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Erratum: Charming new B-physics

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In our original work we removed contributions proportional to B_4' and B_5' from our results, incorrectly neglecting them as being $\mathcal{O}\left(\frac{\Lambda_{\rm QCD}}{m_b}\right)$. After restoring them, eqs. (3.19) to (3.21) should read:

$$\begin{aligned}\Gamma_{12}^{c\bar{c}} &= \frac{4G_F^2\lambda_c^2}{M_{B_s}}\sum_{i=1}^{20}\sum_{j=1}^{20} C_i^c C_j^c \langle B_s|\mathrm{Im}\left\{i\int d^4x T[Q_i^c(x)Q_j^c(0)]\right\}|\bar{B}_s\rangle \\ &= \frac{G_F^2\lambda_c^2 m_b^2 M_{B_s} f_{B_s}^2}{12\pi}\sqrt{1-z}\left[8G(z)B + F(z)\tilde{B}_S' + \frac{1}{4}H(z)B_4' + \frac{1}{12}J(z)B_5'\right] \\ &\quad + \mathcal{O}\left(\frac{\Lambda_{\rm QCD}}{m_b}\right) + \mathcal{O}(\alpha_s)\,.\end{aligned} \tag{3.19}$$

The arising four quark operators can be parametrised as

$$\begin{aligned}\langle Q\rangle &= \frac{8}{3}M_{B_s}^2 f_{B_s}^2 B\,, \qquad \langle\tilde{Q}_S\rangle = \frac{1}{3}M_{B_s}^2 f_{B_s}^2 \tilde{B}_S'\,, \\ \langle Q_4\rangle &= \frac{1}{2}M_{B_s}^2 f_{B_s}^2 B_4'\,, \qquad \langle Q_5\rangle = \frac{1}{6}M_{B_s}^2 f_{B_s}^2 B_5'\,,\end{aligned} \tag{3.20}$$

with

$$\begin{aligned}\tilde{B}_S' &= \frac{M_{B_s}^2}{(\bar{m}_b(\bar{m}_b)+\bar{m}_s(\bar{m}_b))^2}\tilde{B}_S\,, \\ B_4' &= \left(\frac{M_{B_s}^2}{(\bar{m}_b(\bar{m}_b)+\bar{m}_s(\bar{m}_b))^2} + \frac{1}{6}\right)B_4\,, \\ B_5' &= \left(\frac{M_{B_s}^2}{(\bar{m}_b(\bar{m}_b)+\bar{m}_s(\bar{m}_b))^2} + \frac{3}{2}\right)B_5\,,\end{aligned} \tag{3.21}$$

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which matches the definitions in [1] for Q and $\tilde{Q}_s$ and [2–4] for Q_4 and Q_5; these bag parameters have been recently determined in [2–4].

The coefficient functions $F(z)$ and $G(z)$ (eqs. (3.22) and (3.23)) remain unchanged, and we add here the new functions $J(z)$ and $H(z)$:

$$\begin{aligned}
H(z) = z\Big[&2(3C_3^c+C_4^c)C_1^{c'}+2(6C_2^c+C_3^c+C_4^c)C_2^{c'}+3C_4^cC_4^{c'}+2C_2^c(C_3^{c'}+C_4^{c'})-24C_5^cC_6^{c'}\\
&+2C_1^c(3C_3^{c'}+C_4^{c'})-6(12C_5^c+4C_6^c+3C_7^c+C_8^c+36C_9^c)C_5^{c'}-6C_7^cC_6^{c'}-18C_5^cC_7^{c'}\\
&-6C_6^cC_7^{c'}-6C_7^cC_7^{c'}-2C_8^cC_7^{c'}-6C_5^cC_8^{c'}-2C_7^cC_8^{c'}+C_8^cC_8^{c'}-72(3C_5^c-C_6^c)C_9^{c'}\\
&-48C_7^cC_9^{c'}-16C_8^cC_9^{c'}-4C_8^cC_{10}^{c'}-4C_{10}^c(18C_5^{c'}+4C_7^{c'}+C_8^{c'}+56C_9^{c'}-4C_{10}^{c'})\\
&-72C_5^cC_{10}^{c'}-16C_7^cC_{10}^{c'}-8C_9^c(9C_6^{c'}+6C_7^{c'}+2C_8^{c'}+84C_9^{c'}+28C_{10}^{c'})\Big]\\
+3\sqrt{z}\Big[&2(-6C_5^c-2C_6^c+3C_7^c+C_8^c+12C_9^c)C_1^{c'}-4C_5^cC_2^{c'}+2C_7^cC_2^{c'}-2C_8^cC_2^{c'}-6C_5^cC_3^{c'}\\
&-2C_6^cC_3^{c'}+8C_{10}^c(C_1^{c'}+C_2^{c'}+C_3^{c'})-2C_5^cC_4^{c'}+C_8^cC_4^{c'}-4C_{10}^cC_4^{c'}\\
&+8C_9^c(C_2^{c'}+3C_3^{c'}+C_4^{c'})-2(2C_2^c+3C_3^c+C_4^c)C_5^{c'}-2C_3^cC_6^{c'}+2C_2^cC_7^{c'}-2C_2^cC_8^{c'}\\
&+C_4^cC_8^{c'}+8C_2^cC_9^{c'}+24C_3^cC_9^{c'}+8C_4^cC_9^{c'}+8C_2^cC_{10}^{c'}+8C_3^cC_{10}^{c'}-4C_4^cC_{10}^{c'}\\
&+2C_1^c(-6C_5^{c'}-2C_6^{c'}+3C_7^{c'}+C_8^{c'}+12C_9^{c'}+4C_{10}^{c'})\Big]\\
+2\Big[&2C_1^c(3C_3^{c'}+C_4^{c'})+2(3C_3^cC_1^{c'}+C_4^cC_1^{c'}+C_3^cC_2^{c'}-2C_4^cC_2^{c'}+C_2^cC_3^{c'}-2C_2^cC_4^{c'})\\
&+24(3C_5^cC_5^{c'}+C_6^cC_5^{c'}+C_5^cC_6^{c'})+3C_7^cC_7^{c'}+C_8^cC_7^{c'}+C_7^cC_8^{c'}+C_8^cC_8^{c'}+60C_7^cC_9^{c'}\\
&+20C_8^cC_9^{c'}+20C_7^cC_{10}^{c'}-4C_8^cC_{10}^{c'}+4C_{10}^c(5C_7^{c'}-C_8^{c'}+52C_9^{c'}+4C_{10}^{c'})\\
&+4C_9^c(15C_7^{c'}+5C_8^{c'}+52(3C_9^{c'}+C_{10}^{c'}))\Big]\,,
\end{aligned}$$

and

$$\begin{aligned}
J(z) = z\Big[&12C_2^cC_1^{c'}+6C_3^cC_1^{c'}+2C_4^cC_1^{c'}+2C_3^cC_2^{c'}+2C_4^cC_2^{c'}+2C_2^cC_3^{c'}+9C_3^cC_3^{c'}+3C_4^cC_3^{c'}\\
&+2C_2^cC_4^{c'}+3C_3^cC_4^{c'}+2C_1^c(18C_1^{c'}+6C_2^{c'}+3C_3^{c'}+C_4^{c'})-24C_6^cC_6^{c'}-6C_8^cC_6^{c'}\\
&+3C_7^cC_7^{c'}+C_8^cC_7^{c'}-12C_9^cC_7^{c'}-6C_6^cC_8^{c'}+C_7^cC_8^{c'}-2C_8^cC_8^{c'}-4C_9^cC_8^{c'}-12C_7^cC_9^{c'}\\
&-4C_8^cC_9^{c'}+48C_9^cC_9^{c'}-72C_6^cC_{10}^{c'}-4C_7^cC_{10}^{c'}-16C_8^cC_{10}^{c'}+16C_9^cC_{10}^{c'}\\
&-4C_{10}^c(18C_6^{c'}+C_7^{c'}+4C_8^{c'}-4C_9^{c'}+56C_{10}^{c'})\Big]\\
+3\sqrt{z}\Big[&-6C_7^cC_1^{c'}-2C_8^cC_1^{c'}+24C_9^cC_1^{c'}-4C_6^cC_2^{c'}-2C_7^cC_2^{c'}+2C_8^cC_2^{c'}+8C_9^cC_2^{c'}\\
&+3C_7^cC_3^{c'}+C_8^cC_3^{c'}-12C_9^cC_3^{c'}-2C_6^cC_4^{c'}+C_7^cC_4^{c'}-4C_9^cC_4^{c'}\\
&+4C_{10}^c(2C_1^{c'}+2C_2^{c'}-C_3^{c'}+2C_4^{c'})-4C_2^cC_6^{c'}-2C_4^cC_6^{c'}-2C_2^cC_7^{c'}+3C_3^cC_7^{c'}\\
&+C_4^cC_7^{c'}+2C_2^cC_8^{c'}+C_3^cC_8^{c'}+8C_2^cC_9^{c'}-12C_3^cC_9^{c'}-4C_4^cC_9^{c'}+8C_2^cC_{10}^{c'}-4C_3^cC_{10}^{c'}\\
&+8C_4^cC_{10}^{c'}-2C_1^c(3C_7^{c'}+C_8^{c'}-4(3C_9^{c'}+C_{10}^{c'}))\Big]\\
+2\Big[&-12C_3^cC_1^{c'}-4C_4^cC_1^{c'}-4C_3^cC_2^{c'}+2C_4^cC_2^{c'}-4C_2^cC_3^{c'}+2C_2^cC_4^{c'}-4C_1^c(3C_3^{c'}+C_4^{c'})\\
&+24C_6^cC_6^{c'}+3C_7^cC_7^{c'}+C_8^cC_7^{c'}-12C_9^cC_7^{c'}+C_7^cC_8^{c'}+C_8^cC_8^{c'}-4C_9^cC_8^{c'}-12C_7^cC_9^{c'}\\
&-4C_8^cC_9^{c'}+48C_9^cC_9^{c'}-4C_{10}^c(C_7^{c'}-5C_8^{c'}-4C_9^{c'}-52C_{10}^{c'})-4C_7^cC_{10}^{c'}+20C_8^cC_{10}^{c'}\\
&+16C_9^cC_{10}^{c'}\Big]\,.
\end{aligned}$$

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The interested reader can download a `Mathematica` program containing the full correct algebraic expressions as supplementary material.

These previously missing contributions have no effect on our phenomenological results in section 4, as we chose not to study scenarios with mixed BSM contributions from un-primed and primed operators. We expected (and continue to expect) that such scenarios provide little further value of the scenarios already considered — the $b \to s\ell\ell$ and $B \to X_s\gamma$ only depend on single coefficients, so the constraints factorise, and the lifetime ratio $\tau(B_s)/\tau(B_d)$ bounds depend on the currently unknown bag parameters $\overset{(\sim)}{B}_{1,2}$.

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