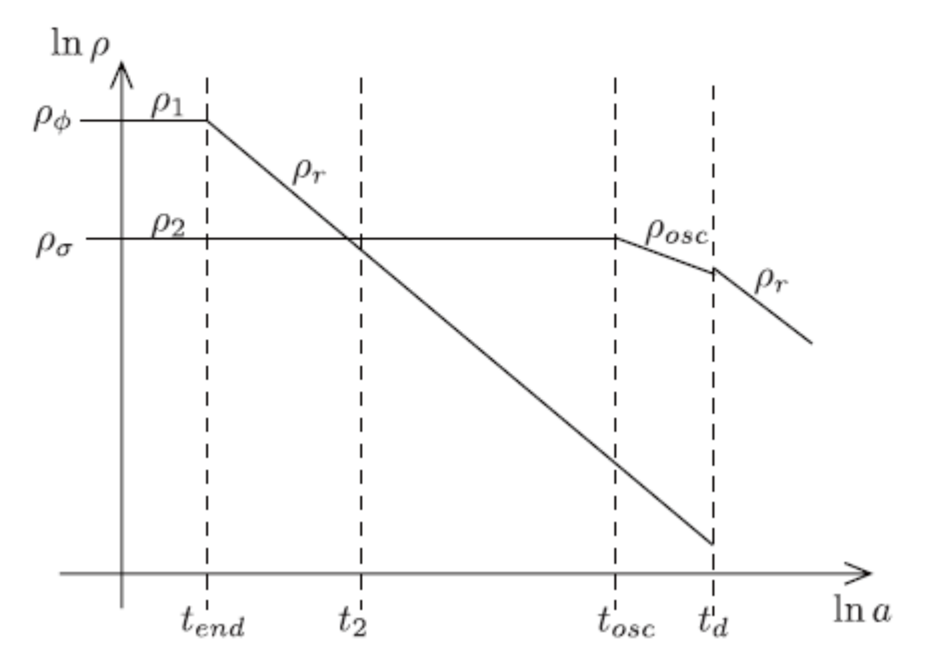
BARYOGENESIS: AFFLECK DINE BARYOGENESIS

DARK MATTER: NON-THERMAL (WINO-LIKE) LSP FROM THE DECAY OF MODULI FIELD

WE ALSO ASSUME MODULI FIELD IS INFLATING CURVATON AND RESPONSIBLE FOR PRIMORDIAL DENSITY PERTURBATION

Inflating curvaton

1110.2951 dimopoulos, kohri, lyth, and matsuda



Ex: when curvaton with a quadratic potential start to oscillate:

$$\rho_r \sim 3m^2 M_P^2$$

$$\rho_\sigma \sim \frac{1}{2} m^2 \sigma^2$$

$$\rho_r > \rho_\sigma \quad \Rightarrow \quad \sigma < \sqrt{6} M_P$$

If $\sigma > \sqrt{6} M_P$

$\Rightarrow$ Curvaton will drive a second stage of inflation!

INFLATING CURVATON

IN THE INFLATING CURVATON SCENARIO, COSMOLOGICAL SCALES ARE DEMANDED TO BE OUTSIDE THE HORIZON AT THE TIME WHEN THE SECOND INFLATING STARTS:

$$N_2 \lesssim 45 - \frac{1}{2}\ln\left(\frac{10^{-5}M_P}{H_2}\right)$$

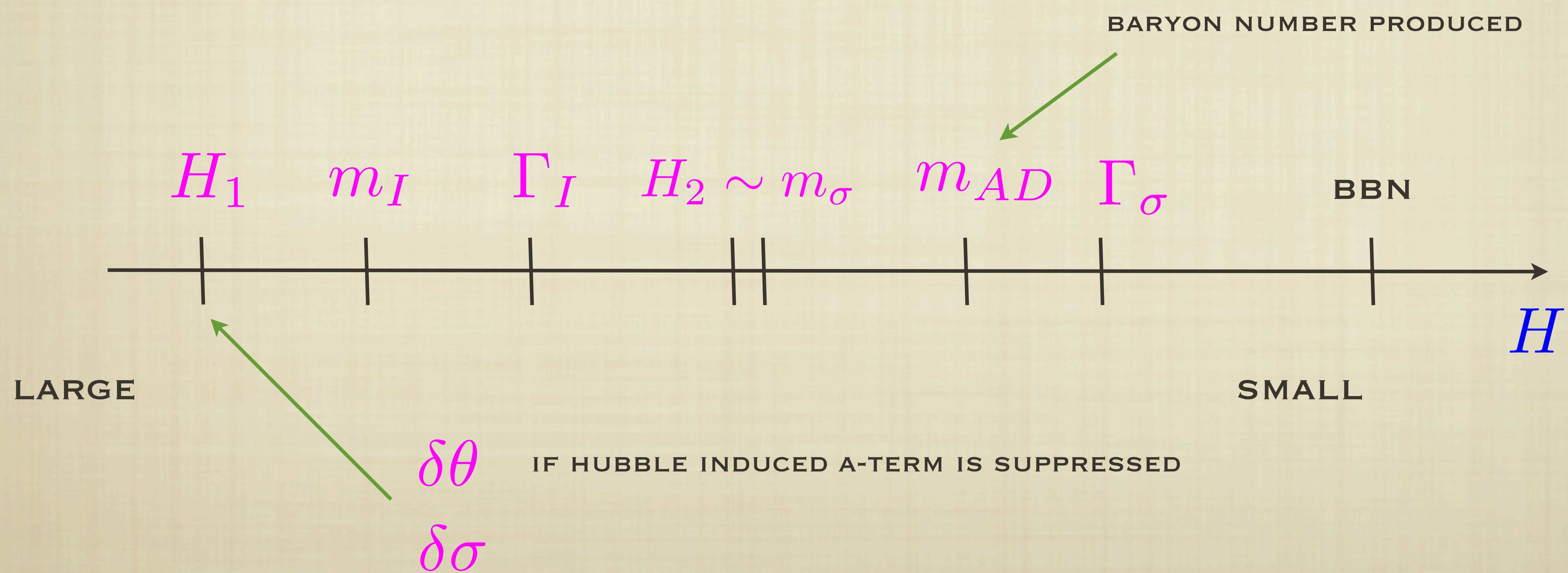
CURVATURE PERTURBATION IS GIVEN BY

$$P_\zeta^{1/2} \sim \frac{1}{3}\frac{V'_\sigma}{\dot{\sigma}^2(t_2)}\frac{H_1}{2\pi}$$

INFLATON m_I

MODULI INFLATING CURVATON σ m_σ

AFFLECK DINE FIELD ϕ m_{AD}



PNGB inflating curvaton

Actually quadratic potential CANNOT work as inflating curvaton because the spectrum cannot dominate.

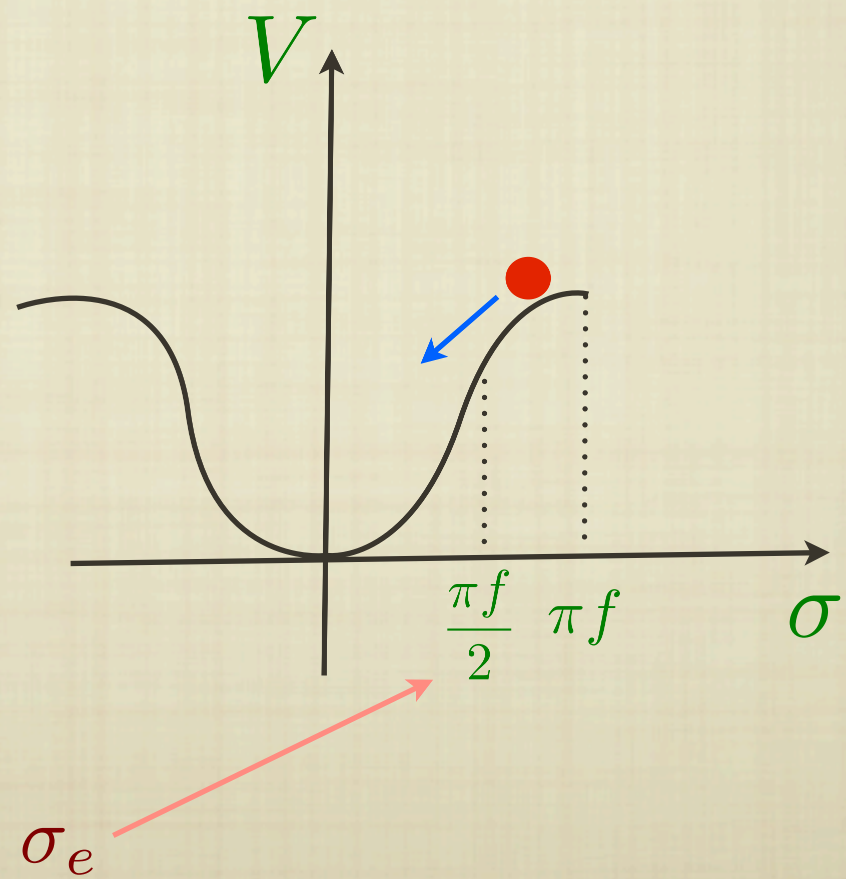
$$V_\sigma(\sigma) = m_\sigma^2 f^2 \left[1 - \cos\left(\frac{\sigma}{f}\right)\right]$$

for moduli field we expect:

$$m_\sigma \sim m_{3/2}$$

$$f \sim M_P$$

fast-roll inflation



CURVATURE PERTURBATION

$$N_2 \sim \frac{1}{F} \ln \left(\frac{\frac{\pi f}{2}}{\pi f - \sigma_2} \right)$$

$$P_\zeta^{1/2} \sim \frac{1}{3} \left(\frac{m_\sigma}{F H_2} \right)^2 \frac{H_1}{2\pi(\pi f - \sigma_2)} \sim 5 \times 10^{-5}$$

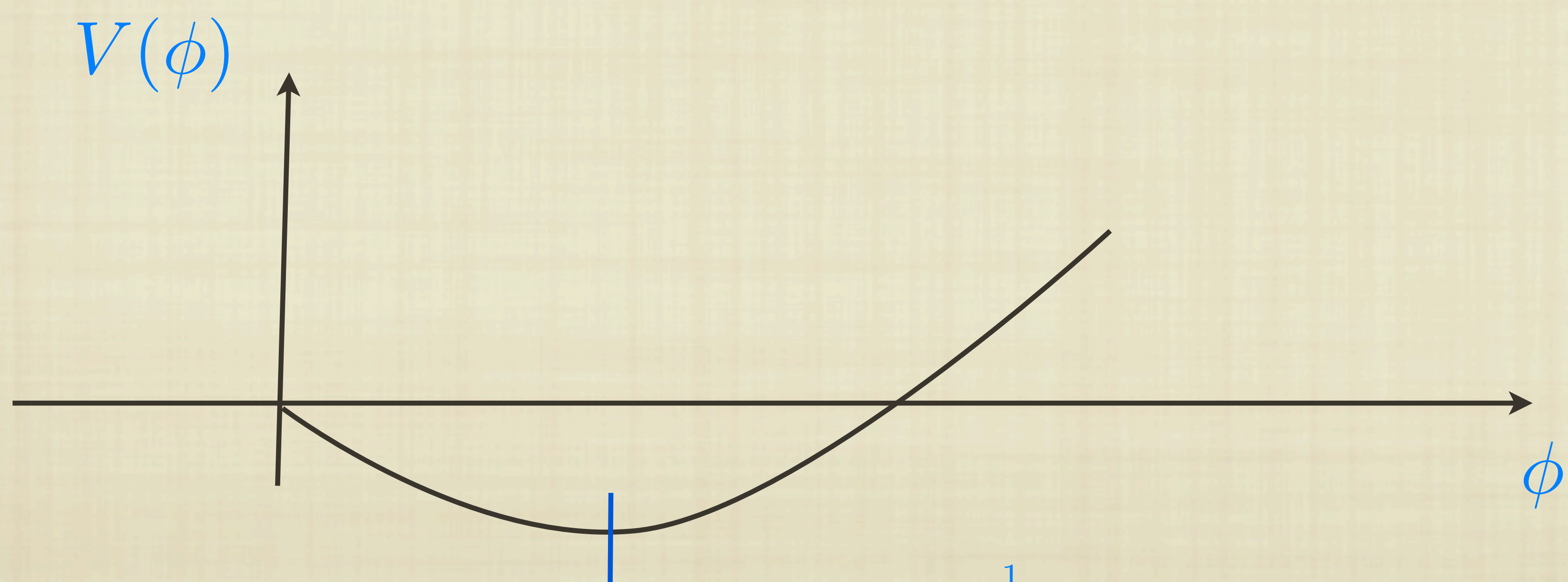
CMB NORMALIZATION

$$F \equiv \frac{3}{2} \left(\sqrt{1 + \frac{4 m_\sigma^2}{9 H_2^2}} - 1 \right)$$

AD baryogenesis

$$V_{AD}(\phi) = (-cH + m_{AD}^2)|\phi|^2 + \frac{A_H H + A m_{3/2}}{M^{p-3}}\lambda\phi^p + |\lambda|^2 \frac{|\phi|^{2p-2}}{M^{2p-6}}$$

soft mass	A-term	F-term
$W \sim \frac{\lambda\phi^p}{M^{p-3}}$	$\sim AmW$	$\sim \lvert W_\phi\rvert^2$



$$|\phi| \sim \left(\frac{c}{|\lambda|^2}\right)^{\frac{1}{2(p-2)}} M \left(\frac{H}{\sqrt{p-1}M}\right)^{\frac{1}{p-2}}$$

AD baryogenesis

$$n_B = iq(\phi\dot{\phi}^* - \dot{\phi}\phi^*) = q|\phi|^2\dot{\theta} \qquad \phi = |\phi|e^{i\theta}$$

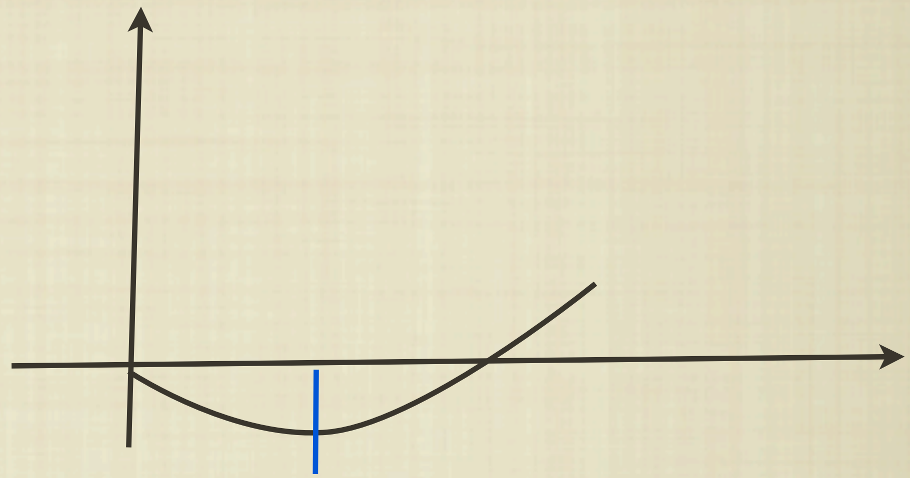
$p = 9$ The reason for large p is we need large vev

$$\frac{n_B}{s} \sim 6 \times 10^{-11} \times \left(\frac{m_\sigma}{150\text{TeV}}\right)^{3/2} \left(\frac{75\text{TeV}}{m_{AD}}\right)^{5/7} \left(\frac{m_{3/2}}{m_{AD}}\right)$$

BARYON ISOCURVATURE PERTURBATION

If Hubble induced A-term is suppressed: $A_H \ll 1$

$$\delta\theta = \frac{H_1}{2\pi|\phi_1|}$$



$\phi_1 \equiv \phi_{min}(H_1)$

$$S_B \equiv \frac{\delta\rho_B}{\rho_B} - \frac{3}{4}\frac{\delta\rho_\gamma}{\rho_\gamma} = \delta \log\left(\frac{n_B}{s}\right)$$

$$H_1 \lesssim 8 \times 10^{-6} M_P \qquad f \lesssim 5 M_P \qquad \frac{m_{AD}}{m_\sigma} < \frac{5}{\sqrt{6}}$$

This condition is satisfied in our model since we consider

$$m_\sigma > m_{AD}$$

HOW ABOUT OSCILLATING CURVATON + AD BARYOGENESIS?

Ikegami and Moroi hep-ph/0404253

RESIDUAL BARYON ISOCURVATURE PERTURBATION

$$\zeta = (1-f)\zeta_r + f\zeta_\sigma \qquad f = \frac{3\rho_\sigma}{4\rho_r + 3\rho_\sigma}$$

$$S_B = 3(\zeta_B - \zeta_r) \qquad \zeta_i = -\psi - H\left(\frac{\delta\rho_i}{\dot{\rho}_i}\right)$$

IF BARYON NUMBER IS PRODUCED BEFORE CURVATON DOMINATION $f \ll 1$ ⇒ $\zeta_B = 0$

EVENTUALLY WE WILL HAVE $S_B = -3\zeta$

BARYON ISOCURVATURE PERTURBATION WILL BE TOO LARGE

Oscillating (moduli) curvaton with AD baryogenesis?

Moduli will start to dominate when: $$H_{eq} = \sqrt{2} m_\sigma \left(\frac{\sigma_0}{\sqrt{6} M_P} \right)^4$$

To avoid large correlated baryon isocurvature perturbation we need

$$m_{AD} < H_{eq}$$

$$\sigma_0 > \sqrt{6} M_P \left(\frac{m_{AD}}{\sqrt{2} m_\sigma} \right)^{1/4}$$

But this implies curvaton will inflate!

NON-THERMAL WIMP

MOROI AND RANDALL HEP-PH/9906527

ACHARYA, KANE, WATSON, AND KUMAR 0908.2430

$$n_\chi^c \equiv \frac{H}{\langle \sigma v \rangle} \sim \frac{\Gamma_\sigma}{\langle \sigma v \rangle} \sim \frac{m_\sigma^3}{M_P^2 \langle \sigma v \rangle}$$

$$\Omega_\chi = 0.1 h^{-2} \left(\frac{m_\chi}{100\mathrm{GeV}} \right) \left(\frac{3 \times 10^{-7} \mathrm{GeV}^{-2}}{\langle \sigma v \rangle} \right) \left(\frac{150\mathrm{TeV}}{m_\sigma} \right)^{3/2}$$

WINO LSP

$$\Omega_\chi^{(\mathrm{thermal})} h^2 = 5 \times 10^{-4} \times \left(\frac{m_\chi}{100\ \mathrm{GeV}} \right)^2$$

Conclusion

- AD baryogenesis can work for p=9 flat direction
- no isocurvature perturbation
- wino dark matter
- primordial density perturbation (no large non-gaussianity)