A $U(2)^3$ flavour symmetry in SUSY

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based on:
Barbieri,Isidori,Jones-Perez,Lodone,Straub arXiv:1107.0266 [hep-ph]
Barbieri,Campli,Isidori,S,Straub arXiv:1108.5125 [hep-ph]

Outline

- Introduction/Motivations
- The $U(2)^3$ flavour symmetry in SUSY
- Phenomenology of $\Delta F = 2$ and $\Delta B = 1$ observables
- Conclusions

Minimal Flavour Violation in one slide

Flavour: excellent agreement between data and CKM picture

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MFV paradigm

$$U(3)^3 = U(3)_{Q_L} \times U(3)_{U_R} \times U(3)_{D_R}$$

$Y_u \sim (3, \bar{3}, 1)$, $Y_d \sim (3, 1, \bar{3})$ so that SM is formally invariant

Assumption: BSM also formally invariant, only with Y_u, Y_d

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Scorecard:

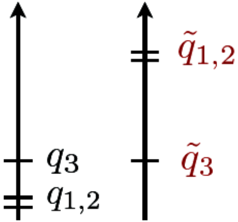
✓ Flavour violation controlled by the CKM matrix

$\Rightarrow$ TeV scale new physics OK with flavour bounds

× Flavour blind CP violation (smallness of EDMs)?

× Hierarchies (pattern of masses and mixing angles)?

A way to proceed



SUSY with heavy $1, 2$ generations

✓ Flavour blind CP violation

Other virtue:
Ok with naturalness and collider bounds

Reduce symmetry, round 1

From $U(3)^3$ to $U(2)$

✓ Partial explanation for hierarchies

× Too large flavour-violating effects in the RH sector

$U(2)^3$ in SUSY

Reduce symmetry, round 2

$$
\begin{array}{ccccccc}
U(2)^3 & = & U(2)_{Q_L} & \times & U(2)_{U_R} & \times & U(2)_{D_R} \\
 & & \downarrow & & \downarrow & & \downarrow \\
 & & \begin{pmatrix} q_L^1 \\ q_L^2 \end{pmatrix} & & \begin{pmatrix} u_R \\ c_R \end{pmatrix} & & \begin{pmatrix} d_R \\ s_R \end{pmatrix} \\
 & & q_L^3 & & t_R & & b_R
\end{array}
$$

Scorecard:

- ✓ Small flavour-violating effects (good flavour alignment)
- ✓ Small CP-violating flavour-conserving observables (EDMs)
- ✓ Partial explanation for Yukawa hierarchies

Breaking $U(2)^3$

Exact $U(2)^3$ $\longrightarrow$ $m_u = m_d = m_s = m_c = 0,\ V_{CKM} = 1$

$$Y_u = y_t \left(\begin{array}{c|c} 0 & 0 \\ \hline 0 & 1 \end{array}\right) \qquad Y_d = y_b \left(\begin{array}{c|c} 0 & 0 \\ \hline 0 & 1 \end{array}\right)$$

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Consequences

Diagonalize Yukawas and Squark mass matrix:

$$V_{\text{CKM}} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & s_u s e^{-i\delta} \\ -\lambda & 1-\lambda^2/2 & c_u s \\ -s_d s\, e^{i(\phi+\delta)} & -s c_d & 1 \end{pmatrix}$$

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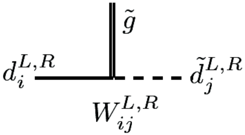

$$W^L = \begin{pmatrix} c_d & \kappa^* & -\kappa^* s_L e^{i\gamma} \\ -\kappa & c_d & -c_d s_L e^{i\gamma} \\ 0 & s_L e^{-i\gamma} & 1 \end{pmatrix}$$

$$W^R = 1$$

- 1 new angle s_L and 1 new CP-violating phase γ
- Crucial: minimal breaking leads to flavour alignement

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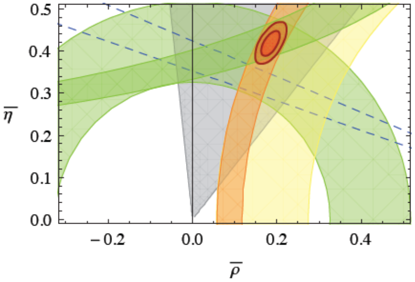
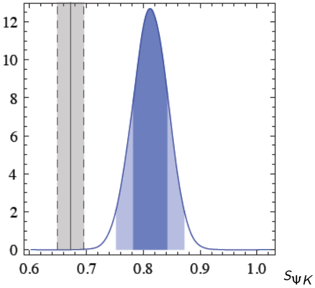
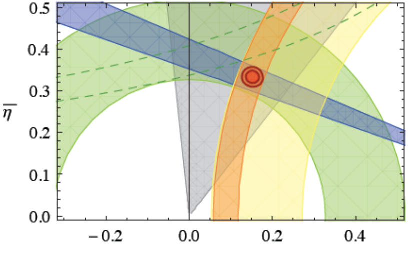
CKM fit tensions in the SM

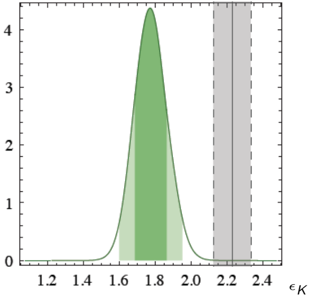
No $S_{\Psi K}$, SM:

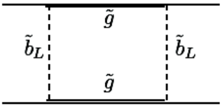




No ϵ_K, SM:





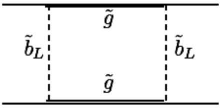


$$\xi_L = \frac{c_d s_L}{|V_{ts}|} e^{i\gamma}, \; F_0(m_{\tilde{b}}, m_{\tilde{g}}) > 0$$

$$\phi_\Delta = \arg\left(1 + \xi_L{}^2 F_0\right)$$

$$\begin{aligned} \epsilon_K &= \epsilon_K^{\mathrm{SM},tt}\left(1 + |\xi_L|^4 F_0\right) + \epsilon_K^{\mathrm{SM},tc+cc} \\ \Delta M^{d,s} &= \Delta M^{d,s}_{\mathrm{SM}}\left(1 + \xi_L^2 F_0\right) \\ S_{\psi K_S} &= \sin\left(2\beta + \phi_\Delta\right) \\ S_{\psi\phi} &= \sin\left(2|\beta_s| - \phi_\Delta\right) \end{aligned}$$

$\Delta F = 2$: K and B mixings



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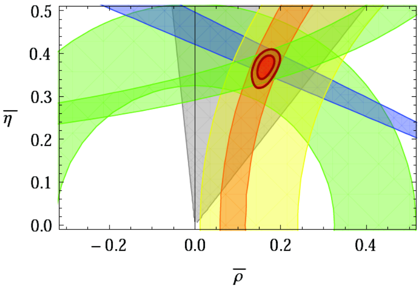

$$0.8 < |\xi_L| < 2.1$$

$$-9^\circ < \phi_\Delta < -1^\circ$$

$$-86^\circ < \gamma < -25^\circ \quad \text{or} \quad 94^\circ < \gamma < 155^\circ$$

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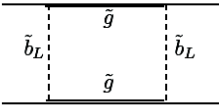

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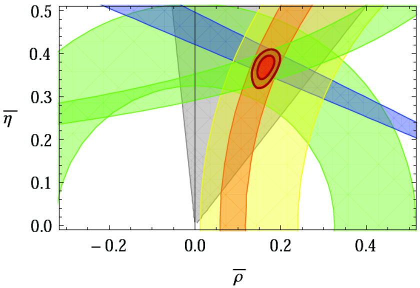

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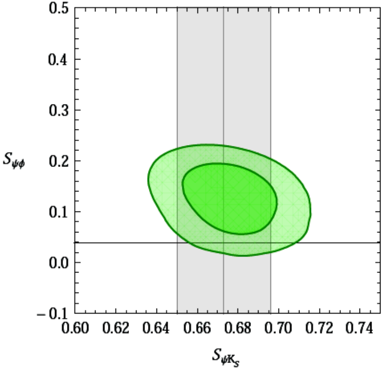
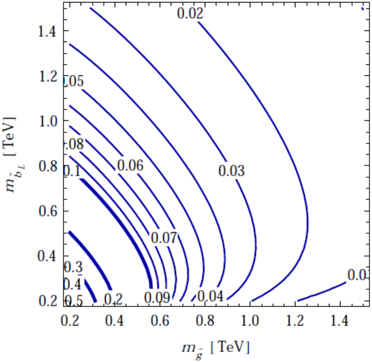
Predictions

1. Sizeable non-standard $S_{\psi\phi}$

2. $m_{\tilde{b}}, m_{\tilde{g}} < 1 \div 1.5\,\mathrm{TeV}$





F_0

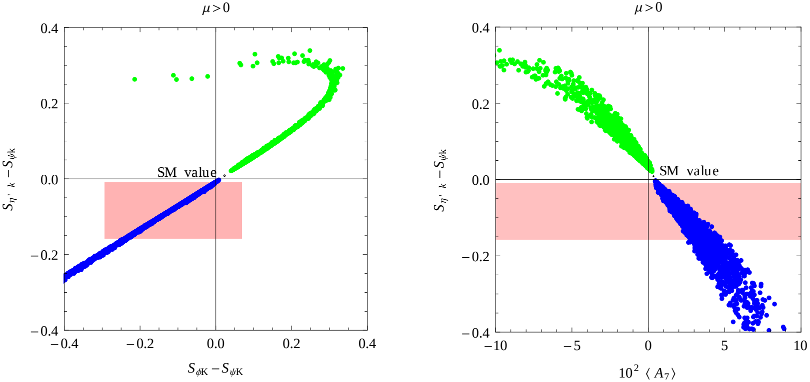
$\Delta B = 1$: shopping list

- $\mathrm{BR}(B \to X_s\gamma)$
- direct CP asymmetry in $B \to X_s\gamma$
- angular CP asymmetries in $B \to K^*\mu^+\mu^-$ ($\langle A_7\rangle$, $\langle A_8\rangle$)
- CP asymmetries in non-leptonic decays like $B \to \phi K_S$ or $B \to \eta' K_S$

	$\mathrm{BR}(B \to X_s\gamma)$	$S_{\phi K_S}$	$S_{\eta' K_S}$
Future improvements in sensitivity:	$\sim$ a 2 factor	$\sim$ a $5 \div 10$ factor!	

$\Delta B = 1$: some results

$$S_f = \sin(2\beta + \phi_\Delta + \delta_f), \quad \delta_f(\xi_L, \gamma, m_{\tilde{b}}, m_{\tilde{g}}, \mu \tan\beta - A_b), \quad f = \phi K_S, \eta' K_S$$



Blue: $\gamma > 0$, Green: $\gamma < 0$, Red shaded: experimental bound

Summary

$\Delta F = 2$

- new phase ϕ_Δ in $\Delta M^{d,s}$ [model-independent]
- $\Delta M^d / \Delta M^s$ SM-like [model-independent]
- no new phase in K mixing [model-independent]
- sign of correction to ϵ_K
- $0.05 \lesssim S_{\psi\phi} \lesssim 0.20$ $\quad m_{\tilde{b}}, m_{\tilde{g}} < 1 \div 1.5\,\mathrm{TeV}$

$\Delta B = 1$

- clean correlations between observables
- effects *can* be large

Importance of correlated studies to distinguish between models

Conclusions

We studied $U(2)^3$ in SUSY with heavy first 2 generations

$U(2)^3$ Enough flavour alignment

Yukawa hierarchies (partial explanation)

SUSY Small CP violation in flavour conserving observables

Ok with naturalness and collider bounds

Both Solve CKM fit tensions

Peculiar phenomenological pattern: wait for the LHC