COSMOLOGICAL ASPECTS OF SUPERSYMMETRY BREAK DOWN

SUSY02, JUNE 2002, DESY, HP

INFLATION : FLATNESS,
HORIZON,
MONOPOLE PROBLEM

MEETS

SUSY : NEW PARTICLES
RELEVANT FOR
COSMOLOGY

GRAVITINO

RELATION SUSY – COSMO

"SOMEWHAT PROBLEMATIC"

* SUSY BROKEN IN EARLY UNIVERSE ($V \neq 0$, $T \neq 0$)

* ABUNDANCE OF GRAVITINO + MODULI

MORE POSITIVE

* D-TERM INFLATION

* BARYOGENESIS

* DARK MATTER CANDIDATES

OUTLINE

* GRAVITINO PROBLEM (THERMAL)

* NONTHERMAL PRODUCTION (PREHEATING)

* SUSY BREAKDOWN AND MULTIFIELD SYSTEMS

* HIDDEN SECTOR SUSY BREAKDOWN

* HOW TO HIDE THE HIDDEN SECTOR (EVEN MORE,

GRAVITATIONAL RELICS AND BIG BANG NUCLEOSYNTHESIS

WEINBERG 82

$m_{\tilde{G}} \gtrsim 20$ TeV or

$m_{\tilde{G}} \lesssim 30$ MeV

GRAVITY MEDIATED SUSY

$m_{\tilde{G}} = m_{3/2} \sim 100$ GeV - TeV

CAN BE AVOIDED WITH INFLATION, BUT

$T_{reheating} \lesssim 10^9$ GeV

(THERMAL PRODUCTION)

10^9 GeV IS A RATHER LOW SCALE

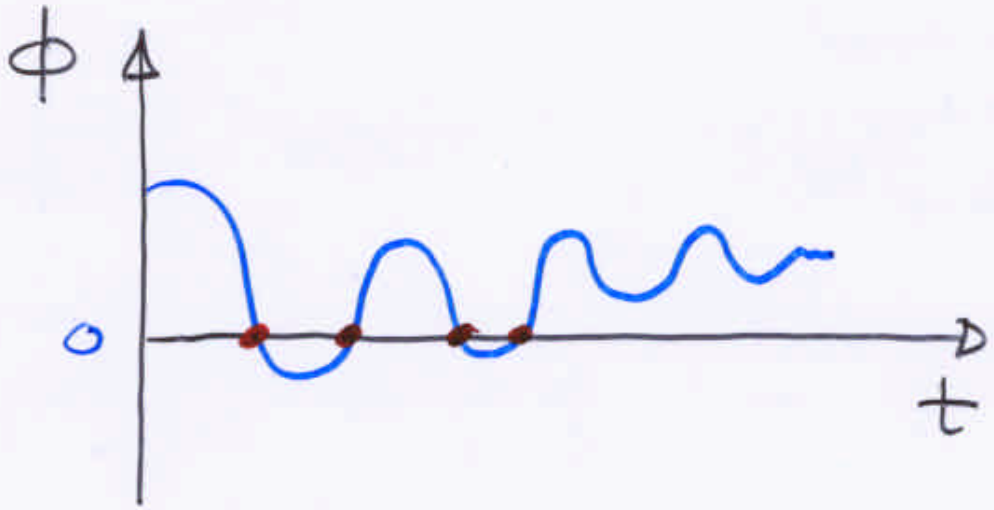
* BARYOGENESIS
* LEPTOGENESIS ?
* UHECR

PREHEATING

(NONTHERMAL PRODUCTION OF FERMIONS)

TRASCHEN, BRANDENBERGER 9(
KOFMAN, LINDE, STAROBINSKY 9(
GIUDICE, PELOSO, RIOTTO, TKACHEV 9

$$m = m_0 + g\phi$$



FERMIONS OF MASS

>> T_R CAN BE PRODUCED

PROBLEM

NONTHERMAL PRODUCTION

OF GRAVITINOS

KALLOSH, KOFMAN, LINDE, VAN PROEYE

SIN DICE, RIOTTO, TKACHEV

GRAVITINO IS GAUGE PARTICLE OF SUPERSYMMETRY

TRANSVERSE HELICITY $\pm \frac{3}{2}$

LONGITUDINAL " $\pm \frac{1}{2}$

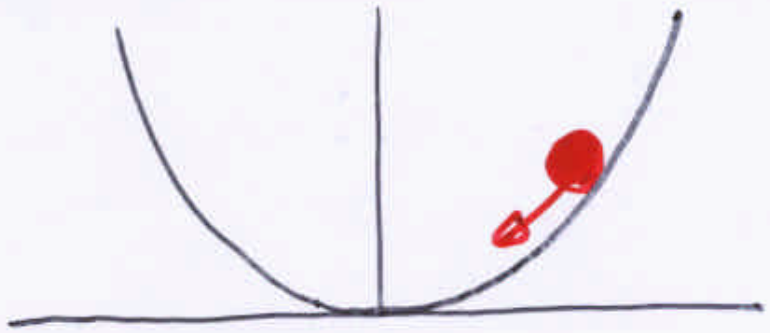
(SUPERHIGGS EFFECT)

NONPERTURBATIVE PRODUCTION OF TRANSVERSE COMPONENTS SUPPRESSED

MAROTO, MAZUMDAR
KALLOSH et al.
SIUDICE et al.

BUT LONGITUDINAL ONE RELATED TO GOLDSTINO

ONE FIELD MODEL



SUSY BREAKDOWN

$$\delta\chi \sim D_\phi (e^{K/2} W) + \gamma^0 \dot{\phi}$$

THUS EFFECTIVE BREAKDOWN OF SUSY (ALTHOUGH RESTORED IN VACUUM)

→ OVER PRODUCTION OF "GRAVITINO" BY AS MUCH AS 13 ORDERS OF MAGNITUDE (COSMO. 99)

QUESTION:

DID WE PRODUCE

GRAVITINOS AND/OR

"INFLATINOS" ???

AFTER ALL SUSY IS

UNBROKEN IN THE VACUUM

WE NEED TO ANALYZE SYSTEM

WITH AT LEAST TWO FIELDS

DIFFICULT TO TREAT

ANALYTICALLY

GENERAL SETUP:

HPN, PELOSO, SORBO

JHEP 0104

SIMPLEST CASE:

$$W = \frac{m_\phi}{2}\phi^2 + \mu^2(\beta+S)$$

"HIDDEN" SECTOR SUSY BREAKD.

(ALTERNATIVELY $\frac{\Delta^2}{2M_p}(\phi - M_p)^2$,

TWO SECTORS ARE WEAKLY COUPLED (THIS MIGHT BE A QUITE GENERAL REQUIREMENT)

TWO DIFFERENT SCALES

$$m_\phi \approx 10^{13}\,\text{GeV}$$

$$m_{3/2} \approx \frac{\mu^2}{M_{\text{planck}}} \approx 100\,\text{GeV}$$

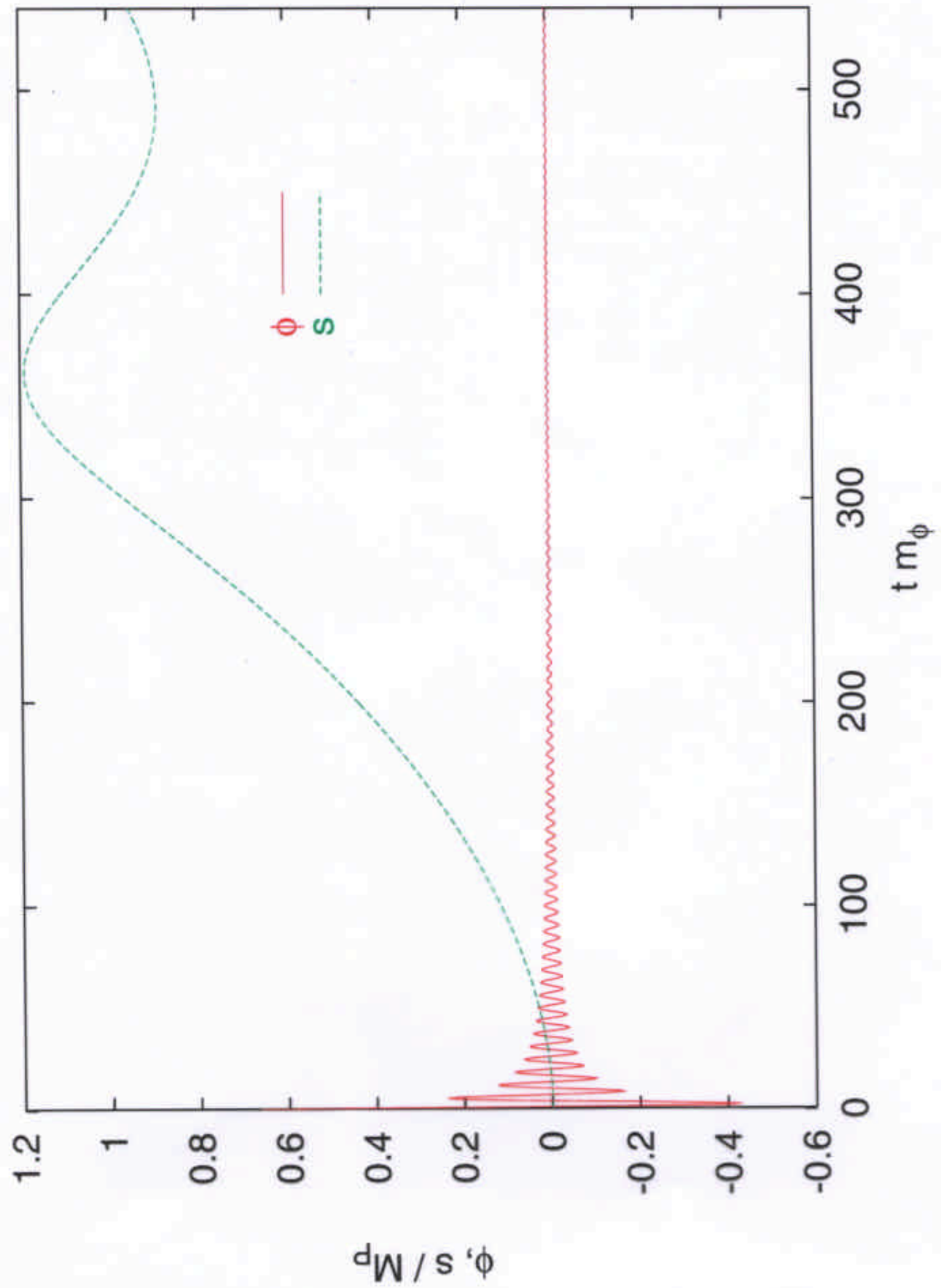
$$\hat{\mu}^2 \equiv \frac{m_{3/2}}{m_\phi} = \frac{\mu^2}{m_\phi M_{Pl}} \approx 10^{-11}$$

UNFORTUNATELY NO ANALYTIC TREATMENT AVAILABLE!

NUMERICAL SIMULATION

HPN, PELOSO, SORBO
Phys. Rev. Lett. 87

TWO DIFFERENT MASS SCALES LEAD TO TWO DIFFERENT TIME SCALES FOR EVOLUTION


1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
100
200
300
400
500
t m$_\phi$
ϕ, s / M$_P$
ϕ
s

WHO IS WHO?

$\tilde{\phi}$ INFLATINO

$\tilde{S}$ POLONYI FERMION

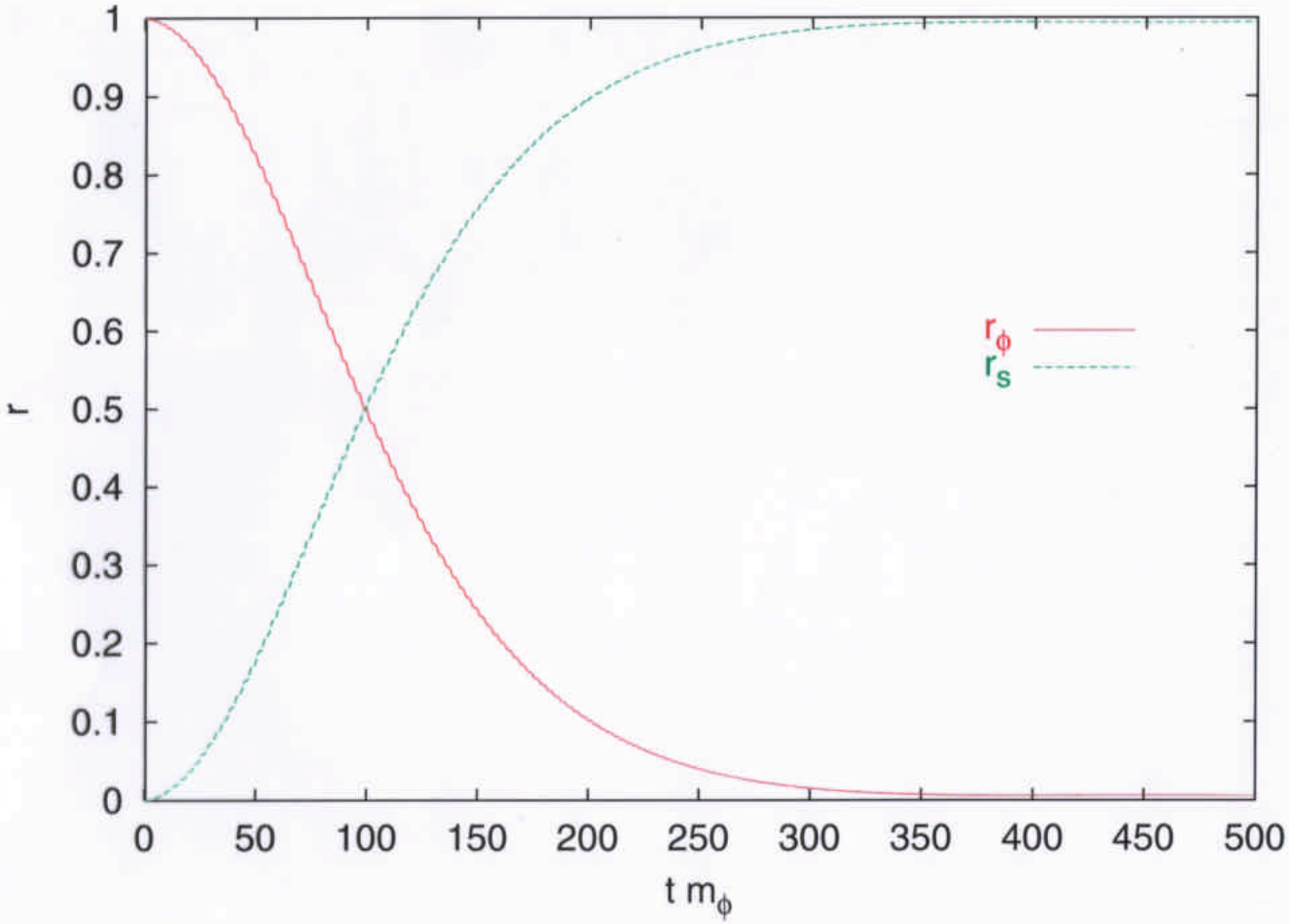
Θ GOLDSTINO

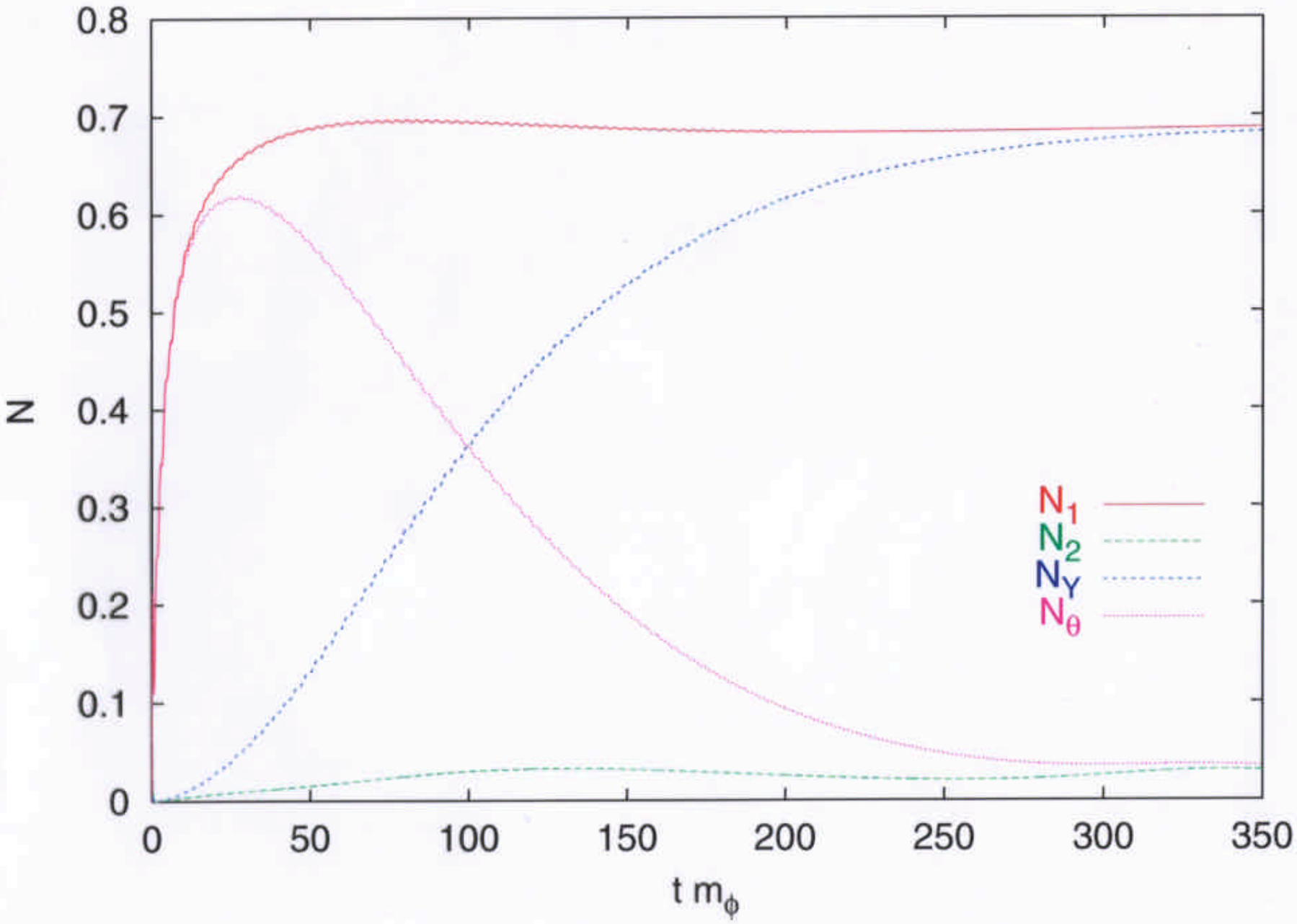
$$\Theta = \Gamma_\phi \tilde{\phi} + \Gamma_S \tilde{S}$$

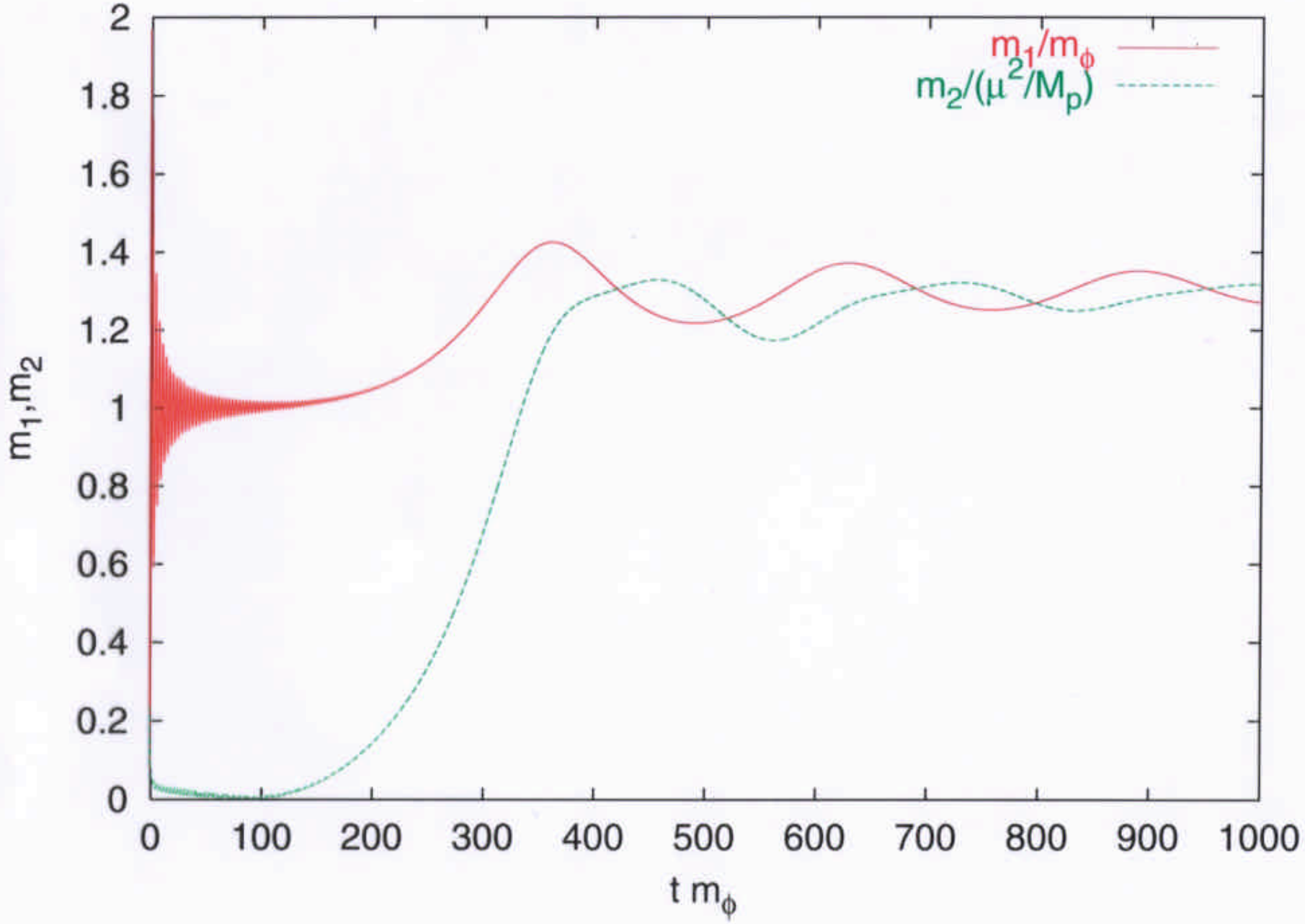
AT INITIAL TIME $\Theta = \tilde{\phi}$

WHILE AT LATE TIMES $\Theta = \tilde{S}$

NEED CONSISTENT FORMALISM TO QUANTIZE SYSTEM IN EXTERNAL BACKGROUND, DEFINE OCCUPATION NUMBERS, DIAGONALIZE . . . .


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
r
0
50
100
150
200
250
300
350
400
450
500
t m$_\phi$
r$_\phi$
r$_s$


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
z
0
50
100
150
200
250
300
350
t m$_\phi$
N$_1$
N$_2$
N$_Y$
N$_\theta$


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
700
800
900
1000
m1,m2
t mϕ
m1/mϕ
m2/(μ2/Mp)

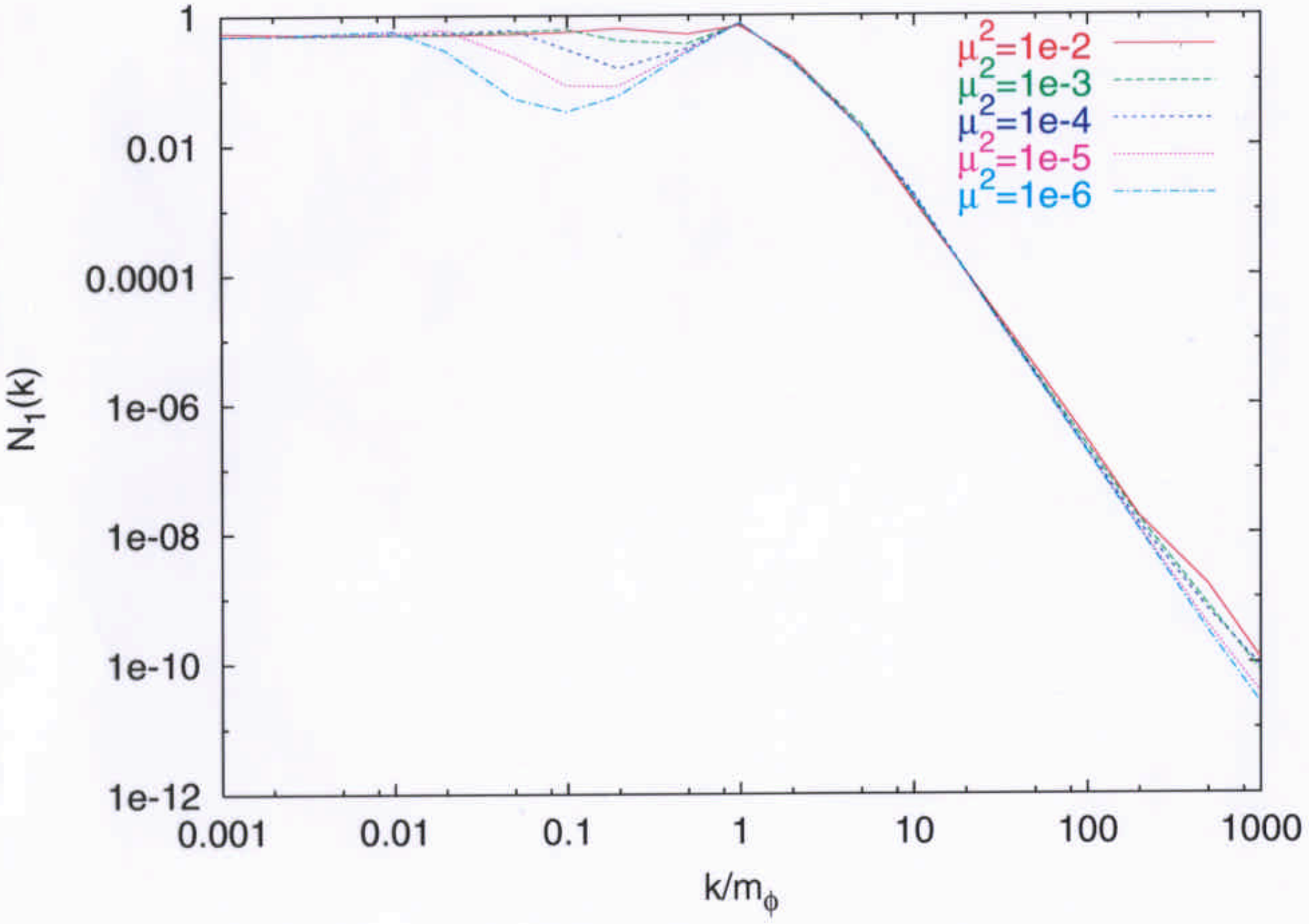
TECHNICAL PROBLEM:

$\hat{\mu}^2 \approx 10^{-11}$ VERY DIFFICULT TO TREAT

CAN GO DOWN TO 10^{-6} + EXTRAPOLATION

PRODUCTION OF INFLATINO PRACTICALLY INDEPENDENT OF $\hat{\mu}^2$ (INFLUENCE OF POLONYI FIELD IRRELEVANT)

($n_\phi \sim 0.01\, m_\phi^3$)


1
0.01
0.0001
1e-06
1e-08
1e-10
1e-12
$N_1(k)$
0.001
0.01
0.1
1
10
100
1000
k/m_ϕ
μ^2=1e-2
μ^2=1e-3
μ^2=1e-4
μ^2=1e-5
μ^2=1e-6

PRODUCTION OF GRAVITINOS

DECREASES WITH $\hat{\mu}^2$

IN CONTROLLABLE WAY

(LIMIT $\hat{\mu}^2 \to 0$ CAN BE

TREATED ANALYTICALLY)

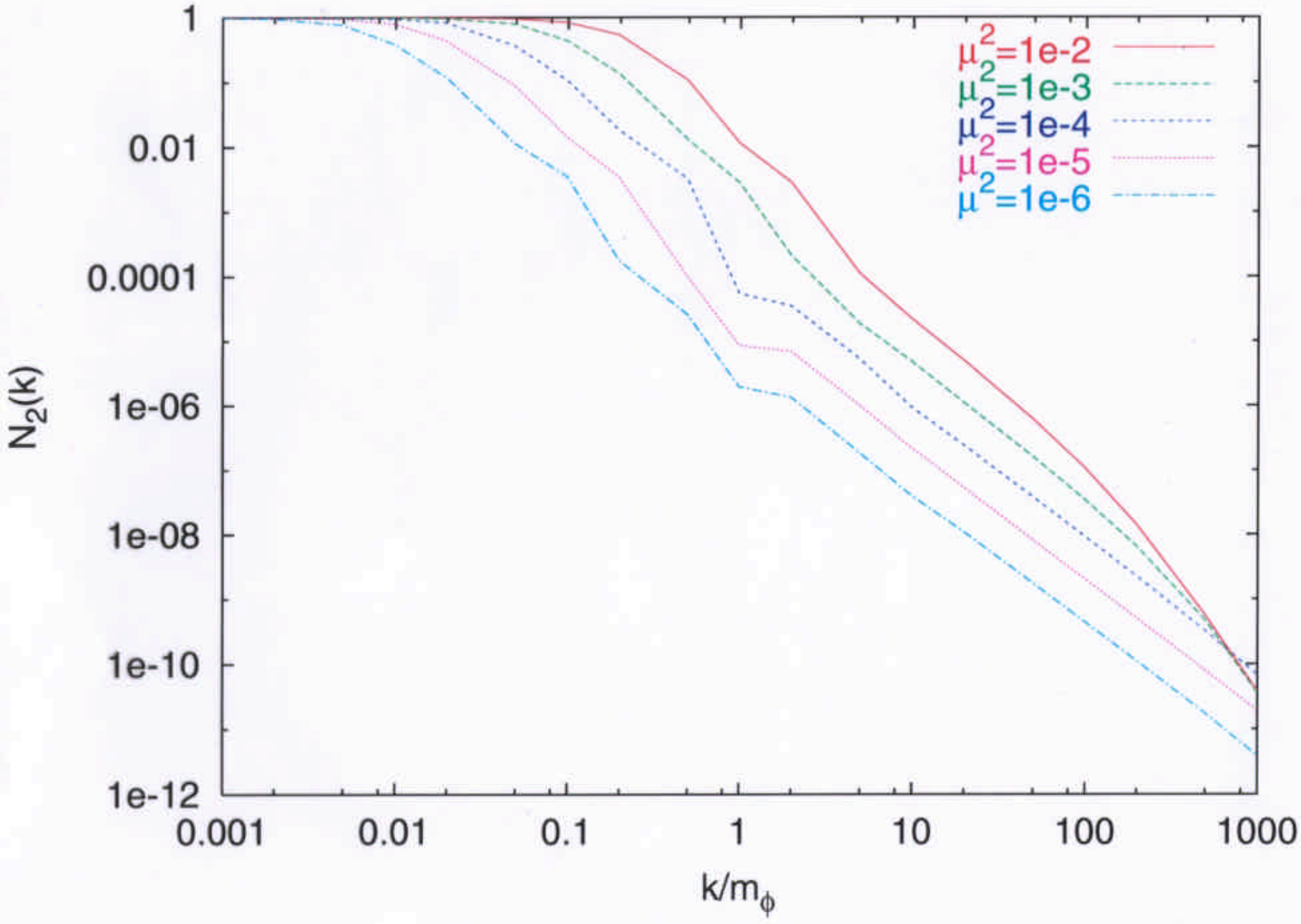
CONCLUSION:

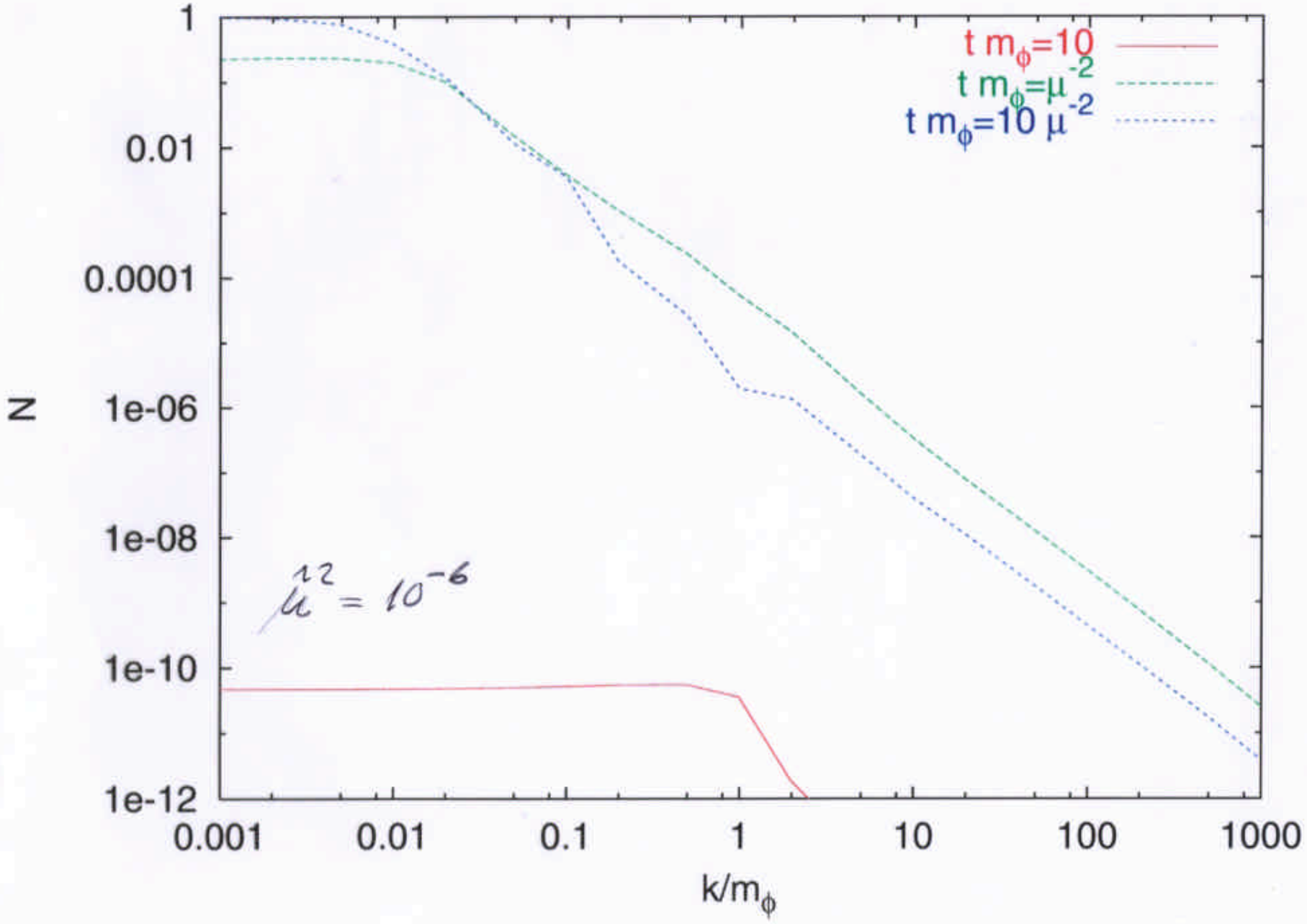
PRODUCE ESSENTIALLY

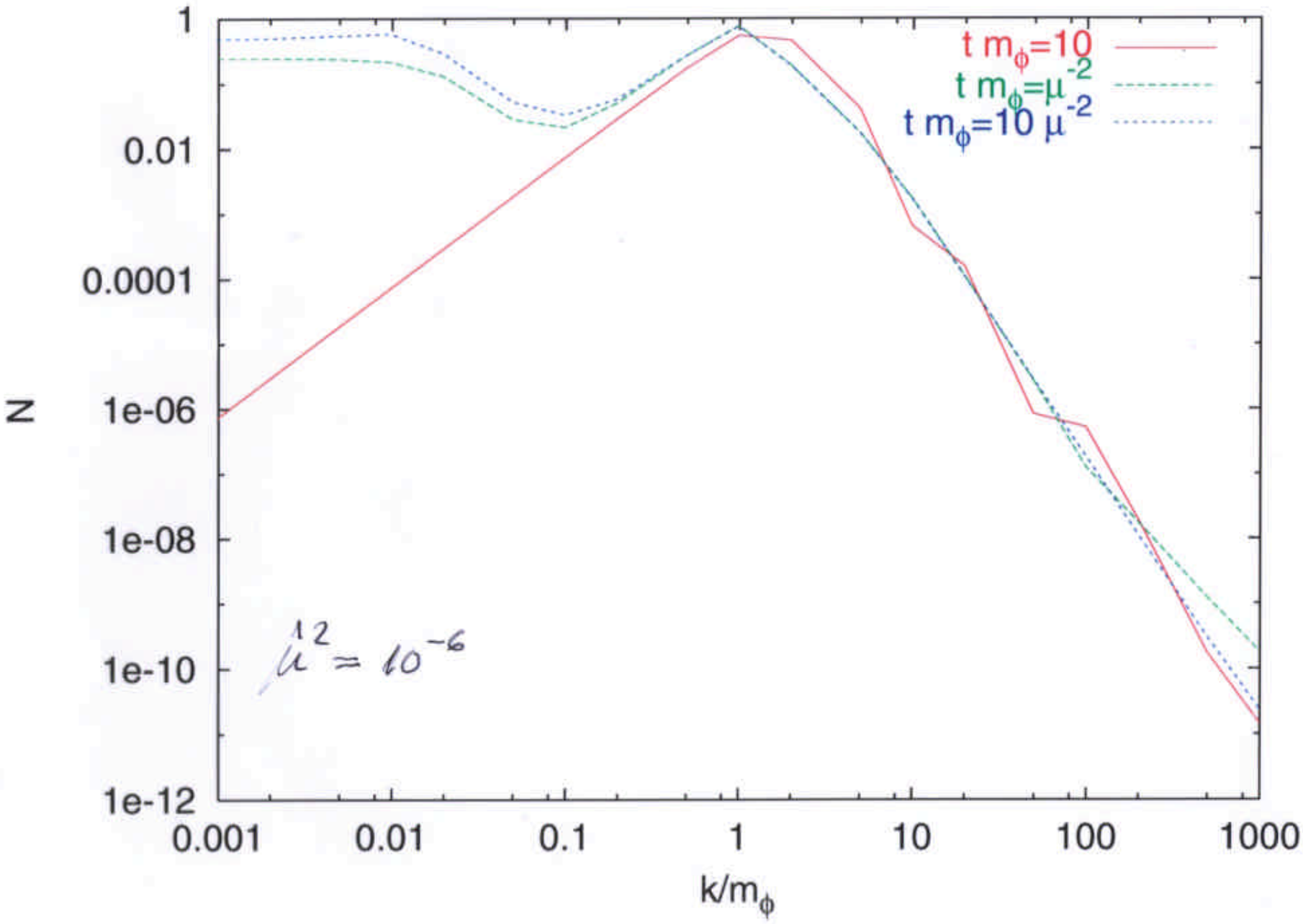
INFLATINOS

NO GRAVITINO

PROBLEM!


1
0.01
0.0001
1e-06
1e-08
1e-10
1e-12
$N_2(k)$
0.001
0.01
0.1
1
10
100
1000
k/m_ϕ
μ^2=1e-2
μ^2=1e-3
μ^2=1e-4
μ^2=1e-5
μ^2=1e-6


1
0.01
0.0001
1e-06
1e-08
1e-10
1e-12
Z
0.001
0.01
0.1
1
10
100
1000
k/m$_\phi$
t m$_\phi$=10
t m$_\phi$=μ^{-2}
t m$_\phi$=10 μ^{-2}
$\mu^2 = 10^{-6}$


1
0.01
0.0001
1e-06
1e-08
1e-10
1e-12
N
0.001
0.01
0.1
1
10
100
1000
k/m_φ
t m_φ=10
t m_φ=μ^-2
t m_φ=10 μ^-2
μ^2 = 10^-6

INFLATION AND SUSY BREAKDOWN

WE CONSIDERED EXTREMELY WEAK COUPLING BETWEEN INFLATON SECTOR AND SUSY-BREAKING SECTOR.

IN THE SPIRIT OF "HIDDEN SECTOR SUPERGRAVITY"

IN GENERAL: SUSY BREAKDOWN SHOULD BE "REMOTE"

NEED MORE EXPLICIT MODELS

D-TERM INFLATION AND SUSY BREAKDOWN ....

BACK TO "OLD LIMITS"

* $m_{\tilde{G}} \geq 20$ TeV WOULD BE OK

REQUIRES THE GRAVITINO TO COUPLE STRONGER TO SUSY BREAKDOWN SECTOR THAN ORDINARY MATTER

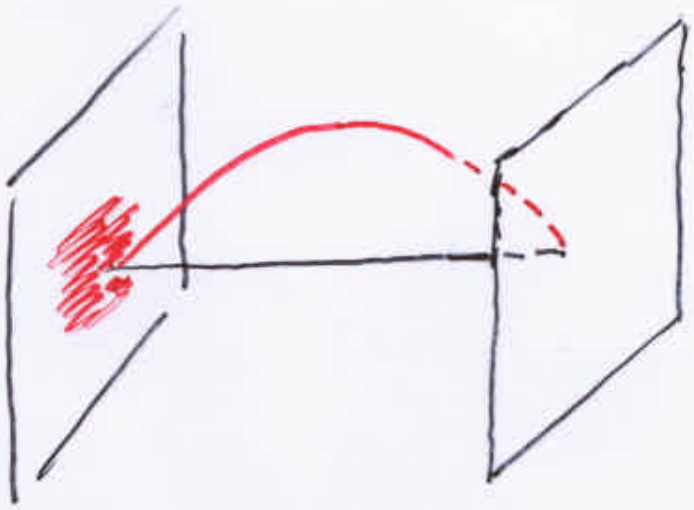
(NP 1982,
ELLIS ET AL. 1985
⋮
LUTY 2002)

SEEMS TO NEED
"SOME" FINE-TUNING!

* $T_{REHEATING} \gg 10^9$ GeV

DECOUPLE GRAVITINO FROM "ORDINARY MATTER"

(PELOSO, NFP)



* GRAVITON "EVEN" — GRAVITINO "ODD"

* LOCALIZED GRAVITON

GRAVITINO OVERPRODUCTION

NOT NECESSARILY A

PROBLEM

MODULI ??

SOME EXPLICIT WORK HAS

TO BE DONE:

"MULTI" FIELD CASE HAS

TO BE ANALYZED BEFORE

DRAWING CONCLUSIONS