COSMOLOGICAL ASPECTS
OF
SUPERSYMMETRY
BREAK DOWN

SUSY02, JUNE 2002, DESY, NP
INFLATION: FLATNESS, HORIZON, MONOPOLE PROBLEM

MEETS

SUSY: NEW PARTICLES RELEVANT FOR COSMOLOGY

GRAVITINO
RELATION SUSY - COSMO

"SOMewhat PROBLEMATIC"

* SUSY BROKEN IN EARLY UNIVERSE (V ≠ 0, T ≠ 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

$M_\tilde{\zeta} \geq 20 \text{ TeV}$ or
$M_\tilde{\zeta} \leq 30 \text{ MeV}$

GRAVITY MEDIATED SUSY

$M_\tilde{\zeta} = M_{3/2} \sim 100 \text{ GeV} - \text{ TeV}$

CAN BE AVOIDED WITH INFLATION, BUT

$T_{\text{reheating}} \leq 10^{9} \text{ GeV}$

( THERMAL PRODUCTION )
$10^{9.5}$ GeV is a rather low scale

* Baryogenesis

* Leptogenesis

* UHECR

Preheating

(Nonthermal production of fermions)

Traschen, Brandenberger 90
Kofman, Linde, Starobinsky 99
Giudice, Peloso, Riotto, Tracchessi

$$m = m_0 + g \phi$$
FERMIIONS OF MASS

\[ \phi \] T \rightarrow \text{CAN BE PRODUCED} 

\underline{PROBLEM}

NONTHERMAL PRODUCTION
OF GRAVITINOS

KALLOSH, KOHNAN, LINDE, VAN PROEYE
SIN DICE, RIOTTO, TRACHEV
Gravitino is a 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.
GiuDICE et al.

But longitudinal one related to Goldstino
ONE FIELD MODEL

SU SY BREAKDOWN

$\delta \chi \sim D\phi (e^{K/2W}) + y_0 \phi$

THUS EFFECTIVE BREAKDOWN
OF SU SY (ALTHOUGH RESTORED
IN VACUUM)

— OVER PRODUCTION OF
"GRAVITINO" BY AS MUCH
AS 13 ORDERS OF
MAGNITUDE

(cos 10^{-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 01/04
SIMPLEST CASE:

\[ N = \frac{m_{\phi}}{2} \phi^2 + \mu^2 (\beta + 5) \]

"HIDDEN" SECTOR SUSY BREAKING

(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

\[ m_\phi \approx 10^{13} \text{ GeV} \]

\[ M_{3/2} \approx \frac{M^2}{M_{\text{Planck}}} \approx 100 \text{ GeV} \]
\[ \mu^2 \equiv \frac{M_{3/2}}{m_\phi} = \frac{\mu^2}{m_\phi M_{pl}} \approx 10^{-11} \]

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.
WHO IS WHO?

$\Phi$ INFLATION

$\Theta$ POLONYI FERMION

$\Theta = \sqrt{\phi^2 + \gamma_5 s^2}$

AT INITIAL TIME $\Theta = \phi$

WHILE AT LATE TIMES $\Theta = s$

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

\[ \mu^2 \approx 10^{-11} \] very difficult to treat

Can go down to \( 10^{-6} \)

+ extrapolation

Production of inflation

Practically independent of \( \mu^2 \) (influence of polonyi field irrelevant)

( \( n = 0.01 m_\phi^3 \) )
Production of gravitinos decreases with $\mu^2$ in controllable way (limit $\mu^2 \to 0$ can be treated analytically).

Conclusion:

Produce essentially inflatinos

No gravitino problem!
INFLATION AND SUSY BREAKDOWN

WE CONSIDERED EXTREMELY WEAK COUPLING BETWEEN INFLATION 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"

\[ m_{\chi} \geq 20 \text{ TeV} \] WOULD BE OK

REQUIRES THEgravitino TO COUPLE STRONGER TO SUSY BREAKDOWN SECTOR THAN ORDINARY MATTER

\[ \text{(NP 1982)} \]

\[ \text{ELLIS ET AL. 1985} \]

\[ \text{;} \]

\[ \text{LUTY 2002} \]

SEEMS TO NEED "SOME" FINE-TUNING!
Reheating \( \rightarrow 10^{9} \text{ GeV} \)

Decouple gravitino from "ordinary matter"

(Peloso, NP)

* 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