A new look at quarks confinement

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Abstract

Quarks confinement is an experimental fact. 'tHooft and later on Gross, Wilczek and Politzer have contributed in various ways to our present considerable theoretical understanding of the problem. However, an exact water proof theoretical derivation of the problem is at best still in progress. The present note argues that to understand quarks confinement, a deeper understanding of the Planck scale physics is indispensable and shows using analytical topological arguments that absolute confinement is a result of a phase transition of quantum spacetime at the Planck scale.

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1. Introduction

Starting with ‘tHooft’s unpublished work on quarks confinement, QCD has in the meantime explained what had seemed paradoxical namely that quarks can be permanently confined and yet act independently when probed at high energy. Thanks to the subsequent work of Gross, Wilczek and Politzer we have an insight into the phenomenon via what is called asymptotic freedom [1–3]. In addition, ‘tHooft presented us with additional understanding via his perturbative confinement approach to the problem [3].

Nevertheless and despite these far-reaching and fundamental achievements, it is fair to say that a waterproof exact theoretical derivation is still both desirable and lacking [1–4].

There are also few reasons for lurking doubts even among the founding fathers of asymptotic freedom. For instance Wilczek [5] remarked correctly that the strong coupling at the Planck length cannot be measured directly and that its value must be understood within a unification approach to the fundamental interaction. However, the classical theory is not making the necessary distinction between $\alpha_S$ at the Planck scale and the coupling constant of the entire Planckian field which must be unity [4]. In fact a hint is given here by the fact that in terms of the coupling itself $g_S$ at the Planck scale is of the order of 1/2 as compared with 1/30 for the strong coupling as given by Wilczek [5].

In the present work we seek to eliminate these minor, but for an exact solution profound obstacles. We do that by looking with extreme care at the exact meaning of each term of a modified renormalization equation which is based on the existence of four rather than three coupling constants.

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2. The exact “renormalization” equation at the Planck phase transition

The simplest way to explain our approach to the confinement is to go back to the reconstruction of \( \tilde{z}_0 \) from the exact theoretical coupling constant of the electroweak unification. We recall that the experimental values are given by [6]

\[
x_1 = 1/98.4, \quad x_2 = \frac{1}{29.6}, \quad x_3 = 1/8.5
\]

In our more convenient inverse coupling notation this is

\[
\tilde{x}_1 = (3/5)(98.4) = 59.04
\]
\[
\tilde{x}_2 = 29.6
\]

and

\[
\tilde{x}_3 = 8.5
\]

Now the exact value reported in many previous publications need not be seen here more than an idealized integer value approximating the experimental one. Consequently, we set \( \tilde{z}_1 = 60 \) and \( \tilde{z}_2 = 1/2 \tilde{z}_1 = 30 \). As for \( \tilde{z}_3 = 8.5 \) this is more involved. First let us take it to be simply 10, but we divide this 10 into two parts 9 and 1. The motivation to do that will become obvious in the course of our analysis.

Using the experimental value, one finds \( \tilde{z}_0 \) to be [4,7–11]

\[
\tilde{z}_0 = (5/3)(98.4) + 29.6 + 8.5 = 98.4 + 29.6 + 8.5 = 136.5
\]

This is close to \( \tilde{z}_0 \approx 137 \) but could not be described as accurate estimation of \( \tilde{z}_0 \) which is known experimentally to a very high precision. By contrast let us use our “idealized” theoretical value where \( (5/3) \rightarrow 1/\phi = (\sqrt{5} + 1)/2 = 1.618033989 \):

\[
\tilde{z}_0 = (1/\phi)\tilde{z}_1 + \tilde{z}_2 + \tilde{z}_3 + \tilde{z}_4 = 97.02039325 + 30 + 9 + 1 = 137 + k_0 = 137.082039325
\]

This is the exact \( E \)-infinity theoretical value and the experimental value is found by a simple projection [7–11].

\[
\tilde{z}_0 \text{ (experimental)} = \frac{\tilde{z}_0 - k_0}{\cos(\pi/\tilde{z}_0)} = \frac{137}{\cos(\pi/137 + k_0)} = 137.0359852
\]

There is hardly any difference between this result and the most accurate measurement. The reader should note the dramatic deterioration in our result if \( \tilde{z}_4 \) would have been ignored. In fact this point may be made clearer by looking at the 2-Adic expansion of \( \tilde{z}_0 \approx 137 \) which gives [11]

\[
\| \tilde{z}_0 \|_2 = \| 2^7 + 2^4 + 2^0 \| = \| 128 + 8 + 1 \|_2 = \| \tilde{z}_{ew} + \tilde{z}_s + \tilde{z}_{QG} \|_2 = \| \tilde{137} \|_2 = 1
\]

We see that \( \tilde{z}_{QG} = \| \tilde{z}_0 \|_2 = 1 \). This is a most important result reinforcing Witten’s \( T \)-duality outside the realm of string theory. We see also that \( \tilde{z}_4 = 1 \) plays the same role as \( \tilde{z}_{QG} = 1 \) as well as the result of Kaluza–Klein theory which shows that \( \tilde{z}_0 \rightarrow \tilde{x} = 1 \) when \( R \rightarrow \ell_{\text{Planck}} \). We can thus conclude that at the Planck scale, a phase transition of quantum spacetime takes place. The result is a quasi-Planckian Aether with mini-black holes as the only elementary particles. In a sense the quarks as the building block of matter have undergone a phase transition to becoming Planck elementary particles with a mass \( (10)^{19} \) Gev analogous to the \( (10)^{16} \) Gev of the monopoles of grand unification. Thus no wonder we cannot see a free quark.

Next let us see if our analytical procedure supports this qualitative conclusion. From [4,7–11]

\[
\tilde{x}_0 = \tilde{x}_3 + \tilde{x}_4 + \ell n \frac{M_U}{M(\mu)}
\]

We see that for \( M_U = M(\mu) \rightarrow M_{\text{Planck}} \) we must have \( \tilde{x}_u = \tilde{x}_d = 1 \). Consequently, \( \tilde{x}_3 \), which plays the role of \( \tilde{x}_5 \) must be Zero and therefore \( \tilde{x}_5 = \infty \). This is the proper statement of confinement.

3. Conclusion

At the Planck scale, quantum spacetime undergoes yet another phase transition, leading to an absolute confinement of quarks. In fact at this stage there are no conventional quarks there to observe because they have transmuted to mini-black holes of a Planckian mass.

The present picture may be seen as radical because it changes some of our basic concepts of high energy physics. However, it is extremely simple and intuitive and leads to the same conclusion supported by experiments as well as the alternative theories.
It is true that to deviate from the concepts of asymptotic freedom, the end result is the same; only more rigorous and permanent confinement is the final conclusion in all events. At a minimum these different correct theories could be regarded simply as different sides of the same medal and could coexist without great difficulties at least until we have a much better understanding of the physics beyond the Planck scale.

References