CP Violation, B Mesons, and New Physics

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CP violation: first seen in 1964 when the decay $K_L \to \pi^+\pi^-$ was observed. Physical states are combination of CP $+$ and CP $-$.

Jump forward 35 years. The SM includes the CKM quark mixing matrix, which contains a weak-interaction phase. The CKM matrix describes CP violation in the Kaon system (one piece of data, one parameter). In order to *test* this explanation, have to look at predictions.

$$V_{CKM} \simeq \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3\left(\rho - i\eta\right) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3\left(1-\rho-i\eta\right) & -A\lambda^2 & 1 \end{pmatrix} ,$$

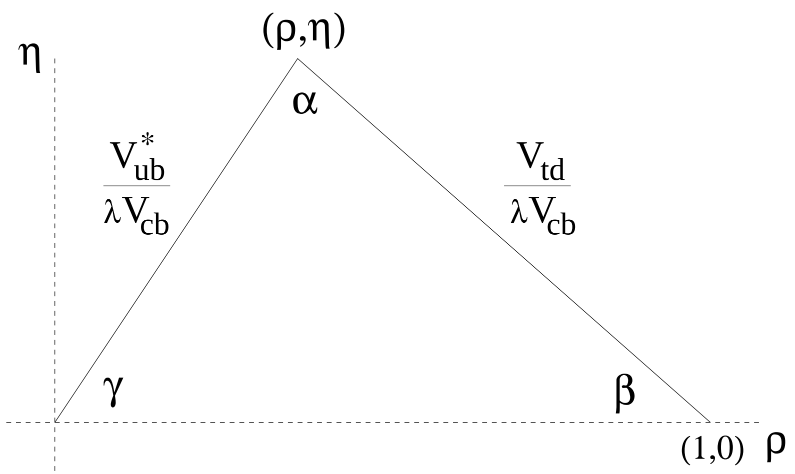
where $\lambda = 0.22$ (the Cabibbo angle). V_{CKM} is unitary to $O(\lambda^3)$.

With this parametrization, the most important phases are found in the elements of the corners, V_{ub} and V_{td}. Write: $V_{ub} = |V_{ub}| \exp(-i\gamma)$, $V_{td} = |V_{td}| \exp(-i\beta)$.

The first and third columns are orthogonal:

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 = |V_{ud}||V_{ub}|e^{i\gamma} + |V_{cd}||V_{cb}^*| + |V_{td}||V_{tb}|e^{-i\beta} \; .$$

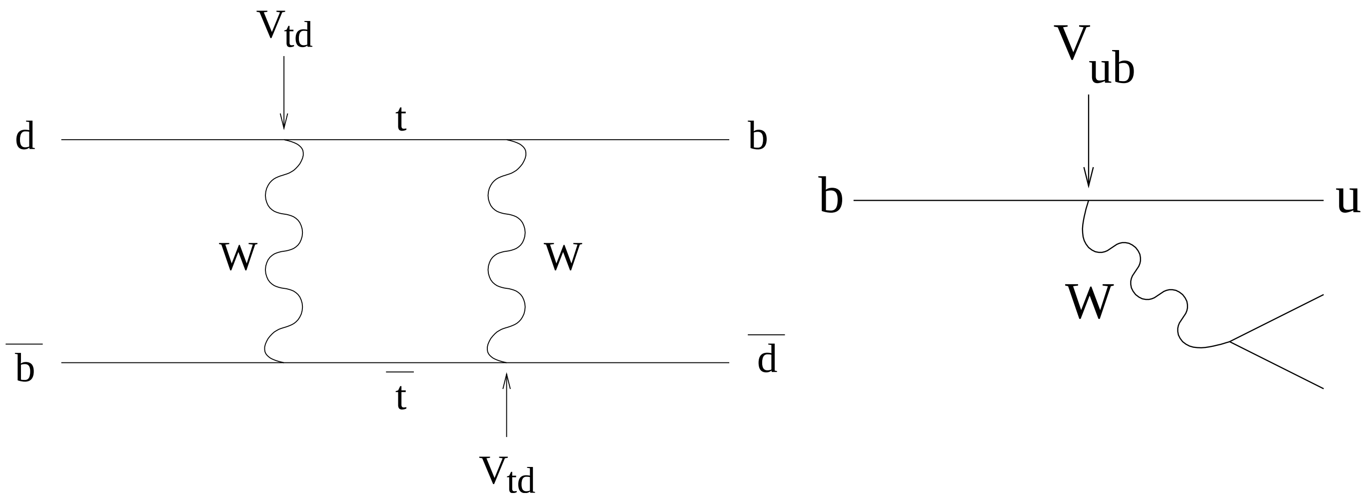
This is a triangle relation in the complex plane. It can be represented by the unitarity triangle:



The interior angles α, β and γ are all proportional to $\eta \Longrightarrow$ a nonzero value of one of these angles implies CP violation. The angles are not independent: $\alpha + \beta + \gamma = \pi$.

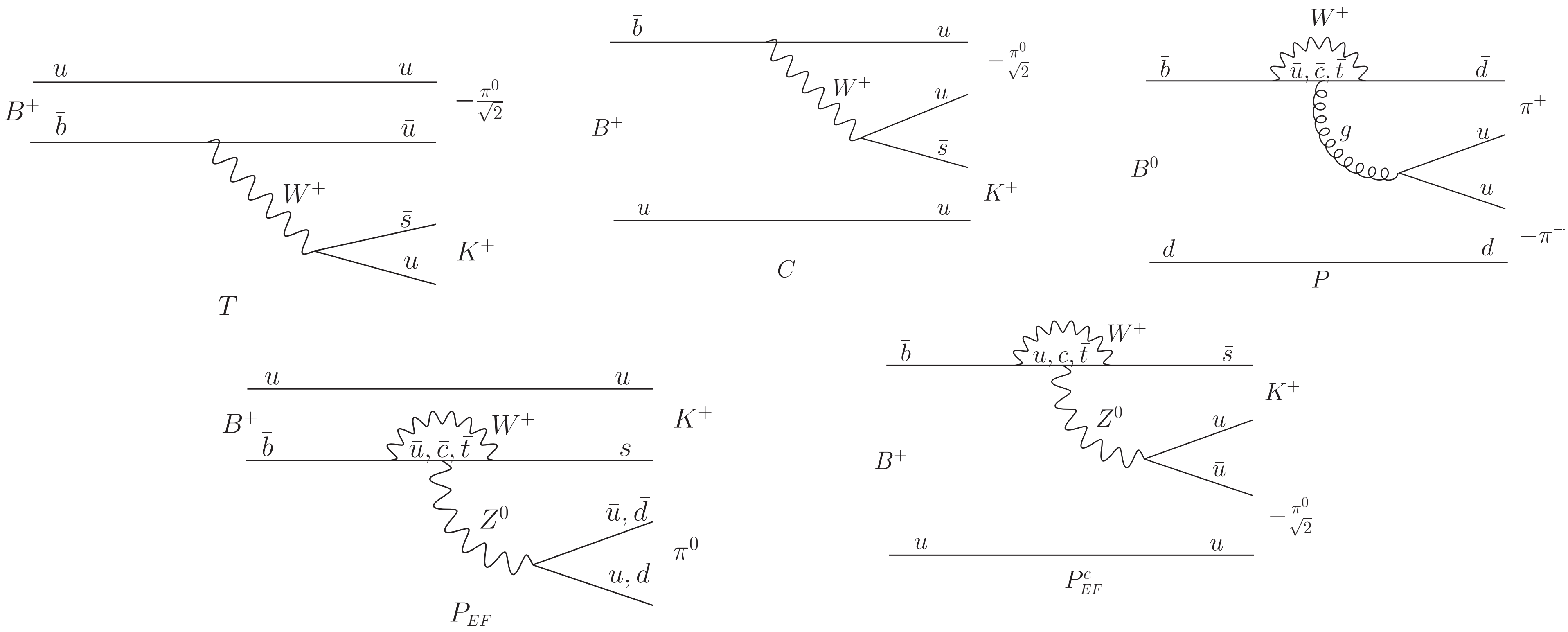
The idea is to measure the angles and sides of the unitarity triangle in many different ways to test the consistency of the SM explanation.

The two phases in the corner elements, β and γ, are found in processes involving B mesons:



In fact, we can measure all the angles α, β and γ in decays of B mesons.

Direct CP violation: the CP symmetry relates the decays $B \to f$ and $\bar{B} \to \bar{f} \Longrightarrow$ a difference between these two implies CP violation. Any CPV arises due to the interference of two amplitudes. In B decays, the possible amplitudes are the diagrams T, C, P, P_{EW}, P_{EW}^{C}.



The direct CP asymmetry is proportional to $\sin(\phi_1 - \phi_2)\sin(\delta_1 - \delta_2)$, where the ϕ_i and δ_i are the weak and strong phases of the interfering diagrams. We thus see that this effect requires that the two strong phases be unequal. Moreover, since the strong phases are unknown, it is impossible to obtain clean information about the weak phases from such asymmetries.

Indirect (mixing-induced) CP violation: $\exists\ B^0$–$\bar{B}^0$ mixing $\Longrightarrow$ a particle "born" as a B^0 will become in time a combination of B^0 and $\bar{B}^0$: $B^0(t)$. The $B^0(t)$ can decay as a B^0 or $\bar{B}^0$. If we consider a final state f to which both B^0 and $\bar{B}^0$ can decay, the process $B^0(t) \to f$ has two paths: $B^0 \to f$ or $\bar{B}^0 \to f$. These two amplitudes can interfere, leading to CPV. Unlike direct CP violation, if the final state is chosen carefully (and perhaps a few extra steps followed), strong phases do not enter.

By considering different final states f, one can extract all three CP-violating angles in $B^0(t) \to f$:

- α: $B_d^0(t) \to \pi\pi$, $\rho\pi$, $\rho\rho$, etc.
- β: $B_d^0(t) \to J/\psi K_S$, ϕK_S, etc.
- γ: $B \to DK$, $B_s^0(t) \to D_s^{\pm} K^{\mp}$, etc.

Latest values:

$$B_d^0(t) \to \pi\pi, \rho\pi, \rho\rho : \alpha = \left(87.5^{+6.2}_{-5.3}\right)^\circ \ .$$

$$\mathrm{charmonium} : \beta = (21.5 \pm 1.0)^\circ \ .$$

$$B \to DK : \gamma = \left(76.8^{+30.4}_{-31.5}\right)^\circ \ .$$

Almost all the results are consistent with each other and with the SM. However, there are some hints of disagreements.

$B \to \pi K$ decays

S. Baek, P. Hamel, D.L., A. Datta, D.A. Suprun, Phys. Rev. D71:057502, 2005;
S. Baek, D.L., Phys. Lett. B653:249, 2007.

There are four decays – $B^+ \to \pi^+ K^0$ (designated as $+0$), $B^+ \to \pi^0 K^+$ ($0+$), $B_d^0 \to \pi^- K^+$ ($-+$) and $B_d^0 \to \pi^0 K^0$ (00) – whose amplitudes are related by an isospin quadrilateral relation. The amplitudes can be written in terms of T', C', P'_{tc}, P'_{uc}, P'_{EW}, P'^C_{EW}. However, (i) P'_{EW} and P'^C_{EW} can be related to T' and C' using flavour SU(3) symmetry, and (ii) the relative sizes of the $B \to \pi K$ diagrams can be roughly estimated as $|P'_{tc}|$: 1; $|T'|$, $|P'_{EW}|$: $\mathcal{O}(\bar\lambda)$; $|C'|$, $|P'_{uc}|$, $|P'^C_{EW}|$: $\mathcal{O}(\bar\lambda^2)$, where $\bar\lambda \sim 0.2$. Ignoring the small $\mathcal{O}(\bar\lambda^2)$ diagrams, the four $B \to \pi K$ amplitudes are

$$
\begin{aligned}
A^{+0} &= -P'_{tc} \,, \\
\sqrt{2} A^{0+} &= -T' e^{i\gamma} + P'_{tc} - P'_{EW} \,, \\
A^{-+} &= -T' e^{i\gamma} + P'_{tc} \,, \\
\sqrt{2} A^{00} &= -P'_{tc} - P'_{EW} \,.
\end{aligned}
$$

The $B \to \pi K$ data is given by

Mode	$BR[10^{-6}]$	A_{CP}	S_{CP}
$B^+ \to \pi^+ K^0$	23.1 ± 1.0	0.009 ± 0.025	
$B^+ \to \pi^0 K^+$	12.8 ± 0.6	0.047 ± 0.026	
$B_d^0 \to \pi^- K^+$	19.7 ± 0.6	-0.093 ± 0.015	
$B_d^0 \to \pi^0 K^0$	10.0 ± 0.6	-0.12 ± 0.11	0.33 ± 0.21

The above table contains 4 branching ratios, 4 direct CP asymmetries A_{CP}, and 1 mixing-induced CP asymmetry S_{CP} for the four $B \to \pi K$ decay modes (2006).

A fit to the data was performed using the above amplitudes. Result: $\chi^2_{min}/d.o.f. = 25.0/5 \ (1.4 \times 10^{-4}) \Longrightarrow$ an extremely poor fit.

Add C' to the amplitudes:

$$\begin{aligned} A^{+0} &= -P'_{tc} , \\ \sqrt{2}A^{0+} &= -T'e^{i\gamma} - C'e^{i\gamma} + P'_{tc} - P'_{EW} , \\ A^{-+} &= -T'e^{i\gamma} + P'_{tc} , \\ \sqrt{2}A^{00} &= -C'e^{i\gamma} - P'_{tc} - P'_{EW} . \end{aligned}$$

Repeat the fit. Result: a good fit is found: $\chi^2_{min}/d.o.f. = 1.0/3\ (80\%)$. Does this mean there is, in fact, no $B \to \pi K$ puzzle?

No: $|C'/T'| = 1.6 \pm 0.3$ is required. This value is much larger than the previous naive estimates, as well as the predictions of NLO pQCD ($|C'/T'| \sim 0.3$), and SCET (QCDf) ($|C'/T'| \lesssim 0.6$). This shows explicitly that the $B \to \pi K$ puzzle is still present, at $\gtrsim$ the 3σ level.

Breaking news: with the latest data, it appears that the $B \to \pi K$ puzzle may have gone away. Seungwon Baek says that $|C'/T'| \simeq 0.63$ is now required, which is quite acceptable.

$B_d^0(t) \to \phi K_s$

The decay $B_d^0 \to J/\Psi K_S$ is dominated by $V_{cb}^* V_{cs}$, which is real. Thus, the indirect CP asymmetry here (or in any charmonium decay) measures the phase of B_d^0–$\bar{B}_d^0$ mixing, which is β. Similarly, the decay $B_d^0(t) \to \phi K_S$ is dominated by $V_{tb}^* V_{ts}$, which is also real. There are contributions from $V_{ub}^* V_{us}$, but $|V_{ub}^* V_{us}| \ll |V_{tb}^* V_{ts}|$. Thus, the indirect CP asymmetry in $B_d^0(t) \to \phi K_S$ should also measure β. (When the small corrections are carefully taken into account, $A_{CP}^{indir}(B_d^0(t) \to \phi K_S)$ is expected to be slightly larger than $A_{CP}^{indir}(\text{charmonium})$.)

Data:

$$
\begin{aligned}
A_{CP}^{indir}(\text{charmonium}) \quad &: \quad \sin 2\beta = 0.672 \pm 0.024 \ , \\
A_{CP}^{indir}(B_d^0(t) \to \phi K_S) \quad &: \quad \sin 2\beta = 0.44^{+0.17}_{-0.18} \ .
\end{aligned}
$$

Thus, there is a $\sim 1.5\sigma$ discrepancy here.

B_s^0-$\bar{B}_s^0$ Mixing

B_s^0-$\bar{B}_s^0$ mixing is dominated by $V_{tb}^* V_{ts}$, which is real. Thus, the weak phase of this mixing is expected to be $\beta_s \simeq 0$ in the SM.

Data:

$$\beta_s = 0.38^{+0.17}_{-0.18} \ .$$

Thus, there is a $\sim 2\sigma$ discrepancy here.

$B_s^0(t) \to J/\psi\phi$

Similarly, this decay is also real ($V_{cb}^* V_{cs}$). The indirect CP asymmetry is expected to be $\simeq 0$.

Data:

$$A_{CP}^{indir}(B_s^0(t) \to J/\psi\phi) : \phi_s = -0.57^{+0.24+0.07}_{-0.30-0.02} \; .$$

There is a $\sim 2\sigma$ discrepancy here.

$B_d^0 \to \phi K^*$

S. Baek, A. Datta, P. Hamel, O.F. Hernandez, D.L., Phys. Rev. D72:094008, 2005;
A. Datta, A.V. Gritsan, D.L., M. Nagashima, A. Szynkman, Phys. Rev. D76:034015, 2007

ϕ and K^* are both vector mesons, so that the final state can be transversely (2 states) or longitudinally (1 state) polarized. Naive calculation: in the B rest frame,

$$\epsilon_T^{(1)} = (0,1,0,0) \ , \quad \epsilon_T^{(2)} = (0,0,1,0) \ , \quad \epsilon_L = \frac{1}{m_V}(|\vec{p}|,0,0,E) \ .$$

Thus, we expect the transverse amplitudes to be suppressed by m_V/m_B with respect to the longitudinal amplitude. That is, the fraction of transverse decays, f_T, should be much less than the fraction of longitudinal decays, f_L.

However: $B_d^0 \to \phi K^*$: $f_T/f_L \simeq 1$. This is the “polarization puzzle.”

New physics is not necessarily needed here. If one goes beyond the naive SM, this result can be accounted for by large penguin annihilation (PA) or non-perturbative rescattering. However, the SM explanations of the large f_T/f_L generally require enhanced subleading amplitudes. In addition, large PA is possible within QCDf but not pQCD. Still, the polarization puzzle is not unquestionably a signal of new physics.

In the rest of the talk, I will briefly describe some projects I have recently been involved in, all related to the above hint of new physics.

New physics and the $B \to \pi K$ puzzle

A. Datta, M. Imbeault, D.L., V. Pagé, N. Sinha, R.Sinha, Phys. Rev. D71:096002, 2005;
S. Baek, P. Hamel, D.L., A. Datta, D.A. Suprun, Phys. Rev. D71:057502, 2005;
S. Baek, D.L., Phys. Lett. B653:249, 2007.

What can account for the $B \to \pi K$ puzzle? New physics (NP). The NP contributions to $B \to \pi K$ take the form $\mathcal{O}_{NP}^{ij,q} \sim \bar{s}\Gamma_i b\, \bar{q}\Gamma_j q$ ($q = u, d$) (the $\Gamma_{i,j}$ are Lorentz structures, colour indices are suppressed), each of which has a different weak and strong phase. Key point: NP strong phases are negligible. Thus, all NP matrix elements can now be combined into a single NP amplitude, with a single weak phase:

$$\sum \langle \pi K | \, \mathcal{O}_{NP}^{ij,q} \, | B \rangle = \mathcal{A}^q e^{i\Phi_q} \ .$$

Note: the NP operators come in two classes, differing in their colour structure: $\bar{s}_\alpha \Gamma_i b_\alpha \, \bar{q}_\beta \Gamma_j q_\beta$ and $\bar{s}_\alpha \Gamma_i b_\beta \, \bar{q}_\beta \Gamma_j q_\alpha$. This leads to two types of single NP amplitudes: $\mathcal{A}^{\prime,q} e^{i\Phi'_q}$ and $\mathcal{A}^{\prime C,q} e^{i\Phi'^C_q}$. (Despite the "colour-suppressed" index C, the matrix elements $\mathcal{A}^{\prime C,q} e^{i\Phi'^C_q}$ are not necessarily smaller than the $\mathcal{A}^{\prime,q} e^{i\Phi'_q}$.)

The $B \to \pi K$ amplitudes can now be written in terms of the SM diagrams to $O(\bar{\lambda})$ and 3 NP contributions: $\mathcal{A}^{\prime,comb} e^{i\Phi'}$, $\mathcal{A}^{\prime C,u} e^{i\Phi_u^{\prime C}}$, $\mathcal{A}^{\prime C,d} e^{i\Phi_d^{\prime C}}$, where $\mathcal{A}^{\prime,comb} e^{i\Phi'} \equiv -\mathcal{A}^{\prime,u} e^{i\Phi'_u} + \mathcal{A}^{\prime,d} e^{i\Phi'_d}$.

For the fit we assume that one of the 3 amplitudes is present. Results:

- (i) $\mathcal{A}^{\prime,comb} e^{i\Phi'}$: $\chi^2_{min}/d.o.f. = 0.6/3 \ (90\%)$;
- (ii) $\mathcal{A}^{\prime C,u} e^{i\Phi_u^{\prime C}}$: $\chi^2_{min}/d.o.f. = 4.0/3 \ (26\%)$;
- (iii) $\mathcal{A}^{\prime C,d} e^{i\Phi_d^{\prime C}}$: $\chi^2_{min}/d.o.f. = 21.1/3 \ (0.01\%)$.

A good fit is found only if the NP is in the form of $\mathcal{A}^{\prime,comb} e^{i\Phi'}$ (though the fit with $\mathcal{A}^{\prime C,u} e^{i\Phi_u^{\prime C}}$ is not terrible). This is consistent with the result found earlier that a modification of the SM electroweak-penguin operator could explain the puzzle. With $\mathcal{A}^{\prime,comb} e^{i\Phi'}$ we show that the intermediate particle need not be a vector (e.g. it could be a scalar – 2HDM).

The $B \to \pi K$ puzzle and SUSY

M. Imbeault, S. Baek, D.L., Phys. Lett. B663, 410, 2008

Here we explore whether supersymmetry (SUSY) can explain the $B \to \pi K$ puzzle. In order to perform our analysis, we have to choose a SUSY model. We use that of Grossman, Neubert and Kagan (GNK), proposed specifically to contribute to $B \to \pi K$ decays. We look at the contributions to $\mathcal{A}^{\prime,comb} e^{i\Phi'}$, $\mathcal{A}^{\prime C,u} e^{i\Phi_u^{\prime C}}$ and $\mathcal{A}^{\prime C,d} e^{i\Phi_d^{\prime C}}$ to see if the values of the NP operators are such that a good fit in $B \to \pi K$ can be obtained.

We find that this does not work – it requires a very precise pattern of SUSY parameters to explain the $B \to \pi K$ puzzle, and this is not found in most of the GNK SUSY parameter space.

Other SUSY models, such as mSUGRA, AMSB, GMSB, etc., do not fare any better. We conclude: “if this discrepancy with the SM remains in the years to come, it could pose a problem for SUSY models.” If the $B \to \pi K$ puzzle has indeed disappeared, it is good news for SUSY.

$B_d^0(t) \to \phi K_s$ and $B_d^0 \to \phi K^*$

A. Datta, M. Imbeault, D.L., Phys. Lett. B671, 256, 2009

Here we make the assumption that new physics (NP) is responsible for the polarization puzzle in $B_d^0 \to \phi K^*$. We note that any such solution must also reproduce the data in $B_d^0(t) \to \phi K_S$. Assuming that there is a NP contribution to $\bar{b} \to \bar{s} s \bar{s}$, it must take the form

$$\bar{s}\Gamma_i b \, \bar{s}\Gamma_j s \ ,$$

where $\Gamma_{i,j}$ represent the Lorentz structure (S/P, V/A or T). There are 10 such possibilities. In the above operators, we take the colors of the quark fields in each current to be the same. This is the case in most typical NP models (multi-Higgs-doublets, supersymmetry, extra Z's, etc.).

We now require that the measurements of both $B_d^0(t) \to \phi K_S$ and $B_d^0 \to \phi K^*$ be reproduced.

We find that no single NP operator can explain the observations in both $B_d^0(t) \to \phi K_S$ and $B_d^0 \to \phi K^*$.

For 2-NP-operator solutions, there are four possibilities, all of S/P type, which are presently allowed. Models which contain only V/A operators, such as those with supersymmetry or extra Z' bosons, cannot account for the measurements in both decays. Thus, as long as the discrepancy in $B_d^0(t) \to \phi K_S$ remains large, these models cannot generally explain the polarization puzzle. On the other hand, the two-Higgs-doublet model, which has only S/P operators, is favoured.

Now, in any $B \to V_1 V_2$ decay, one can construct the *triple product* (TP). In the rest frame of the B, the TP takes the form $\vec{q} \cdot (\vec{\varepsilon}_1 \times \vec{\varepsilon}_2)$, where $\vec{q}$ is the momentum of one of the final vector mesons, and $\vec{\varepsilon}_i$ is the polarization of the V_i. By adding or subtracting the TP's in B and $\bar{B}$ decays, one can form CP-conserving or CP-violating combinations. The four allowed S/P solutions can be distinguished through the measurements of TP's.

U-spin tests of the SM

M. Nagashima, A. Szynkman, D.L., Mod. Phys. Lett. A23, 1175, 2008

U-spin is the symmetry that transposes d and s quarks: $d \leftrightarrow s$. Gronau has shown that there exists a U-spin relation between the CP-violating rate differences of the $\Delta S = 0$ and $\Delta S = 1$ decays. Including U-spin breaking, this relation can be written

$$\frac{-A_{CP}^{dir}(\text{decay \#1})}{A_{CP}^{dir}(\text{decay \#2})} = \Delta U^2 \frac{BR(\text{decay \#2})}{BR(\text{decay \#1})} ,$$

where decays #1,2 are the $\Delta S = 0$ and $\Delta S = 1$ decays, in either order, related by U-spin. Note that if decays #1,2 include B_d^0 and B_s^0 mesons, there is an additional factor on the right-hand side taking the lifetime difference into account.

For a given decay pair, the U-spin breaking factor ΔU can be calculated using naive factorization. This is what is done here.

The pairs of $B \to PP$ decays (P is a pseudoscalar meson) which are related by U-spin are

1. $B_d^0 \to K^+\pi^-$ and $B_s^0 \to \pi^+K^-$,
2. $B_s^0 \to K^+K^-$ and $B_d^0 \to \pi^+\pi^-$,
3. $B_d^0 \to K^0\pi^0$ and $B_s^0 \to \bar{K}^0\pi^0$,
4. $B^+ \to K^0\pi^+$ and $B^+ \to \bar{K}^0K^+$,
5. $B_s^0 \to K^0\bar{K}^0$ and $B_d^0 \to \bar{K}^0K^0$,

In all cases, the first decay is $\Delta S = 1$; the second is $\Delta S = 0$.

We assume that any NP that breaks the U-spin relation lies in the $\Delta S = 1$ ($\bar{b} \to \bar{s}$) sector. We show that, to a good approximation, the NP operators that affect the above decays are the same as those in $B \to \pi K$: $\mathcal{A}'^{C,u}e^{i\Phi_u'^C}$, $\mathcal{A}'^{C,d}e^{i\Phi_d'^C}$, and $\mathcal{A}'^{,comb}e^{i\Phi'}$. $B_d^0 \to K^+\pi^-$ (pair #1) and $B_s^0 \to K^+K^-$ (pair #2) receive a NP contribution of the form $\mathcal{A}'^{C,u}e^{i\Phi_u'^C}$; $B_d^0 \to K^0\pi^0$ (pair #3) receives $\mathcal{A}'^{,comb}e^{i\Phi'} + \mathcal{A}'^{C,d}e^{i\Phi_d'^C}$; $B^+ \to K^0\pi^+$ (pair #4) and $B_s^0 \to K^0\bar{K}^0$ (pair #5) receive $\mathcal{A}'^{C,d}e^{i\Phi_d'^C}$.

Now, we saw that the $B \to \pi K$ puzzle is explained only if $\mathcal{A}^{\prime, comb} e^{i\Phi'}$ is added. That is, $\mathcal{A}^{\prime C,u} e^{i\Phi_u^{\prime C}}$ and $\mathcal{A}^{\prime C,d} e^{i\Phi_d^{\prime C}}$ can be taken to be small. In this case, we find that the present $B \to \pi K$ data predicts that, of the five U-spin pairs, one expects a measurable discrepancy with the SM (taking U-spin breaking into account) only for pair #3: $B_d^0 \to K^0 \pi^0$ and $B_s^0 \to \bar{K}^0 \pi^0$.

Note that this result is based on the conclusion that a $B \to \pi K$ puzzle is present. However, if all discrepancies in the $B \to \pi K$ system disappear, all NP operators are small, which means that there will be no disagreement with the SM for any U-spin pair.

Final-state Polarization in B_s Decays

A. Datta, D.L., J. Matias, M. Nagashima, A. Szynkman, to be published in Eur. Phys. Jour. C, 2009

Here we make the assumption that penguin annihilation (PA, predicted by QCDf) is responsible for the polarization puzzle in $B_d^0 \to \phi K^*$. It is important to test this explanation in order to determine whether new physics is or is not present. The polarization puzzle has been mainly seen in $\bar{b} \to \bar{s}$ transitions. However, if PA is the true explanation, one also expects to observe large f_T/f_L in $\bar{b} \to \bar{d}$ decays.

QCDf contains incalculable infrared divergences in its expressions for higher-order quantities (of which PA is one). These divergences are regularized with a cutoff. This leads to reasonable order-of-magnitude estimates, but gives too-large uncertainties for making precise predictions of polarizations in decays. We show that the ratio of transverse amplitudes for certain carefully-chosen B decays is essentially independent of these divergences. This allows us to precisely relate the polarizations of particular decays.

Technical point: this holds only with asymptotic light-cone distribution (LCD) amplitudes. These are generally used in QCDf calculations, but if non-asymptotic LCDs are important for mesons, then the ratio does depend on the divergences in PA, and the conclusions given here will be invalidated.

We find that there are several decay pairs for which PA makes a reasonably precise estimate of the SU(3) breaking in relating $\bar{b} \to \bar{s}$ and $\bar{b} \to \bar{d}$. Thus, given the measurement of f_T/f_L in one decay, PA makes a prediction for the transverse polarization in the second decay. We have concentrated on two decay pairs that involve B_s^0 mesons: ($B_s^0 \to \phi\phi, B_d^0 \to \phi K^{0*}$) and ($B_s^0 \to \phi\bar{K}^{0*}, B_d^0 \to \bar{K}^{0*}K^{0*}$). The polarization measurement in the B_d^0 decay ($\bar{b} \to \bar{s}$) allows one to predict the transverse polarization in the B_s^0 decay ($\bar{b} \to \bar{d}$). This will permit the explicit testing of PA, as well as the assumptions of QCDf, probably in the near future at the LHCb.

Conclusions

The B-factories BaBar and Belle were built with the idea of testing the SM explanation of CP violation, by making measurements in the B system. These machines have now stopped taking data, but the analysis will continue for several years. They were both extremely successful: they basically verified the unitarity triangle, showing that the SM explanation is correct.

However, it might not be the complete story. They also found some disagreements with the predictions of the SM, at varying levels of statistical significance. There are further discrepancies in the B_s^0 system, from CDF/D0. These are intriguing, since they are all in $\bar{b} \to \bar{s}$ transitions.

It will be important to keep an eye on these disagreements, to look at the latest data analysis, and follow the results from LHCb, particularly in B_s^0 decays. It will also be important to make further tests (some are described in this talk). Not all the discrepancies can remain (I don't believe there is a NP model which explains them all), but those which do will give us some clues as to the physics which lies beyond the SM.