LEPTOGENESIS IN SUSY THEORIES

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SEESAW 25

PARIS

GRAVITINO PROBLEM

Weinberg

THE GRAVITINO HAS A LONG LIFE-TIME AND DECAYS JUST AFTER THE BIG BANG NUCLEOSYNTHESIS (BBN).

$$\tau_{3/2} \simeq \left[\frac{N_c}{32\pi} \frac{m_{3/2}^3}{M_{PL}^2} \right]^{-1}$$

$$\simeq \frac{1}{N_c} \times 4 \times 10^5 \left(\frac{1\ \mathrm{TeV}}{m_{3/2}} \right)^3 \mathrm{sec.}$$

THE DECAY PRODUCTS DESTROY THE SUCCESS OF THE BBN.

CONSTRAINT ON $n_{3/2}$ FOR KEEPING THE SUCCESS OF THE BBN :

$$m_{3/2}\, Y_{3/2} \;<\; 10^{-16} - 10^{-14}\ \mathrm{GeV}$$

$$Y_{3/2} \equiv n_{3/2}/n_{\gamma}$$

Fig 1

GRAVITINOS ARE PRODUCED BY THERMAL SCATTERING PROCESSES AFTER INFLATION.

$$Y_{3/2} \simeq 3 \times 10^{-12} \left(\frac{1\,\mathrm{TeV}}{m_{3/2}} \right)^2 \left(\frac{m_{\tilde{g}}}{1\,\mathrm{TeV}} \right)^2 \times \left(\frac{T_R}{10^{10}\,\mathrm{GeV}} \right) \propto T_R$$

UPPER BOUND OF T_R

SEE FIG 2.

$$T_R \lesssim 10^{4-5}\ \mathrm{GeV} \quad !!$$

Kawasaki, Kohri, Moroi '04

FOR $m_{3/2} \simeq O(1)$ TeV

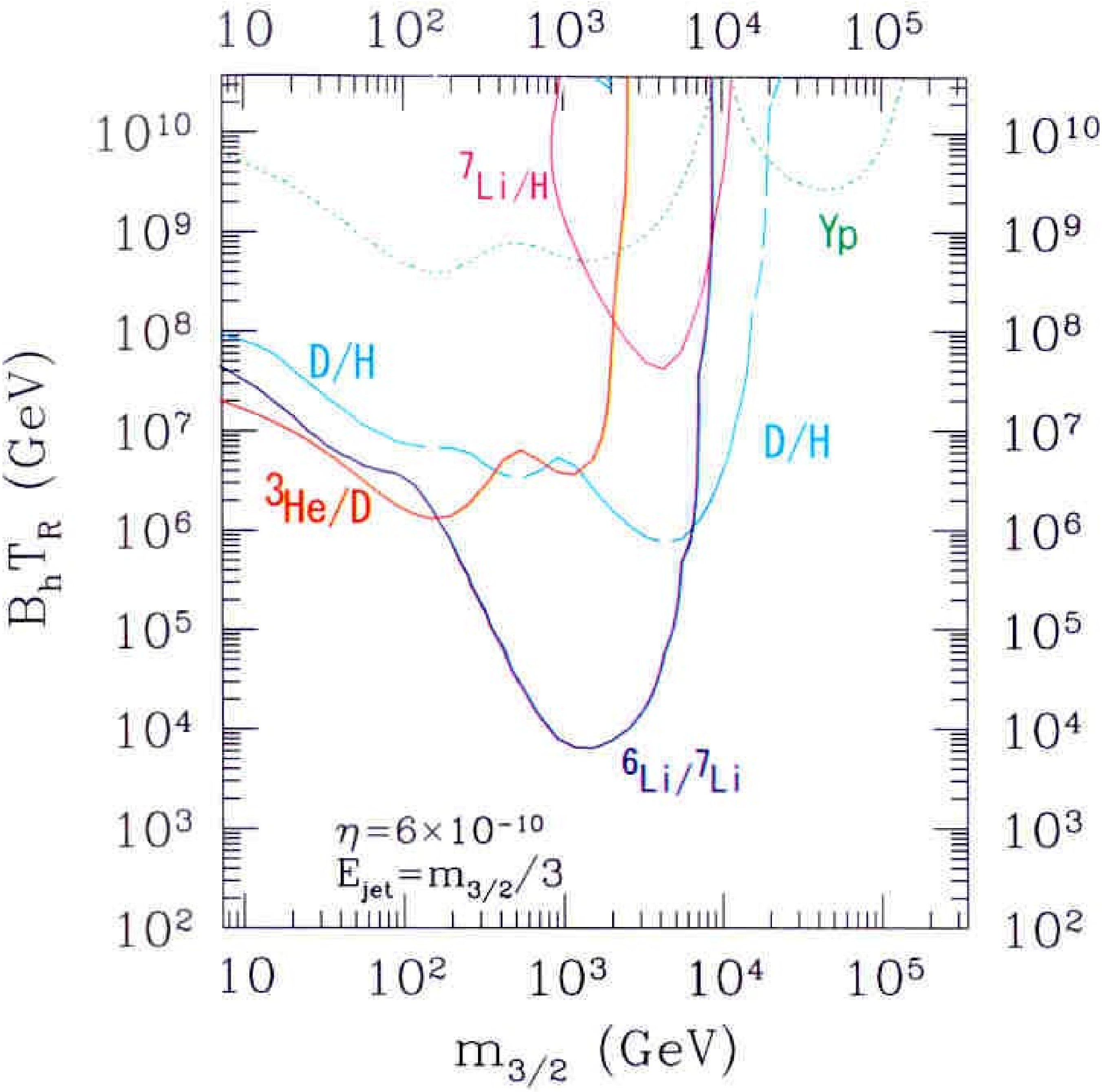


FIG.

Kawasaki et. al.

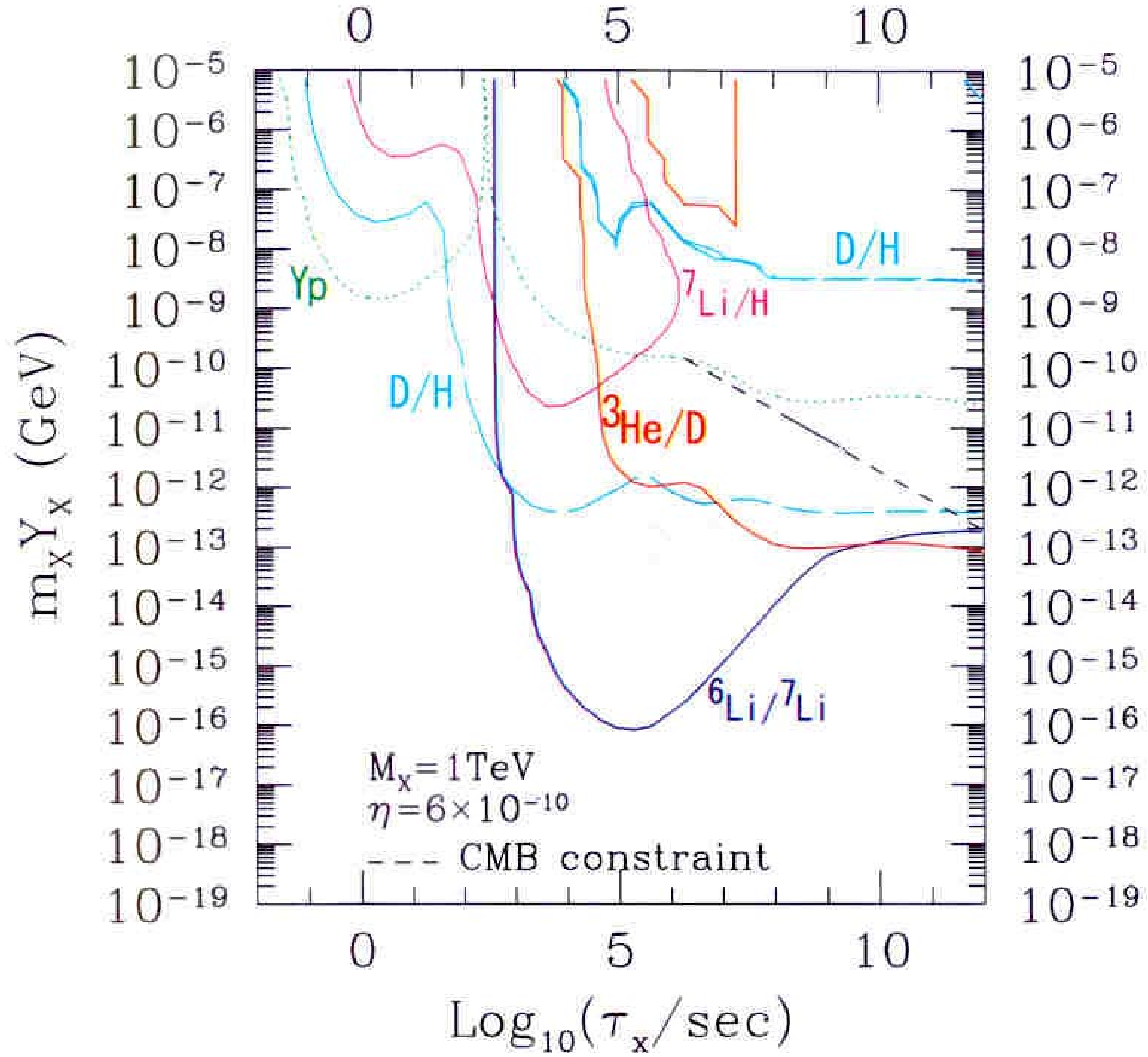


FIG.

Kawasaki et al.

BARYOGENESIS AT LOW TEMPERATURES

$T_R \lesssim 10^4$ GeV

RESONANT LEPTOGENESIS:

IF $M_3 > M_2 > M_1$ DECAYS OF THE MAJORANA N_i PRODUCE TOO SMALL BARYON ASYMMETRY.

ENHANCEMENT BY RESONANCE

$M_1 \simeq M_2$

$$\Delta B \simeq \Delta B_0 \times \frac{M_2}{M_2 - M_1}$$

Pilaftsis

THE OBSERVATION $\Delta B \simeq 0.8 \times 10^{-10}$

REQUIRES

$$\delta M_{12} \equiv 1 - \frac{M_1}{M_2} \lesssim 10^{-6} \text{ !! }.$$

AD BARYOGENESIS:

Affleck-Dine

$\tilde{q}$, $\tilde{l}$ HAVE LARGE VALUES DURING INFLATION.

$\hookrightarrow$ $\frac{m^2_{\tilde{q}.\tilde{l}}}{H^2} \simeq 0$ OR NEGATIVE.

D-TERM INFLATION: + ANOMALOUS U(1)

: $\xi \{V + S + S^+\}$

$$|m^2_{\tilde{q}.\tilde{l}}| \ll H^2 .$$

BUT.

$$\begin{cases} \alpha_\lambda = \frac{\lambda^2}{4\pi} \lesssim 10^{-10} \longleftarrow \text{COSMIC STRING} \\ \alpha_1 = \frac{g^2}{4\pi} \lesssim 10^{-5} \end{cases}$$

Kawasaki, Moroi

· PROBLEM IN DILATON FIXING

Arkani-Hamed, Dine

SWaWa : $S = \frac{1}{4 g_0}$ $\therefore \langle S \rangle \simeq 10^3$???

· $\xi \simeq 10^{15}$ GeV

F-TERM INFLATION :

WE NEED A LARGE COUPLING IN KÄHLER POTENTIAL AS

$$\mathcal{K} = \kappa \cdot \phi^* \phi \, \psi_i^* \psi_i + \cdots$$

INFLATON

$\tilde{q}_i, \tilde{l}_i \ldots$

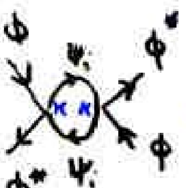
$$\kappa \sim O(1)$$

TO GENERATE THE NEGATIVE $m^2_{\tilde{q}, \tilde{l}}$.

BUT THE INFLATON ϕ MUST BE WEAKLY COUPLED FIELD :

$$\mathcal{K} = \kappa' \cdot \phi^* \phi \, \phi^* \phi + \cdots$$

$$n_s = 1 - 8\kappa' + \cdots \simeq 1 \pm 0.02$$



$\Rightarrow \kappa' \simeq \frac{N_i}{16\pi^2} \kappa^2 \simeq O(1)$

$$|\kappa'| \lesssim 10^{-2}$$

AD MECHANISM SEEMS UNLIKELY.

ELUDING THE CONSTRAINT ON T_R

- HEAVY GRAVITINO :

$$m_{3/2} \gtrsim 100 \text{ TeV}$$

- LIGHT GRAVITINO :

$$m_{3/2} \lesssim 10 \text{ GeV}$$

$\{$ GRAVITINO IS THE LSP. $\}$

HEAVY GRAVITINO OF $m_{3/2} \gtrsim 100$ TeV :

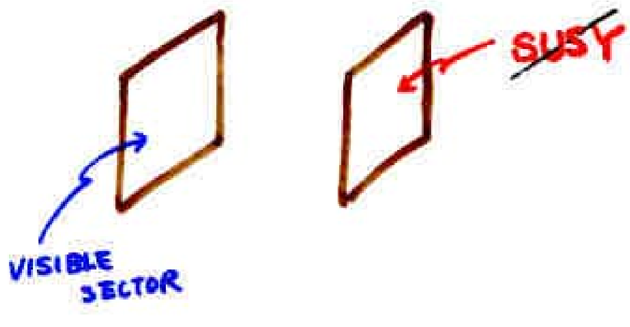
$$\tau_{3/2} \lesssim 0.1 \text{ sec}$$

THE GRAVITINO DECAYS BEFORE THE BBN.

NO CONSTRAINT ! Fig.

BRANE SEPARATION MAY GENERATE

$$m_{\tilde{g},\tilde{\gamma}} \ll m_{3/2} .$$
$$\overset{\shortparallel}{1 \text{ TeV}}$$



Randall Sundrum

BUT, BULK-FIELD CONTRIBUTIONS MAY INDUCE $m_{\tilde{g},\tilde{\gamma}} \simeq O(m_{3/2})$.

Anisimov, Dine, Graesser, Thomas

4 D CONFORMAL FIELD THEORY

Luty, Sundrum

$$K \simeq \frac{C^i{}_j}{M_{PL}^2} T_J^\dagger T^J Q_i^\dagger Q^j$$

$\tilde{q}, \tilde{l}$

$$m^2_{\tilde{q}, \tilde{l}} \simeq \frac{C^i{}_j}{M_{PL}^2} |F_T|^2$$

IF T_J HAVE LARGE ANOMALOUS DIMENSIONS

DUE TO STRONGLY-COUPLED CONFORMAL DYNAMICS,

$C^i{}_j \to 0$ IN THE INFRARED (IR) LIMIT.

$$m_{\tilde{q}, \tilde{l}} \ll m_{3/2}$$

BUT, WE NEED FINE TUNING OF PARAMETERS.

WE HAVE FOUND NO NATURAL MODEL

FOR THE HEAVY GRAVITINO.

EVEN IF EXISTS, THE ANOMALY MEDIATION GIVES

$m^2_{\tilde{l}} < 0$!

Randall, Sundrum

G. L. R. M.

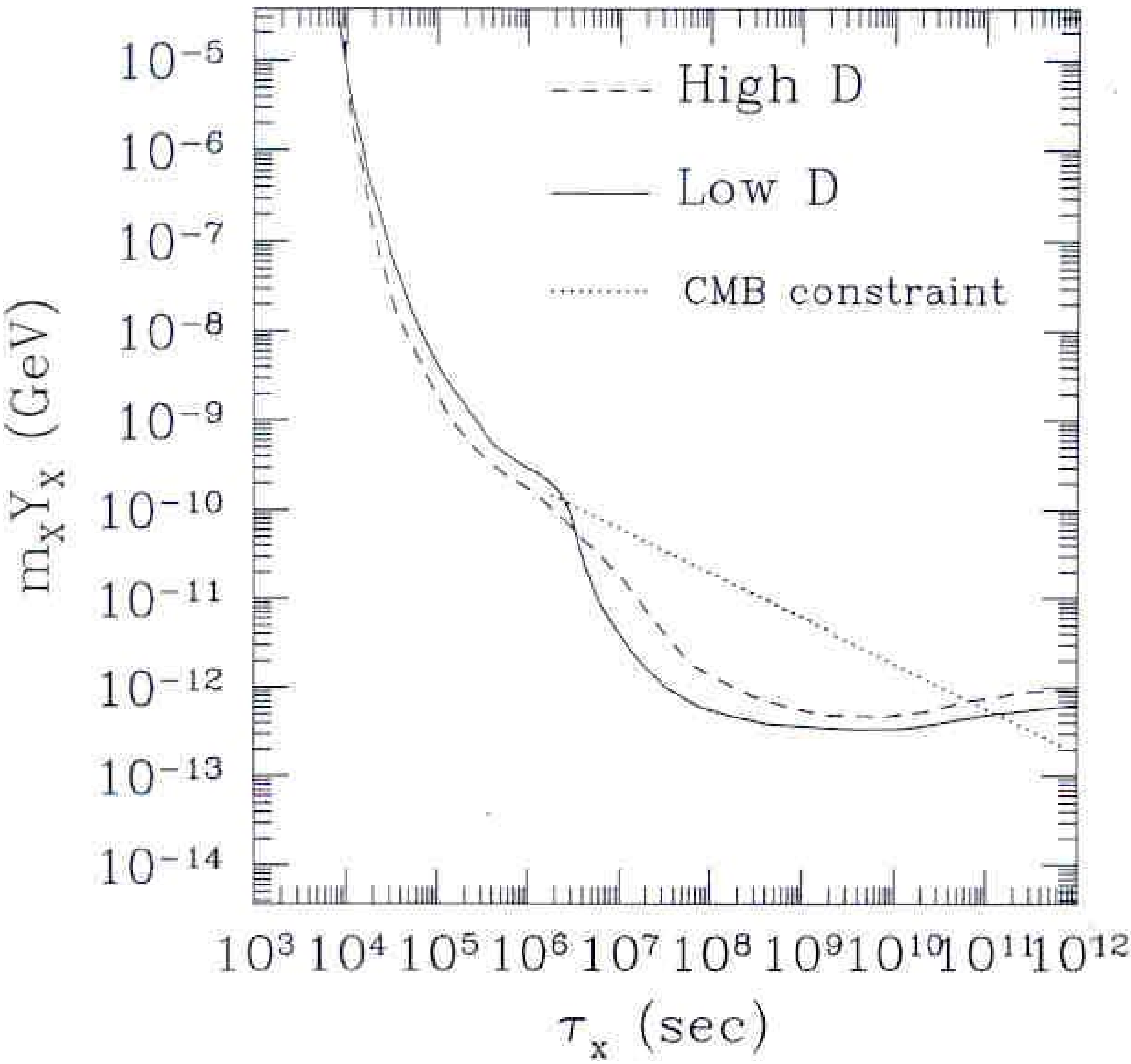


FIG. 2. Plot of the contour of the confidence level in $(\tau_x, m_X Y_X)$ plane. The solid (dashed) line denotes the 95% C.L. for Low D (High D) projected on η axis. The dotted line denotes the upper bound which comes from CMB constraint.

FIG. ..

Kawasaki et. al.

LIGHT GRAVITINO OF $m_{3/2} \lesssim 10$ GeV:

THE GRAVITINO IS THE STABLE LSP.

THE NEXT LSP DECAYS INTO $3/2 + \cdots$

WHICH MAY DESTROY THE LIGHT ELEMENTS PRODUCED BY THE BBN.

IF THE NLSP IS $\tilde{\tau}$ OR $\tilde{b}$, RADIATIVE DECAYS ARE DOMINANT :

$$\begin{cases} \tilde{\tau} \to \tau + 3/2 \\ \tilde{b} \to \gamma + 3/2 \end{cases}$$

IF $\tau_x \lesssim 10^4$ sec, NO CONSTRAINT IS GIVEN.

Fig.

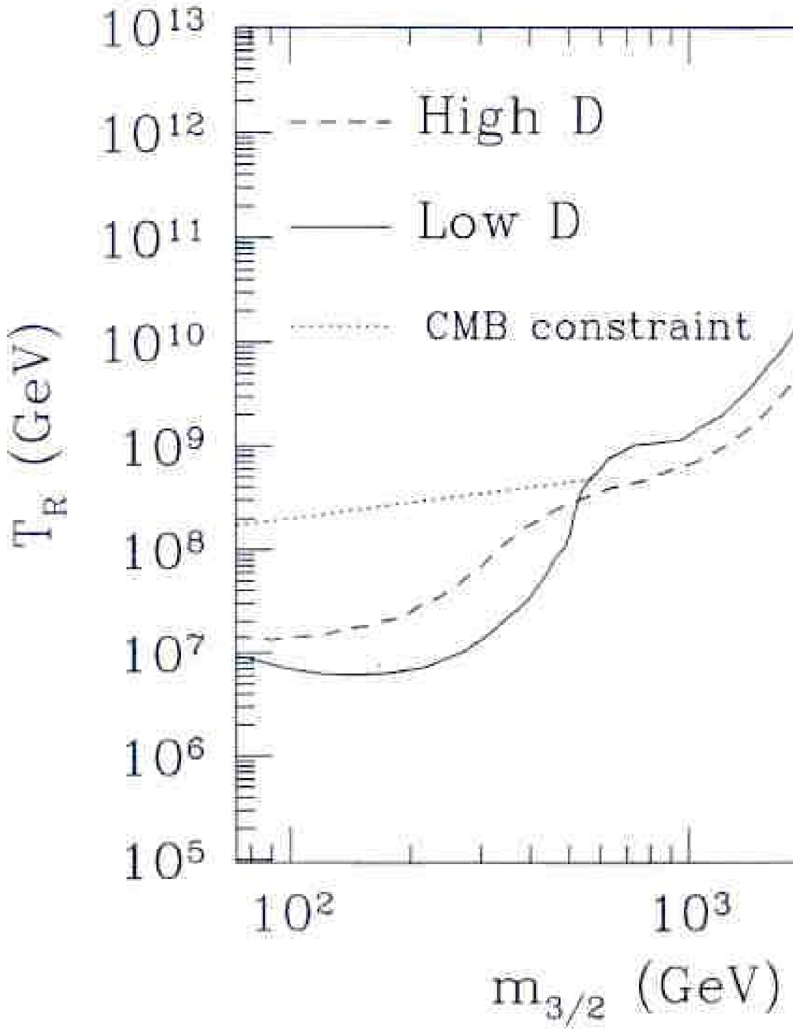


FIG. 3. Plot of the contour of the confidence level in $(m_{3/2}, T_R)$ plane. The solid (dashed) line denotes the 95% C.L. for Low D (High D). The dotted line denotes the upper bound which comes from CMB constraint.

$m_{\tilde{g}} = 1$ TeV

FIG. .

Kawasaki et al

LIFE TIME

$$\tau_{NLSP} \simeq 2\times 10^{6}\,\mathrm{sec}\left(\frac{m_{3/2}}{100\,\mathrm{GeV}}\right)^{2}\cdot\left(\frac{300\,\mathrm{GeV}}{m_{NLSP}}\right)^{5}$$

$$\tau_x \lesssim 10^{4}\,\mathrm{sec} \rightarrow \quad m_{3/2} \lesssim 10\ \mathrm{GeV}$$

GAUGE MEDIATION MODEL

↳ A SOLUTION TO THE FCNC PROBLEM.

10 eV — 1 keV — 100 keV — $m_{3/2}$

HOT DM | WARM DM | COLD DM

$$\frac{\rho_{3/2}}{\rho_{DM}} < 1\%$$

$$T_R \simeq F(m_{3/2})$$

$$\rho_{DM} = \rho_{3/2}$$

NO CONSTRAINT ON T_R

$$\begin{cases} m_{3/2} \lesssim 10\ \mathrm{eV} \\ m_{3/2} \gtrsim 100\ \mathrm{keV} \end{cases}$$

$m_{3/2} \lesssim 10$ eV IS INTERESTING, BECAUSE

THE THERMAL LEPTOGENESIS WORKS.

$T_{LG.} \simeq 10^{10}$ GeV

A GAUGE MEDIATION MODEL WAS FOUND

FOR $m_{3/2} \lesssim 10$ eV. Izawa

BUT, WE SHOULD HAVE A CANDIDATE FOR

DM OTHER THAN THE LSP.

~~ONE MOTIVATION FOR~~ SUSY

⇩

CONSIDER $m_{3/2} \simeq 100$ keV

$- 10$ GeV.

INFLATION MODELS
IN
SUGRA THEORY

PROBLEMS

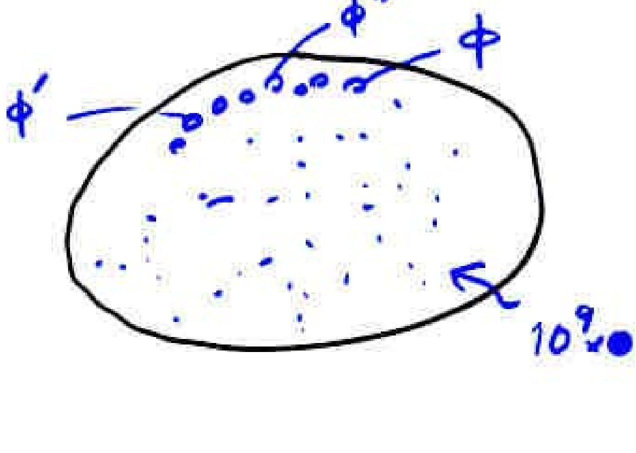
THE INITIAL CONDITION FOR INFLATION:

$$\rho_{inf} \simeq (\sim 10^{15}\,\mathrm{GeV})^4 \quad \leftarrow \frac{\delta T}{T} \simeq 10^{-5}\ \text{COBE}$$

$$\therefore \quad H_{inf} \simeq 10^{12}\,\mathrm{GeV}$$

AT THE TIME $t \simeq 1/H_{inf}$ ϕ_{inf} SHOULD HAVE THE SAME VALUE $\phi_{inf} = \phi_0$ IN THE HORIZON. ...... HORIZON PROBLEM

IF THE UNIVERSE STARTED AT THE PLANCK TIME $t_{PL} = 1/M_{PL}$. WE HAVE 10^9 REGIONS INDEPENDENT AT $t_{inf} \simeq 1/H_{inf}$.



AT t_{inf} $\simeq 1/H_{inf}$

FINE TUNING.

η - PROBLEM IN SUGRA INFLATION MODELS

$$V = e^{K}\left\{ |F_\phi|^2 - 3|W|^2 \right\}$$

DURING INFLATION $F_\phi \neq 0$ AND SUSY IS BROKEN. THEN, THE INFLATON HAS A SUSY BREAKING MASS $\sim |F_\phi|/M_{PL} \simeq H_{inf}$.

BUT, $m_\phi \ll H_{inf}$ TO GET THE SCALE INVARIANT SPECTRUM.

FOR THE HYBRID INFLATION MODEL

$$K = \phi^\dagger\phi + \eta\, \phi^\dagger\phi\, \phi^\dagger\phi + \cdots$$

$$n_s \simeq 1 - 8\times\eta \quad \simeq 1 \pm 0.02$$

WMAP

$$\eta \lesssim 5\times 10^{-3}$$

$$\eta = \frac{V''}{V} \sim \left(\frac{m_\phi}{H}\right)^2$$

FINE TUNING

- CHAOTIC INFLATION MODEL IS FREE FROM THE PROBLEMS. *Linde*

- THE INFLATION STARTS AT THE PLANCK TIME. THE INFLATON HAS A LARGE VALUE $|\phi_{inf}| \gg M_{PL}$. AT THE PLANCK TIME.

- $n_s \simeq 0.96$ FOR $V = \frac{1}{2} m^2 \phi^2$.

  NO η- PROBLEM.

BUT,

$$V = e^{\phi^* \phi} \left\{ |F_\phi|^2 - 3 |W|^2 \right\}$$

IN SUGRA AND HENCE

$$|\phi_{inf}| \lesssim M_{PL}.$$

HARD TO HAVE $|\phi_{inf}| \gg M_{PL}$!!

A SHIFT SYMMETRY

$$\Phi \to \Phi + i\,C M_{PL}$$

↑ REAL NUMBER

Kawasaki, Yamaguchi, T.Y.

$$K(\Phi, \Phi^{+}) = (\Phi + \Phi^{+})^{2} + \cdots\cdots$$

IF INFLATON = $\mathrm{Im}(\phi)$,

NO e^{K} TERM.

THE BREAKING OF THE S.S. IS GIVEN BY THE SUPRION FIELD Ξ :

$$\Xi \to \frac{\Phi}{\phi + iC}\,\Xi \quad . \quad (M_{PL} = 1)$$

$\Xi \cdot \Phi$ IS INVARIANT.

$$W = X \cdot \Xi\,\Phi + \cdots\cdots$$

$\langle \Xi \rangle = m$ INDUCES THE BREAKING MASS FOR INFLATON : $W = m X \Phi$.

$$K_0 = \frac{1}{2}(\Phi + \Phi^*)^2 + XX^*$$

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

INFLATON

$$\mathcal{L} = \frac{1}{2}(\partial_\mu \xi)^2 + \frac{1}{2}(\partial_\mu \varphi)^2 - V(\xi, \varphi, X)$$

NO φ^2 TERM

$$V = m^2 \exp(\xi^2 + |X|^2)$$
$$\times \Big[|X|^2 \{ 1 + 2\xi^2 + \xi^2(\xi^2 + \varphi^2) \}$$
$$+ \frac{1}{2}\{\xi^2 + \varphi^2\}\{1 - |X|^2 + |X|^4\} \Big]$$

$$\varphi \gg M_{PL} \quad : \quad \xi \simeq X \simeq 0$$

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

Linde POTENTIAL FOR CHAOTIC INFLATION

THE OBSERVATION ON $\frac{\delta T}{T} \sim 10^{-5}$

SUGGESTS $m \simeq 10^{13}\,\text{GeV}$.

WMAP

NO η PROBLEM :

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

$\frac{|F_X|^2}{1+K_{X\bar{X}}}$ TERM

$$K = K_0 + \eta' (\Phi + \Phi^*)^2 + \eta \, X X^* (\Phi + \Phi^*)^2 + \cdots$$

$$V \simeq \frac{\frac{1}{2} m^2 \varphi^2}{1 + \eta (\Phi + \Phi^*)^2 + \cdots}$$

BUT $\Phi + \Phi^*$ DOES NOT CONTAIN φ

$$V \simeq \frac{1}{2} m^2 \varphi^2 \{ 1 - 2\eta \, \xi^2 + \cdots \}$$

$$\simeq \frac{1}{2} m^2 \varphi^2 \qquad \text{FOR } \xi \simeq 0 .$$

THE SPECTRUM INDEX OF CMB PERTURBATION:

$$n_s \simeq 0.96$$

WE WILL SEE IT SOON.

WMAP

INFLATON DECAY

Φ HAS VANISHIN R CHARGE.

A POSSIBLE YUKAWA COUPLING IS

$$W = \lambda \langle \Xi \rangle \Phi \underbrace{N_i N_j}_{R=2} .$$

$$\simeq 10^{-5} \times \lambda \Phi N_i N_i$$

$$\because \frac{\langle \Xi \rangle}{M_{PL}} = \frac{m}{M_{PL}} \simeq 10^{-5}$$

$$\Gamma(\varphi \to N_i N_j) \simeq 10^{-10} \frac{\lambda^2}{4\pi} m$$

$$T_R \simeq 10^{-5} \frac{\lambda}{\sqrt{4\pi}} \cdot (g_*)^{-1/4} \sqrt{m \cdot M_{PL}}$$

$$\simeq \lambda \cdot 10^9 \ \mathrm{GeV}$$

LEPTOGENESIS

Fukugita, T. Y.

N DECAY :

$$N \to l + \bar{H} \quad ; \quad \bar{l} + H$$

IF $\Gamma(N \to l + \bar{H}) \neq \Gamma(N \to \bar{l} + H)$

WE HAVE A LEPTON ASYMMETR.

IT IS CONVERTED INTO BARYON ASYMMETRY

BY THE SPHALERON EFFECTS.

THE ASYMMETRY PARAMETER ε

$$\varepsilon \simeq 10^{-6} \cdot \left(\frac{m_\nu}{0.05\,\mathrm{eV}}\right)\left(\frac{M_N}{10^{10}\,\mathrm{GeV}}\right)\delta_{\mathrm{CP}}$$

Pascos et al

Buchmüller et al.

King et al

⋮

FROM N DECAY.

$$\text{INFLATON} \xrightarrow{\text{DECAY}} N \xrightarrow{\text{DECAY}} \ell + \bar{H} \; : \; \bar{\ell} H$$

Ellis, Raidal, T.Y.

Kumekawa et al
Shafi et al
Asaka et al
Giudice et al

$$\frac{n_\ell}{s} \simeq \varepsilon \times \frac{T_R}{m_\phi}$$

$$\simeq 10^{-6} \left(\frac{T_R}{10^{10}\,\mathrm{GeV}}\right) \left(\frac{m_\nu}{0.05\,\mathrm{eV}}\right) \left(\frac{M_N}{m_\phi}\right) \delta_{eff}$$

$T_R \gtrsim 10^{6}\,\mathrm{GeV}$ FOR $\frac{n_B}{s} \simeq 0.8 \times 10^{-10}$

WE EXPECT $M_{N_{1,2}} \simeq 10^{12} - 10^{13}\,\mathrm{GeV}$ AND

HENCE $M_N / m_\phi \simeq 0.3$.

$$\frac{n_B}{s} \simeq 3 \times 10^{-7} \left(\frac{m_\nu}{0.05\,\mathrm{eV}}\right) \left(\frac{T_R}{10^{10}\,\mathrm{GeV}}\right)$$

FOR $\delta_{eff} \simeq 1$.

COINCIDENCE PUZZLE BETWEEN Ω_{DM} AND Ω_B :

$$\Omega_{DM} h^2 \simeq 0.11 \quad \text{WMAP}$$

$$\Omega_B / \Omega_{DM} \simeq 0.2 \quad \text{WHY ?}$$

$$\text{DM} = \text{GRAVITINO} \quad \{ m_{3/2} \simeq 100 \text{ keV} - 10 \text{ GeV} \}$$

THE GRAVITINOS ARE PRODUCED BY THERMAL SCATTERING .

$$n_{3/2} \propto \left(\frac{1}{m_{3/2}}\right)^2 \left(m_{gluino}\right)^2 T_R$$

$\rho_c \simeq 10^{-5} h^2 \text{ GeV cm}^{-3}$

$$\Omega_{3/2} h^2 \simeq 0.2 \left(\frac{1 \text{ GeV}}{m_{3/2}}\right) \left(\frac{T_R}{10^8 \text{ GeV}}\right)$$

FOR $m_{gluino} \simeq 1$ TeV.

$$\frac{\Omega_{3/2}}{\Omega_B} \simeq 0.1 \left(\frac{30 \text{ MeV}}{m_{3/2}}\right) \left(\frac{m_\nu}{0.05 \text{ eV}}\right)$$

THIS RATIO IS INDEPENDENT OF T_R !!

THE OBSERVATION SUGGESTS

$$m_{3/2} \simeq 10 \text{ MeV} - 100 \text{ MeV}.$$

BARYON ASYMMETRY

THE OBSERVATION $\frac{n_B}{s} \sim 10^{-10}$

$$\Rightarrow \quad T_R \simeq 10^6 - 10^7 \text{ GeV}.$$

$$\lambda \simeq 10^{-2} - 10^{-3}$$

THIS IN NATURALLY EXPLAINED

BY. F-N MECHANISM.

F-N U(1) SYMMETRY :

	10_1	10_2	10_3	ε	H	$\bar{H}$
$U(1)_{FN}$	2	1	0	-1	0	0

$$W = \left\{ \varepsilon^4 10_1 \cdot 10_1 + \varepsilon^2 \cdot 10_2 \cdot 10_2 + 10_3 \cdot 10_3 \right\} H$$

$$m_t : m_c : m_u \simeq 1 : \varepsilon^2 : \varepsilon^4$$

$$\varepsilon \simeq 1/17$$

	5^*_1	5^*_2	5^*_3
$U(1)_{FN}$	1	0	0
		OR	
	2	1	1

$$m_\tau : m_\mu : m_e \simeq 1 : \varepsilon : \varepsilon^3$$

b s d

ν MASS MATRIX :

$$(5^*_1 \;\; 5^*_2 \;\; 5^*_3) \begin{pmatrix} \varepsilon^2 & \varepsilon & \varepsilon \\ \varepsilon & 1 & 1 \\ \varepsilon & 1 & 1 \end{pmatrix} \begin{pmatrix} 5^*_1 \\ 5^*_2 \\ 5^*_3 \end{pmatrix}$$

$\theta_{23} \simeq 1 \qquad \theta_{12} \simeq$ *large*

FN CHARGE FOR N_i

	N_1	N_2	N_3
$U(1)_{FN}$	2	1	0
		OR	
	1	0	0
		$\vdots$	

$m_{\nu_3} \simeq 0.05\,eV$ IMPLIES $M_3 \simeq 10^{15}\,GeV$

$$M_{1,2} \simeq \varepsilon^2 \cdot M \simeq 3\times 10^{12}\,GeV$$

ONE OF N_i MAY HAVE $\varepsilon^2 \cdot M$ AT LEAST.

IT IS SUFFICIENT FOR OUR SCENARIO IF THERE IS A N_i WHOSE FN CHARGE (+1).

CONSIDER THE COUPLING TO INFLATON:

$$W = \langle \Xi \rangle \, \Phi \cdot \varepsilon^2 N_i N_i$$

$$\hookrightarrow \lambda \simeq \varepsilon^2 \simeq 3 \times 10^{-3}$$

THE BARYON ASYMMETRY:

$$\frac{\Delta B}{s} \simeq 10^{-6} \left(\frac{T_R}{10^{10}\,\mathrm{GeV}} \right) \left(\frac{M_N}{m_\phi} \right)$$

$$\begin{cases} M_N = \varepsilon^2 \times 10^{15}\,\mathrm{GeV} \\ m_\phi \simeq 10^{13}\,\mathrm{GeV} \\ T_R \simeq \lambda \times 10^{9}\,\mathrm{GeV} \end{cases}$$

$$\frac{\Delta B}{S} \simeq 10^{-5} \times \varepsilon^4$$

QUARK - LEPTON MASS HIERARCHY

$\hookrightarrow \varepsilon \sim 1/17$

$\therefore \varepsilon^4 \sim 10^{-5}$

WE EXPLAIN THE OBSERVED

ASYMMETRY $\sim \frac{\Delta B}{S} \simeq 10^{-10}$!!!

CONCLUSION

THE GRAVITINO PROBLEM :

$T_R \lesssim 10^{4-5}$ GeV FOR $m_{3/2}$
$\simeq O(100)$ GeV
$- O(1)$ TeV

ELUDING THE LATE DECAY OF GRAVITINO.

⇩

(A) HEAVY GRAVITINO OF

$m_{3/2} \gtrsim 100$ TeV

ANOMALY MEDIATION

$m_{3/2} \gg m_{\tilde{g}, \tilde{\ell}}$ → FINE TUNING IS NEEDED.

(B) LIGHT GRAVITINO OF

$m_{3/2} \lesssim 10$ GeV

GAUGE MEDIATION

WE CONSIDER THE GAUGE MEDIATION.

NO FCNC PROBLEM.

THE SUSY SPECTRUM IS DETERMINED BY LOW-ENERGY PHYSICS.

→ RANDOMNESS AT THE PLANCK SCALE.

— ANY OPERATORS ARE ALLOWED UNLESS THEY ARE FORBIDDEN BY SYMMETRIES. —

CHAOTIC INFLATION IS INTERESTING!

· NO INITIAL CONDITION PROBLEM.

· NO η PROBLEM

$$K = \phi^*\phi + \eta\,\phi^*\phi\,\phi^*\phi$$

$$\eta \lesssim 10^{-2}.$$

SHIFT SYMMETRY

$$\Phi \to \Phi + iC M_{PL}.$$

Φ MAY HAVE A LARGE VALUE

$\Phi \gg M_{PL}.$

THE INFLATON φ DECAYS INTO $N_i + N_i$.

$$\varphi \to N_i + N_i$$

THE DECAY OF N_i CREATES THE LEPTON ASYMMETRY WHICH IS CONVERTED TO THE BARYON ASYMMETR. LEPTOGENESIS

$$\frac{n_B}{s} \simeq 10^{-5} \times \varepsilon^{4n}$$

	N_1	N_2	N_3
FN U(1)	k	n	ℓ

IF ONE OF $U(1)_{FN}$ CHARGE IS $(+1 = n)$, WE EXPLAIN THE OBSERVATION

$$\frac{n_B}{s} \sim 10^{-10}.$$

e.g.

5^*_1	5^*_2	5^*_3		10_1	10_2	10_3
1	0	0		2	1	0
OR						
2	1	1				

$$T_R = \varepsilon^{2n} \times 10^{9}\ \mathrm{GeV}$$

$$\simeq 3 \times 10^{6}\ \mathrm{GeV} \qquad \text{FOR} \quad n = 1$$

$\Omega_{DM} h^2 \simeq 0.11$ SUGGESTS $m_{3/2} \simeq O(100)$ MeV.

DM = THE GRAVITINO

$\tilde{\tau}$ MAY BE THE NEXT LSP.

$$\tilde{\tau} \to 3/2 + \tau$$

$$\Gamma_{\tilde{\tau}} = \frac{(m_{\tilde{\tau}}^2 - m_{3/2}^2 - m_{\tau}^2)^4}{48\pi\, m_{3/2}^2\, m_{\tilde{\tau}}^3\, M_{PL}^2} \left[1 - \frac{4 m_{3/2}^2 m_{\tau}^2}{(m_{\tilde{\tau}}^2 - m_{3/2}^2 - m_{\tau}^2)^2} \right]^{3/2}$$

$\tau_{\tilde{\tau}}$ MAY BE MEASURED BY STOPPED $\tilde{\tau}$.

IF WE MEASURE $m_{3/2}$, WE CAN FIND

IF $M_{PL} \simeq 2 \times 10^{18}$ GeV.

THIS IS INDEPENDENT TEST OF SUGRA!!!

Buchmuller Hamaguchi
Ratz. T. Y.