Implications of baryon asymmetry for the electric dipole moment of the neutron

Mayumi Aoki, Akio Sugamoto

Department of Physics and Graduate School of Humanities and Sciences
Ochanomizu University
Otsuka 2-1-1, Bunkyo-ku, Tokyo 112, Japan

Noriyuki Oshimo

Institute for Cosmic Ray Research
University of Tokyo
Midori-cho 3-2-1, Tanashi, Tokyo 188, Japan

Abstract

We study baryogenesis at the electroweak phase transition of the universe within the framework of the supersymmetric standard model (SSM) based on $N = 1$ supergravity. This model contains a new source of $CP$ violation in the mass-squared matrices for squarks, which could enable $t$ squarks to mediate the charge transport mechanism for generating baryon asymmetry. The same $CP$-violating source also induces the electric dipole moment (EDM) of the neutron at the one-loop level. If the new $CP$-violating phase is not suppressed, it is shown, the $t$-squark transport can lead to baryon asymmetry consistent with its observed value within reasonable ranges of SSM parameters. For these parameter ranges the magnitude of the neutron EDM is predicted to be not much smaller than its present experimental upper bound.

*Research Fellow of the Japan Society for the Promotion of Science.
The invariance for $CP$ transformation is not respected in nature. Up to now $CP$ violation has only been observed in the $K^0$-$\bar{K}^0$ system, which can be well described by the Kobayashi-Maskawa (KM) mechanism of the standard model (SM). On the other hand, baryon asymmetry of our universe could also be an outcome of $CP$ violation [1], which was shown not to be explained by the SM. Some extension for the SM seems to be necessary for baryogenesis. In fact, the SM can only generate baryon asymmetry much smaller than its observed value. However, it may nevertheless be understood within the framework of physics at the electroweak scale, if there exists some new source of $CP$ violation other than the KM mechanism.

The supersymmetric standard model (SSM) based on $N = 1$ supergravity [2] is one of the most plausible extensions of the SM at the electroweak scale, which has new $CP$-violating phases in addition to the standard KM phase. These new sources of $CP$ violation do not affect much the $K^0$-$\bar{K}^0$ or $B^0$-$\bar{B}^0$ system, while they could induce baryon asymmetry. In particular, under the condition that the electroweak phase transition of the universe is strongly first order, an enough amount of asymmetry may be generated through the charge transport mechanism mediated by charginos or $t$ squarks [3, 4, 5]. On the other hand, the same $CP$-violating phases give contributions to the electric dipole moments (EDMs) of the neutron and the electron at the one-loop level. If the baryon asymmetry is really attributed to the new phases, the EDMs will be predicted to have sizable values.

In this letter we study the possibility of baryogenesis in the SSM and its implications for the EDMs of the neutron and the electron. It is shown that the charge transport mechanism mediated by $t$ squarks can explain the baryon asymmetry, provided that the relevant $CP$-violating phase is not much suppressed. The masses of supersymmetric particles which allow the baryogenesis are mostly in the ranges of 100–1000 GeV. In these parameter ranges the EDMs of the neutron and the electron have magnitudes not much smaller than their present experimental upper bounds, which would be examined experimentally in the near future.

We first discuss new sources of $CP$ violation in the SSM. For the physical complex parameters intrinsic in this model, without loss of generality, we can take a Higgsino mass parameter $m_H$ for the bilinear term of the Higgs superfields in superpotential and several dimensionless coupling constants $A_f$ for the trilinear terms of the scalar fields which break supersymmetry softly. We express these parameters as

$$m_H = |m_H| \exp(i\theta),$$
$$A_f = A = |A| \exp(i\alpha).$$

(1)
Since $A_f$’s are considered to have the same value of order unity at the grand unification scale, their differences at the electroweak scale are small and thus can be neglected.

The new sources of $CP$ violation give contributions to the EDMs of the neutron and the electron through one-loop diagrams in which the charginos, neutralinos, or gluinos are exchanged together with the squarks or sleptons. If the $CP$-violating phase $\theta$ is of order unity, the neutron and electron EDMs receive large contributions from the chargino diagrams. From the experimental constraints, the masses of the squarks and sleptons are then predicted to be larger than 1 TeV, while the charginos and neutralinos could have masses of order 100 GeV [3]. In this case, it has been shown [2], the charginos can mediate the charge transport mechanism and generate an enough amount of baryon asymmetry. However, some extension of the Higgs sector may be necessary for the electroweak phase transition to be strongly first order. Therefore, we assume that the phase $\theta$ is much smaller than unity, so that sizable new $CP$-violating phenomena could only be induced by the phase $\alpha$. Then the gluino and neutralino diagrams, respectively, give dominant contributions to the neutron and electron EDMs, leading to relaxed constraints on the masses of supersymmetric particles [6].

The $CP$-violating phase $\alpha$ is contained in the squark mass-squared matrices. Corresponding to two chiralities for the quark, there are two species of squark for each flavor: the left-handed squark $\tilde{q}_L$ and the right-handed squark $\tilde{q}_R$. Neglecting generation mixings, these squarks are in mass eigenstates in the SU(2)\times U(1) symmetric vacuum. When this symmetry is broken, they are mixed to form mass eigenstates $\tilde{q}_1$ and $\tilde{q}_2$, owing to non-vanishing vacuum expectation values of the Higgs bosons. The mass-squared matrix $M^2_{\tilde{q}}$ for the squarks corresponding to a quark $q$ with the mass $m_q$, the electric charge $Q_q$, and the third component of the weak isospin $T_{3q}$ becomes

$$M^2_{\tilde{q}} = \begin{pmatrix} m_q^2 + \cos 2\beta (T_{3q} - Q_q \sin^2 \theta_W) M^2_Z + \tilde{M}^2_{qL} & m_q (R_q m_H + A^* m_{3/2}) \\ m_q (R_q m_H^* + A m_{3/2}) & m_q^2 + Q_q \cos 2\beta \sin^2 \theta_W M^2_Z + \tilde{M}^2_{qR} \end{pmatrix},$$

$$R_q = \frac{1}{\tan \beta} \quad (T_{3q} = \frac{1}{2}),$$

$$= \tan \beta \quad (T_{3q} = -\frac{1}{2}),$$

$$\tan \beta = \frac{v_2}{v_1},$$
where $v_1$ and $v_2$ stand for the vacuum expectation values of the Higgs bosons; $\tilde{M}_{qL}^2$ and $\tilde{M}_{qR}^2$, the mass-squared parameters for $\tilde{q}_L$ and $\tilde{q}_R$; and $m_{3/2}$ the gravitino mass. The value of $m_q$ is determined by $v_1$ for $T_{3q} = -1/2$ and by $v_2$ for $T_{3q} = 1/2$. The masses for $\tilde{q}_1$ and $\tilde{q}_2$ are obtained by diagonalizing $M_\tilde{q}^2$ in Eq. (2), which are denoted by $\tilde{M}_{q1}$ and $\tilde{M}_{q2}$. The phase $\alpha$ is also contained in the slepton mass-squared matrices, which are obtained by appropriately changing Eq. (2).

The baryon asymmetry could be generated by the charge transport mechanism [7], if the electroweak phase transition of the universe is strongly first order. At the phase transition, bubbles of the broken phase nucleate in the SU(2) $\times$ U(1) symmetric phase. On the bubble wall, left-handed $t$ squarks $\tilde{t}_L$ coming from the symmetric phase can be reflected to become right-handed $t$ squarks $\tilde{t}_R$, and vice versa. Mass eigenstates of $t$ squarks $\tilde{t}_1$ and $\tilde{t}_2$ in the broken phase can be transmitted to the symmetric phase and become left- or right-handed $t$ squarks. In these processes $CP$ violation makes differences in reflection or transmission probabilities between $CP$ conjugate states. Consequently some net charges are induced in the symmetric phase, which otherwise should remain vanishing. These net charges could lead to biases on equilibrium conditions in front of the wall favoring a non-vanishing value for the baryon number, which is then realized through electroweak anomaly. Although other squarks or sleptons could generate the net charges, their contributions can be neglected because of their small Yukawa coupling constants.

The reflection and transmission rates are obtained by solving the Klein-Gordon equations for the $t$ squarks. In the rest frame of the wall the equations are given by

$$\begin{pmatrix}
\frac{\partial^2}{\partial t^2} + (M_t^2)_{11} & (M_t^2)_{12} \\
(M_t^2)_{21} & \frac{\partial^2}{\partial z^2} + (M_t^2)_{22}
\end{pmatrix}
\begin{pmatrix}
\tilde{t}_L \\
\tilde{t}_R
\end{pmatrix} = \begin{pmatrix}
\frac{\partial^2}{\partial z^2} \left(\tilde{t}_L \right) \\
\frac{\partial^2}{\partial z^2} \left(\tilde{t}_R \right)
\end{pmatrix},$$

where $(M_t^2)_{ij}$ represents the $(i,j)$ component of the $t$-squark mass-squared matrix. The bubble wall is taken to be parallel to the $xy$-plane and perpendicular to the velocity of the particles. In the symmetric phase the vacuum expectation values $v_1$ and $v_2$ vanish, while in the broken phase they are related to the $W$-boson mass as $M_W = (g/2)\sqrt{v_1^2 + v_2^2}$. The vacuum expectation values vary along the $z$-axis in the wall. Taking the symmetric and broken phases in the regions $z < 0$ and $2\delta_W < z$, respectively, we assume that the $z$-dependences of $v_1$ and $v_2$ are given by

$$\sqrt{v_1^2 + v_2^2} = \frac{M_W}{g} \{1 + \tanh(\frac{z}{\delta_W} - 1)\pi\},$$

$$\frac{v_2}{v_1} = \left(5 - \frac{2z}{\delta_W}\right) \tan \beta,$$
where \( \tan \beta \) represents the ratio of \( v_2 \) to \( v_1 \) in the broken phase. The wall width \( \delta_W \) has been estimated in the SM as \( \delta_W \sim 10/T \) [8], although there are large uncertainties and model dependences. If the phase transition is strongly first order, the wall width becomes thinner. It is seen from Eq. [3] that the complex phase of \( (M_t^2)_{12} \) has to vary with \( z \) in order to violate \( CP \) invariance. This is satisfied, if the ratio \( v_2/v_1 \) has a \( z \)-dependence, as Eq. [5]. The Klein-Gordon equations are solved numerically following the procedure given in Ref. [4].

For the charge which gives a bias on the equilibrium conditions in the \( SU(2) \times U(1) \) symmetric phase, we take hypercharge. Since the hypercharges of \( \bar{t}_L \) and \( \bar{t}_R \) are respectively 1/6 and 2/3, \( CP \) asymmetries in the reflection and transmission rates lead to a net flux of hypercharge emitted from the bubble wall. In front of the wall the gauge interactions and the Yukawa interactions proportional to the \( t \)-quark mass are considered to be in chemical equilibrium. We also assume that the self interactions of Higgs bosons, Higgsinos, and \( SU(2) \times U(1) \) gauginos are in equilibrium, respectively. Among the supersymmetric particles, the gluinos are assumed to be heavy enough and out of equilibrium. Taking the densities for total baryon number, baryon number of the third generation, and lepton number to be approximately vanishing, the chemical potential \( \mu_B \) of the baryon number is related to the hypercharge density \( \rho_Y \) through the equilibrium conditions as

\[
\mu_B = -\frac{2\rho_Y}{9T^2},
\]

where \( T \) stands for the temperature of the electroweak phase transition. The number densities of the right-handed quarks and leptons except the \( t \) quark and of their superpartners have also been taken to be vanishing. We can see that the non-vanishing hypercharge density in the symmetric phase becomes a bias for the baryon number density.

In the symmetric phase, baryon number can change through electroweak anomaly at a nonnegligible rate. Assuming detailed balance for the transitions among the states of different baryon numbers, the rate equation of the baryon number density \( \rho_B \) is given by [3]

\[
\frac{d\rho_B}{dt} = -\frac{\Gamma}{T}\mu_B,
\]

\[
\Gamma = 3\kappa(\alpha_W T)^4,
\]

where \( \Gamma \) denotes the rate per unit time and unit volume for the transition between the neighboring states different by unity in baryon number, \( \kappa \) being 0.1 – 1 \([10]\).
From Eqs. (6) and (7) the baryon number density of the symmetric phase captured by the wall is roughly estimated as

$$\rho_B \approx \frac{2\Gamma F_Y \tau_T}{9T^3 v_W},$$  \hspace{1cm} (8)

where \(\tau_T\) represents the time which carriers of the hypercharge flux spend in the symmetric phase before captured by the wall; \(v_W\) the velocity of the wall; and \(F_Y\) the hypercharge flux emitted from the wall. The transport time \(\tau_T\) may be approximated by the mean free time of the carriers. The rough estimate for \(\tau_T\) gives values of order of \(10/\lambda T\) for the quarks [11], which would also be applicable to the squarks. The wall velocity \(v_W\) is estimated as \(v_W = 0.1 - 1\) [8]. The net hypercharge flux \(F_Y\) is given by

$$F_Y = F_{i_L} + F_{i_R} + \sum_{i=1}^{2} F_{i_i},$$  \hspace{1cm} (9)

$$F_{i_L} = -\frac{(1-v_W^2)T}{(2\pi)^2} \int_{\tilde{M}_{i_L}}^{\infty} dEE \ln[1 - \exp \left( -\frac{E - v_W \sqrt{E^2 - \tilde{M}_{i_L}^2}}{T \sqrt{1 - v_W^2}} \right)]$$

$$\frac{2}{3} \{R(\tilde{t}_L \rightarrow \tilde{t}_R) - R(\tilde{t}_L^* \rightarrow \tilde{t}_R^*)\},$$

$$F_{i_R} = -\frac{(1-v_W^2)T}{(2\pi)^2} \int_{\tilde{M}_{i_R}}^{\infty} dEE \ln[1 - \exp \left( -\frac{E - v_W \sqrt{E^2 - \tilde{M}_{i_R}^2}}{T \sqrt{1 - v_W^2}} \right)]$$

$$\frac{1}{6} \{R(\tilde{t}_R \rightarrow \tilde{t}_L) - R(\tilde{t}_R^* \rightarrow \tilde{t}_L^*)\},$$

$$F_{i_i} = -\frac{(1-v_W^2)T}{(2\pi)^2} \int_{\tilde{M}_{i_i}}^{\infty} dEE \ln[1 - \exp \left( -\frac{E + v_W \sqrt{E^2 - \tilde{M}_{i_i}^2}}{T \sqrt{1 - v_W^2}} \right)]$$

$$\left[ \frac{1}{6} \{R(\tilde{t}_i \rightarrow \tilde{t}_L) - R(\tilde{t}_i^* \rightarrow \tilde{t}_L^*)\} + \frac{2}{3} \{R(\tilde{t}_i \rightarrow \tilde{t}_R) - R(\tilde{t}_i^* \rightarrow \tilde{t}_R^*)\} \right],$$

where \(R(\tilde{t}_L \rightarrow \tilde{t}_R)\) etc. denote the probabilities for transitions at the wall. Although the procedure for obtaining Eq. (8) assumes various simplifications, it would still be reasonable for making only a rough estimate of the baryon number density.

The baryon number captured in the broken phase does not change, since there baryon number violation by electroweak anomaly is negligibly small. Consequently the ratio of baryon number to entropy becomes constant afterward, which is given by

$$\frac{\rho_B}{s} = \frac{15\kappa \alpha^2_H F_Y \tau_T}{\pi^2 g_s v_W T^2},$$  \hspace{1cm} (10)
where \( g_* \) represents the relativistic degree of freedom for the particles. For definiteness, we take \( g_* = 214.75 \), where all the particles except for the gluinos are taken into account. The ratio has been observed as \( \rho_B/s = (2 - 9) \times 10^{-11} \) \([12]\).

We show the ratio \( \rho_B/s \) in Fig. 1 as a function of the gravitino mass \( m_{3/2} \) for \( \alpha = \pi/4, \theta = 0, \tan \beta = 2, \) and \( |m_H| = 100 \) GeV. For simplicity, we set \( |A| = 1 \) and \( m_{3/2} = \tilde{M}_{4L} = \tilde{M}_{4R} \). In the mass ranges where curves are not drawn, the lightest squark has a mass smaller than 45 GeV, which is ruled out by experiments at LEP \([12]\). The temperature is taken for \( T = 200 \) GeV. We take four sets of values for \( v_W \) and \( \delta_W \) listed in Table 1, which correspond to four curves (i.a)−(ii.b). For definiteness we set \( \tau_T = 10/T \) and \( \kappa = 1 \). The resultant ratio can be compatible with the observed value, if the wall width is thin and \( \kappa \) is of order unity. The gravitino mass should be of order 100 GeV, whereas the ratio does not vary much with \( |m_H| \) and \( \tan \beta \). If the \( CP \)-violating phase \( \alpha \) is smaller than 0.1, it is difficult to generate an enough amount of asymmetry through this mechanism. The sign of \( \rho_B \) depends on the shape of \( v_2/v_1 \) in the wall as well as \( \alpha \).

In the parameter ranges where the baryon asymmetry can be explained, the EDMs of the neutron and the electron receive large contributions, respectively, from the gluino and the neutralino diagrams. The gluino contribution to the quark EDM is given by \([6]\)

\[
\begin{align*}
\frac{d_G}{e} &= \frac{2\alpha_S}{3\pi} \left( \sin \alpha |A| - R_q \sin \theta \frac{|m_H|}{m_{3/2}} \right) \frac{m_{3/2} m_q}{M_q^3} Q_q \tilde{m}_q \tilde{M}_q \left( \frac{\tilde{m}_q^2}{\tilde{M}_q^2} \right) K(r), \\
K(r) &= -\frac{1}{2(1-r)^3} \left[ 1 + 5r + \frac{2r(2+r)}{1-r} \ln r \right],
\end{align*}
\]

where \( \tilde{m}_q \) and \( \tilde{M}_q \) denote the gluino mass and the average mass for \( \tilde{M}_{q1} \) and \( \tilde{M}_{q2} \), respectively. Assuming the same mass for the gauginos at the grand unification scale, \( \tilde{m}_g \) is related to the SU(2) gaugino mass \( \tilde{m}_2 \) by \( \tilde{m}_g = \sin^2 \theta_W (\alpha_S/\alpha_{EM}) \tilde{m}_2 \). Since \( \theta \) is taken for zero, the chargino contribution to the EDM is negligible. From the non-relativistic quark model, the EDM of the neutron \( d_n \) is given by \( d_n = (4d_d - d_u)/3 \), where \( d_u \) and \( d_d \) are respectively the EDMs of the \( u \) quark and the \( d \) quark.

In Fig. 2 the neutron EDM is shown as a function of \( m_{3/2} \) for the same values of \( \alpha, \theta, \tan \beta, \) and \( |m_H| \) as those in Fig. 1. We also set \( |A| = 1 \) and \( m_{3/2} = \tilde{M}_{4L} = \tilde{M}_{4R} \) in the mass-squared matrices for the \( u \) squarks and the \( d \) squarks. Three curves correspond to three values for \( \tilde{m}_2 \): (i)200 GeV, (ii)500 GeV, (iii)1 TeV. In the mass ranges where curves are not drawn, the lightest squark is lighter than either 45 GeV or the lightest neutralino, the latter of which is disfavored by
cosmology. The experimental upper bound on the magnitude of the neutron EDM is about $1 \times 10^{-25}$ cm \cite{12}. For $m_2 = 500 - 1000$ GeV the EDM has a value of $10^{-25} - 10^{-26}$ cm, which is consistent with the experimental constraint though not much smaller than the upper bound. For the same parameter ranges the magnitude of the electron EDM is also not much smaller than its present experimental upper bound.

We have discussed whether baryon asymmetry of the universe could be generated at the electroweak phase transition in the SSM. If one $CP$-violating phase $\alpha$ is not suppressed while another phase $\theta$ being kept small, the $t$ squarks with the masses of order 100 GeV efficiently mediate the charge transport mechanism. An enough amount of asymmetry could be induced, provided that the bubble wall is thin and the value of $\kappa$ for the baryon number violation rate is not much smaller than unity. The masses of the other squarks and sleptons are of the the same order of magnitude as the $t$-squark masses. For $m_2, |m_H| \lesssim 1$ TeV the charginos and neutralinos have masses of 100 - 1000 GeV, whereas the gluinos are heavier than 1 TeV. For these parameter values the electroweak phase transition of the universe may be strongly first order \cite{13}, which is necessary for the charge transport mechanism. If the $CP$-violating phase $\theta$ is not suppressed, the charge transport mechanism can be mediated by the charginos with the masses of order 100 GeV instead of the $t$ squarks, providing an enough amount of asymmetry \cite{13}. In this case the squarks and sleptons have masses larger than 1 TeV, which may necessitate some extension for the Higgs sector of the SSM in order for the phase transition to be strongly first order.

The charge transport mechanism for baryogenesis in the SSM implies that the neutron and electron EDMs have magnitudes not much smaller than their present experimental upper bounds. For $\alpha \sim 1, \theta \ll 1$ the gluino diagrams give dominant contributions to the EDM of the neutron, while for $\theta \sim 1$ do the chargino diagrams. In both cases, the observed baryon asymmetry leads to the prediction for the neutron EDM of $10^{-25} - 10^{-26}$ cm. The EDM of the electron also receives a large contribution from the neutralino diagram for $\alpha \sim 1, \theta \ll 1$ or from the chargino diagram for $\theta \sim 1$. These predicted values would be within reach of experiments in the near future. In particular, the superthermal method for the production of ultracold neutrons \cite{14} could improve the accuracy of measurements for the neutron EDM by one order of magnitude. Possible detection of the EDMs would make the SSM a more credible candidate for the theory at the electroweak scale.
Acknowledgments

We thank J. Arafune and K. Yamamoto for many valuable discussions. The work of M.A. is supported in part by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture, Japan. This work is supported in part by the Grant-in-Aid for Scientific Research (No. 08640357) and by the Grant-in-Aid for Joint Scientific Research (No. 08044089) from the Ministry of Education, Science and Culture, Japan.

References

[1] For reviews, see e.g. A.G. Cohen, D.B. Kaplan, and A.E. Nelson, Annu. Rev. Nucl. Part. Sci. 43, 27 (1993); K. Funakubo, Prog. Theor. Phys. 96, 475 (1996).

[2] For reviews, see e.g. H.P. Nilles, Phys. Rep. 110, 1 (1984); P. Nath, R. Arnowitt, and A.H. Chamseddine, Applied N=1 Supergravity (World Scientific, Singapore, 1984); H.E. Haber and G.L. Kane, Phys. Rep. 117, 75 (1985).

[3] A.E. Nelson, D.B. Kaplan, and A.G. Cohen, Nucl. Phys. B373, 453 (1992).

[4] P. Huet and A.E. Nelson, Phys. Rev. D53, 4578 (1996).

[5] M. Aoki, N. Oshimo, and A. Sugamoto, OCHA-PP-87 (1996).

[6] Y. Kizukuri and N. Oshimo, Phys. Rev. D45, 1806 (1992); Phys. Rev. D46, 3025 (1992).

[7] A.G. Cohen, D.B. Kaplan, and A.E. Nelson, Phys. Lett. B245, 561 (1990); Nucl. Phys. B349, 727 (1991).

[8] N. Turok, Phys. Rev. Lett. 68, 1803 (1992); M. Dine, R.G. Leigh, P. Huet, A. Linde, and D. Linde, Phys. Rev. D46, 550 (1992); B.H. Liu, L. McLerran, and N. Turok, Phys. Rev. D46, 2668 (1992); P. Huet, K. Kajantie, R. G. Leigh, B.-H. Liu, and L. McLerran, Phys. Rev. D48, 2477 (1993).
[9] M. Dine, O. Lechtenfeld, B. Sakita, W. Fischler, and J. Polchinski, Nucl. Phys. B342, 381 (1990).

[10] J. Ambjorn and A. Krasnitz, Phys. Lett. B362, 97 (1995);
    P. Arnold, D. Son, and L.G. Yaffe, UW-PT-96-19.

[11] M. Joyce, T. Prokopec, and N. Turok, Phys. Lett. B338, 269 (1994); Phys. Rev. D53, 2930 (1996).

[12] Particle Data Group, Phys. Rev. D54, 1 (1996).

[13] B. de Carlos and J.R. Espinosa, SUSX-TH-97-005.

[14] H. Yoshiki et al., Phys. Rev. Lett. 68, 1323 (1992).
Figure 1: The ratio of baryon number to entropy as a function of $m_{3/2}$ for $\alpha = \pi/4$ and $\theta = 0$. The values of $v_W$ and $\delta_W$ for curves (i.a)–(ii.b) are given in Table 1. The other parameters are taken for $\tan \beta = 2$, $|m_H| = 100$ GeV, and $T = 200$ GeV.

|       | (i.a) | (i.b) | (ii.a) | (ii.b) |
|-------|-------|-------|--------|--------|
| $v_W$ | 0.1   | 0.1   | 0.6    | 0.6    |
| $\delta_W$ | 1/T   | 5/T   | 1/T    | 5/T    |
Figure 2: The electric dipole moment of the neutron as a function of $m_{3/2}$ for $\alpha = \pi/4$ and $\theta = 0$. Three curves correspond to three values for $\tilde{m}_2$: (i) 200 GeV, (ii) 500 GeV, (iii) 1 TeV. The other parameters are taken for $\tan \beta = 2$ and $|m_H| = 100$ GeV.