CAN THE CURVATON SCENARIO ACCOMODATE LOW SCALE INFLATION?

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CURVATON SCENARIO

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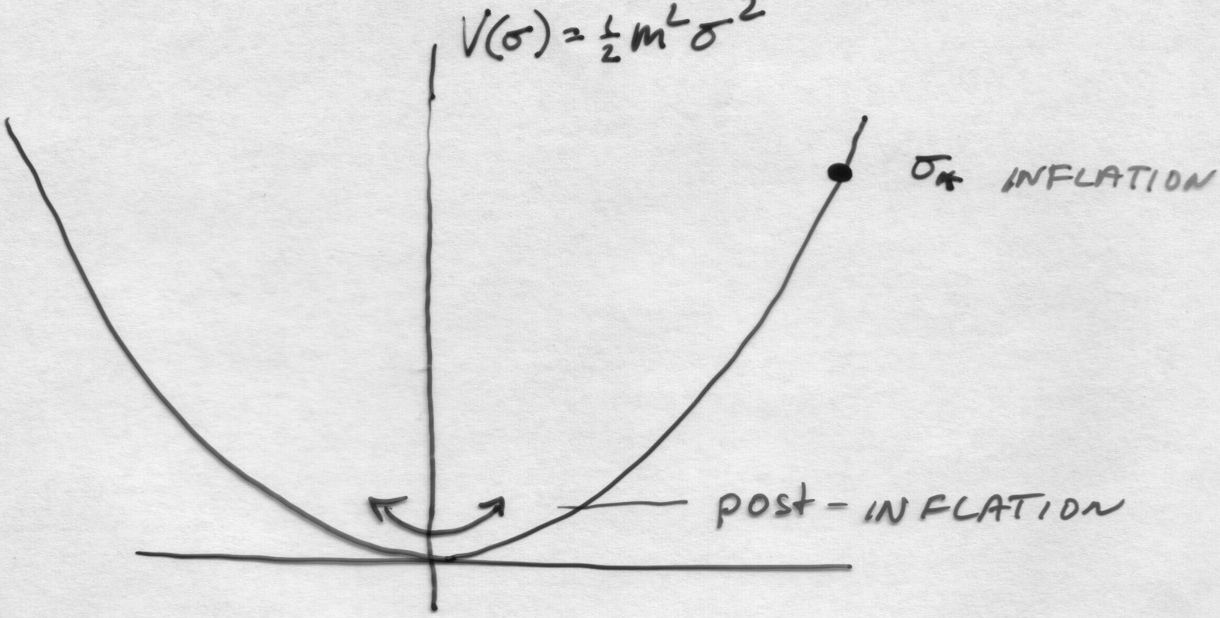

INFLATION

$$m^2 \ll H_*^2 \quad \Rightarrow \quad \sigma_* \,, \quad \delta\sigma \sim H_*$$

POST-INFLATION $\Rightarrow$ $m^2 \sim H^2$
oscillations

$$\left.\begin{array}{l} \rho_\sigma \propto a^{-3} \\ \rho_\gamma \propto a^{-4} \end{array}\right\} \quad \Omega_\sigma \equiv \frac{\rho_\sigma}{\rho_{tot}} \propto a \quad \text{grows!}$$

MOTIVATION

CONNECT INFLATION TO SUSY

$$H_* \sim 10^3 \text{ GeV}$$

INFLATION

$$\delta \propto \frac{H_*}{M_{pl}}$$

CURVATON

$$\delta \propto \frac{H_*}{\sigma_*}$$

THE BOUND ON H_*

Lyth

WMAP

$$\left(\frac{\delta\sigma}{\sigma}\right)_{\rm Dec} = q\,\frac{H_*/2\pi}{\sigma_*} = 10^{-4}\left(\Omega_\sigma\right)^{-1}_{\rm DEC} \qquad (1)$$

$$\left(\Omega_\sigma\right)_{\rm DEC} \leq \frac{m_\sigma^2\,\sigma_*^2}{H_{osc}^2\,M_{pl}^2}\left(\frac{H_{osc}}{\Gamma_\sigma}\right)^{\alpha} \qquad (2)$$

$$\boxed{H_* \geq \frac{H_{osc}\,M_{pl}\,A}{m_\sigma\,q\,\left(\Omega_\sigma\right)^{1/2}_{\rm DEC}}\left(\frac{\Gamma_\sigma}{H_{osc}}\right)^{\alpha/2}}$$

$A = 1.5\pi\,10^{-4}$

$\Gamma_\sigma > \max\left[H_{BBN}, \Gamma_{grav}\right]$

$\left(\Omega_\sigma\right)_{\rm DEC} > 10^{-2}$

SIMPLEST / STANDARD SCENARIO

$$H_* \gtrsim \frac{H_{osc} M_{pl} A}{m_\sigma \, q \, \Omega_{dec}^{1/2}} \left(\frac{\Gamma_\sigma}{H_{osc}} \right)^{\alpha/2}$$

* CURVATON POTENTIAL QUADRATIC

$$q = 1$$
$$H_{osc} \approx m_\sigma$$

* INFLATON DECAY INTO RADIATION

$$\left. \begin{array}{l} \rho_\sigma \propto a^{-3} \\ \rho_\gamma \propto a^{-4} \end{array} \right\} \Longrightarrow \alpha = 1/2$$

* $\Gamma_\sigma > \max \left[H_{BBN}, \frac{m_\sigma^3}{M_{pl}^2} \right]$

$$H_* \gtrsim \max \left[10^7 \text{ GeV} \left(\frac{H_*}{m_\sigma} \right)^{1/5}, \; 5\,10^{11} \text{ GeV} \left(\frac{m_\sigma}{H_*} \right) \right]$$

$$H_* > 8 \cdot 10^7 \text{ GeV}$$

EVADING THE BOUND

$$H_* \gtrsim \frac{H_{osc}\, M_{pl}\, A}{m_\sigma\, q\, \Omega_{dec}^{1/2}} \left(\frac{\Gamma_\sigma}{H_{osc}}\right)^{\alpha/2}$$

* ρ_{KIN} BACKGROUND $\Rightarrow \rho_{KIN} \propto a^{-6}$ ✓

$\alpha = 1$

$H_* > 10^2$ GeV

GIOVANNINI
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* $V = \lambda \sigma^n \qquad n \neq 2$ ✗

$n > 2 \quad \Rightarrow \quad \alpha < 1/2$

$n < 2$ INSTABILITIES

* $H_{osc}/m_\sigma < 1$ "HEAVY CURVATON" ✓

$$H_{PT}: \quad m_\sigma^2 \longrightarrow m_\sigma^2 + (\Delta m_\sigma)^2 \gg H_{PT}^2$$

LYTH
MATSUDA
MP

HEAVY CURVATON

$H_{PT} \sim H_*$

H_{PT}: $(m_\sigma)_* \longrightarrow m_\sigma \gg (m_\sigma)_*$

$$m_\sigma < \min [m_{en} , m_{dec}]$$

ENERGY CONSERVATION : $m_{en}^2 \sigma_*^2 \leq \rho_{tot}$

IMMEDIATE DECAY : $\lambda^2 m_{DEC} \leq H_{PT}$

$$H_* \gtrsim \frac{H_{osc} M_{pl} A}{m_\sigma \Omega_{dec}^{1/2}} \left(\frac{\Gamma_\sigma}{H_{osc}} \right)^{1/4}$$

minimized:

$m_{dec} > m_{en}$

$m_{en} > m_{DEC} \Rightarrow$ DECAY BEFORE DOMINATION

X

$H_* > 2 \cdot 10^8$ GeV

$\Omega_{PT} \sim \Lambda_{DEC} \sim 1 \quad \Rightarrow \Gamma_\sigma \sim H_{PT}$

$\lambda \sim \lambda_{grav} \simeq \frac{m_\sigma}{M_p}$

HEAVY CURVATON

$H_{PT} \ll H_*$

$$H_{osc} = \max\left[(m_\sigma)_*,\ H_{PT}\right]$$

$$H_{osc} \gtrsim \Gamma_\sigma \gtrsim H_{BBN}$$

$$H_* \gtrsim \frac{H_{osc}\, M_{pl}\, A}{\Omega_{dec}\, m_\sigma} \left(\frac{\Gamma_\sigma}{H_{osc}}\right)^{1/4}$$

$$\gtrsim \max\left[\frac{\lambda^2 A M_{pl}}{\Omega_{PT}^{3/2}},\ \frac{A\, H_{PT}^{2/3}\, M_{pl}^{1/3}}{\Omega_{PT}^{1/6}}\right] \gtrsim 10^{-14}\,\text{GeV}$$

minimized:

$$\begin{cases} m_{en} \lesssim m_{DEC} \\ \Omega_{PT} \sim \Omega_{dec} \sim 1 \\ H_{osc} \to H_{BBN} \end{cases}$$

e.g.

$H_* \sim \text{TeV}$

$\Downarrow$

$H_{osc} \lesssim \text{GeV}$

$\Omega_{PT} > 10^{-12}$

$\Omega_{PT} \ll 1$: PERIOD OF OSCILLATIONS NEEDED

$$\Gamma_\sigma < H_{DOM} = \Omega_{PT}^2\, H_{PT}$$

$$m_{en} \propto \Omega_{PT}^{1/2}$$

CONCLUSIONS

LOW SCALE INFLATION COMPATTIBLE WITH THE CURVATON SCENARIO, BUT...

THE COSTS ARE HIGH !

* NON-MINIMAL MODEL
* TUNING $\Gamma_\sigma \to H_{BBN}$

  $m_\sigma < \mathrm{GeV}$
* LOW MASS SCALES
* ISOCURVATURE PERTURBATIONS AVOIDED IF BARYOGENESIS AFTER CURVATON DECAY

ADDITIONAL INGREDIENTS

* Small curvaton masses

  $(m_\sigma)_* < \text{GeV}$

* Baryons / CDM created after / from curvaton decay to avoid large isocurvature pert.

* thermal evaporation

  $W \ni \lambda \sigma \psi \bar{\psi}$

  thermal eq. $\quad T > \lambda \sigma$

  evaporation $\quad \Gamma_{scat} \sim \lambda \alpha_q T \gtrsim H$

HIGGSED CURVATON

$$W = \kappa S(\phi^2 - v^2) + h\sigma(\phi^2 - v^2)$$

$$m_\phi^2 = -(\eta v)^2 + (\kappa S)^2 + (h\sigma)^2 \qquad \eta^2 = \kappa^2 + h^2$$

$$m_\sigma^2 = (m_\sigma^2)_* + (h\phi)^2$$

INFLATION: $\langle\sigma\rangle$, $\langle S\rangle$

$H_{PT} \sim m_S \Rightarrow m_\sigma$ INCREASES

$$H_* > 4\,10^{-7}\ \mathrm{GeV}\ \frac{\sqrt{\eta}}{h}$$

$\Omega_{PT} \sim 1$ not possible
for $h, \kappa, \eta \lesssim 1$