The Colour-Independent Charges of Quarks of Magnitude 2/3 and -1/3 in the Standard Model are Basically Wrong!

Syed Afsar Abbas (1,3),
Mohsin Ilahi (2,3),
Sajad Ahmad Sheikh (1,*),
Sheikh Salahudin (1,*)

1. Centre for Theoretical Physics, JMI University, New Delhi-110025, India
2. Department of Physics, Aligarh Muslim University, Aligarh-202002, India
3. Jafar Sadiq Research Institute, AzimGreenHome, NewSirSyed Nagar, Aligarh-202002, India

(e-mail : drafsarabbas@gmail.com)

Abstract

The Standard Model in spite of being the most successful model of particle physics, has a well-known shortcoming/weakness; and which is that the electric charges of quarks of magnitude 2/3 and -1/3 are not properly quantized in it and are actually fixed arbitrarily. In this paper we show that under a proper in-depth study, in reality these charges are found to be basically "wrong". This is attributed to their lack of proper colour-dependence. Here the proper and correct quark charges are shown to be actually intrinsically colour dependent and which in turn give consistent and correct description of baryons in QCD. Hence these colour dependent charges are the correct ones to use in particle physics.

Keywords: QCD, QED, electric charge, Standard Model

PACS: 12.10.Dm, 12.38.Aw, 12.15.Ex

*** Summer Project Student, CTP, New Delhi**

As we know the physical world is corrcetly described by the Yang-Mills theory of Quantum Chromodynamics (QCD) for three colours in $SU(3_c)$. However QCD built around $SU(N_c)$ for arbtrary number of colours [1,2] has been found to to be a very fruitful concept as the theory does simplify for $N_c \to \infty$ (e.g. see [3]).

These studies of QCD for arbitrary number of colours [2] inter alia, show that for an arbitrary number of colours, baryon has a finite size and has a mass going as:

$$M(baryon) \propto N_c \tag{1}$$

This is amongst the most significant results of this analysis within QCD. This is part of what the intrinsic structure of QCD predicts.

In their model the baryons are made up of N_c number of quarks [2] where the quark charges were taken as 2/3 for u-quark and -1/3 for the d-quark. These chargs are the conventional charges obtained in the Standard Model (SM) bulit around the group $SU(3)_c \otimes SU(2)_W \otimes U(1)_W$.

The electric charge in the Standard Model is [e.g. see [3]]:

$$Q = {T_3}^W + \frac{Y_W}{2} \tag{2}$$

The value of the weak-hypercharges is put in by hand to ensure that the electric charges of the u- and the d- quarks are 2/3 and -1/3 respectively. Because of the above it is well known (e.g. [3]) that the charges in the Standard Model have this shortcoming of being arbitrary and not being quantized. Note that there is no colour dependecne in quark charges here.

One takes [2] $N_c = 2k+1$; $k = 0, 1, 2, 3, ...$ to ensure that odd number of colours only arise for fermionic baryons. Thus k = 1 for three colours. Now one takes proton made up of (k+1) number of u-quarks and k number of d-quarks. Thus proton has $\frac{N_c+1}{2}$ u-quarks and $\frac{N_c-1}{2}$ d-quarks; and vice versa for neutron. The proton and neutron charges are:

$$Q_p = \left(\frac{N_c+1}{2}\right) Q_u + \left(\frac{N_c-1}{2}\right) Q_d \tag{3}$$

$$Q_n = \left(\frac{N_c-1}{2}\right) Q_u + \left(\frac{N_c+1}{2}\right) Q_d \tag{4}$$

Now with the Standard Model charge values of 2/3 and -1/3 one gets:

$$Q_p = \frac{N_c + 3}{6} \;\; ; \;\; Q_n = \frac{N_c - 3}{6} \tag{5}$$

Hence proton and neutron charges are one and zero respectively only for $N_c = 3$. Both are non-integral or non-zero for arbirary number of colours.

Note the important fact that now in the Standard Model the composite proton and neutron have colour dependent charges. So though the individual quark charges are colour independent, they lead to a colour dependent charges of composite proton and neutron. So proton and neutron know of colour in the SM.

However, Witten asssumed that he could ignore QED in his analysis [2]. This led him to obtain composite baryon masses as given in eqn. [1]. But we know that for composite entities like nuclei, Coulomb-self-energy plays a very important and basic role. The same should be true here also. So Witten's neglect of Coulomb-self-energy of these composite baryons was an unfortunate error. Quite clealy the fundamental Coulomb-self-energy would contribute too to the baryon masses. And thus the QCD plus QED contributions to baryon mass are,

$$M(proton) \propto N_c + C \frac{\left(\frac{N_c+3}{6}\right)^2}{R} \tag{6}$$

where C is a constant and R is the finite size of proton. Now the baryon mass is blowing as ${N_c}^2$ due to the QED part. This is disastrous as it is messing up the whole analysis based on self-consistent QCD only. Thus here QCD plus QED tells us that there are no stable baryons for any number of colours.

What is the way out from this crisis? We attribute the above crisis within QED to the use of the static charges 2/3 and -1/3 of the Standard Model. We show below that this indeed turns out to be true.

Indeed, it has been shown that, in line with the full group stucture for arbitary number of colours $SU(N)_c \otimes \; SU(2)_L \otimes U(1)_Y$ (also for $N_c = 3$ as well), and having the same theoretical structure as the above electro-weak model, and with the same Englert-Brout-Higgs mechanism of spontaneous symmetry breaking etc., one obtains a more general definition of the electric charges [4,5] as,

$$Q_u = \frac{1}{2}(1 + \frac{1}{N_c}) \;\; ; \; Q_d = \frac{1}{2}(-1 + \frac{1}{N_c}) \tag{7}$$

Thus in this model the electric charges of quarks intrinsically know of the colour degree of freedom. It was also shown that these are correct and proper charges for a consistent description of hadrons [4,5]

Take our correct colour dependent charges in eqns. (7), and put these charges in eqns. (3) and (4) to get;

$$Q_p = \left(\frac{N_c+1}{2}\right)\frac{1}{2}(1+\frac{1}{N_c}) + \left(\frac{N_c-1}{2}\right)\frac{1}{2}(-1+\frac{1}{N_c}) = 1 \tag{8}$$

$$Q_n = \left(\frac{N_c-1}{2}\right)\frac{1}{2}(1+\frac{1}{N_c}) + \left(\frac{N_c+1}{2}\right)\frac{1}{2}(-1+\frac{1}{N_c}) = 0 \tag{9}$$

And lo and behold, the proton charge is always one and neutron is always neutral for any arbitrary colour. Thus the Coulomb-self-energy term is always finite and indeed the baryon mass only goes as eqn.(1). And thus the prediction of the self-consistent analysis in QCD is honoured and retained within the new self-consistent structures arising in QED with the proper colour dependent charges.

Hence the colour-dependent charges give a good and correct descrption of QED which goes consistenly with the QCD. Thus it is QCD+QED (but with proper colour dependent charges) which provides a complete and consistent descrption of hadrons.

So we arrive at the important conclusion that the static (colour-independent) quark charges of the SM lead to inconsistent QED structures. Thus these conventional static charges 2/3 and -1/3 of the Standard Model are wrong, and hence should be discarded. The new colour dependent charges give consistent QED description and which conjoins well with the proper and correct structure of QCD for arbitrary number of colours and thus should be used as correct charges in particle physics.

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