Supersymmetry in Cosmology

Raghavan Rangarajan
Ahmedabad University

raghavan@ahduni.edu.in

OUTLINE

- THE GRAVITINO PROBLEM
- SUSY FLAT DIRECTIONS AND THEIR COSMOLOGIAL IMPLICATIONS
- SUSY DARK MATTER

SUMMARY

PREAMBLE

A BRIEF HISTORY OF OUR UNIVERSE

OBSERVATIONS + GENERAL THEORY OF RELATIVITY

14 b yr, COMPOSITION, EXPANDING, PAST – HOT AND DENSE

A BRIEF HISTORY OF OUR UNVIERSE

- First second – hot primordial plasma of electrons,.. photons, quarks/protons, neutrons, dark matter, …
- 1 s – 3 min – light nuclei (helium, lithium, ..)
- 400,000 years – Atoms form, CMBR
- 300 million years – First stars form
- 1 billion years – First galaxies form
- 9 billion years – Solar system formed, DE domin
- 14 billion years – Today

THE FIRST SECOND

- 10^{-44} s – Planck time (E ~ 10^{19} GeV) [Q Gravity]

Grand Unified Theory

- 10^{-38} s – GUT Phase Transition (E ~ 10^{16} GeV, T ~ 10^{29} K)

Standard Model [q, l, H, GB] /Modified SM

- 10^{-11} s – Electroweak Phase Transition (E ~ 100 GeV, T ~ 10^{15} K)
- 10^{-6} s – quarks → protons, neutrons (E ~ 1 GeV, T ~ 10^{13} K)
- 1 s – Primordial Nucleosynthesis begins (E ~ 1 MeV, T ~ 10^{10} K)

THE FIRST SECOND

- 10^{-44} s – Planck time (E ~ 10^{19} GeV) [Q Gravity]

Grand Unified Theory

- 10^{-38} s – GUT Phase Transition (E ~ 10^{16} GeV, T ~ 10^{29} K)

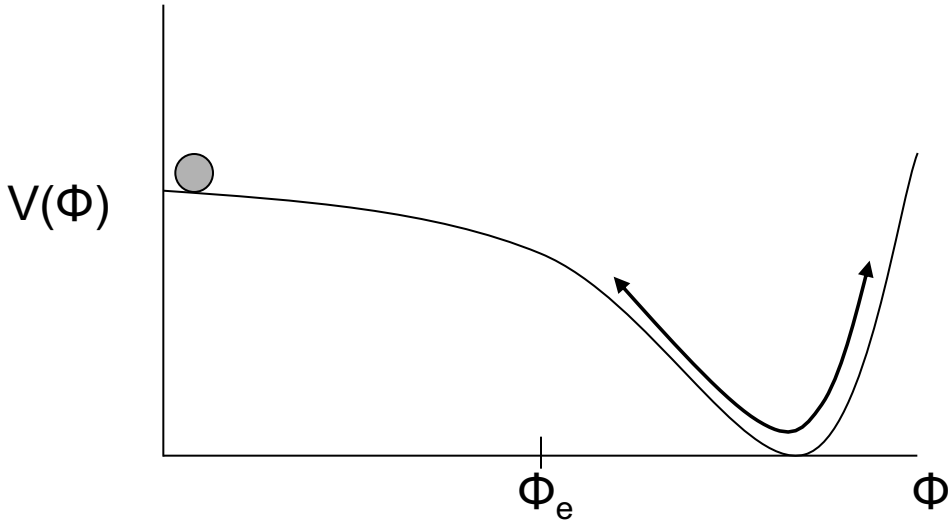
Standard Model [q, l, H, GB] /Modified SM

- 10^{-11} s – Electroweak Phase Transition (E ~ 100 GeV, T ~ 10^{15} K)
- 10^{-6} s – quarks → protons, neutrons (E ~ 1 GeV, T ~ 10^{13} K)
- 1 s – Primordial Nucleosynthesis begins (E ~ 1 MeV, T ~ 10^{10} K)

INFLATION and REHEATING

INFLATION – PERIOD OF *ACCELERATED* EXPANSION IN THE EARLY UNIVERSE ($t \sim 10^{-38}$ s or later)

WHEN THE ENERGY DENSITY OF A SLOWLY VARYING FIELD CALLED THE INFLATON Φ DOMINATES

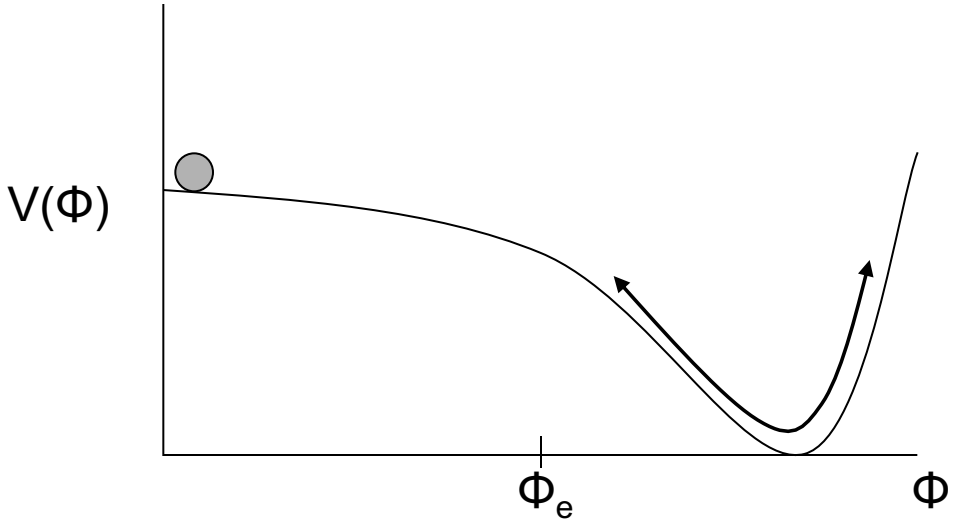


ENERGY DENSITY DOMINATES, DETERMINES EVOL OF UNIV

$$H^2 = \left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi}{3} G\rho$$

R IS THE SCALE FACTOR; IN EXPANDING UNIV d = d_1 R(t)/R(t_1)

$$G = 1/M_{Pl}^2$$

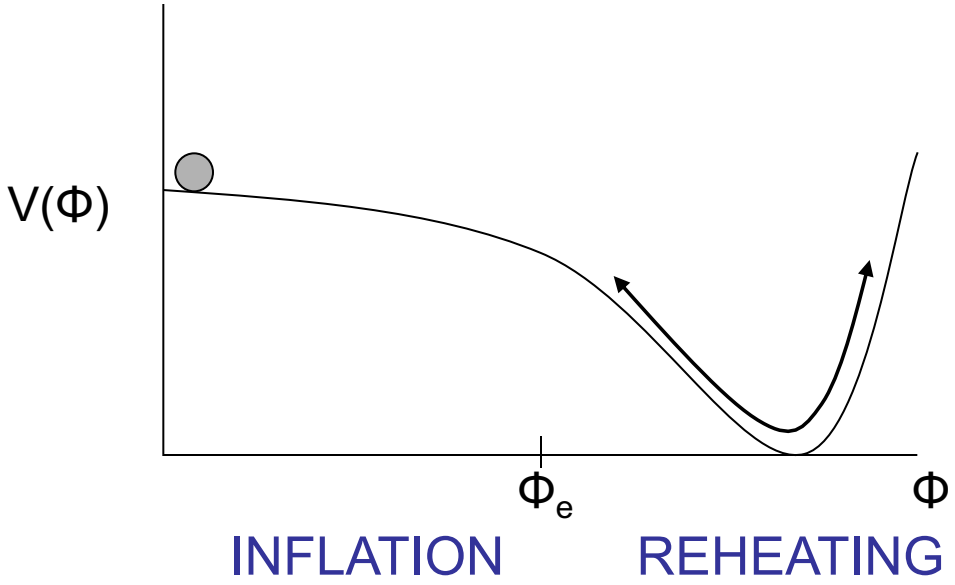


SLOW ROLL OSCILLATE AND DECAY

DURING THE SLOW ROLL PHASE

ENERGY DENSITY = T + V ~ V ~ CONSTANT

INFLATION and REHEATING



DURING INFLATION, R~ exp(H_I t)

n OF ALL SPECIES → 0. COLD

INFLATON DECAY PRODUCTS THERMALISE, T_{reh}
THERMAL BATH HAS q, l, h, dm, BSM INCLUDING SUSY, GUT PARTICLES AND HEAVY NEUTRINOS REHEATING

MATTER-ANTIMATTER ASYMMETRY OF THE UNIVERSE

SOLAR SYSTEM, MILKY WAY, CLUSTER (20 Mpc)

- ANTIMATTER RULED OUT TILL d~1000 Mpc
- SIZE OF OBSERVABLE UNIVERSE ~ 14000 Mpc

(1 Mpc = 3 x 10^{19} km = 3 x 10^{6} lt-yr)

MATTER-ANTIMATTER ASYMMETRY OF THE UNIV

HOW GENERATE ASYMMETRY?

- EARLY TIMES (t << 1 s = PRIM. NUCL.) EQUAL AMOUNTS OF MATTER AND ANTIMATTER

- DISEQUILIBRIUM IN THE EARLY UNIVERSE

  100 *M* + 100 *A* → 103 *M* + 101 *A* → 2 *M*

$X \rightarrow M$ $\qquad$ $X \rightarrow A$

$r_M > r_A$, GET MORE MATTER THAN ANTIMATTER

- X = GUT BOSONS ($M_X \sim 10^{16}$ GeV), HEAVY NEUTRINOS ($M_N \sim 10^{10}$ GeV)

GUT BARYOGENESIS, LEPTOGENESIS

MATTER-ANTIMATTER ASYMMETRY

WHEREFROM GUT BOSONS, HEAVY NEUTRINOS?

In the hot early Universe when temperatures were very high ($k_B T > M$) ($k_B=1$)

THE GRAVITINO PROBLEM

GRAVITINOS

$\tilde{G} =$ SUPERSYMMETRIC PARTNER OF THE GRAVITON

SUPERSYMMETRY

- EXTENSION OF THE STANDARD MODEL (GAUGE HIERARCHY)
- SUPERPARTNERS: FERMION – BOSON

  PHOTON – PHOTINO, ELECTRON – SELECTRON

LOCAL (spacetime dep) SUPERSYMMETRY: SUPERGRAVITY

GRAVITON – GRAVITINO $(\tilde{G})$

BROKEN (EQUAL m, IF SUSY)

GRAVITINO MASS

SUPERSYMMETRY BREAKING
$\Rightarrow$ SM SUPERPARTNERS GET A MASS $m_0 \sim 100$ GeV
$\Rightarrow$ GRAVITINO GETS A MASS

GAUGE MEDIATED SUSY BREAKING (V. LIGHT, LIGHT < 100 GeV)

GRAVITY MEDIATED SUSY BREAKING (HEAVY $\gtrsim$ 100 GeV)

ANOMALY MEDIATED SUSY BREAKING (V. HEAVY$\gg$100 GeV)

$$(m_{\tilde{G}} : \mathrm{eV} - \mathrm{TeV})$$

GRAVITINOS

$\tilde{G} =$ SUPERSYMMETRIC PARTNER OF THE GRAVITON

PRODUCED AFTER INFLATION $t \sim 10^{-38}\,\mathrm{s}$ $(m_{\tilde{G}} : \mathrm{eV} - \mathrm{TeV})$

COSMOLOGICAL CONSEQUENCES (m, n)

- STABLE : AFFECTS EXPANSION RATE, $\rho_{\tilde{G}} > \rho_c$ (L/H)
- UNSTABLE : AFFECT EXPANSION RATE PRIOR TO DECAY

  DECAY PRODUCTS $\rho > \rho_c$

  DESTROY LIGHT ELEMENTS $^4He,\ ^3He,\ D$
  (NUCLEOSYNTHESIS)

GRAVITINO PROBLEM(S)

GRAVITINOS

$\tilde{G} =$ SUPERSYMMETRIC PARTNER OF THE GRAVITON

PRODUCED AFTER INFLATION $t \sim 10^{-34}\,\mathrm{s}$ $(m_{\tilde{G}} : \mathrm{eV} - \mathrm{TeV})$

COSMOLOGICAL CONSEQUENCES (m, n)

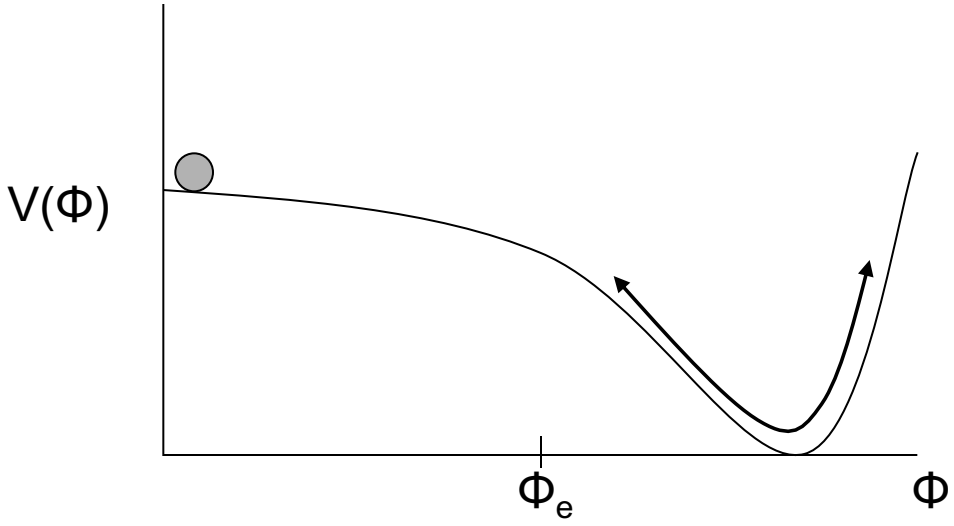
- STABLE : AFFECTS EXPANSION RATE, $\rho_{\tilde{G}} > \rho_c$ (L/H)
- UNSTABLE : AFFECT EXPANSION RATE PRIOR TO DECAY

  DECAY PRODUCTS $\rho > \rho_c$

  DESTROY LIGHT ELEMENTS $^4He,\ ^3He,\ D$
  (NUCLEOSYNTHESIS)

GRAVITINO PROBLEM(S) => UPPER BOUND ON $\rho_{\tilde{\mathbf{G}}} \propto \mathbf{n}_{\tilde{\mathbf{G}}}$

STANDARD PICTURE OF GRAVITINO PRODUCTION



INFLATION → REHEATING (OSC. + DECAY) $(\mathrm{T_{reh}})$

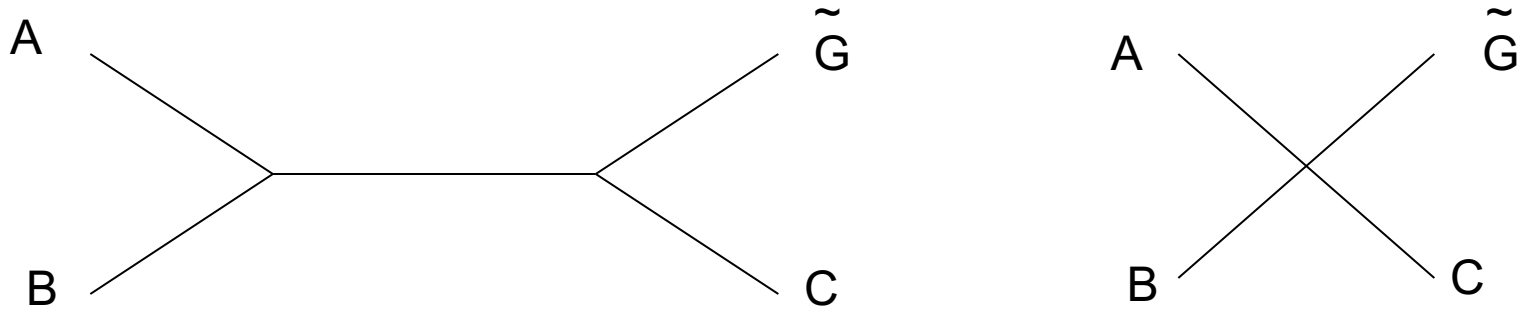
→ RADIATION DOMINATED UNIV
(Relativistic particles)

THERMAL SCATTERING → $\tilde{G}$
(gluons, quarks, squarks, gluinos)

ALSO PROD DURING
P/REHEATING

GRAVITINO PRODUCTION

$\tilde{G}$ PRODUCED BY THE SCATTERING OF INFLATON DECAY PRODUCTS



e.g. $q + \bar{q} \to \tilde{g} + \tilde{G}$ $q + \bar{\tilde{q}} \to g + \tilde{G}$ $g + \tilde{g} \to g + \tilde{G}$

$$\langle \Sigma_{\rm tot} |v| \rangle = \alpha / M_{Pl}^2$$

PRADLER AND STEFFEN

$G_N = 1/M_{Pl}^2$

STANDARD CALC OF GRAVITINO PRODUCTION

CALCULATE GRAVITINO PRODUCTION IN THE RAD DOM ERA

MAINLY PRODUCED AT THE BEGINNING OF THE RAD DOM ERA WHEN $\mathrm{T} \sim \mathrm{T}_{\mathrm{reh}}$, AND $n_{\tilde{G}} \propto \mathrm{T}_{\mathrm{reh}}$.

UPPER BOUND ON $n_{\tilde{G}}$

$\Rightarrow$ UPPER BOUND ON T_{reh} OF $10^{6—9}$ GeV (MASS 100 GeV – 10 TeV)

$k_B T$ in GeV $\quad$ $k_B=1$ $\quad$ 1 GeV $=10^{13}$ K

GRAVITINOS, REHEAT TEMPERATURE AND MATTER-ANTIMATTER ASYMMETRY

REHEATING, GRAVITINOS AND MATTER-ANTIMATTER ASYMMETRY

- THE UPPER BOUND ON THE REHEAT TEMPERATURE $10^{6\text{-}9}$ GeV TO SUPPRESS GRAVITINO PRODUCTION

1 GeV =10^{13} K

REHEATING, GRAVITINOS AND MATTER-ANTIMATTER ASYMMETRY

- THE UPPER BOUND ON THE REHEAT TEMPERATURE $10^{6\text{-}9}$ GeV TO SUPPRESS GRAVITINO PRODUCTION

- MATTER-ANTIMATTER ASYMMETRY GENESIS MODELS REQUIRE HEAVY X, MASS 10^{10}, 10^{16} GeV

1 GeV = PROTON MASS

REHEATING, GRAVITINOS AND MATTER-ANTIMATTER ASYMMETRY

- THE UPPER BOUND ON THE REHEAT TEMPERATURE $10^{6\text{-}9}$ GeV TO SUPPRESS GRAVITINO PRODUCTION

- MATTER-ANTIMATTER ASYMMETRY GENESIS MODELS REQUIRE HEAVY X, MASS 10^{10}, 10^{16} GeV

  DIFFICULT TO HAVE ENOUGH HEAVY X IN THE RADIATION DOMINATED UNIV AFTER REHEATING

$$n_X \sim \exp(- M c^2/k_B T)$$

REHEATING, GRAVITINOS AND MATTER-ANTIMATTER ASYMMETRY

- THE UPPER BOUND ON THE REHEAT TEMPERATURE $10^{6\text{-}9}$ GeV TO SUPPRESS GRAVITINO PRODUCTION

- MATTER-ANTIMATTER ASYMMETRY GENESIS MODELS REQUIRE HEAVY X, MASS 10^{10}, 10^{16} GeV

  DIFFICULT TO HAVE ENOUGH HEAVY X IN THE RADIATION DOMINATED UNIV AFTER REHEATING

LOW REHEAT TEMP TO SUPPRESS GRAVITINOS IS A PROBLEM FOR GUT BARYOGENESIS AND LEPTOGENESIS

SOLUTIONS TO THE GRAVITINO PROBLEM

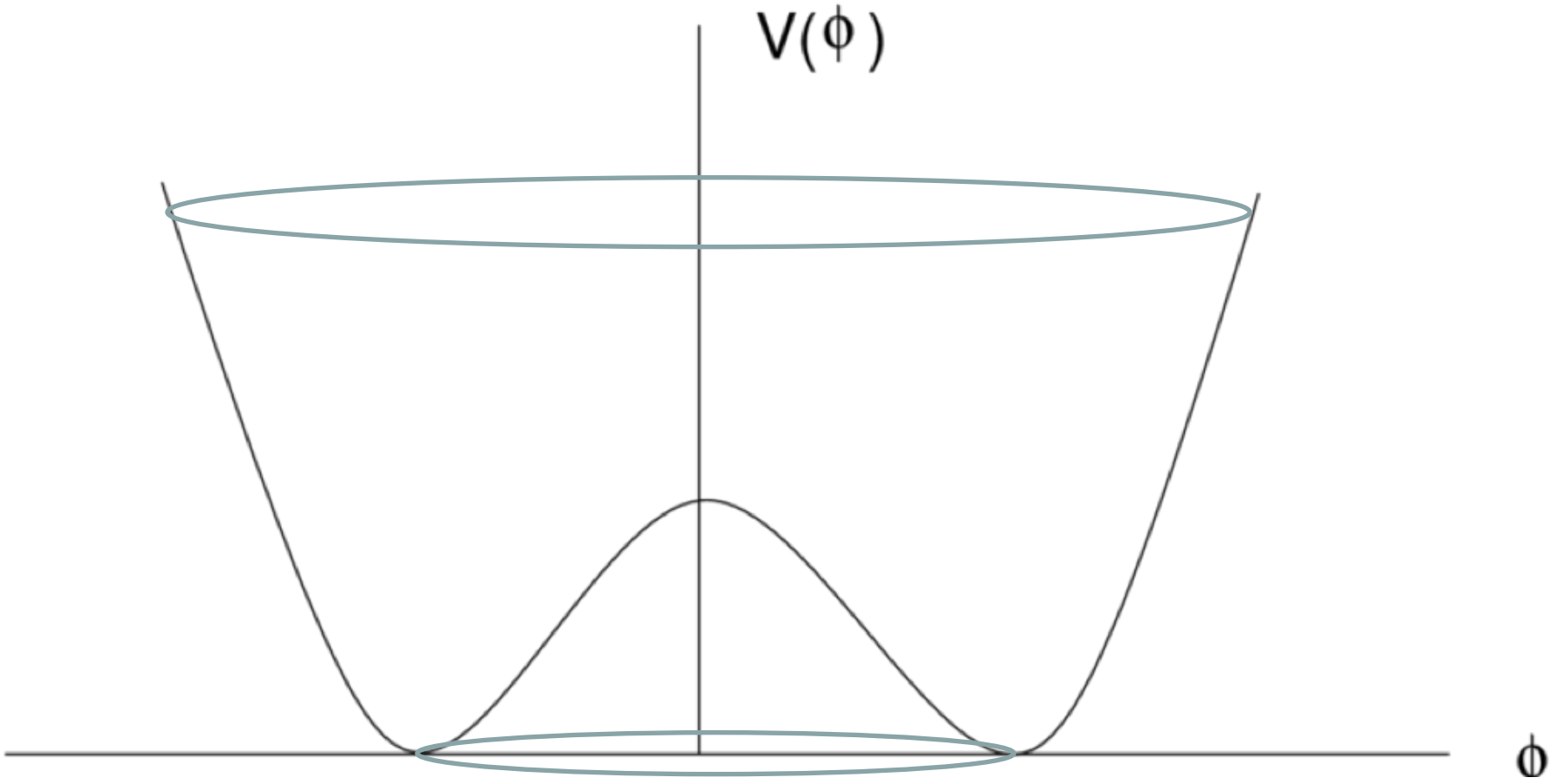
INCREASE GUT BOSON/HEAVY NEUTRINO PRODUCTION, OR SUPPRESS GRAVITINO PRODUCTION

- SCATTERINGS DURING REHEATING BEFORE TOTAL THERMALISATION (NOT X DECAYS)
- T: 0 → T_{max} → T_{reh} $T_{max} \sim 1000\ T_{reh}$
- PREHEATING
- SUPPRESS GRAVITINOS USING SUSY FLAT DIRECTIONS

CAVEAT (ALWAYS CHECK)

SUSY FLAT DIRECTIONS AND THEIR COSMOLOGIAL IMPLICATIONS

FLAT DIRECTIONS



V’ = 0 ALONG BOTTOM. POTENTIAL IS FLAT

MAG NOT CHANGE, PHASE DOES

SUSY FLAT DIRECTIONS

STANDARD MODEL , *H* SCALAR (SPIN 0)
MINIMISE V

SCALAR POTENTIAL *V* IN SUSY IS A FUNCTION OF

$$(H_u, H_d, \tilde{q}_i, \tilde{l}_i)$$

DIRECTIONS IN FIELD SPACE OF SCALARS ALONG WHICH THE SCALAR POTENTIAL IS MINIMISED

V' = 0, POTENTIAL IS FLAT — FLAT DIRECTIONS

[POTENTIAL IS CONSTANT AND ZERO ALONG FLAT DIRECTION
NOT JUST PHASE CHANGE, MAGNITUDE CHANGE TOO]

SUSY FLAT DIRECTIONS

SM: $\langle \phi \rangle = v$ PHASE

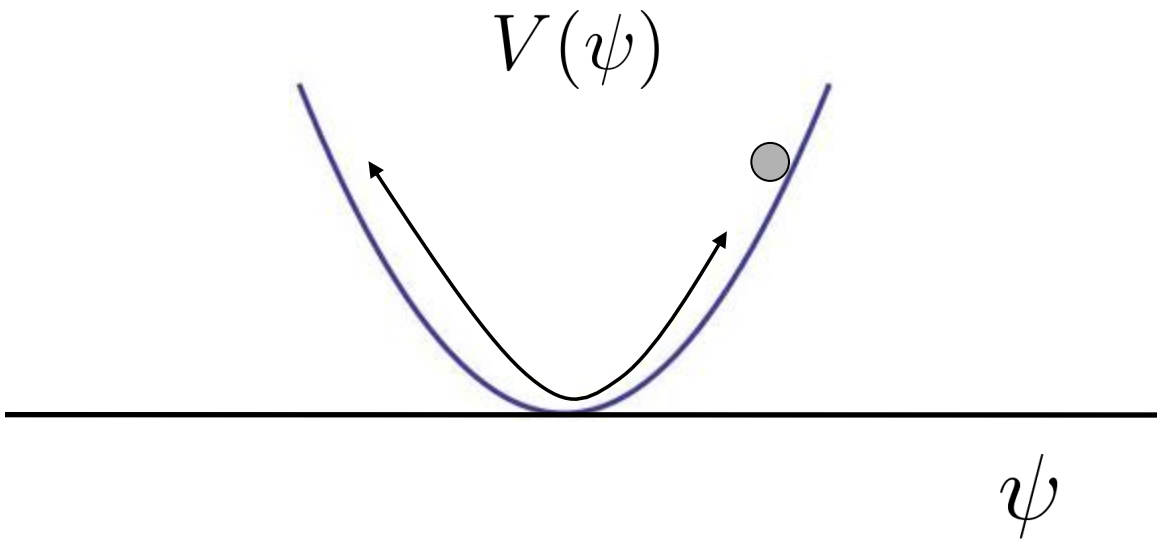
UDD: $\langle \tilde{u}_L \rangle = \psi, \ \langle \tilde{s}_L \rangle = \psi, \ \langle \tilde{b}_L \rangle = \psi$ PHASES

PARAMETER ψ IS REPRESENTED BY A COMPLEX SCALAR FIELD ψ (AFFLECK-DINE FIELD) WHOSE EXP VALUE IS ψ

GHERGHETTA, KOLDA AND MARTIN

FLAT DIRECTION FIELD ψ IS NOT THE INFLATON

SUSY BREAKING

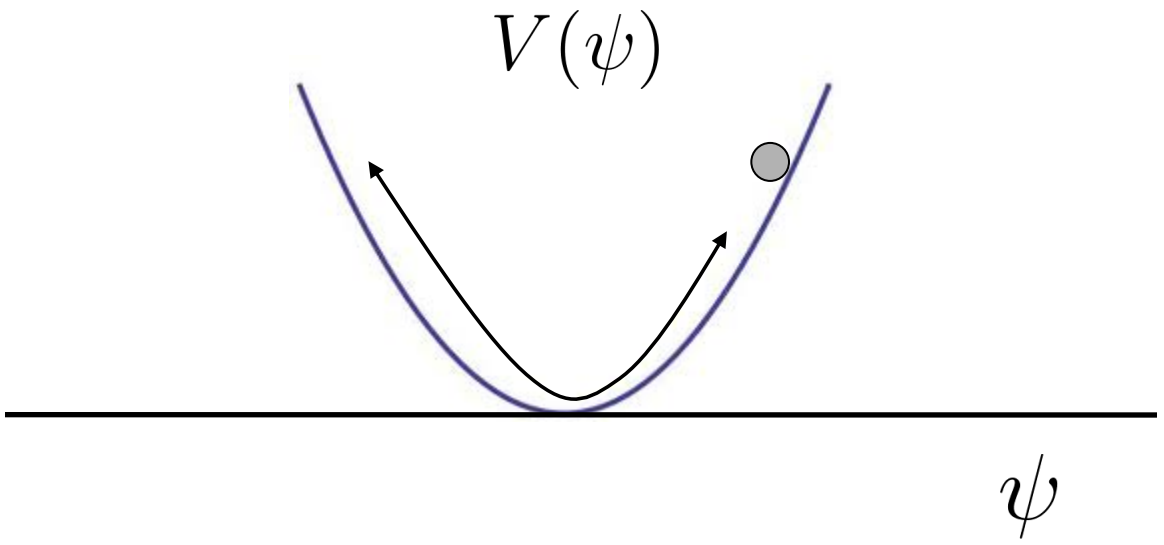


FLAT DIRECTION → QUADRATIC POT WITH CURV m_0^2

$\psi_0 \neq 0$ DUE TO QUANTUM FLUCTUATIONS DURING INFLATION; OTHER REASONS

A FIELD CONFIGURATION WITH THE FIELD AWAY FROM ITS MINIMUM IS OFTEN CALLED A CONDENSATE, CAN TREAT LIKE CLASSICAL FIELD, DO EOM

SUSY BREAKING



FLAT DIRECTION → QUADRATIC POT WITH CURV m_0^2

$\psi_0 \neq 0$ DUE TO QUANTUM FLUCTUATIONS DURING INFLATION; OTHER REASONS

WHEN $t_U \sim t_F$ (OR $H \sim m_0$), ψ OSCILLATES, $\psi \sim 1/R^{3/2}$

THEN IT DECAYS (BEFORE EWSB $t \sim 10^{-11}$ s)

COSMOLOGICAL CONSEQUENCES

AFFLECK-DINE BARYOGENESIS

SUPPRESS GRAVITION PRODUCTION VIA DELAYED THERMALISATION DURING REHEATING

GENERATION OF PRIMORDIAL MAGNETIC FIELDS

AFFLECK-DINE BARYOGENESIS

AFFLECK AND DINE, LINDE

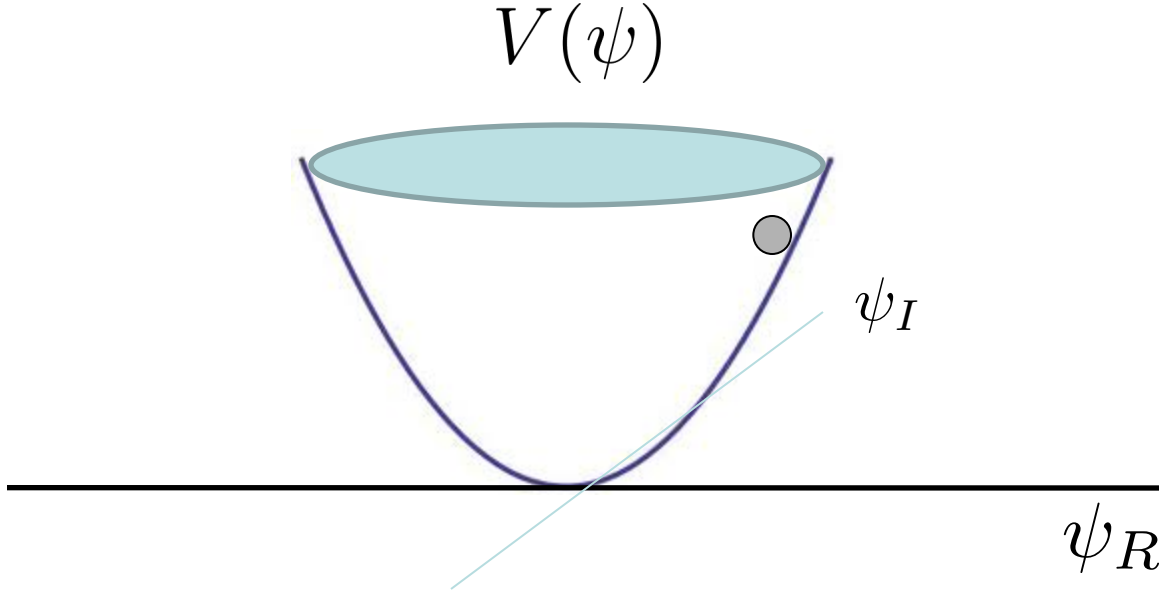
TO CREATE A BARYON ASYMMETRY REQUIRES

- B VIOLATION
- CP VIOLATION
- OUT OF THERMAL EQUILIBRIUM

$$V(\psi) = m^2\psi^*\psi + \frac{i}{2}\lambda(\psi^4 - \psi^{*4})$$

B(ψ) =1/3 => B VIOLATION VIA QUARTIC COUPLINGS

B VIOLATING COUPLINGS ARE COMPLEX => CP VIOLATION



$$j^B_\mu = -i(\psi^* \partial_\mu \psi - \partial_\mu \psi^* \, \psi) B_\psi$$

$$\int j^B_0 dV = B$$

ψ UNIFORM $\qquad j^B_0 = B/V = n^B$

$$n_B = -i(\psi^* \dot{\psi} - \dot{\psi}^* \, \psi) B_\psi = \frac{1}{2}(\psi_R \dot{\psi}_I - \dot{\psi}_R \, \psi_I) B_\psi$$

AFFLECK-DINE BARYOGENESIS

$$V(\psi) = m^2\psi^*\psi + \frac{i}{2}\lambda(\psi^4 - \psi^{*4})$$

WHEN ψ IS LARGE B AND CP VIOLATING QUARTIC COUPLINGS DOMINATE. n_B IS CREATED

LATER QUADRATIC TERMS DOMINATE. NO NEW n_B

ψ DECAYS (e.g. $\tilde{q}_c \rightarrow q/\bar{q} + \tilde{\gamma}$) AND GET BAU

SUSY FLAT DIRECTIONS

DECREASE $\tilde{G}$

DELAYED THERMALISATION DURING REHEATING

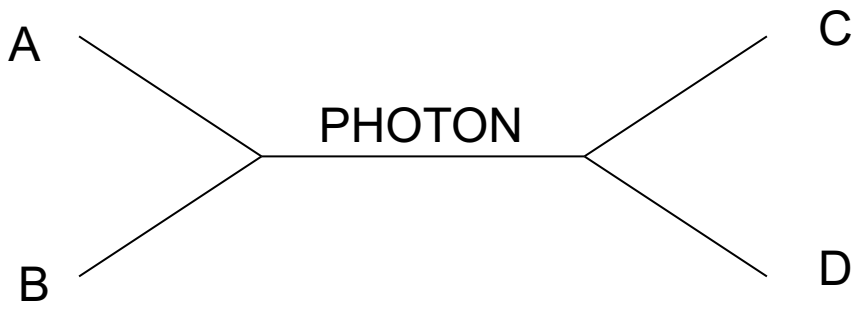
e.g., $\tilde{q}^* \tilde{q} A^\mu A_\mu$

NON-ZERO VALUE OF ψ GIVES MASS TO GAUGE BOSONS (BREAKS GAUGE SYMMETRY),

FLAT DIRECTION EXPECTATION VALUE CAN BE 10^{13} GEV OR HIGHER

THERMALISATION DURING REHEATING DUE TO PROCESSES MEDIATED BY GAUGE BOSONS – PHOTONS (EM), GLUONS (STRONG)

IF ALL GAUGE BOSONS GET MASS [LLddd, QuQue], IT SLOWS DOWN THERMALISATION AFTER INFLATION



STANDARD PICTURE OF REHEATING:

INFLATON DECAYS $\rightarrow n_0 \rightarrow$ THERMALISE

KINETIC EQM n_0

CHEMICAL EQM n_1 $\quad [10^4]$

FLAT DIRECTIONS:

INFLATON DECAYS $\rightarrow n_0 \rightarrow$ DELAYED THERMALISATION

$$n \sim n_0 \ll n_1$$

DILUTE PLASMA

GRAVITINOS PRODUCED BY SCATTERING OF INFLATON DECAY PRODUCTS [n.n]

$n_{\tilde{G}} \downarrow\downarrow$ ALLAHVERDI AND MAZUMDAR; RR AND A. SARKAR

GRAVITINO PROBLEM AGAIN!

- WITH SOME FLAT DIRECTIONS, HIT A RESONANCE
- GRAVITINO ABUNDANCE GENERATED IS VERY LARGE AND GREATER THAN THE COSMOLOGICAL UPPER BOUND FOR MOST PARAMETER SPACE
- COSMOLOGICAL UPPER BOUND IS $Y < 10^{-14}$
- FOR DIFFERENT SETS OF PARAMETERS

$Y = 10^{-8}$ — 10^{-2} MAHAJAN, RR AND A. SARKAR

WHY AMBIGUITY?

SUSY FLAT DIRECTIONS

GENERATE PRIMORDIAL MAGNETIC FIELDS

PRIMORDIAL MAGNETIC FIELDS

- DETECTED MAGNETIC FIELDS ON DIFFERENT COSMOLOGICAL LENGTH SCALES FROM GALAXIES TO CLUSTERS
- ORIGIN IS UNKNOWN
- DYNAMO THEORY: PRIMORDIAL MAGNETIC FIELD, AMPLIFIED BY DYNAMO PROCESS
- SOURCE OF PRIMORDIAL MAGNETIC FIELD UNKNOWN

PRIMORDIAL MAGNETIC FIELDS

- GENERATE THE PRIMORDIAL MAGNETIC FIELD DURING INFLATION

- GAUGE FIELD

$$A^{\mu}(x) = \sum_{\lambda} \int d^3k \, \epsilon^{\mu}_{\lambda}(k) A_k(t) \exp(i\mathbf{k}.\mathbf{x}) a_{\mathbf{k}} + h.c.$$

- SOLVE EOM FOR A_k IN CURVED SPACETIME

- $|A_k(t)|$ CAN GROW IF $m_A \neq 0$
  EQUIVALENT TO CREATING E AND B FIELDS

  E DISAPPEARS. GET PRIMORDIAL B.

PRIMORDIAL MAGNETIC FIELDS

$$\tilde{q}^* \tilde{q} A^\mu A_\mu$$

NON-ZERO VALUE OF AFFLECK-DINE FIELD ψ
GIVES MASS TO A^μ

FLAT DIRECTIONS CAN GIVE RISE TO
PRIMORDIAL MAGNETIC FIELDS

ENQVIST, JOKINEN AND MAZUMDAR

SUSY DARK MATTER

- IF R PARITY IS CONSERVED, LSP IS STABLE
- IF IT IS FEEBLY INTERACTING WITH LIGHT AND OTHER PARTICLES (NEUTRAL, COLOURLESS), AND HAS THE RIGHT ENERGY DENSITY TODAY IT CAN BE THE DARK MATTER
- IT TURNS OUT THAT AN LSP (NEUTRALINO, SNEUTRINO) SATISFIES THESE PROPERTIES AND WITH THE MASS ~ 100 GeV HAS THE RIGHT ENERGY DENSITY (WIMP MIRACLE)

SUSY DARK MATTER

- EARLY UNIVERSE ALL SUSY AND SM PARTICLES IN THERMAL EQUILIBRIUM,

$$\Gamma > H$$

- AS PARTICLES BECOME NON-RELATIVISTIC THEY TEND TO ANNIHILATE AND DISAPPEAR (HEAVY QUARKS, MUONS, TAU, HIGGS, SUSY PARTICLES)

- ONLY THE LIGHTEST SURVIVE (ELECTRON; u, d → p, n; PHOTON, LIGHT NEUTRINOS, LSP)

- SOME LIGHTEST PARTICLES GO OUT OF EQUILIBRIUM WHEN THEY ARE RELATIVISTIC (LIGHT NEUTRINOS) AND SOME AFTER THEY BECOME NON-RELATIVISTIC (ELECTRON, n, p, LSP)

$\Gamma = H$ (FREEZE OUT CONDITION)

- AFTER OUT OF EQUILIBRIUM, $n \sim 1/R^3$, Y=n/s FROZEN

$$\rho_0 = m\, n_0 = m\, n_{eq} \frac{R_{eq}^3}{R_0^3}$$

$$= m\, n(T_{eq}) \frac{T_0^3}{T_{eq}^3}$$

R ~ 1/T IF NO ENTROPY RELEASE

- KNOWING T_{eq} IS IMPORTANT. OBTAIN IT FROM

$$\Gamma = n < \sigma v > = H$$

- < .. > IS FOR THERMALLY AVERAGED CROSS SECTION

  WHEN A SPECIES BECOMES NON-RELATIVISTIC, n ~ exp(-m/T) AND σ FALL, AND $\Gamma < H$

- FOR THE LSP, WE FIND $T_{eq} = m/20$

  (WEAK INTERACTIONS. FOR ELECTRON IT IS $m/10^6$ AND FOR PROTON IT IS $m/10^9$)

- FOR THE LSP, WE FIND T_{eq} = m/20

$$\rho = m\, n(T_{eq})\, \frac{T_0^3}{T_{eq}^3}$$

$$n(T) = g \left(\frac{mT}{2\pi} \right)^{3/2} e^{-m/T}$$

- FOR m ~ 100 GeV, $\rho_0 = \rho_{DM}$

- WIMP MIRACLE

CANDIDATE SUSY DARK MATTER

- NEUTRALINOS (LIGHTEST COMBO OF WINO, BINO, 2 NEUTRAL HIGGSINOS)
- SNEUTRINOS
- m ~ 100 GeV; WIMP MIRACLE
- NEUTRALINO NOT SEEN YET (MODEL DEPENDENT)
- SNEUTRINOCURRENTLY RULED OUT IN MSSM

CANDIDATE SUSY DARK MATTER

- GRAVITINO

  VERY WEAKLY COUPLED, DIFFICULT TO DETECT;

  CREATED THROUGH DECAY OF NLSP AS NOT THERMAL IN EARLY UNIV DUE TO VERY WEAK COUPLING, m ~ eV

- AXINO

  CREATED THROUGH THERMAL SCATTERING OF PARTICLES (LIKE GRAVITINO) OR OUT OF EQM DECAY OF NLSP

  m ~ keV - TeV

SUMMARY

1. POPULAR MODELS OF GENERATING THE MATTER-ANTIMATTER ASYMMETRY OF THE UNIVERSE REQUIRE A LARGE REHEAT TEMPERATURE AFTER INFLATION

   BUT THAT GENERATES TOO MANY GRAVITINOS IN THE UNIVERSE

   COSMOLOGISTS ARE LOOKING FOR MECHANISMS TO ENHANCE NEUTRINO ABUNDANCE/SUPPRESS GRAVITINO ABUNDANCE

SUMMARY

2. SUSY FLAT DIRECTIONS CAN

GENERATE THE MATTER ANTIMATTER ASYMMETRY OF THE UNIVERSE (AFFLECK-DINE BARYOGENESIS),

SOLVE OR AGGRAVATE THE GRAVITINO PROBLEM

GENERATE PRIMORDIAL MAGNETIC FIELDS

(DETAILS OF THE SUSY MODEL)

3. SUSY DARK MATTER – NEUTRALINOS, SNEUTRINOS, GRAVITINOS, AXINOS