Baryon color & flavour transformations

Abstract: An examination and description of Baryon color and flavor transformations.

From the Helmholtzian operator matrix product four-vector-doublet factorization, the fermions may be tabulated as follows:

$e = e(1) = \overline{(E^1,E^2,E^3)}_1$	$\mu = e(2) = \overline{(E^1,E^2,E^3)}_2$	$\tau = e(3) = \overline{(E^1,E^2,E^3)}_3$
$\nu_e = \nu(1) = (B^1,B^2,B^3)_1$	$\nu_\mu = \nu(2) = (B^1,B^2,B^3)_2$	$\nu_\tau = \nu(3) = (B^1,B^2,B^3)_3$
$u_R = u_1(1) = (B^1,E^2,E^3)_1$	$c_R = u_1(2) = (B^1,E^2,E^3)_2$	$t_R = u_1(3) = (B^1,E^2,E^3)_3$
$u_G = u_2(1) = (E^1,B^2,E^3)_1$	$c_G = u_2(2) = (E^1,B^2,E^3)_2$	$t_G = u_2(3) = (E^1,B^2,E^3)_3$
$u_B = u_3(1) = (E^1,E^2,B^3)_1$	$c_B = u_3(2) = (E^1,E^2,B^3)_2$	$t_B = u_3(3) = (E^1,E^2,B^3)_3$
$d_R = d_1(1) = \overline{(E^1,B^2,B^3)}_1$	$s_R = d_1(2) = \overline{(E^1,B^2,B^3)}_2$	$b_R = d_1(3) = \overline{(E^1,B^2,B^3)}_3$
$d_G = d_2(1) = \overline{(B^1,E^2,B^3)}_1$	$s_G = d_2(2) = \overline{(B^1,E^2,B^3)}_2$	$b_G = d_2(3) = \overline{(B^1,E^2,B^3)}_3$
$d_B = d_3(1) = \overline{(B^1,B^2,E^3)}_1$	$s_B = d_3(2) = \overline{(B^1,B^2,E^3)}_2$	$b_B = d_3(3) = \overline{(B^1,B^2,E^3)}_3$

(and their anti-matter counterparts) [2]

Denoting quark types (u,d) , colors $(1,0,-1)$ & flavours $(1,2,3)$.

(The associated anti-fermion has negaive charge & color of it's counterpart.)

But this may be simplified into a purely mathematical data structure
(especially since Left & Right neutrinos have different characteristics):

$\nu_{e_R} = \nu(1) = f(0,\ 1,-1,-1)$	$\nu_\mu = \nu(2) = f(0,\ 1,-1,\ 0)$	$\nu_\tau = \nu(3) = f(0,\ 1,-1,\ 1)$
$e^- = e(1) = f(0,-1,\ 0,-1)$	$\mu^- = e(2) = f(0,-1,\ 0,\ 0)$	$\tau^- = e(3) = f(0,-1,\ 0,\ 1)$
$\nu_{e_L} = \nu(1) = f(0,\ 1,\ 1,-1)$	$\nu_\mu = \nu(2) = f(0,\ 1,\ 1,\ 0)$	$\nu_\tau = \nu(3) = f(0,\ 1,\ 1,\ 1)$
$u_R = u_1(1) = f(1,-1,-1,-1)$	$c_R = u_1(2) = f(1,-1,-1,\ 0)$	$t_R = u_1(3) = f(1,-1,-1,\ 1)$
$u_G = u_0(1) = f(1,-1,\ 0,-1)$	$c_G = u_0(2) = f(1,-1,\ 0,\ 0)$	$t_G = u_0(3) = f(1,-1,\ 0,\ 1)$
$u_B = u_{-1}(1) = f(1,-1,\ 1,-1)$	$c_B = u_{-1}(2) = f(1,-1,\ 1,\ 0)$	$t_B = u_{-1}(3) = f(1,-1,\ 1,\ 1)$
$d_R = d_1(1) = f(1,\ 1,-1,-1)$	$s_R = d_1(2) = f(1,\ 1,-1,\ 0)$	$b_R = d_1(3) = f(1,\ 1,-1,\ 1)$
$d_G = d_0(1) = f(1,\ 1,\ 0,-1)$	$s_G = d_0(2) = f(1,\ 1,\ 0,\ 0)$	$b_G = d_0(3) = f(1,\ 1,\ 0,\ 1)$
$d_B = d_{-1}(1) = f(1,\ 1,\ 1,-1)$	$s_B = d_{-1}(2) = f(1,\ 1,\ 1,\ 0)$	$b_B = d_{-1}(3) = f(1,\ 1,\ 1,\ 1)$

For: $f(x_1,x_2,x_3,x_4)$:

$x_1 = \begin{cases} 0 : & \text{lepton} \\ 1 : & \text{quark} \end{cases}$	$x_2 = \begin{cases} -1 : & \text{up} \\ 1 : & \text{down} \end{cases}$
$x_3 = color = \begin{cases} -1 : & \text{R} \\ 0 : & \text{G} \\ 1 : & \text{B} \end{cases}$	$x_4 = generation = \begin{cases} -1 : \\ 0 : \\ 1 : \end{cases}$

Mesons are quark pairs/doublets. Baryons are quark triplets.

Meson & baryon color indices must add up to 0 .

(thus, meson pairs may only be composed of a quark & an anti-quark of the same-negated color.

The color doublet operation is simply a permutation operation on the two quarks
(color indices adding to 0), two at a time (i.e.: flipping with each other) :

So, all the possible quark doublets are given by:

$u_0(h) : \overline{u}_0(j)$	$u_1(h) : \overline{u}_1(j)$	$u_{-1}(h) : \overline{u}_{-1}(j)$
$d_0(h) : \overline{d}_0(j)$	$d_1(h) : \overline{d}_1(j)$	$d_{-1}(h) : \overline{d}_{-1}(j)$

$$\|$$

$$f(1,x_2,x_3,x_4) : \overline{f(1,x_2,-x_3,x_4)}$$

(The u/d nomenclature is used for the following transformations, since it is horizontally slimmer than the f .)

NOTE: $\rho_\Phi(m) : \overline{\rho}_\Pi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Phi(s) = \rho_\Phi(m) : \overline{\sigma}_\Phi(s) + \sigma_\Pi(r) : \overline{\overline{\rho}}_\Pi(n)$

$\Rightarrow \rho_\Pi(m) : \overline{\rho}_\Pi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Pi(s) = \rho_\Pi(m) : \overline{\sigma}_\Pi(s) + \sigma_\Pi(r) : \overline{\overline{\rho}}_\Pi(n)$; $(\Phi = \Pi)$

where: $\rho,\sigma \in \{u,d\}$ & $\Pi,\Phi \in \{1,0,-1\}$ & $m,n,r,s \in \{1,2,3\}$

Since the color force is much stronger than the electromagnetic at short range, the
color/anti-color pairs dominate & requires another color force to uncouple.

$\rho_\Phi(m) : \overline{\rho}_\Pi(n)$ & $\sigma_\Pi(r) : \overline{\sigma}_\Phi(s)$, are electromagnetically bonded = 'weak' bond

$\rho_\Phi(m) : \overline{\sigma}_\Phi(s)$ & $\sigma_\Pi(r) : \overline{\overline{\rho}}_\Pi(n)$, are color bonded = 'strong' bond

Note how meson color pairs tend to couple together:

Meson $\rho_\Pi(m) : \overline{\sigma}_\Pi(n) \rightarrow \rho_\Pi(h) : \overline{\rho}_\Pi(r)$ flavour transformations:

$$\rho_\Pi(m) : \overline{\sigma}_\Pi(n) + \overline{\rho}_\Pi(r) : \sigma_\Phi(s) + \sigma_\Pi(h) : \overline{\rho}_\Phi(j)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \overline{\rho}_\Pi(r) + \overline{\sigma}_\Pi(n) : \sigma_\Phi(s) + \sigma_\Pi(h) : \overline{\rho}_\Phi(j)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \overline{\rho}_\Pi(r) + \overline{\sigma}_\Pi(n) : \sigma_\Pi(h) + \sigma_\Phi(s) : \overline{\rho}_\Phi(j)$$

where: $\rho,\sigma \in \{u,d\}$ & $\Pi,\Phi \in \{1,0,-1\}$ & $m,n,r,s,h,j \in \{1,2,3\}$

Meson $\rho_\Pi(m) : \overline{\sigma}_\Pi(n) \rightarrow \rho_\Pi(h) : \overline{\rho}_\Pi(r)$ flavour transformations:

This pairing is clearly the stronger bonding, since it is both color and electromagnetic attraction.

These operation transactions are fundamental to the color triplet operation.

As with the color doublet operation.the color triplet operation is simply a permutation operation on the three quarks (color indices adding to 0), two at a time :

So, all the possible quark triplets are given by:

$u_1(h) : u_0(j) : u_{-1}(k)$	$u_1(h) : u_0(j) : d_{-1}(k)$	$u_1(h) : d_0(j) : u_{-1}(k)$	$u_1(h) : d_0(j) : d_{-1}(k)$
$d_1(h) : d_0(j) : d_{-1}(k)$	$d_1(h) : d_0(j) : u_{-1}(k)$	$d_1(h) : u_0(j) : d_{-1}(k)$	$d_1(h) : u_0(j) : u_{-1}(k)$

$$\|$$

$u_1(h) : u_0(j) : u_{-1}(k)$	$d_1(h) : d_0(j) : d_{-1}(k)$
$u_1(h) : u_0(j) : d_{-1}(k)$	$d_1(h) : d_0(j) : u_{-1}(k)$
$u_1(h) : d_0(j) : u_{-1}(k)$	$d_1(h) : u_0(j) : d_{-1}(k)$
$u_1(h) : d_0(j) : d_{-1}(k)$	$d_1(h) : u_0(j) : u_{-1}(k)$

$$\|$$

$f(1,-1,1,h) : f(1,-1,0,j) : f\left(1,\ 1,-1,k\right)$	$f\left(1,\ 1,1,h\right) : f\left(1,\ 1,0,j\right) : f\left(1,\ 1,-1,k\right)$
$f(1,-1,1,h) : f(1,-1,0,j) : f\left(1,\ 1,\ 1,k\right)$	$f\left(1,\ 1,1,h\right) : f\left(1,\ 1,0,j\right) : f(1,-1,-1,k)$
$f(1,-1,1,h) : f\left(1,\ 1,0,j\right) : f\left(1,-1,\ 1,k\right)$	$f\left(1,\ 1,1,h\right) : f(1,-1,0,j) : f\left(1,\ 1,-1,k\right)$
$f(1,-1,1,h) : f\left(1,\ 1,0,j\right) : f\left(1,\ 1,\ 1,k\right)$	$f\left(1,\ 1,1,h\right) : f(1,-1,0,j) : f(1,-1,-1,k)$

and anti's (plus possible excited states)

$3 \times 3 \times 3 \times 4 \times 2 \times 2 = 432 \Rightarrow$ neglecting Top's $\Rightarrow 360 \Rightarrow$ neglecting anti's $\Rightarrow 180$

Clearly, as seen above, for each set of: i,j,k there are 8 unique quark **RGB**/**RBG**/**BRG**/**GRB**/**GBR**/**BGR** triplets.
So, the color triplet permutation operation on the three quarks force is made up of an $8 \times 8 \times 8 - plex$ manifestation.
(The u/d nomenclature is used for the following transformations, since it is horizontally slimmer than the f.)

Baryon $\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k)$ transformations:

$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(j) : \overline{\rho}_\Pi(h) + \sigma_\Phi(h) : \overline{\sigma}_\Phi(j)$$
$$\Downarrow$$
$$\rho_\Pi(j) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\sigma}_\Phi(j) + \overline{\rho}_\Pi(h) : \sigma_\Phi(h)$$
$$\Downarrow$$
$$\rho_\Pi(j) : \sigma_\Phi(h) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Pi(h) + \overline{\sigma}_\Phi(j) : \sigma_\Phi(j)$$
$$\left(generations\ j,h : color\ swap : \mathbf{\Phi \rightarrow \Pi, \Pi \rightarrow \Phi \Rightarrow \Phi\Pi \rightarrow \Pi\Phi}\right)$$

and:

$$\rho_\Pi(j) : \sigma_\Phi(h) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Pi(j) + \overline{\sigma}_\Phi(h) : \sigma_\Phi(j)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \sigma_\Phi(h) : \theta_\Psi(k) + \rho_\Pi(j) : \overline{\rho}_\Pi(h) + \sigma_\Phi(h) : \overline{\sigma}_\Phi(j)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(j) : \overline{\rho}_\Pi(h) + \sigma_\Phi(h) : \overline{\sigma}_\Phi(j)$$

where: $\rho,\sigma,\theta \in \{u,d\}$ & $\Pi,\Phi,\Psi \in \{1,0,-1 \mid \Pi \neq \Phi, \Pi \neq \Psi, \Phi \neq \Psi\}$ & $h,j,k \in \{1,2,3\}$

These transformations are sufficient to describe all permutations
(simply change designations as necessary).
(i.e.: $(\Pi,\Phi,\Psi) \Rightarrow (\Phi,\Pi,\Psi) \Rightarrow (\Phi,\Psi,\Pi) \Rightarrow (\Pi,\Psi,\Phi) \Rightarrow (\Psi,\Pi,\Phi) \Rightarrow (\Psi,\Phi,\Pi)$)

Baryon $\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k)$ color & flavour transformations:

$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Phi(m) : \overline{\sigma}_\Phi(s) + \sigma_\Pi(r) : \overline{\rho}_\Pi(n)$$
$$\Downarrow$$
$$\rho_\Phi(m) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\sigma}_\Phi(s) + \sigma_\Pi(r) : \overline{\rho}_\Pi(n)$$
$$\Downarrow$$
$$\rho_\Phi(m) : \sigma_\Pi(r) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\sigma}_\Phi(s) + \sigma_\Phi(j) : \overline{\rho}_\Pi(n)$$
$$\|$$
$$\rho_\Phi(m) : \sigma_\Pi(r) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Pi(n) + \sigma_\Phi(j) : \overline{\sigma}_\Phi(s)$$

and:

$$\rho_\Phi(m) : \sigma_\Pi(r) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Pi(n) + \sigma_\Phi(j) : \overline{\sigma}_\Phi(s)$$
$$\Downarrow$$
$$\rho_\Phi(m) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Pi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Phi(s)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Phi(m) : \overline{\rho}_\Pi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Phi(s)$$
$$\|$$
$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Phi(m) : \overline{\sigma}_\Phi(s) + \sigma_\Pi(r) : \overline{\rho}_\Pi(n)$$

and:

$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Phi(m) : \overline{\rho}_\Phi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Phi(m) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Phi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Phi(m) : \sigma_\Pi(r) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Phi(n) + \sigma_\Phi(j) : \overline{\sigma}_\Pi(s)$$
$$\|$$
$$\rho_\Phi(m) : \sigma_\Pi(r) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\sigma}_\Pi(s) + \sigma_\Phi(j) : \overline{\rho}_\Phi(n)$$

and:

$$\rho_\Phi(m) : \sigma_\Pi(r) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\sigma}_\Pi(s) + \sigma_\Phi(j) : \overline{\rho}_\Phi(n)$$
$$\Downarrow$$
$$\rho_\Phi(m) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Phi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Phi(m) : \overline{\rho}_\Phi(n) + \sigma_\Pi(r) : \overline{\sigma}_\Pi(s)$$

where: $\rho,\sigma,\theta \in \{u,d\}$ & $\Pi,\Phi,\Psi \in \{1,0,-1 \mid \Pi \neq \Phi, \Pi \neq \Psi, \Phi \neq \Psi\}$ & $h,j,k \in \{1,2,3\}$

Again, these transformations are sufficient to describe all permutations
(simply change designations as necessary).
(i.e.: $(\Pi,\Phi,\Psi) \Rightarrow (\Phi,\Pi,\Psi) \Rightarrow (\Phi,\Psi,\Pi) \Rightarrow (\Pi,\Psi,\Phi) \Rightarrow (\Psi,\Pi,\Phi) \Rightarrow (\Psi,\Phi,\Pi)$)

All the permutations are handled by this operation (perhaps randomly, not necessarily in any order)
A pair of virtual weak/strong mesons combines in and a pair of virtual strong/weak mesons uncombines out.
(with charge & color conservation).

Baryon $\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k)$ color transformations:

$(\Pi,\Phi,\Psi) \Rightarrow (\Phi,\Pi,\Psi)$:
$$\rho_\Pi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Phi(h) : \overline{\rho}_\Phi(n) + \sigma_\Pi(j) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Phi(h) : \sigma_\Phi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\rho}_\Phi(n) + \sigma_\Pi(j) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Phi(h) : \sigma_\Pi(j) : \theta_\Psi(k) + \rho_\Pi(h) : \overline{\sigma}_\Pi(s) + \sigma_\Phi(j) : \overline{\rho}_\Phi(n)$$

$(\Phi,\Pi,\Psi) \Rightarrow (\Phi,\Psi,\Pi)$:
$$\rho_\Phi(h) : \sigma_\Pi(j) : \theta_\Psi(k) + \sigma_\Psi(j) : \overline{\sigma}_\Psi(r) + \theta_\Pi(k) : \overline{\theta}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Phi(h) : \sigma_\Psi(j) : \theta_\Psi(k) + \sigma_\Pi(j) : \overline{\sigma}_\Psi(r) + \theta_\Pi(k) : \overline{\theta}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Phi(h) : \sigma_\Psi(j) : \theta_\Pi(k) + \sigma_\Pi(j) : \overline{\theta}_\Pi(s) + \theta_\Psi(k) : \overline{\sigma}_\Psi(r)$$

$(\Phi,\Psi,\Pi) \Rightarrow (\Pi,\Psi,\Phi)$:
$$\rho_\Phi(h) : \sigma_\Psi(j) : \theta_\Pi(k) + \rho_\Pi(h) : \overline{\rho}_\Pi(r) + \theta_\Phi(k) : \overline{\theta}_\Phi(s)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \sigma_\Psi(j) : \theta_\Pi(k) + \rho_\Phi(h) : \overline{\rho}_\Pi(r) + \theta_\Phi(k) : \overline{\theta}_\Phi(s)$$
$$\Downarrow$$
$$\rho_\Pi(h) : \sigma_\Psi(j) : \theta_\Phi(k) + \theta_\Pi(k) : \overline{\rho}_\Pi(r) + \rho_\Phi(h) : \overline{\theta}_\Phi(s)$$

$(\Pi,\Psi,\Phi) \Rightarrow (\Psi,\Pi,\Phi)$:
$$\rho_\Pi(h) : \sigma_\Psi(j) : \theta_\Phi(k) + \rho_\Psi(h) : \overline{\rho}_\Psi(r) + \sigma_\Pi(j) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Psi(h) : \sigma_\Psi(j) : \theta_\Phi(k) + \rho_\Pi(h) : \overline{\rho}_\Psi(r) + \sigma_\Pi(j) : \overline{\sigma}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Psi(h) : \sigma_\Pi(j) : \theta_\Phi(k) + \sigma_\Psi(j) : \overline{\rho}_\Psi(r) + \rho_\Pi(h) : \overline{\sigma}_\Pi(s)$$

$(\Psi,\Pi,\Phi) \Rightarrow (\Psi,\Phi,\Pi)$:
$$\rho_\Psi(h) : \sigma_\Pi(j) : \theta_\Phi(k) + \sigma_\Phi\left(j\right) : \overline{\sigma}_\Phi(r) + \theta_\Pi(k) : \overline{\theta}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Psi(h) : \sigma_\Phi\left(j\right) : \theta_\Phi(k) + \sigma_\Pi(j) : \overline{\sigma}_\Phi(r) + \theta_\Pi(k) : \overline{\theta}_\Pi(s)$$
$$\Downarrow$$
$$\rho_\Psi(h) : \sigma_\Phi\left(j\right) : \theta_\Pi(k) + \theta_\Phi(k) : \overline{\sigma}_\Phi(r) + \sigma_\Pi(j) : \overline{\theta}_\Pi(s)$$

$(\Phi,\Pi,\Psi) \Rightarrow (\Phi,\Psi,\Pi) \Rightarrow (\Pi,\Psi,\Phi) \Rightarrow (\Psi,\Pi,\Phi) \Rightarrow (\Psi,\Phi,\Pi)$
$(\Phi,\Psi,\Pi) \Rightarrow (\Pi,\Psi,\Phi) \Rightarrow (\Psi,\Pi,\Phi) \Rightarrow (\Psi,\Phi,\Pi)$

Each meson has mass, and no net charge or color.

Clearly this, along with their speeds and binary-orbital velocities (as well as each bond switching between meson & baryon), is responsible, at least in part, for binding energy of baryons/nucleons.

References

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