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Quark-Colorization of Cabibbo-Kobayashi-Maskawa Matrix CKM

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Abstraction- This paper proposes an interesting representation $\mathrm{V}^{\mathrm{CKM}}(q_{\mathrm{RGB}}, \Phi, \xi)$ of Cabibbo-Kobayashi-Maskawa Matrix CKM, which based on scalar products of quark color quantum numbers $q_{\mathrm{R}}, q_{\mathrm{G}}, q_{\mathrm{B}}$, or q_{RGB} (00.1). This representation is called colorization of CKM in weak interaction. The colors of down-type quarks $q_w, (w{=}d, s, b)$ in the quarkcolor scalar products of CKM are "*Color-Broken*, $\xi \neq 0$, which results in isospin $I_3(q_w)$ to be violated in weak interaction, further charges $Q^{\mathrm{CKM}}_{\mathbf{dsb}}(\xi_{rw})$, to be a slight deviated from $\frac{-1}{3}e$ of SM theoretical value. A short discussion of possible existence of higher-charges of quark *q* is given in Epilogue.

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QUARKCOLORIZATIONOFCABIBBOKOBAYASHIMASKAWAMATRIXCKM

Strictly as per the compliance and regulations of:

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0. Introduction

The three-colors R, G, B of quarks is really a curious and excellent concept in monder particle physics. In Standard Model SM, R, G, B are used to treat strong interaction quark classfication and weak interaction flavor-transitions among particles in different generations.

In previous papers [1] when discussing SM, Colous Spectrum Diagram of Flavour CSDF is introduced by Spin Topological Space STS math frame [2], in which the concretization of color values q_R, q_G, q_B of each quark can be selected from the third components $\pi_3(q)$ of one-sixth spin $\vec{\pi}(q)$ below

$$\pi_3(q) = \ldots, \underline{\frac{-29}{6}, \frac{-23}{6}, \frac{-17}{6}, \frac{-11}{6}, \frac{-5}{6}}, \underline{\frac{+1}{6}, \frac{+7}{6}, \frac{+13}{6}, \frac{+19}{6}, \frac{+25}{6}}, \ldots \subseteq q_{RGB} \equiv q_R, q_G, q_B \tag{00.1}$$

$$\vec{\pi}(q) \times \vec{\pi}(q) = i\vec{\pi}(q) \tag{00.2}$$

To discuss hadronic constiteunts in strong interaction [3], *colored quark*, $q(\chi, \alpha) = q(\chi) + q_\alpha$ is introduced (where quark spin $q(\chi)$, $\chi = \uparrow, \downarrow$ and quark color $q_\alpha = q_{RGB}$ (00.1), $\alpha =$ R, G, B). We will again make use of quark color q_α, turn to disscuss weak interaction in this paper.

- **1)** One of the most distinguishing between weak interaction and strong interaction is the behavior of isospin of particle: The third isospin component I_3 and total isospin I are conserved in strong interaction. but both I_3 and I are not invariant in weak interaction, that means flavor are not " pure ", there are flavor-transitions among particles in different generations. Now I_3 be violated, be broken. How to devise a beautiful math platform to demonstrate such kind process of physical values of I_3 ?

Because these colors q_α or q_R, q_G, q_B can offer an unified isospin $I_3(q)$ representation [1] for all six quarks below. so we decide to use $I_3(q)$ (0.0) to research weak interaction following

$$I_3(q) = \frac{1}{3}(q_R + q_G + q_B) \equiv I_3(q_{RGB}) \tag{0.0}$$

Or

$$\vec{u} = (u_R, u_G, u_B) = (\tfrac{-5}{6}, \tfrac{+1}{6}, \tfrac{+13}{6}), \qquad I_3(u) = \tfrac{1}{3}(\tfrac{-5}{6} + \tfrac{+1}{6} + \tfrac{+13}{6}) = \tfrac{+1}{2} \tag{0.1}$$

$$\vec{d} = (d_R, d_G, d_B) = (\tfrac{-11}{6}, \tfrac{-5}{6}, \tfrac{+7}{6}), \qquad I_3(d) = \tfrac{1}{3}(\tfrac{-11}{6} + \tfrac{-5}{6} + \tfrac{+7}{6}) = \tfrac{-1}{2} \tag{0.2}$$

$$\vec{c} = (c_R, c_G, c_B) = (\tfrac{+1}{6}, \tfrac{+7}{6}, \tfrac{+19}{6}), \qquad I_3(c) = \tfrac{1}{3}(\tfrac{+1}{6} + \tfrac{+7}{6} + \tfrac{+19}{6}) = \tfrac{+3}{2} \tag{0.3}$$

$$\vec{s} = (s_R, s_G, s_B) = (\tfrac{-17}{6}, \tfrac{-11}{6}, \tfrac{+1}{6}), \qquad I_3(s) = \tfrac{1}{3}(\tfrac{-17}{6} + \tfrac{-11}{6} + \tfrac{+1}{6}) = \tfrac{-3}{2} \tag{0.4}$$

$$\vec{t} = (t_R, t_G, t_B) = (\tfrac{+7}{6}, \tfrac{+13}{6}, \tfrac{+25}{6}), \qquad I_3(t) = \tfrac{1}{3}(\tfrac{+7}{6} + \tfrac{+13}{6} + \tfrac{+25}{6}) = \tfrac{+5}{2} \tag{0.5}$$

$$\vec{b} = (b_R, b_G, b_B) = (\tfrac{-23}{6}, \tfrac{-17}{6}, \tfrac{-5}{6}), \qquad I_3(b) = \tfrac{1}{3}(\tfrac{-23}{6} + \tfrac{-17}{6} + \tfrac{-5}{6}) = \tfrac{-5}{2} \tag{0.6}$$

- **2)** Many weak interaction phenomena can be explained by V_{CKM}, CKM matrix (0) [4] that based on experimental observation.

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 0.975 & 0.224 & 0.004 \\ 0.224 & 0.974 & 0.042 \\ 0.009 & 0.041 & 0.999 \end{pmatrix} \tag{0}$$

After that, CKM matrix *is parameterized* [5] to be written as a product of three rotation matrices, that called a smart Wolfenstein parametrization, one of its advantage is CP violation can be involved. (Ref [6],[7],...[12])

In this paper, CKM matrix *is colorized* by means of quark color q_R, q_G, q_B. And scalar products of colors q_R, q_G, q_B and isospin broken $I_3(\xi_{rw})_{CKM}$ are concerned about into Cabibbo-Kobayashi-Maskawa Matrix CKM.

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Outline Flowchart for Isospin Violated In CKM Matrix

I. Quarkcolor Scalar Products in CKM Matrix

$$V_{CKM} = V^{CKM}(q_{RGB}) \quad \Rightarrow \quad V(\vec{r} \cdot \vec{w}) \quad (1)★ \quad \Rightarrow \quad V(\vec{r'} \cdot \vec{w'_r}) \quad (2)★ \quad \Rightarrow \quad V(\vec{r'} \cdot \vec{\mathrm{w}}_r) \quad (3)★$$

Here

【1】

$$\vec{r} \cdot \vec{w} = r_R w_R + r_G w_G + r_B w_B \quad (1.0)$$

【2】

$$\vec{r'} \cdot \vec{w'_r} = r'_R w'_{rR} + r'_G w'_{rG} + r'_B w'_{rB} \quad (2.0)$$

【3】

$$\vec{r'} \cdot \vec{\mathrm{w}}_r = r'_R \mathrm{w}_{rR} + r'_G \mathrm{w}_{rG} + r'_B \mathrm{w}_{rB} \quad (3.0)$$

Symbols (1)★, (2)★, (3)★ respectively stand for the quarkcolor scalar products (1.0),(2.0),(3.0) of CKM Matrix in different interaction regions shown below

【1】Strong interaction color represention of flavor, when $I_3(q)$ is conserved

$$\vec{r} = \vec{r}(q) = (\ r_{\mathrm{R}}, r_{\mathrm{G}}, r_{\mathrm{B}}\ ) \tag{1.1}$$

$$\vec{w} = \vec{w}(q) = (\ w_{\mathrm{R}}, w_{\mathrm{G}}, w_{\mathrm{B}}\ ) \tag{1.2}$$

【2】Weak interaction color represention of flavor, when isospin $I_3(q)$ is conserved $(\xi = 0)$.

$$\vec{r'} = \vec{r}(q) + \frac{1}{6}\vec{\Phi}_{\mathrm{r}} \tag{2.1}$$

$$\vec{w'_{\mathrm{r}}} = \vec{w}(q) + \frac{1}{6}\vec{\Phi}_{\mathrm{rw}} = (\ w_{\mathrm{R}}, w_{\mathrm{G}}, w_{\mathrm{B}}\ ) + \frac{1}{6}(\ (\Phi_{\mathrm{rw}})_{\mathrm{R}}, (\Phi_{\mathrm{rw}})_{\mathrm{G}}, (\Phi_{\mathrm{rw}})_{\mathrm{B}}\ ) \tag{2.2}$$

【3】Weak interaction color represention of flavor, when isospin $I_3(q)$ is broken $(\xi \neq 0)$

$$\vec{r'} = \vec{r}(q) + \frac{1}{6}\vec{\Phi}_{\mathrm{r}} \tag{3.1}$$

$$\vec{\mathrm{W}}_{\mathrm{r}} \equiv \vec{w'_{\mathrm{r}}}(\xi) = \vec{w}(q) + \frac{1}{6}\vec{\Phi}_{\mathrm{rw}}(\xi) \tag{3.2}$$

Where $r = u, c, t$ are *up-type quarks*, quark charge $Q_r = \frac{+2}{3}e$ and $w = d, s, b$ are *down-type quarks*, quark charge $Q_w = \frac{-1}{3}e$. It will be shown that in case【3】, the charge Q_w of *down-type quark* will be a slight deviated from $\frac{-1}{3}$ due to isospin broken $I_3(q)$. Superscript " $'$ ", that written on the top right of r and w, stands for quark being in weak interaction region.

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Detail Processes for Isospin Violated In CKM Matrix

II. ISOSPIN I_3 BE CONSERVED IN CKM MATRIX

For clear logical route to quark-colorization of Cabibbo-Kobayashi-Maskawa Matrix CKM, in following an example (labelled by mark " ♦ ") of color scalar procuct $\vec{u'} \cdot \vec{d}_u$ is given, which (includes **2.1.** $\vec{u} \cdot \vec{d}$♦ and **2.2.** $\vec{u'} \cdot \vec{d'_u}$♦) arranged in the top left element V_{11} of CKM matrix.

2.1. In【1】Strong interaction color represention of flavor, (4) is color scalar product of *u quark* and *d quark*

$$\vec{u} \cdot \vec{d}♦ = u_R d_R + u_G d_G + u_B d_B = (\tfrac{-5}{6})(\tfrac{-11}{6}) + (\tfrac{+1}{6})(\tfrac{-5}{6}) + (\tfrac{+13}{6})(\tfrac{+7}{6}) = \tfrac{1}{36}\{ +55 - 5 + 91 \} = \tfrac{+141}{36}♦ \quad (4)$$

obtain isospin $I_3(q_{RGB})$

$$I_3(u) = \tfrac{1}{3}(\tfrac{-5}{6} + \tfrac{+1}{6} + \tfrac{+13}{6}) = \tfrac{+1}{2} \quad (0.1)$$

$$I_3(d) = \tfrac{1}{3}(\tfrac{-11}{6} + \tfrac{-5}{6} + \tfrac{+7}{6}) = \tfrac{-1}{2} \quad (0.2)$$

In this way, for CKM Matrix we get following

$$\text{Matrix (1)}★ \quad V^{CKM}(q_{RGB}) = \begin{pmatrix} \vec{u}\cdot\vec{d}♦ & \vec{u}\cdot\vec{s} & \vec{u}\cdot\vec{b} \\ \vec{c}\cdot\vec{d} & \vec{c}\cdot\vec{s} & \vec{c}\cdot\vec{b} \\ \vec{t}\cdot\vec{d} & \vec{t}\cdot\vec{s} & \vec{t}\cdot\vec{b} \end{pmatrix} = \frac{1}{36}\begin{pmatrix} +141♦ & +87 & +33 \\ +87 & -75 & -237 \\ +33 & -237 & -507 \end{pmatrix} \quad (5)$$

Matrix (5) always appears in strong interaction.

2.2. In【2】Weak interaction color represention of flavor, (10) is color scalar product of u' *quark* and d'_u *quark*

To research for the properties of quark color scalar product and quark isospin in Weak Interaction, so-called " *weak interaction pairing* $\vec{\Phi}$ " of CSDF is introduced and $\vec{\Phi}$ be attached to each of the six flavors $\vec{t}, \vec{c}, \vec{u}, \vec{d}, \vec{s}, \vec{b}$ of strong interaction.

(6),(7) are the concrete expressions of *weak interaction pairing*, for *up-type quark u* and *down-type quark d*, by which, $\vec{u'}$ and $\vec{d'_u}$ of express (2.1) and (2.2) are obtained.

$$\vec{\Phi}_u = \left(\frac{+1}{2}, \frac{+16}{2}, \frac{-17}{2}\right) \tag{6}$$

$$\vec{\Phi}_{ud} = \left(\frac{+5}{2}, \frac{+10}{2}, \frac{-15}{2}\right) \tag{7}$$

$$\vec{u'} = \vec{u} + \frac{1}{6}\vec{\Phi}_u = \left(\frac{-5}{6}, \frac{+1}{6}, \frac{+13}{6}\right) + \frac{1}{6}\left(\frac{+1}{2}, \frac{+16}{2}, \frac{-17}{2}\right) = \left(\frac{-9}{12}, \frac{+18}{12}, \frac{+9}{12}\right) \tag{8}$$

$$\vec{d'_u} = \vec{d} + \frac{1}{6}\vec{\Phi}_{ud} = \left(\frac{-11}{6}, \frac{-5}{6}, \frac{+7}{6}\right) + \frac{1}{6}\left(\frac{+5}{2}, \frac{+10}{2}, \frac{-15}{2}\right) = \left(\frac{-17}{12}, \frac{0}{12}, \frac{-1}{12}\right) \tag{9}$$

$$\vec{u'} \cdot \vec{d'_u}\blacklozenge = \left(\vec{u} + \frac{1}{6}\vec{\Phi}_u\right) \cdot \left(\vec{d} + \frac{1}{6}\vec{\Phi}_{ud}\right) = \left(\frac{-9}{12}, \frac{+18}{12}, \frac{+9}{12}\right) \cdot \left(\frac{-17}{12}, \frac{0}{12}, \frac{-1}{12}\right) = 1.000\blacklozenge \tag{10}$$

Formulas (11) (12) show in case【2】, isospin I_3 is conserved too, as that I_3 (0.1) and (0.2) in strong interaction. (11) (12) are I_3 *crucial piont states* of weak interaction.

$$I_3(u') = \frac{1}{3}\left(\frac{-9}{12}+\frac{+18}{12}+\frac{+9}{12}\right) = \frac{+1}{2} \tag{11}$$

$$I_3(d'_{\mathrm{u}}) = \frac{1}{3}\left(\frac{-17}{12}+\frac{0}{12}+\frac{-1}{12}\right) = \frac{-1}{2} \tag{12}$$

There are nine *weak interaction pairings* $\vec{\Phi}$. in Matrix (2)★ below. Similar to *pairing* $\vec{\Phi}$ (6)-(7), after deliberate calculations, at last the eight other weak interaction pairings $\vec{\Phi}$ are found out, and using them, further previous Matrix (1)★ and (5) of CKM Matrix of strong interaction could be reconstructed into Matrix (2)★ and (13) of weak interaction. we get following

$$\Downarrow\ \Downarrow\ \Downarrow \qquad\qquad \Downarrow\ \Downarrow\ \Downarrow$$

$$\text{Matrix (2)★}\quad V^{\mathrm{CKM}}(q_{\mathrm{RGB}},\Phi) = \begin{pmatrix} \vec{u'}\cdot\vec{d'_{\mathrm{u}}}♦ & \vec{u'}\cdot\vec{s'_{\mathrm{u}}} & \vec{u'}\cdot\vec{b'_{\mathrm{u}}} \\ \vec{c'}\cdot\vec{d'_{\mathrm{c}}} & \vec{c'}\cdot\vec{s'_{\mathrm{c}}} & \vec{c'}\cdot\vec{b'_{\mathrm{c}}} \\ \vec{t'}\cdot\vec{d'_{\mathrm{t}}} & \vec{t'}\cdot\vec{s'_{\mathrm{t}}} & \vec{t'}\cdot\vec{b'_{\mathrm{t}}} \end{pmatrix} = \begin{pmatrix} 1.000♦ & 0.000 & 0.000 \\ 0.000 & 1.000 & 0.000 \\ 0.000 & 0.000 & 1.000 \end{pmatrix} \tag{13}$$

(13) is the representation of crucial piont state of CKM in weak interaction and (13) is unitary obviously.

III. Isospin I_3 be Broken in CKM Matrix

Taking broken parameter $\xi_{ud} = \xi = 0.2$ into (7) of *pairing*-$\vec{\Phi}$ (6)-(7) obtain (14) and (15)

$$\vec{\Phi}_{ud}(\xi) = (\tfrac{+5}{2}, \tfrac{+10-\xi}{2}, \tfrac{-15}{2}) = (\tfrac{+5}{2}, \tfrac{+10-0.2}{2}, \tfrac{-15}{2}) = (\tfrac{+5}{2}, \tfrac{+9.8}{2}, \tfrac{-15}{2}) \tag{14}$$

Abbreviation

$$\vec{d}_u \equiv \vec{d}'_u(\xi) = \vec{d} + \tfrac{1}{6}\vec{\Phi}_{ud}(\xi) = (\tfrac{-11}{6}, \tfrac{-5}{6}, \tfrac{+7}{6}) + \tfrac{1}{6}(\tfrac{+5}{2}, \tfrac{+9.8}{2}, \tfrac{-15}{2}) = (\tfrac{-17}{12}, \tfrac{-0.2}{12}\blacklozenge, \tfrac{-1}{12}) \tag{15}$$

When broken parameter ξ appears in $\vec{\Phi}$, we call $\vec{\Phi}$ be "*Color-Broken*" and call the colors of down-type quark $\vec{d}$ (15), or quarkcolor scalar products (16) of CKM be "*Color-Broken*".

From $\vec{d}_u$, simultaneously & respectively obtain two physical quantities $\vec{u}' \cdot \vec{d}_u$ (16) and $I_3(\vec{d}_u)$ (18) below:

$$\vec{u}' \cdot \vec{d}_u\blacklozenge = (\tfrac{-9}{12}, \tfrac{+18}{12}, \tfrac{+9}{12})(\tfrac{-17}{12}, \tfrac{-0.2}{12}\blacklozenge, \tfrac{-1}{12}) = \tfrac{1}{144}\{+144 - 3.6\} = \tfrac{1}{144}\{+140.4\} = 0.975\blacklozenge \tag{16}$$

$$I_3(u') = \tfrac{1}{3}(\tfrac{-9}{12} + \tfrac{+18}{12} + \tfrac{+9}{12}) = \tfrac{+1}{2} \tag{17}$$

$$I_3(\vec{d}_u)\blacklozenge = \tfrac{1}{3}(\tfrac{-18}{12} + \tfrac{-0.2}{12}) = \tfrac{-1}{3}(\tfrac{3}{2} + \tfrac{0.1}{6}) = \tfrac{-1}{2}(1 + \tfrac{0.1}{9}) = \tfrac{-1}{2}(1 + \tfrac{1}{90}) = \tfrac{-1}{2}(1.011)\blacklozenge \tag{18}$$

• Formula (18) shows in case【3】$\xi \neq 0$, isospin I_3 is not conserved in weak interaction, there is a deviation 0.011 from $I_3(d) = \frac{-1}{2}$ (0.2)

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There are nine independent real parameters ξ_{rw} (19) in CKM matrix, in which the third components I_3 are broken (20)

$$\xi_{rw} = \begin{pmatrix} \xi_{ud} & \xi_{us} & \xi_{ub} \\ \xi_{cd} & \xi_{cs} & \xi_{cb} \\ \xi_{td} & \xi_{ts} & \xi_{tb} \end{pmatrix} = \begin{pmatrix} +0.200\blacklozenge & -1.792 & -0.032 \\ -1.0753 & +0.1248 & -0.2016 \\ -0.03086 & -0.140571 & +0.003429 \end{pmatrix} \tag{19}$$

$$I_3(\xi_{rw})_{\mathrm{CKM}} = \begin{pmatrix} I_3(\vec{\mathrm{d}}_{\mathrm{u}})\blacklozenge & I_3(\vec{\mathrm{s}}_{\mathrm{u}}) & I_3(\vec{\mathrm{b}}_{\mathrm{u}}) \\ I_3(\vec{\mathrm{d}}_{\mathrm{c}}) & I_3(\vec{\mathrm{s}}_{\mathrm{c}}) & I_3(\vec{\mathrm{b}}_{\mathrm{c}}) \\ I_3(\vec{\mathrm{d}}_{\mathrm{t}}) & I_3(\vec{\mathrm{s}}_{\mathrm{t}}) & I_3(\vec{\mathrm{b}}_{\mathrm{t}}) \end{pmatrix} = \begin{pmatrix} \frac{-1}{2}\cdot(\mathrm{d}) & \frac{-3}{2}\cdot(\mathrm{s}) & \frac{-5}{2}\cdot(\mathrm{b}) \\ \frac{-1}{2}\cdot(1.011)\blacklozenge & \frac{-3}{2}\cdot(0.9668) & \frac{-5}{2}\cdot(0.9996) \\ \frac{-1}{2}\cdot(0.9403) & \frac{-3}{2}\cdot(1.0023) & \frac{-5}{2}\cdot(0.9978) \\ \frac{-1}{2}\cdot(0.9983) & \frac{-3}{2}\cdot(0.9974) & \frac{-5}{2}\cdot(1.00038) \end{pmatrix} \tag{20}$$

(20) is an elegant expression of isospin I_3 broken in CKM Matrix math frame. Respectively compaire the first, the second and the third column of $I_3(\xi_{rw})_{\mathrm{CKM}}$ (20) with $I_3(d)$(0.2), $I_3(s)$(0.4) and $I_3(b)$(0.6) of $I_3(q_{\mathrm{RGB}})$ (0.0).

• Mindful of the deviated values of the third isospin components above: for diagonal terms $I_3(\vec{\mathrm{d}}_{\mathrm{u}}), I_3(\vec{\mathrm{s}}_{\mathrm{c}}), I_3(\vec{\mathrm{b}}_{\mathrm{t}})$ >1 and for off-diagonal terms $I_3(\xi_{rw})$ <1

• Formula (16) be filled in (21). After the fullness of the eight other elements in CKM Matrix, ultimately we complete the processes of CKM Matrix colorization below

$$\Downarrow\ \Downarrow\ \Downarrow \qquad\qquad \Downarrow\ \Downarrow\ \Downarrow$$

$$\text{Matrix (3)}\bigstar \quad \mathrm{V}^{\mathrm{CKM}}(q_{\mathrm{RGB}}, \Phi, \xi) = \begin{pmatrix} \vec{u'}\cdot\vec{\mathrm{d}}_{\mathrm{u}}\blacklozenge & \vec{u'}\cdot\vec{\mathrm{s}}_{\mathrm{u}} & \vec{u'}\cdot\vec{\mathrm{b}}_{\mathrm{u}} \\ \vec{c'}\cdot\vec{\mathrm{d}}_{\mathrm{c}} & \vec{c'}\cdot\vec{\mathrm{s}}_{\mathrm{c}} & \vec{c'}\cdot\vec{\mathrm{b}}_{\mathrm{c}} \\ \vec{t'}\cdot\vec{\mathrm{d}}_{\mathrm{t}} & \vec{t'}\cdot\vec{\mathrm{s}}_{\mathrm{t}} & \vec{t'}\cdot\vec{\mathrm{b}}_{\mathrm{t}} \end{pmatrix} = \begin{pmatrix} 0.975\blacklozenge & 0.224 & 0.004 \\ 0.224 & 0.974 & 0.042 \\ 0.009 & 0.041 & 0.999 \end{pmatrix} \tag{21}$$

IV. Conclusions

In interaction【3】region, isospin $I_3 = I_3(\xi_{rw})_{\text{CKM}}$, is not conseved, which lead to *charge-deviated of quarks* $Q^{\text{CKM}}_{\mathbf{dsb}}(\xi_{rw})$ (Ref. (E))

$$Q_{d_U} = I_3(d_u) + \frac{+1}{6} = \frac{-1}{2}(1.011) + \frac{+1}{6} = \frac{-1}{3}(1.011)e$$

$$Q_{d_C} = I_3(d_c) + \frac{+1}{6} = \frac{-1}{2}(0.9403) + \frac{+1}{6} = \frac{-1}{3}(0.91045)e$$

$$Q_{d_t} = I_3(d_t) + \frac{+1}{6} = \frac{-1}{2}(0.9983) + \frac{+1}{6} = \frac{-1}{3}(0.99745)e$$

$$Q_{s_U} = I_3(s_u) + \frac{+7}{6} = \frac{-3}{2}(0.9668) + \frac{+7}{6} = \frac{-1}{3}(0.8506)e$$

$$Q_{s_C} = I_3(s_c) + \frac{+7}{6} = \frac{-3}{2}(1.0023) + \frac{+7}{6} = \frac{-1}{3}(1.01035)e$$

$$Q_{s_t} = I_3(s_t) + \frac{+7}{6} = \frac{-3}{2}(0.9974) + \frac{+7}{6} = \frac{-1}{3}(0.9883)e$$

$$Q_{b_u} = I_3(b_u) + \frac{+13}{6} = \frac{-5}{2}(0.9996) + \frac{+13}{6} = \frac{-1}{3}(0.997)e$$

$$Q_{b_C} = I_3(b_c) + \frac{+13}{6} = \frac{-5}{2}(0.9978) + \frac{+13}{6} = \frac{-1}{3}(0.9835)e$$

$$Q_{b_t} = I_3(b_t) + \frac{+13}{6} = \frac{-5}{2}(1.00038) + \frac{+13}{6} = \frac{-1}{3}(1.00285)e$$

OR

$$Q_{\mathbf{dsb}}^{\mathrm{CKM}}(\xi_{rw}) = \begin{pmatrix} Q_{\mathrm{d_U}} & Q_{\mathrm{s_U}} & Q_{\mathrm{b_u}} \\ Q_{\mathrm{d_C}} & Q_{\mathrm{s_C}} & Q_{\mathrm{b_c}} \\ Q_{\mathrm{d_t}} & Q_{\mathrm{s_t}} & Q_{\mathrm{b_t}} \end{pmatrix} = \begin{pmatrix} \frac{-1}{3}\cdot(1.011)e & \frac{-1}{3}\cdot(0.8506)e & \frac{-1}{3}\cdot(0.997)e \\ \frac{-1}{3}\cdot(0.91045)e & \frac{-1}{3}\cdot(1.01035)e & \frac{-1}{3}\cdot(0.9835)e \\ \frac{-1}{3}\cdot(0.99745)e & \frac{-1}{3}\cdot(0.9883)e & \frac{-1}{3}\cdot(1.00285)e \end{pmatrix} \quad (22)$$

• Mindful of the deviated values in (22): diagonal terms $Q_{\mathrm{d_U}}, Q_{\mathrm{s_C}}, Q_{\mathrm{b_t}}$ >1; off-diagonal terms $Q_{\mathrm{d_C}}, Q_{\mathrm{d_t}}$、 $Q_{\mathrm{s_U}}, Q_{\mathrm{s_t}}$、 $Q_{\mathrm{b_u}}, Q_{\mathrm{b_c}}$ <1 (22). In weak interaction, charges $Q_{\mathbf{dsb}}^{\mathrm{CKM}}(\xi_{rw})$ of *down-type quark* will be a slight deviated from $\frac{-1}{3}e$ (SM theoretical value), due to isospin broken $I_3(\xi_{rw})_{\mathrm{CKM}}$ of CKM Matrix *colorized*.

Epilogue

- The charge Q_q of all known six quarks can be expressed by the sum (E) of isospin I_3 (0.0) and quark color q_{RGB} (00.1) below

$$Q_q = I_3(q) + q_{\text{RGB}} \tag{E}$$

$$q_{\text{RGB}} = \left(\tfrac{1}{6} + n\right), \qquad n = 0, \pm1, \pm2 \ldots \tag{E1}$$

For *up-type quark*, $n = 0, -1, -2\ldots$ (E2)

$$Q_{\text{t}} = I_3(t) + \tfrac{-11}{6} = \tfrac{+5}{2} + \tfrac{-11}{6} = \tfrac{+15}{6} + \tfrac{-11}{6} = \tfrac{+4}{6} = \tfrac{+2}{3}e \tag{E.5}$$

$$Q_{\text{c}} = I_3(c) + \tfrac{-5}{6} = \tfrac{+3}{2} + \tfrac{-5}{6} = \tfrac{+9}{6} + \tfrac{-5}{6} = \tfrac{+4}{6} = \tfrac{+2}{3}e \tag{E.3}$$

$$Q_{\text{u}} = I_3(u) + \tfrac{+1}{6} = \tfrac{+1}{2} + \tfrac{+1}{6} = \tfrac{+3}{6} + \tfrac{+1}{6} = \tfrac{+4}{6} = \tfrac{+2}{3}e \tag{E.1}$$

For *down-type quark*, $n = 0, +1, +2\ldots$ (E3)

$$Q_{\text{d}} = I_3(d) + \tfrac{+1}{6} = \tfrac{-1}{2} + \tfrac{+1}{6} = \tfrac{-3}{6} + \tfrac{+1}{6} = \tfrac{-2}{6} = \tfrac{-1}{3}e \tag{E.2}$$

$$Q_{\text{s}} = I_3(s) + \tfrac{+7}{6} = \tfrac{-3}{2} + \tfrac{+7}{6} = \tfrac{-9}{6} + \tfrac{+7}{6} = \tfrac{-2}{6} = \tfrac{-1}{3}e \tag{E.4}$$

$$Q_{\text{b}} = I_3(b) + \tfrac{+13}{6} = \tfrac{-5}{2} + \tfrac{+13}{6} = \tfrac{-15}{6} + \tfrac{+13}{6} = \tfrac{-2}{6} = \tfrac{-1}{3}e \tag{E.6}$$

Compairing (E) with Gell-Mann-Nishijiama relation (E4) [13],[14], then obtain (E5) below

$$Q = I_3 + Y/2 \quad \text{(E4)}$$

$$Y = 2q_{\text{RGB}} \quad \text{(E5)}$$

Where, hypercharge $Y = B + S$. B baryon number and S strange number of quark q. We see Gell-Mann-Nishijiama relation (E4) is a special situation of (E), The latter (E), *math-mysterious*, is the extension of the former (E4), *empirical*.

- The algebra symmetry of q_{RGB} of color representation of flavor *Table* 1 [3] could permute many possible arrangements. Further a series of magic figures, those are multiples of 1/3, are constructed, that may illuminate the hypothesis about possible existence of higher-charges of quark q.

Two examples of quark charge formula (E) with $q_{\text{RGB}} = \frac{+1}{6}$, and with the fourth general quark are given below

For $I_3 = \frac{+1}{2}, \frac{-1}{2}$

$$I_3 + \frac{+1}{6} = \frac{+1}{2} + \frac{+1}{6} = \frac{+3}{6} + \frac{+1}{6} = \frac{+4}{6} = \frac{+2}{3}e$$

$$I_3 + \frac{+1}{6} = \frac{-1}{2} + \frac{+1}{6} = \frac{-3}{6} + \frac{+1}{6} = \frac{-2}{6} = \frac{-1}{3}e$$

For $I_3 = \frac{+3}{2}, \frac{-3}{2}$

$$I_3 + \frac{+1}{6} = \frac{+3}{2} + \frac{+1}{6} = \frac{+9}{6} + \frac{+1}{6} = \frac{+10}{6} = \frac{+5}{3}e$$

$$I_3 + \frac{+1}{6} = \frac{-3}{2} + \frac{+1}{6} = \frac{-9}{6} + \frac{+1}{6} = \frac{-8}{6} = \frac{-4}{3}e$$

For $I_3 = \frac{+5}{2}, \frac{-5}{2}$

$$I_3 + \frac{+1}{6} = \frac{+5}{2} + \frac{+1}{6} = \frac{+15}{6} + \frac{+1}{6} = \frac{+16}{6} = \frac{+8}{3}e$$

$$I_3 + \frac{+1}{6} = \frac{-5}{2} + \frac{+1}{6} = \frac{-15}{6} + \frac{+1}{6} = \frac{-14}{6} = \frac{-7}{3}e$$

For $I_3 = \frac{+7}{2}, \frac{-7}{2}$

$$I_3 + \frac{+1}{6} = \frac{+7}{2} + \frac{+1}{6} = \frac{+21}{6} + \frac{+1}{6} = \frac{+22}{6} = \frac{+11}{3}e$$

$$I_3 + \frac{+1}{6} = \frac{-7}{2} + \frac{+1}{6} = \frac{-21}{6} + \frac{+1}{6} = \frac{-20}{6} = \frac{-10}{3}e$$

Charges of the fourth general quark $I_3 = \frac{+7}{2}, \frac{-7}{2}$

I_3	||	$\frac{+7}{2}$	$\frac{-7}{2}$	$\frac{+7}{2}$	$\frac{-7}{2}$	$\frac{+7}{2}$	$\frac{-7}{2}$	$\frac{+7}{2}$	$\frac{-7}{2}$	$\frac{+7}{2}$	$\frac{-7}{2}$	$\frac{+7}{2}$	$\frac{-7}{2}$	$\frac{+7}{2}$	$\frac{-7}{2}$
q_{RGB}	||	$\frac{+19}{6}$	$\frac{+19}{6}$	$\frac{+13}{6}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$	$\frac{-17}{6}$
Q	||	$\frac{+20}{3}e$	$\frac{-1}{3}e$	$\frac{+17}{3}e$	$\frac{-4}{3}e$	$\frac{+14}{3}e$	$\frac{-7}{3}e$	$\frac{+11}{3}e$	$\frac{-10}{3}e$	$\frac{+8}{3}e$	$\frac{-13}{3}e$	$\frac{+5}{3}e$	$\frac{-16}{3}e$	$\frac{+2}{3}e$	$\frac{-19}{3}e$

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