Phenomenological Consequences of Right-Handed Down Squark Mixings

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The mixings of d_R quarks, hidden from view in the standard model (SM), are naturally the largest if one has an Abelian flavor symmetry. With supersymmetry (SUSY) their effects can surface via $\tilde{d}_R$ squark loops. Squark and gluino masses are at TeV scale, but they can still induce effects comparable to SM in B_d (or B_s) mixings, while D^0 mixing could be close to recent hints from data. In general, CP phases would be different from SM, as may be indicated by recent B factory data. Presence of nonstandard soft SUSY breakings with large $\tan\beta$ could enhance $b \to d\gamma$ (or $s\gamma$) transitions.

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With the impressive advent of B factories, we are entering a new episode of flavor and CP violation studies. Charmless rare B decays hint that $\phi_3 \equiv \arg V_{ub}^*$ (in phase convention of [1]) may be larger than [2] suggested by a Cabibbo-Kobayashi-Maskawa (CKM) unitarity fit [3]. First results from both B factories [4] give smaller $\sin 2\phi_1$ (or $\sin 2\beta$, $\phi_1 \equiv \beta \equiv \arg V_{td}^*$) values than "expected" [3]. A plausible picture is that B_d or B_s mixings have additional new physics sources which invalidate the $\Delta m_{B_s}/\Delta m_{B_d}$ constraint, a notion that can be further probed at B factories, or at the Fermilab Tevatron collider. There are also recent hints [5] for D^0 mixing, which, if one has a strong phase difference [6] between $D^0 \to K^+\pi^-$ and $K^-\pi^+$ amplitudes, can again be taken as hinting at new physics. In this Letter we study a generic flavor violation scenario whereby B_d (or B_s) and D^0 mixings, as well as $b \to d\gamma$ (or $s\gamma$) transitions, could be measurably affected.

New physics in the flavor sector is likely since little is understood. For example, fermion masses and mixings exhibit an intriguing hierarchical pattern in powers of $\lambda \equiv |V_{us}|$. It suggests [7] a possible underlying symmetry, the breaking of which gives an expansion in $\lambda \sim \langle S\rangle/M$, with S a scalar field and M a high scale. If this "horizontal" (in flavor space) symmetry is Abelian, the commuting nature of horizontal charges in general gives $M_{ij}M_{ji} \sim M_{ii}M_{jj}$ (i, j not summed); hence [8]

$$\frac{M_u}{m_t} \sim \begin{bmatrix} \lambda^7 & \lambda^5 & \lambda^3 \\ \lambda^6 & \lambda^4 & \lambda^2 \\ \lambda^4 & \lambda^2 & 1 \end{bmatrix}, \qquad \frac{M_d}{m_b} \sim \begin{bmatrix} \lambda^4 & \lambda^3 & \lambda^3 \\ \lambda^3 & \lambda^2 & \lambda^2 \\ \lambda & 1 & 1 \end{bmatrix}. \tag{1}$$

The diagonal elements correspond to quark masses while the upper right (lower left) parts are diagonalized by U_{qL} (U_{qR}) rotations. We note that M_d^{32}/m_b and M_d^{31}/m_b are the most prominent off-diagonal elements [9]. Thus, B_d and B_s mixings are naturally susceptible to new physics arising from the right-handed down flavor sector.

As a leading candidate for new physics, SUSY offers a large toolbox for phenomenology. For example, squark mixings could generate flavor changing neutral currents (FCNC) because of strong $\tilde{q}$-$\tilde{g}$ coupling. It is customary to take squarks as almost degenerate at scale $\tilde{m}$, and the squark mixing angle in quark mass basis is $\delta_{qAB}^{ij} \cong [U_{qA}^\dagger(\tilde{M}_q^2)_{AB}U_{qB}]^{ij}/\tilde{m}^2$, where $A, B = L, R$, i, j are generation indices and $\tilde{M}_q^2$ are squark mass matrices. As U_{qL} is constrained by the CKM matrix V, mixing angles in U_{qR} are in general larger. If the breakings of flavor symmetry and SUSY are not closely related, then $(\tilde{M}_q^2)_{LR}$ and $(\tilde{M}_q^2)_{RL} = (\tilde{M}_q^2)_{LR}^\dagger$ are *roughly* proportional to respective quark mass matrices; hence their effects are suppressed by $m_q/\tilde{m}$. From Eq. (1), one easily gets $(\tilde{M}_Q^2)_{LL}/\tilde{m}^2 \sim V$, while

$$(\tilde{M}_d^2)_{RR} \sim \tilde{m}^2 \begin{bmatrix} 1 & \lambda & \lambda \\ \lambda & 1 & 1 \\ \lambda & 1 & 1 \end{bmatrix}, \tag{2}$$

illustrating that the RR sector could contribute significantly to B_d and B_s mixings via $\delta_{dRR}^{13} \sim \lambda$ and $\delta_{dRR}^{23} \sim 1$.

Defining $x \equiv m_{\tilde{g}}^2/\tilde{m}^2$, one has the effective Hamiltonian $H_{\rm eff} = -(\alpha_s^2/216\tilde{m}^2)(C_1\mathcal{O}_1 + \tilde{C}_1\tilde{\mathcal{O}}_1 + C_4\mathcal{O}_4 + C_5\mathcal{O}_5)$ induced by $\tilde{g}$-$\tilde{q}$ box diagrams, where $\mathcal{O}_1 = \bar{d}_{iL}^\alpha\gamma_\mu b_L^\alpha \bar{d}_{iL}^\beta\gamma^\mu b_L^\beta$, $\mathcal{O}_{4(5)} = \bar{d}_{iR}^\alpha b_L^{\alpha(\beta)}\bar{d}_{iL}^\beta b_R^{\beta(\alpha)}$, and [10]

$$\begin{aligned} C_1 &= [24xf_6(x) + 66\tilde{f}_6(x)](\delta_{LL}^{i3})^2, \\ C_{4(5)} &\cong [504(24)xf_6(x) - 72(+120)\tilde{f}_6(x)]\delta_{LL}^{i3}\delta_{RR}^{i3}, \end{aligned} \tag{3}$$

with $\tilde{C}_1\tilde{\mathcal{O}}_1$ obtained from $C_1\mathcal{O}_1$ by $L \to R$. Chargino and neutralino box diagram contributions are incorporated but numerically unimportant. Taking into account QCD running [11], it is easy to evaluate the B mixing parameter $M_{12}^B \equiv |M_{12}^B|e^{2i\phi_B} = |M_{12}^{\rm SM}|e^{2i\phi_1} + |M_{12}^{\rm SUSY}|e^{i\phi_{\rm SUSY}}$.

With $|V_{ub}| = 0.41|\lambda V_{cb}|$, $\phi_3 = 65°, 85°$, we get $|V_{td}| \times 10^3 = 8.0, 9.2$ and $\Delta m_{B_d}^{\rm SM} \sim 0.41, 0.55$ ps^{-1}, respectively, compared with $\Delta m_{B_d}^{\rm exp} = 0.472 \pm 0.017$ ps^{-1} [1]. Allowing $|M_{12}^{\rm SUSY}|$ to be at most of similar size, we find that $m_{\tilde{q}} \sim \tilde{m}$, $m_{\tilde{g}}$ cannot be much lighter than 1.5 TeV. For illustration we plot, in Figs. 1(a) and 1(b), $\Delta m_{B_d} \equiv 2|M_{12}^B|$ and $\sin 2\phi_{B_d}$ vs $\phi \equiv \arg\delta_{dRR}^{13}$, respectively, for $\tan\beta = 2$ and $|\mu| < m_{\tilde{g}}$. We see that $\sin 2\phi_{B_d}$ as measured from $B_d \to J/\psi K_S$ can range from 0.3 to 1,

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as compared to $\sin 2\phi_1 \simeq 0.75$–0.71 for $\phi_3 = 65°$–$85°$ in the SM. *The low* $\sin 2\phi_{B_d} \sim 0.3$–$0.4$ *possibility may be of particular interest* when compared to BaBar and Belle central values [4]. Whether B_s mixing is similarly affected, it is clear that the CKM unitarity bound from $\Delta m_{B_s}/\Delta m_{B_d}$ [3] should be relaxed, and the potential conflict on the ϕ_3 value with respect to charmless rare B decays [2] may be alleviated. With $\tilde{m}$, $m_{\tilde{g}} \gtrsim$ TeV and LR squark mixings suppressed by quark masses, there is little impact on penguins, and charmless B decays have better access to CKM unitarity phases, except being clouded by hadronic uncertainties.

Equations (1) and (2) are of course too naive. Since Δm_K is much smaller than Δm_{B_d} while ε_K is even tighter, $\delta^{12}_{dLL,RR} \sim \lambda$ is impossible to sustain, even with $\tilde{m}$, $m_{\tilde{g}} \gtrsim$ TeV. Through formulas similar to Eq. (3), the most severe constraint is on $\delta^{12}_{dLL}\delta^{12}_{dRR}$, which has to be suppressed by approximate "texture" zeros, achieved by invoking quark-squark alignment [8]. By using two (or more) singlet fields S_i to break the $U(1) \times U(1)$ (or higher) Abelian horizontal symmetry, and making use of the holomorphy nature of the superpotential in SUSY models, one can have $M_d^{12,21} = 0$ which implies $U^{12}_{dL,R} = 0$ (or highly suppressed), and likewise for $(\tilde{M}_d^2)^{12}_{LL,RR}$. Thus, $\delta^{12}_{dLL,RR}$ can be suppressed and the kaon mixing constraint satisfied accordingly.

There is one subtlety arising from our choice of nonvanishing M_d^{31}. Since M_d is diagonalized by bi-unitary transform, M_d^{23}/m_b, $M_d^{31}/m_b \sim \lambda^2$, λ are absorbed by U^{23}_{dL}, $U^{13}_{dR} \sim \lambda^2$, λ, respectively. Imposing $M_d^{12} = M_d^{21} = 0$, one finds $U^{12}_{dR} \sim \lambda$ is still needed to ensure $M_d^{21} \cong 0$. We see that $\delta^{12}_{dRR} \sim \lambda$ would again be generated, which is not acceptable. If we now set M_d^{23}/m_b to zero but retain $M_d^{32}/m_b \sim 1$, one finds $U^{23}_{dL} \sim \lambda^2$ is still needed, again leading to $U^{12}_{dR} \sim \lambda$. Thus, to keep $(\tilde{M}_d^2)^{13}_{RR}/\tilde{m}^2 \sim \lambda$, we need to decouple s flavor from other generations, i.e., M_d^{23} *and* M_d^{32} both set to zero, and we would have no new physics effects in B_s mixing and $b \to s\gamma$ decays. Stringent Δm_K and ε_K constraints lead to four texture zeros in M_d. In the usual approach of quark-squark alignment, one drops M_d^{31} and M_d^{32} (hence δ^{13}_{dRR} and δ^{23}_{dRR}) to satisfy B_d mixing and $b \to s\gamma$ constraints, allowing for lower $m_{\tilde{q}}$, $m_{\tilde{g}}$ that can give collider and other signatures. In an earlier work we considered decoupling the d flavor [12], which again has four texture zeros. We return to a discussion of this case later.

A general consequence of quark-squark alignment [8] is worthy of note: $U^{12}_{dL} \simeq 0$ implies $U^{12}_{uL} \sim |V_{cd}| = \lambda$, which would generate D^0–$\bar{D}^0$ mixing since $\delta^{12}_{uLL} \sim \lambda$. This is of interest since recent data hint at [5] the possible existence of D^0 mixing. The FOCUS experiment reports a 2.2σ deviation of the lifetime ratio of $D^0 \to K^-K^+$ vs $K^-\pi^+$ from 1, while the CLEO experiment reports a 1.8σ effect on $y'_D = y_D \cos\delta_D - x_D \sin\delta_D$, where $x_D \equiv \Delta m_D/\Gamma_D$, $y_D \equiv \Delta\Gamma_D/\Gamma_D$, and δ_D is the relative strong phase between $D^0 \to K^+\pi^-$ and $K^-\pi^+$ decay amplitudes. The two results can be better reconciled if $\delta_D \neq 0$ [6]. While it is certainly premature to conclude that one has nonvanishing x_D (which would imply new physics), what we find intriguing is that $\delta^{12}_{uLL} \sim \lambda$ *with* $\tilde{m}$, $m_{\tilde{g}} \sim$ TeV *brings* x_D *right into the ballpark of present sensitivities.* We illustrate x_D vs $\tilde{m}$ in Fig. 2 for several $m_{\tilde{g}}$ values $\gtrsim$TeV. The zeros reflect a possible cancellation between various terms in case the δ's have a common phase. In practice this is unlikely, since the SUSY phases in $\delta^{12}_{uLL,RR}$ are largely unconstrained, but it illustrates the adjustability of x_D. However, one has an explicit example where detectable D^0 mixing would likely [13] carry a CP violating phase.

Having satisfied Δm_K, ε_K by construction, one can still have interesting and measurable effects in B_d and D^0 mixings even if SUSY breaking is at TeV scale. This is because of large $\tilde{d}_R$-$\tilde{b}_R$ and $\tilde{u}_L$-$\tilde{c}_L$ mixings which follow from Abelian horizontal charges and low energy constraints. Unfortunately, the SUSY scale is so high such that there is practically no impact on penguins such as ε'/ε, $b \to s\gamma$ and $b \to d\gamma$. One also has the depressing situation that the squarks and gluino cannot be produced at the Tevatron or the CERN LHC. While we cannot change the latter, we find that radiative penguins can pick up some exotic effects in SUSY breaking, such as the presence of nonstandard soft breaking C terms.

We are interested in bona fide evidence for physics beyond the SM. One such effect is mixing dependent

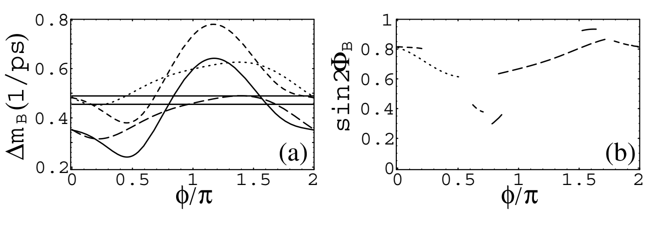

FIG. 1. (a) Δm_{B_d} and (b) $\sin 2\phi_{B_d}$ vs $\phi \equiv \arg\delta^{13}_{dRR}$, including both SM and SUSY effects, for squark mass $\tilde{m} = 1.5$ TeV. The solid (short-dashed), long-dashed (dotted) curves correspond to $m_{\tilde{g}} = 1.5$, 3 TeV for $\phi_3 = 65°$ (85°), respectively. The horizontal lines in (a) indicate the 2σ experimental range; theoretical error would allow larger $\sin 2\Phi_B$ range than shown.

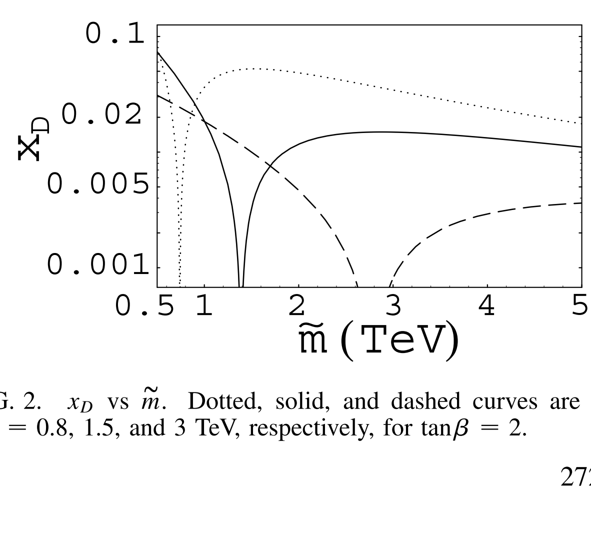

FIG. 2. x_D vs $\tilde{m}$. Dotted, solid, and dashed curves are for $m_{\tilde{g}} = 0.8$, 1.5, and 3 TeV, respectively, for $\tan\beta = 2$.

CP violation in $b \to s\gamma$ or $d\gamma$ transitions [14]. The effective Hamiltonian is given by $H_{\rm eff} \propto m_b \bar{d}(C_7 R + C_7' L)\sigma_{\mu\nu}F^{\mu\nu}b$. Mixing dependent CP violation in $B^0 \to M^0\gamma$ decay is rather analogous to the golden $J/\psi K_S$ mode; i.e., $a_{M^0\gamma} = \xi \sin 2\vartheta \sin[2\phi_B - \phi(C_7) - \phi(C_7')]\sin \Delta mt$, where $CP(M^0) = \xi M^0$, $\phi(C_7^{(\prime)})$ is the phase of $C_7^{(\prime)}$, and $\sin 2\vartheta \equiv 2|C_7 C_7'|/(|C_7|^2 + |C_7'|^2)$. One clearly needs both C_7 and C_7' for the interference to occur. In the SM, however, $C_7'/C_7 \propto m_{d,s}/m_b$ and is hence negligible. Thus, $a_{M^0\gamma}$ is sensitive to new physics [14].

At $\tilde{m}$ scale the SUSY contribution is

$$C'_{7,\tilde{g}} \propto \frac{g_s^2 Q_d}{G_F \tilde{m}^2}\left[\delta^{13}_{dRR} g_2(x) - \delta^{13}_{dRL}\frac{m_{\tilde{g}}}{m_b} g_4(x)\right], \quad (4)$$

where $g_l(x) = -d/dx[xF_l(x)]$ with $F_l(x)$ taken from [15]. Exchanging $L \leftrightarrow R$ gives the correction to C_7, and QCD running can be taken from [16]. The chiral or RL enhancement in Eq. (4) is apparent, noted already in our study [12] of large $\tilde{s}$-$\tilde{b}$ mixings. It has also been invoked to generate ε'/ε via an analogous δ^{12}_{LR} term [17] under a horizontal U(2) (hence non-Abelian) symmetry model.

We see that large δ^{13}_{dRR} or $\delta^{13}_{dRL} m_{\tilde{g}}/m_b$ are needed, which is precisely our case with Abelian horizontal symmetry. The RL enhancement factor $m_{\tilde{g}}/m_b$ can compensate for quark mass suppression in $(\tilde{M}_d^2)_{RL}$. Unfortunately, the high SUSY scale leads to too severe a suppression in $1/G_F\tilde{m}^2$. We find, however, that large $a_{M^0\gamma}$ is still possible when considering certain *nonstandard soft breaking terms* [18,19]. Allowing for a nonstandard $C\langle H_u^*\rangle Y'' \tilde{D}_L \tilde{D}_R^*$ [20] besides the standard $A_d\langle H_d\rangle Y' \tilde{D}_L \tilde{D}_R^*$, it is natural that $A_d \sim C \sim \tilde{m}$; hence $(\tilde{M}_d^2)^{ij}_{LR} \sim \tilde{m} M_d^{ij} \tan\beta$, and one gains a $\tan\beta \equiv |\langle H_u^*\rangle/\langle H_d\rangle|$ enhancement factor, while $(\tilde{M}_u^2)^{ij}_{LR} \sim \tilde{m} M_u^{ij}$ is unaffected. Some zeros in $(\tilde{M}_q^2)_{LR}$ may be lifted since these C terms are no longer holomorphic, but they are still suppressed. Arising from the superpotential, M_q, and hence $U_{qL,R}$, is unchanged, so the result for D^0 mixing remains unchanged. The δ^{12}_{dRL} contribution to kaon mixing remains protected by the smallness of $M_d^{21}/\tilde{m}$. Likewise, for B_d mixing, $\tan\beta$ enhancement of $\delta^{13}_{dLR,RL}$ is insufficient to overcome $m_q/\tilde{m}$ suppression and δ^{13}_{dRR} still dominates.

We illustrate in Figs. 3(a) and 3(b) the ratio $\mathcal{B}(B \to X_d\gamma)/\mathcal{B}(B \to X_d\gamma)_{\rm SM}$ and $\sin 2\vartheta$ with respect to $\tilde{m}$, for $m_{\tilde{g}} = 1.5$ TeV and $\tan\beta = 50, 20$, and 2 (this also illustrates the case of the standard A term only). The rate enhancement over the SM can reach a factor of 5, 1.8, and a few percent, respectively; *hence* $\mathcal{B}(B \to \rho\gamma)$ *could reach the* 10^{-5} *level, while* $\sin 2\vartheta$ *can easily reach maximum for large* $\tan\beta$. We note that current limits on $B \to \rho\gamma$ are beginning [21] to probe such levels, as the B factories have demonstrated their K/π (hence K^*/ρ) separation capabilities, and data are accumulating fast. There is a further advantage in studying mixing dependent CP asymmetries $a_{\rho^0\gamma}$, $a_{\omega\gamma}$: $\rho^0, \omega \to \pi^+\pi^-(\pi^0)$ gives vertex information

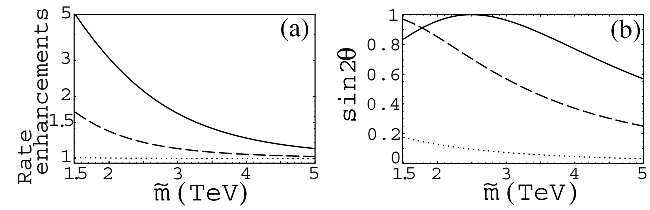

FIG. 3. (a) $\mathcal{B}(B \to X_d\gamma)/\mathcal{B}(B \to X_d\gamma)_{\rm SM}$ and (b) $\sin 2\vartheta$ vs $\tilde{m}$ for $m_{\tilde{g}} = 1.5$ TeV. The solid, dashed, and dotted curves correspond to $\tan\beta = 50, 20$, and 2, respectively.

but *not* in the $K^{*0} \to K^0\pi^0$ case, and one would have to go to modes such as $B^0 \to K_1^0\gamma$, where one is penalized by $K_1^0 \to \rho^0 K^0$ branching ratios.

Our exotic "nonstandard C term," together with large d_R-b_R mixing [Eqs. (1) and (2)] and large $\tan\beta$ (motivated by the large m_t/m_b ratio), gives an existence proof for possible prominence of $B \to \rho^0\gamma$, $\omega\gamma$ modes, both in rate and mixing dependent CP asymmetries. They should be priority search and study items for the coming years. Taking a more liberal point of view, in principle, one can have flavor violating soft SUSY breaking terms [12] which could easily generate $\delta^{13}_{dLR,RL}$ without resorting to nonstandard C terms. Thus, the $b \to d\gamma$ search provides a more general probe of flavor violation in SUSY.

We now entertain the case of decoupling d flavor but keeping $M_d^{32} \sim 1$, which was studied in [12] from a different perspective. From a consideration of Δm_K, ε_K, and D^0 mixing, the squarks and gluinos are again at TeV scale, but since $\tilde{s}_R$-$\tilde{b}_R$ mixing is large, there may be one squark that is lighter than the rest. Clearly, B_s mixing can be easily enhanced; hence the CKM unitarity constraint through $\Delta m_{B_s}/\Delta m_{B_d}$ again should be relaxed. Thus, a lower $\sin 2\phi_{B_d}$ than predicted by the CKM fit is possible, while the CP phase of B_s mixing is likely nonvanishing, testable at the Tevatron soon. The model, however, is constrained by $b \to s\gamma$. Since $\delta^{13}_{dRL}/\delta^{23}_{dRL} \sim \lambda \sim V_{td}/V_{ts}$ in the SM, we can take Fig. 3 as a rough estimate for $b \to s\gamma$ in the present case. Allowing for a 20% rate uncertainty for the measured $\mathcal{B}(B \to X_s\gamma) = (3.15 \pm 0.54) \times 10^{-4}$, we see that for the heavier $m_{\tilde{q}} \sim 3$ TeV case, $\tan\beta$ up to 20 is allowed, and $\sin 2\vartheta$ can go up to ~0.5; hence the $a_{M^0\gamma}$ study should also be pursued. For lighter $m_{\tilde{g}}$ such as 1.5 TeV, the enhancement factor for large $\tan\beta$ starts to break the good agreement between the SM and experiment; hence it seems one cannot have both large $\tan\beta$ and $\tilde{m}$, $m_{\tilde{g}}$ too light (TeV or less). This should apply to the lightest squark in the present case. One may alternatively say that, despite the stringent constraint of the $b \to s\gamma$ rate, one can still have nontrivial mixing dependent CP asymmetries.

We give explicit charge assignments for the main case studied. Two S_i fields are used to break the horizontal symmetry, $\langle S_1\rangle/M \sim \langle S_2\rangle/M \sim \tilde{\lambda}^{0.5}$, where $\tilde{\lambda} = 0.18$ (to fit the smallness of V_{ub} better). The horizontal charges are $(-1, 0)$ and $(0, -1)$ for S_1 and S_2, and

$$Q_1: (8,-2), \quad Q_2: (1,3), \quad Q_3: (2,-2),$$
$$\bar{d}_1: (-2, 10\,[5]), \quad \bar{d}_2: (9\,[4], -3), \quad \bar{d}_3: (-2, 8\,[3]),$$
$$\bar{u}_1: (-3, 11), \quad \bar{u}_2: (0,3), \quad \bar{u}_3: (-1,2),$$

for small $\tan\beta$ [$\tan\beta \sim 50$]. With these assignments, M_u^{21}, M_u^{31} and $M_d^{21,12}$, $M_d^{23,32}$ vanish, and corresponding elements in $(\widetilde{M}_d^2)_{RR}^{ij}/\widetilde{m}^2$ become $\sim\tilde{\lambda}^{12\,[7]}$ or $\tilde{\lambda}^{11\,[6]}$. The nonstandard C term restores the vanishing elements of $(\widetilde{M}_d^2)_{RR}^{ij} \sim \widetilde{m}M_q^{ij}$ to some power, but they do not affect quark mass. Additional rotations from the Kähler potential may lift the zeros to the so-called filled zeros [9]. Their effect is small in this model. Detailed discussions will be given elsewhere.

Some remarks are in order. (i) Our numerics are only illustrative, since the δ's cannot be specified fully. (ii) Because of stringent Δm_K and ε_K constraints, $(\varepsilon'/\varepsilon)^{\mathrm{SUSY}}$ in this model is always very small. (iii) The neutron edm is well protected by $m_d/\widetilde{m}$ in the generic picture. However, with nonstandard C terms, one may need to restrict the phase of M_d^{11} [and $(\widetilde{M}_d^2)_{LR}^{11}$ induced by μ] to 0.1 when $\tan\beta$ is very large (such as 50). (iv) Direct CP asymmetries in $b \to d\gamma$ would get diluted rather than enhanced by SUSY, especially if $a_{\rho^0\gamma}$, $a_{\omega^0\gamma}$ are large. (v) For large $\tan\beta$, the neutralino box diagram contribution to neutral meson mixings becomes important, especially if one takes a gaugino mass relation motivated by grand unification, which also holds true in gauge-mediated SUSY breaking models. However, the qualitative features of Figs. 1 and 2 remain the same. (vi) Chargino loops involving light stop or chargino may give rise to very significant effects [22] for large $\tan\beta$ that may require fine tuning. To avoid this, $|\mu| \sim$ TeV scale is needed. As for stop, we have followed Ref. [8] with the tacit assumption that flavor and SUSY scale are not too far apart; hence the stop does not become too light by large accumulative renormalization group running. Finally, with high $m_{\tilde{q}}$ and $m_{\tilde{g}}$ scale but no $\tan\beta$ enhancement, SUSY induced radiative $c \to u\gamma$ is smaller than two-loop SM correction, while for $t \to c\gamma$ it enhances the SM result of $\sim 10^{-13}$ by 3 orders of magnitude.

In summary, d_R quark mixings are naturally the largest in Abelian horizontal models. Such flavor (and CP) violation effects can be brought to light by $\tilde{d}_{jR}$ squark loops. Stringent K^0 mixing and ε_K constraints require setting $M_d^{12} = M_d^{21} = 0$. If we choose to retain $M_d^{31}/m_b \sim \lambda$, the s flavor has to be decoupled, and interestingly one does not have to face $b \to s\gamma$ constraint. Squarks and gluinos have to be at TeV scale, but they can shift $\sin 2\phi_1$ to the low value reported by B factories. Quark-squark alignment induces $\tilde{u}_L$-$\tilde{c}_L$ mixing that can give D^0 mixing close to recent hints from CLEO and FOCUS. Penguin related phenomena are in general untouched, but nonstandard soft SUSY breaking C terms could, through large $\tan\beta$ enhancement, bring $B \to \rho\gamma$, $\omega\gamma$ rates to the 10^{-5} level, while mixing dependent CP asymmetries could be maximal. Similar effects can be induced by generic flavor violating soft SUSY breaking terms. If one keeps $M_d^{32}/m_b \sim 1$, then d flavor has to be decoupled. B_s mixing can be greatly enhanced with likely the nonvanishing CP phase. One again could have measurable D^0 mixing, while the more constrained $b \to s\gamma$ transition could have mixing dependent CP asymmetries of order 50%. The new physics phenomenology outlined here can be tested at B factories and the Tevatron in the next few years.

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