CHAOTIC INFLATION IN SUPERGRAVITY

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(Ref. hep-ph/0004243)

INTRODUCTION

INFLATION

HORIZON PROB. FLATNESS PROB.
DENITY FLUCTUATIONS ...

CHAOTIC INFLATION

- SIMPLE $V = \frac{1}{2} m^2 \varphi^2$
- TAKE PLACE FOR NATURAL INITIAL CONDITIONS

HOWEVER

DIFFICULT TO REALIZE
IN SUPERGRAVITY

→ NO NATURAL MODEL

WE IMPOSE "SHIFT SYMMETRY"
ON KÄHLER POTENTIAL

⇒ SUCCESSFUL CHAOTIC
INFLATION MODEL

CHAOTIC INFLATION IN SUPERGRAVITY

DIFFICULTIES

1) POTENTIAL BECOMES STEEP BEYOND PLANCK SCALE

$$V = e^{\frac{K}{M_G^2}}\left[|DW|^2 - \frac{3}{M_G^2}|W|^2 \right]$$

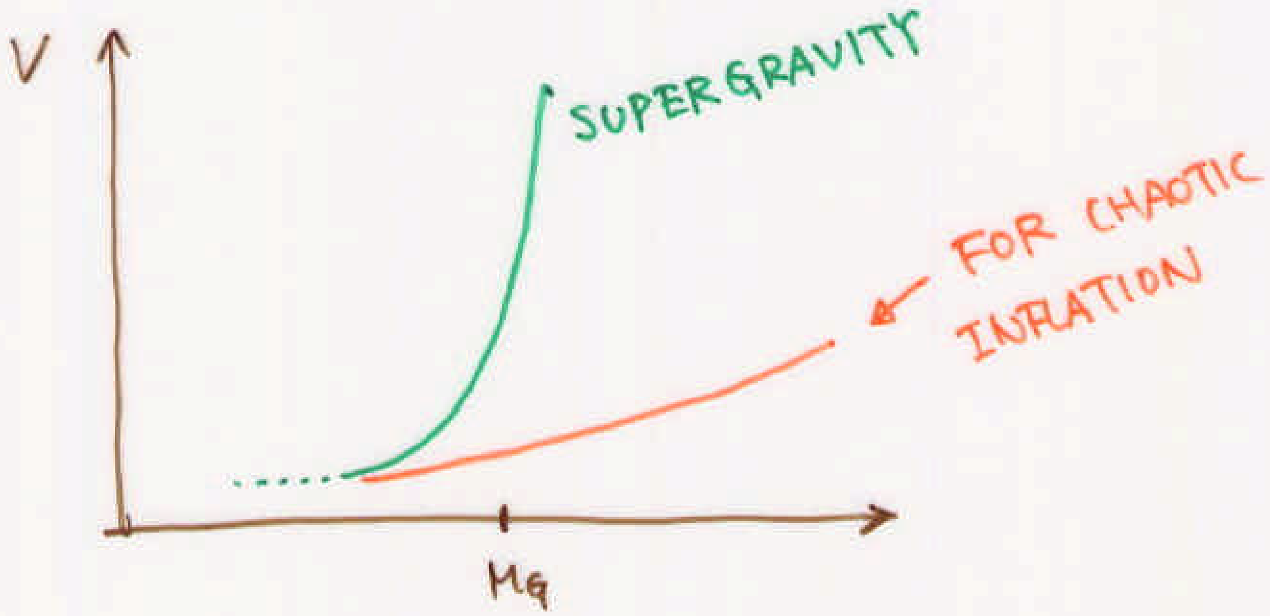
$$M_G = \frac{1}{\sqrt{8\pi G}} = 2.4\times 10^{18}\,\mathrm{GeV}$$

$K(\Phi, \Phi^*)$: KÄHLER POTENTIAL

$W(\Phi)$: SUPER POTENTIAL

MINIMAL KÄHLER

$$K = |\Phi|^2$$



2) η PROBLEM

IN GENERAL

SCALA FIELDS GET $m^2 \sim \frac{V_0}{M_{Pl}^2} \sim H^2$

$\longrightarrow$ ~~FLAT POTENTIAL~~

WE ASSUME

$K(\Phi, \Phi^*)$ HAS SHIFT SYMMETRY

$$\Phi \longrightarrow \Phi + i C M_G$$

C : REAL

$\Rightarrow$ $K(\Phi, \Phi^*) = K(\Phi + \Phi^*)$

$\rightarrow$ $\mathrm{Im}\,\Phi$ FLAT BEYOND M_G

$\downarrow$

INFLATON

NO η PROBLEM

EXACT SHIFT SYMMETRY $\longrightarrow$ NO POTENTIAL FOR $\mathrm{Im}\,\Phi$

$\rightarrow$ SMALL BREAKING TERM

$$\boxed{W = m X \Phi}$$

THE MODEL HAS $U(1)_R$ & Z_2 SYMMETRY

$$U_R(1) : \begin{cases} X(\theta) \longrightarrow e^{-2i\alpha} X(\theta e^{i\alpha}) \\ \Phi(\theta) \longrightarrow \Phi(\theta e^{i\alpha}) \end{cases}$$

$$Z_2 : \begin{cases} X \longrightarrow -X \\ \Phi \longrightarrow -\Phi \end{cases}$$

FULL KÄHLER POTENTIAL $(M_G = 1)$

$$K(\Phi, \Phi^*, X, X^*) = K((\Phi+\Phi^*)^2, XX^*)$$

$$= \frac{1}{2}(\Phi+\Phi^*)^2 + |X|^2 + \cdots$$

→ POTENTIAL FOR Φ, X

$$V(\Phi, X) = m^2 e^K \left[|\Phi|^2 (1+|X|^4) + |X|^2 \left(1 - |\Phi|^2 + (\Phi+\Phi^*)^2 (1+|\Phi|^2)\right) \right]$$

$$\Phi = \frac{1}{\sqrt{2}}(\eta + i\varphi)$$

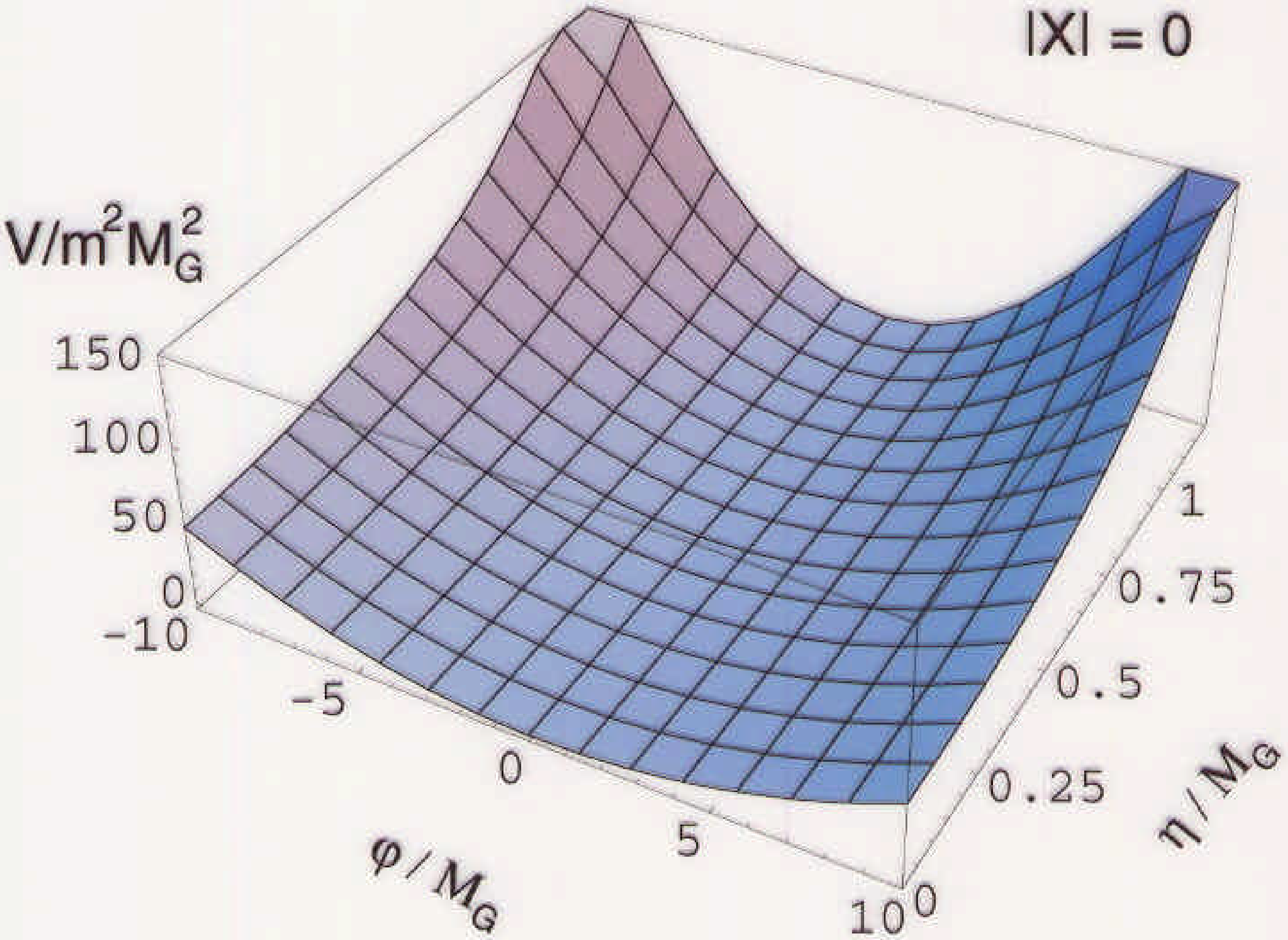
$e^K \longrightarrow |\eta| \lesssim 1 \quad |X| \lesssim 1 \quad |\varphi| >> 1$

η, X HAVE MASSES $\sim H$

$\longrightarrow \quad \eta \to 0 \quad X \to 0$

$$\to \boxed{V(\varphi) \simeq \frac{1}{2} m^2 \varphi^2}$$

Potential for $\Phi = (\eta + i\,\varphi)/\sqrt{2}$



DENSITY FLUCTUATIONS

$$\frac{\delta\rho}{\rho} = \frac{1}{5\sqrt{3}\pi} \frac{m}{2\sqrt{2}} \varphi^2$$

COBE SCALE $\varphi_{COBE} \simeq 14$

$$\frac{\delta\rho}{\rho} \simeq 2 \times 10^{-5}$$

$$\Rightarrow \quad m = 10^{13} \text{ GeV}$$

- SPECTRAL INDEX

$$n = 1 - \frac{8}{\varphi^2}$$

$$= 0.96$$ AT COBE SCALE

- GRAVITATIONAL WAVES (TENOR MODE)

$\hookrightarrow \frac{\Delta T}{T}$

RELATIVE CONTRIBUTION TO $\Delta T/T$

Starobinsky (1982)

$$\frac{GW}{SCALAR} = \frac{T}{S} \simeq \frac{25}{\varphi^2}$$

$$\frac{T}{S} \simeq 0.1$$

REHEATING

$$\varphi \xrightarrow[\text{DECAY}]{} \text{RADIATION WITH } T_R$$

φ DECAY TAKES PLACE IF WE INTRODUCE

$$\boxed{W = \lambda X H \bar{H}}$$

$H \bar{H}$ Higgs Doublet

$$\downarrow$$

$$L \simeq \lambda m \varphi H \bar{H}$$

$$\rightarrow T_R \sim 10^9 \text{GeV} \left(\frac{\lambda}{10^{-5}}\right)\left(\frac{m}{10^{13}\text{GeV}}\right)^{1/2}$$

GRAVITINO PROBLEM

$$\longrightarrow T_R \lesssim 10^9 \text{GeV}$$

$$\Rightarrow \lambda \lesssim 10^{-5}$$

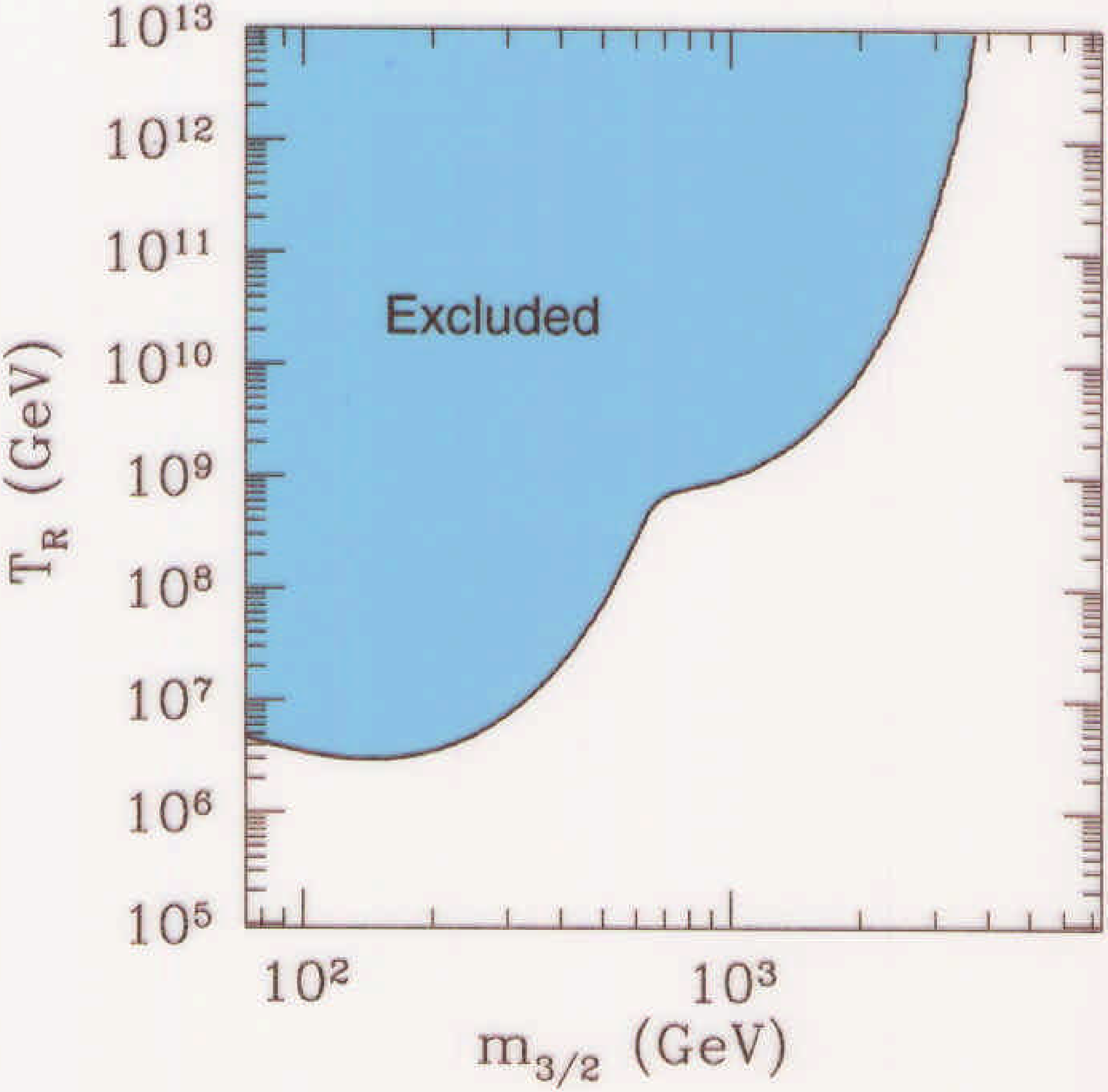
$$\uparrow$$

SMALL λ IS UNDERSTOOD

BY SYMMETRY REASON

IF $H\bar{H}$ IS EVEN UNDER Z_2

(X IS ODD)


Excluded
10^13
10^12
10^11
10^10
10^9
10^8
10^7
10^6
10^5
T_R (GeV)
10^2
10^3
m_3/2 (GeV)

CONCLUSION

- CHAOTIC INFLATION TAKES PLACE IF WE ASSUME

  $K(\Phi, \Phi^*)$ HAS SHIFT SYMMETRY

  AND INTRODUCE

  SMALL BREAKING TERM IN $W(\Phi)$

- CHAOTIC INFLATION

$$\begin{cases} n \simeq 0.96 \\ \frac{T}{S} \simeq 0.1 \end{cases}$$

  → DETECTABLE IN FUTURE OBSERVATIONS

  MAP, PLANCK ...

- REHEATING TEMP.

$$T_R \lesssim 10^9 \, \mathrm{GeV}$$

  → AVOID OVERPRODUCTION OF GRAVITINO

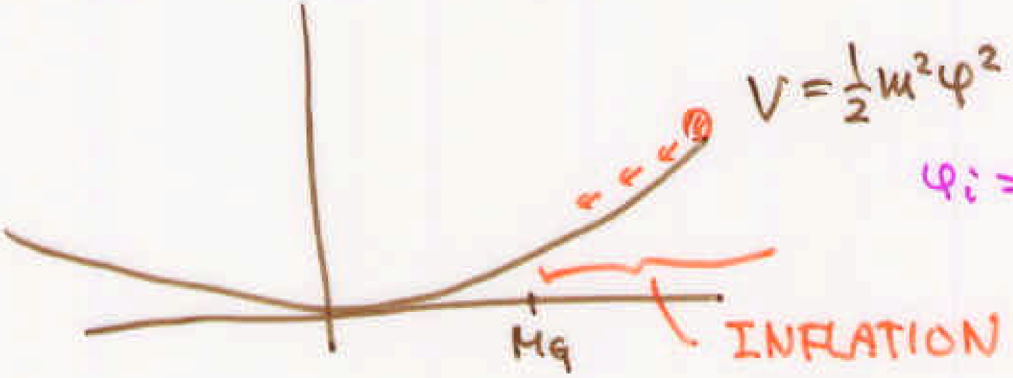
INFLATION MODELS

INFLATION TAKES PLACE AT FLAT PART OF SCALAR POTENTIAL

① NEW INFLATION

$\varphi_i \simeq 0$

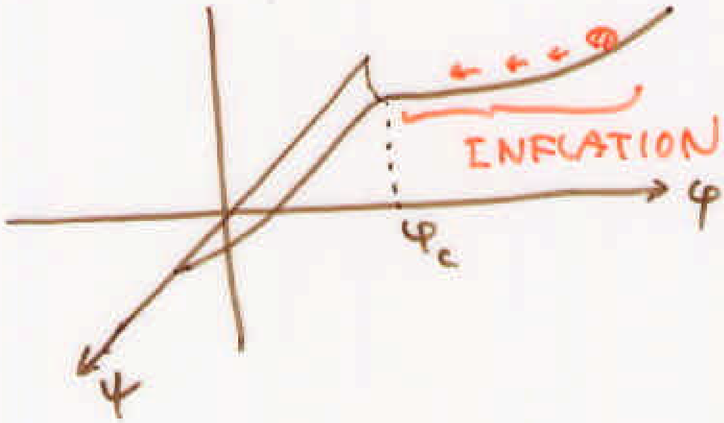
② CHAOTIC INFLATION



$V = \frac{1}{2} m^2 \varphi^2$

$\varphi_i \gg$ PLANCK SCALE $= M_G$

③ HYBRID INFLATION



$\varphi_i \lesssim M_G$

$\psi_i < \varphi_i$

PREVIOUS MODELS

- Gocharov & Linde (1984)

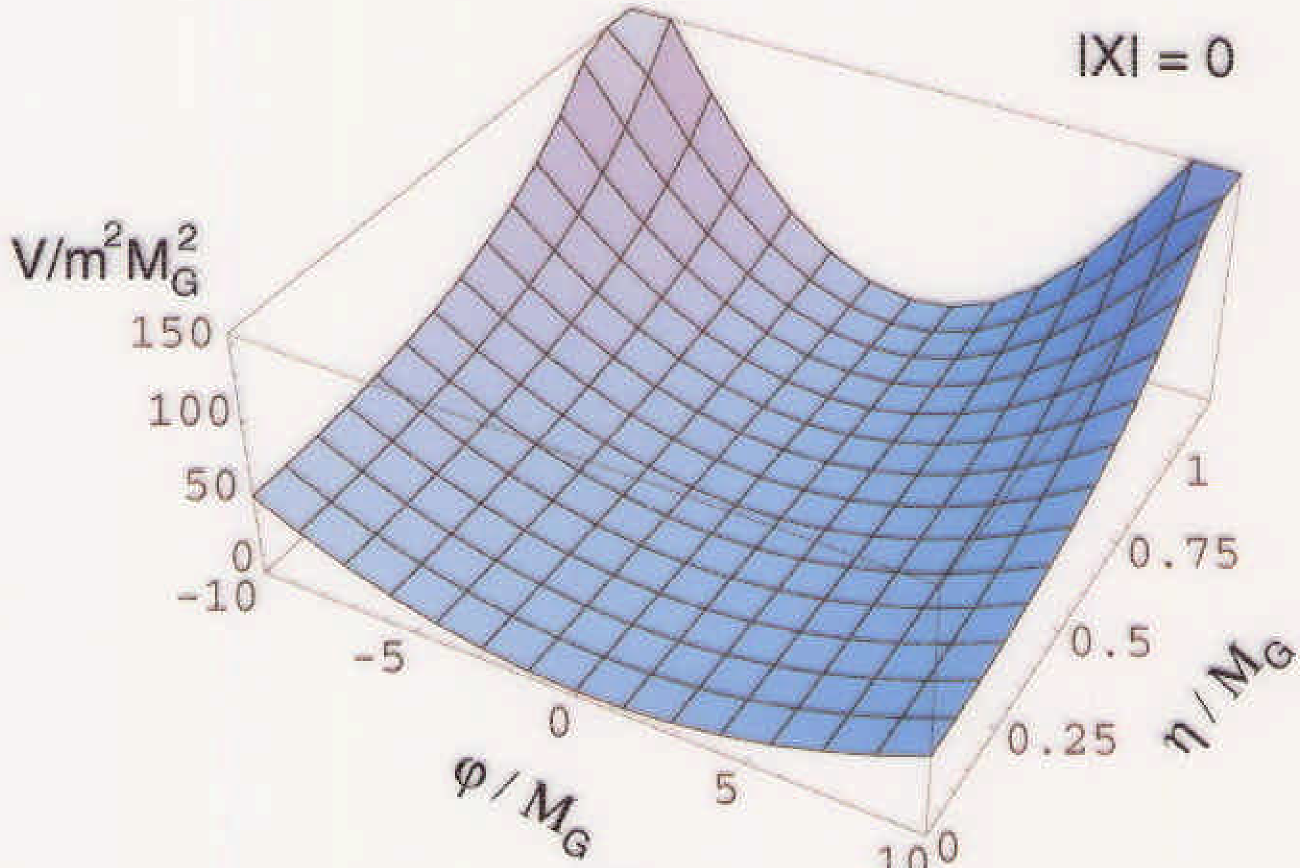
$$K(zz^*) = |z|^2$$
$$W(z) = \mu^3 e^{-\frac{1}{2}z^2} \frac{\sinh^2(\sqrt{3}(z-\varphi_0))}{\cosh(\sqrt{3}(z-\varphi_0))}$$

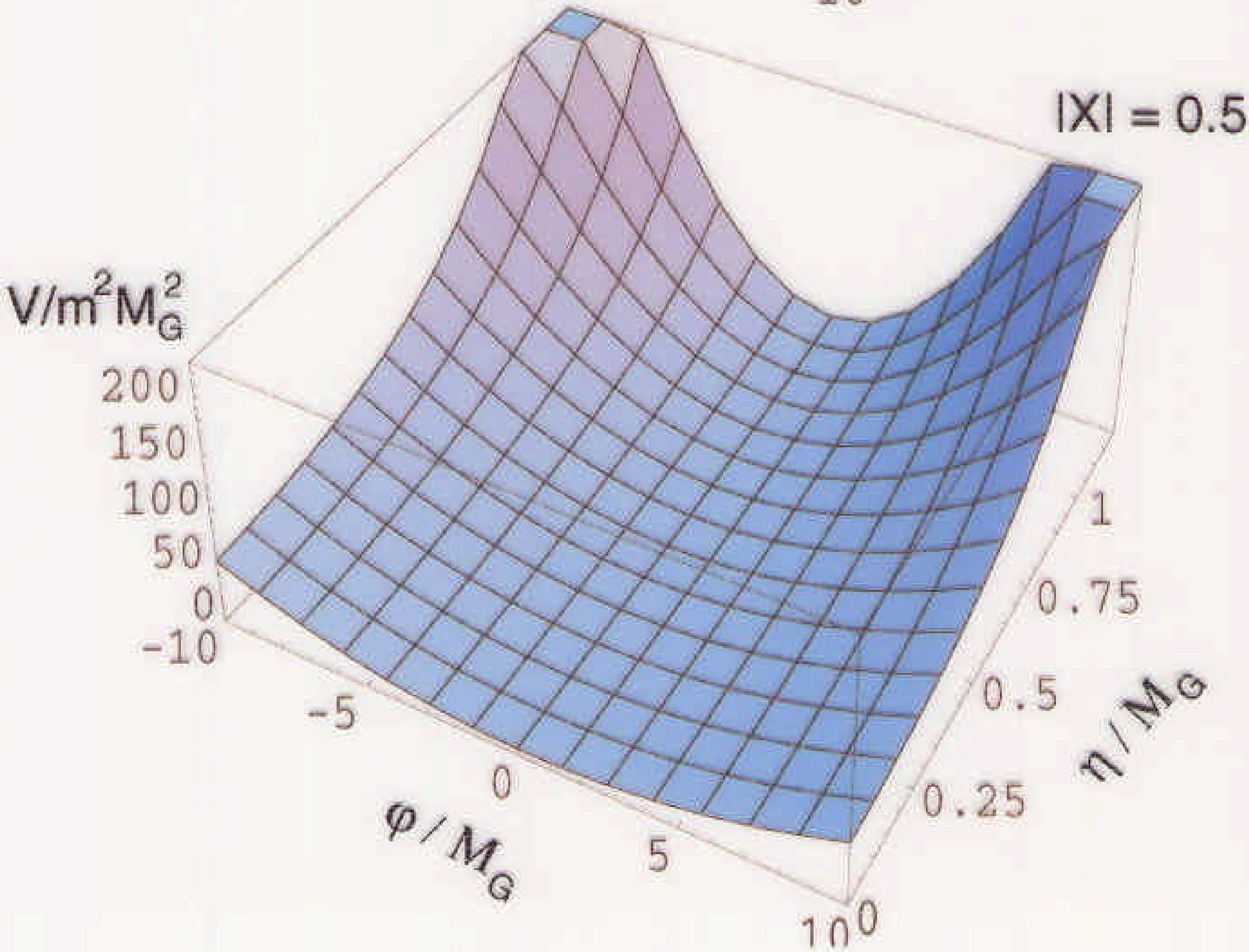
- Murayama, Suzuki, Yanagida, Yokoyama (1994)

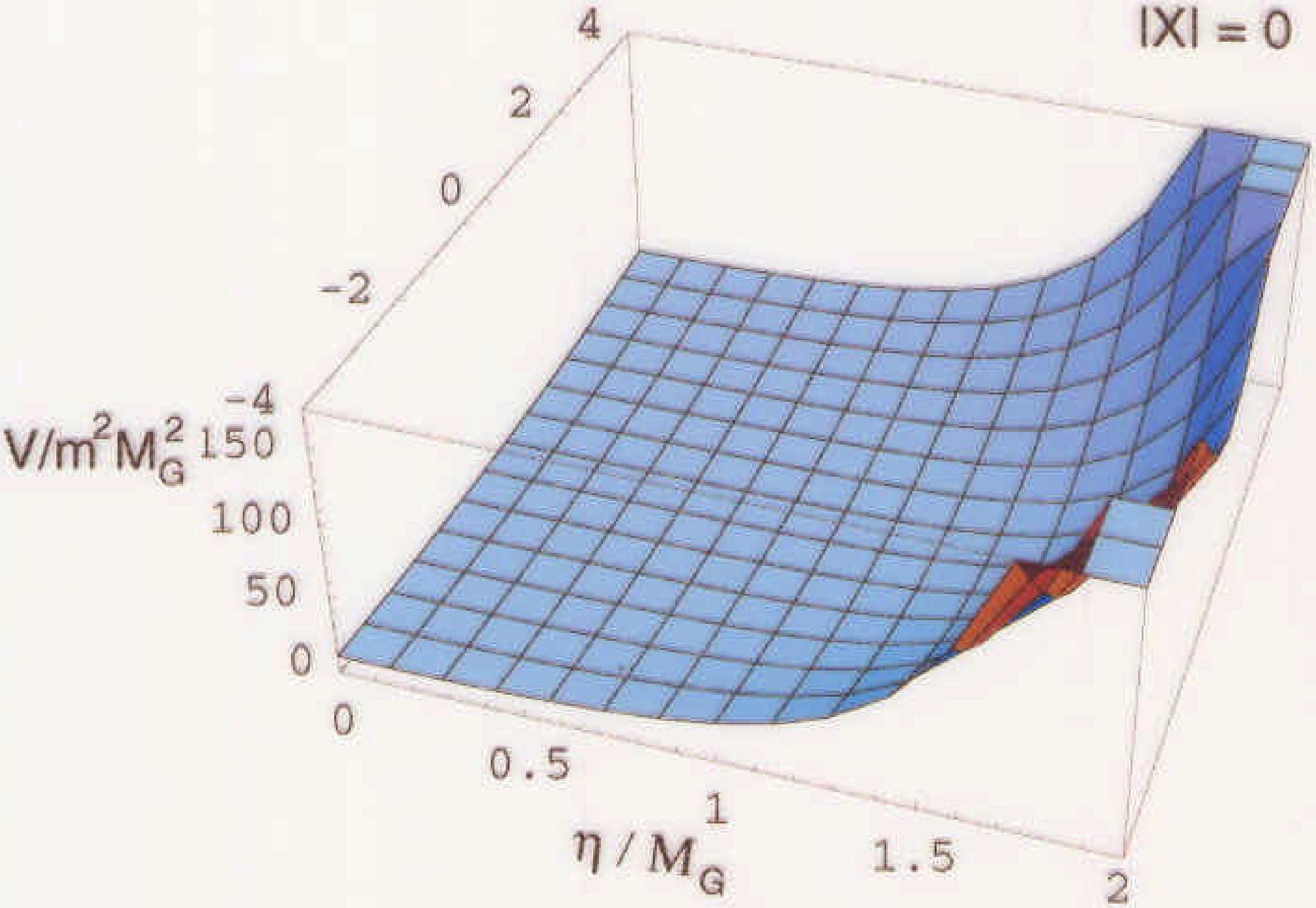
$$K(z, z^*, \varphi\ \varphi^*) = \frac{3}{8}\ln(z+z^*+\varphi^*\varphi) + (z+z^*+\varphi^*\varphi)^2$$

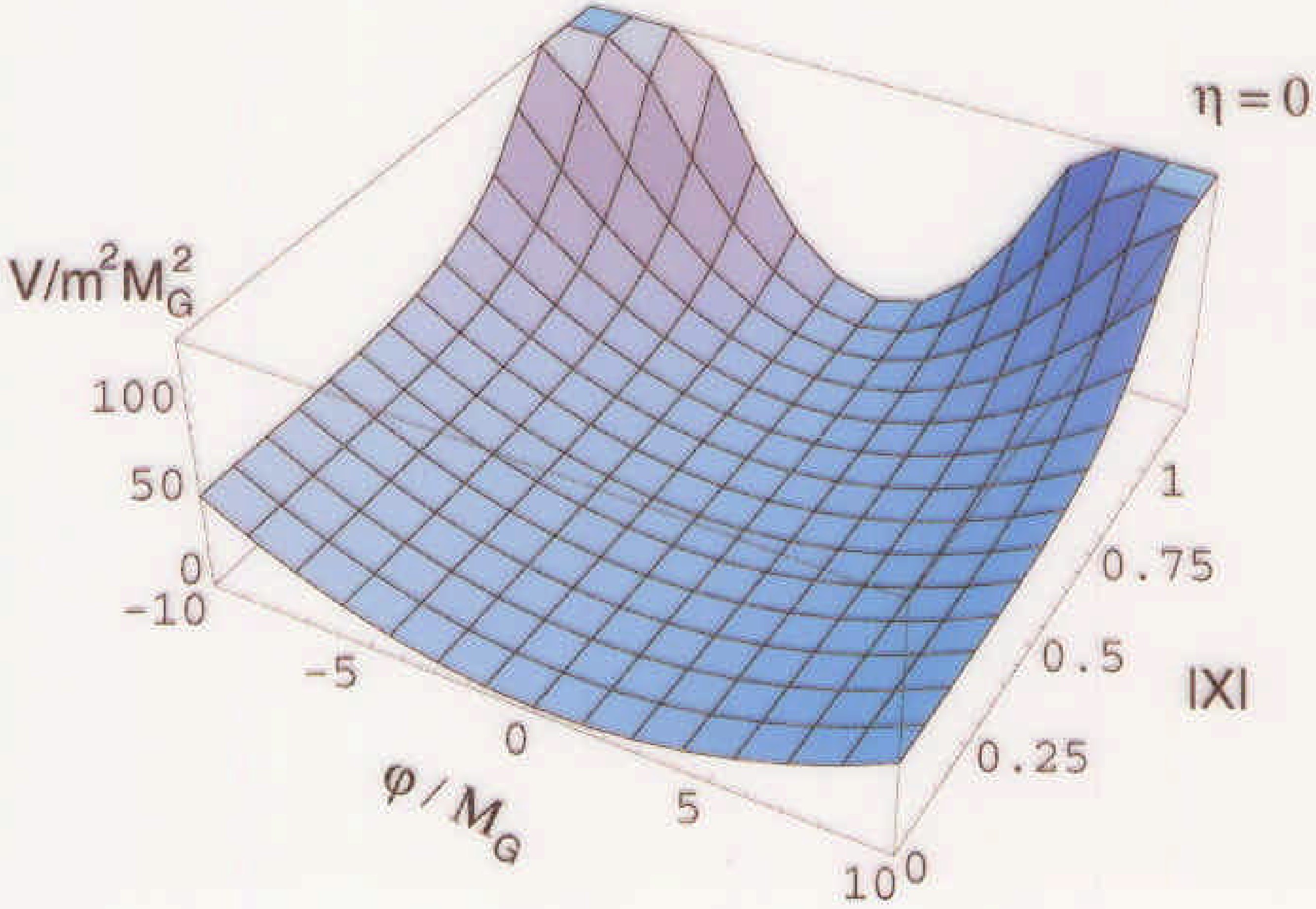
$$W(\varphi) = \frac{1}{2}m^2\varphi^2$$

Potential for $\Phi = (\eta + i\,\varphi)/\sqrt{2}$






|X| = 0
V/m²M_G²
150
100
50
0
4
2
0
-2
-4
0
0.5
1
1.5
2
η / M_G


η = 0
V/m²M_G²
100
50
0
-10
-5
0
5
10
φ / M_G
0
0.25
0.5
0.75
1
|X|

- NON-THERMAL PRODUCTION OF GRAVITINO

Kallosh et al (1999)
Giudice et al (1999)

$$\left(\frac{n_{3/2}}{s}\right)_{NT} \sim \frac{m_\varphi^3}{m_\varphi^2 M_G^2 / T_R}.$$

$$\sim 10^{-13} \left(\frac{m_\varphi}{10^{13}\,\mathrm{GeV}}\right)\left(\frac{T_R}{10^{10}\,\mathrm{GeV}}\right)$$

- THEMAL PRODUCTION

$$\left(\frac{n_{3/2}}{s}\right)_{TH} \sim 10^{-11} \left(\frac{T_R}{10^{10}\,\mathrm{GeV}}\right)$$