On the Confinement of Superluminal Quarks without Applying the Bag Pressure

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Abstract

We explain herein the fatal error or at least an ironic questionable parallel method in formulation of strong interaction (quantum chromodynamics). We postulate that quarks are tachyons and do not obey Yang-Mills theory. By applying this correction to the dynamics of quarks, we can confine quarks in hadrons. We seek to show why quarks do not obey the Pauli exclusion principle and why we cannot observe free quarks. In addition, we obtained the correct sizes of hadrons and derive straightforward formulations of strong interaction. Instead of several discrete QCD methods, we derive a united formulation that enables us to solve the strong interaction for all energy values. Finally we discuss about some experimental evidence such as chiral magnetic effect, scattering angular distribution, cherenkov gluon radiation, hadron mass gap, nucleon spin crisis and *CP* violation in standard model that may result from this assumption.

1 Introduction

In contrast to the observed spin-statistic behavior of quarks, it is a well-established fact that two electrons with identical quantum numbers cannot exist in a hydrogen atom, because each electron is subluminal and its phase velocity is superluminal. When there are two electrons with identical quantum numbers in a hydrogen atom or with identical energy levels in a cubic box, the second electron exists at every location (space-time coordinates) with exactly identical wave function characteristics to those of the first electron. In other words, the two electrons simultaneously exist at an exact point at the same time. This phenomenon is a consequence of the probabilistic characteristics of wave functions and quantum mechanics. Specifically, the wave equation does not provide us with more information about the exact location of each electron. The energy and absolute value of the momentum of each electron are exactly determined, but the electrons do not have specific locations. At a given time, they are ubiquitous at every location where the wave function does not vanish. However, as we know we can have three identical quarks with identical spin states and quantum numbers in baryons. To explain this phenomenon, we propose a strange theorem:

Theorem. *Quarks are superluminal particles.*

First, let's explain the foundations of quantum mechanics somewhat further. Any specific change in the state of a wave function in its associated Hilbert space will propagate in space-time

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coordinates with the phase velocity of the wave function in spacetime. Specifically, entangled particles communicate with each other at their entangled phase velocity. We postulate that quarks are superluminal. As a result, because each quark is superluminal, its phase velocity must be subluminal; thus, If we change the wave function of the second quark, this change will propagate at less than c to the other space-time locations in the bag. In other words, the first quark is unaware of the spin and characteristics of the second quark, because their phase velocities are subluminal. The phase velocity is not measured in a space-like region and quarks with identical spins can occupy the same energy level in hadrons. Specifically, two quarks with identical energies and momenta are located at different points in the bag. Quantum mechanics postulates that, at a specific time, a subluminal particle with a specific energy-momentum does not have a specific location. In other words, it is ubiquitous in the bag. However, because the phase velocity of a superluminal particle is subluminal, a superluminal particle is no longer ubiquitous. These particles are somehow uncollapsed localized wave functions. Thus, two superluminal particles (quarks) that are confined in a hadron no longer exist at the exact space-time points and obey Fermi-Dirac statistics, so it is not necessary for them to obey the Pauli exclusion principle (they are not ubiquitous). The exclusion principle applies to two identical particles with identical wave function characteristics [1](ubiquitous at some region of the space-time coordinate).

Theoretically, the wave function of a tachyon such as a hypothetical superluminal neutrino cannot collapse, because the phase velocity of collapse is subluminal and obeys causality. Before the wave function collapses, the particle does not have a specific location. We can create its location by performing an experiment and measuring its location. However, after we determine the location of a particle, the particle should not be detected in other locations, even in notably far space-like locations that have no causal relation with the location of the collapsed particle. When $\psi_{space}$of a subluminal particle collapses, it communicates at its phase velocity (at infinite velocity in the reference frame of the collapsed wave function) to other locations in spacetime that the wave function should not collapse at other locations of the universe. Thus, a particle cannot be detected in two space-like locations, although the two locations do not have a causal relation with each other. However, if the particle is superluminal, its phase velocity is subluminal, and it cannot perform this communication in space-like regions of spacetime. The phase velocity must be superluminal to allow for the collapse of the wave function[2]. Because quarks are superluminal, we never observe free quarks. Note that, although we can identify quarks in hadrons using deep inelastic scattering, before scattering, the wave functions of quarks are confined in hadrons, and it is not necessary for the wave functions to communicate with the entire universe to be able to collapse. The above argument is applicable to free quarks.

We can express weird paragraph in other words. If there exist a particle that travel faster than the speed of light from location a of creator to location b of detector, always there exist a reference frame in which it appears that particle traveled from location b to a thus existence of a superluminal particles contradicts causality and such particle never can send information from location a to b. There exist three candidate that can not be used directly to send informations. Superluminal neutrino never can be in such domain because if they exist we can apply them for sending a signal and this has explicit conflict with relativity. One candidate is virtual particle and mediator other candidate is superluminal tunneling and another one can be quark. I have not heard that any one send a signal by quarks. On the other hand there exist a one to one relationship between detection of a detectable particle and copenhagen interpretation that express before its detection it either exist at every location or has no specific location. And this fact maybe is a clue for exclusion principle.

Unfortunately the physical concepts and descriptions that we offer above do not create a firm justification for two facts about tachyonic quarks. First, why is it that quarks do not obey the exclusion principle and why have we not yet observed a single free quark? These results must be expressed in the language of mathematics. However, there is seemingly still not a satisfactory quantum field theory for interacting tachyons and we do not know the statistical laws of tachyons similar to Bose-Einstein, Fermi-Dirac or Maxwell-Boltzmann , which apply to traditional particles.

2 Tachyonic field theory

The beginnings of tachyonic quantum field theory were introduced in the Feinberg paper in 1967 [3]. Feinberg introduced the term tachyon for particles that move faster than the speed of light. Before special relativity there were some attempts to describe the specifications of such particles [4, 5, 6, 7]. Cherenkov radiation was one of the predictions of these authors. After the introduction of special relativity, there was no interest in pursuing these attempts and describing particles that were forbidden to exist until 1962, when the first papers to create a relativistic tachyonic equation and the elimination of its philosophical contradictions with special relativity were published [8]. In that era, in addition to theoretical efforts[9, 10, 11, 12], there were also some attempts to detect tachyons by experiment [13, 14, 15] which had negative results. In 1985, for the first time, Alan Chodos et al. suggested that an electron neutrino was a tachyon [16]. Later, several experiments to prove that a neutrino mass was imaginary were performed. Yet, the important point about all of the positive results in favor of superluminal neutrinos was that all the conclusions were in the domain of experimental error. Thus, their validity could not be verified. In addition, this fact contradicted well-established neutrino oscillation which considered the real mass for neutrinos. After the Chodos paper appeared, a large number of theoretical papers on the subject began to appear, oriented in such a way that they designed an appropriate tachyon field theory which described superluminal neutrinos. These developments accelerated up until 2011 when CERN reported a neutrino anomaly. Immediately a large number of manuscripts in favor and against that idea were published. Yet, it later become evident that the origin of the anomaly was due to an error in experiment [17, 18, 19].

The building block of tachyonic field theory is the reinterpretation principle to accommodate causality problem[8, 3]. By suitable Lorentz transformation a positive energy particle in other reference frame is seen as negative energy particle but since particles are never at rest and in such reference frame direction of motion of particle changes too; that transformation is interpreted as negative energy particle that moves backward in time. Thus it is assumed by reinterpretation principle that electric charge of particles changes depending to reference frame of observer but electric current sign will not change and is a Lorentz invariant.

The main problems for constructing an interacting tachyonic field theory are canonical quantization, microcausality, and the spin-statistics theorem. As we know in normal or tardyonic field theory in order for a microcausality condition to hold for bilinear observables, the field must either commute or anti-commute for a space-like interval. If the Dirac equation is quantized according to commutation relations, the Hamiltonian does not have ground states. If the Klein-Gordon equation is quantized according to anti-commutation relations the microcausality will not be valid for space-like or time-like intervals. To create a tachyonic Klein-Gordon equation or Dirac equation we must quantize the field equation. For preserving Lorentz invariance of tachyonic scalar field under unitary operators transformations, Feinberg assumed a Fermi-Dirac statistic (anti-commutation relation) for the quantization of tachyonic spinless particles! (Ironically quarks which are spin one-half particles do not obey the exclusion principle, but we created the loophole of color to accommodate this fact.) and argued that we do not need connection between spin and statistic because we do not assume microscopic causality. However, this method created a problem whereby the field vacuum state and particle number were not Lorentz invariant[3, 20]. After the first Feinberg paper, it was clear that the fields with imaginary mass led to instability similar to a unstable equilibrium point in classical mechanics and would lead to tachyonic condensation [21].

3 Wave equation of a hydrogen atom with a superluminal electron

There is a significant difference between an ordinary hydrogen atom and a model with a superluminal electron. In the subluminal model, we have negative potential energy. When we increase the energy of the electron in the subluminal model, the momentum of the electron decreases; thus, the wavelength of the electron increases, and the electron increases its distance from the proton. In the subluminal model, although the energy cannot be less than the mass of the particle, the minimum momentum can be zero.

$$E^2 = c^2P^2 + m^2c^4 \tag{1}$$

Thus, the wavelength has no maximum, i.e., according to the Wilson-Sommerfeld rule [22, 23] it can approach infinity, which results in the escape of an electron from the hydrogen atom . The minimum principal quantum number for the minimum radius of the hydrogen atom is $n = 1$.

However, in the superluminal model, although the minimum amount of relativistic energy is zero, the momentum has a non-zero minimum: It cannot be less than the mass of the electron, namely, $m_s c$ [8, 9].

$$c^2P^2 = E^2 + m_s^2c^4 \tag{2}$$

$$E = \frac{m_s c^2}{\sqrt{\beta_s^2 - 1}} \qquad \beta_s > 1 \tag{3}$$

$$P = \frac{m_s v}{\sqrt{\beta_s^2 - 1}} \qquad \beta_s > 1 \tag{4}$$

We see that the electron has a maximum wavelength $\lambda = \hbar/cm_s$. Thus, by the Wilson-Sommerfeld rule, the electron cannot have an infinite wavelength and thus cannot escape the hydrogen atom. This fact sets a limit on the maximum radius of the bag. Thus, the electron in the superluminal model is confined. For the superluminal model, the principal quantum number of the maximum radius of the bag is $n = 1$.

$$\frac{(m_\circ^2c^4 + E^2)^{1/2}}{hc}2\pi r = 1 \tag{5}$$

When the electron energy increases, its momentum increases too, but its wavelength decreases; thus, it becomes increasingly confined. The electron falls deeper into the hydrogen atom or bag, which is in contrast to our observation in the subluminal model.

It is at this point that , we seek to derive and solve the wave function of a confined superluminal electron in the hydrogen bag. First, we study the radial Dirac equation. The Dirac equation for a subluminal particle with real mass leads to the following [24]

$$\hbar c\frac{dg(r)}{dr} + (1+\kappa)\hbar c\frac{g(r)}{r} - [E + m_\circ c^2 + \frac{Z\alpha}{r}]f(r) = 0 \tag{6}$$

$$\hbar c\frac{df(r)}{dr}+(1-\kappa)\hbar c f(r)r+[E-m_\circ c^2+\frac{Z\alpha}{r}]g(r)=0 \tag{7}$$

The normalized solutions are proportional to

$$f(r)\approx-\frac{1}{\Gamma(2\gamma+1)}(2\lambda r)^{\gamma-1}e^{-\lambda r}\times$$
$$\left\{(\frac{(n'+\gamma)m_\circ c^2}{E}-\kappa)F(-n',2\gamma+1;2\lambda r)+n'F(1-n',2\gamma+1;2\lambda r)\right\} \tag{8}$$

$$g(r)\approx\frac{1}{\Gamma(2\gamma+1)}(2\lambda r)^{\gamma-1}e^{-\lambda r}\times$$
$$\left\{(\frac{(n'+\gamma)m_\circ c^2}{E}-\kappa)F(-n',2\gamma+1;2\lambda r)-n'F(1-n',2\gamma+1;2\lambda r)\right\} \tag{9}$$

For normalizable wave functions, γ should be positive. κ is the Dirac quantum number, and

$$\lambda=\frac{(m_\circ^2c^4-E^2)^{1/2}}{\hbar c} \tag{10}$$

$$q=2\lambda r \tag{11}$$

$$\gamma=+\sqrt{\kappa^2-(Z\alpha)^2}=+\sqrt{(j+\frac{1}{2})^2-(Z\alpha)^2} \tag{12}$$

To terminate the hypergeometric series, we should discard the negative values of n':

$$n=n'+|\kappa|=n'+j+\frac{1}{2}\quad n=1,2,3 \tag{13}$$

The solution for the hydrogen atom is a hypergeometric function, which is an associated Laguerre polynomial and is characteristic of a wave function in the Coulomb potential.

$$L_n^m(x)=\frac{(n+m)!}{n!m!}F(-n,m+1,x) \tag{14}$$

where $L_n^m(x)$ is the associated Laguerre function.

To create a superluminal Dirac equation for quarks, we can use imaginary mass or substitute the following matrix $\beta_s=i\beta$ (imaginary mass Dirac equation) to calculate $f(r)$ and $g(r)$.

$$H\psi=c(\alpha.p)\psi+i\beta mc^2\psi \tag{15}$$

However, when we want to construct the Dirac current, we will encounter a problem. The other method is to consider the following non-Hermitian matrices, where $\beta_s=\beta\gamma_5$ [25, 16] (tachyonic Dirac equation)

$$H\psi=c(\alpha.p)\psi+\beta_s m_s c^2\psi=c(\alpha.p)\psi+\beta\gamma_5 m_s c^2\psi \tag{16}$$

$$\alpha=\begin{pmatrix}0&\sigma\\\sigma&0\end{pmatrix}\qquad\beta_s=\begin{pmatrix}0&I\\-I&0\end{pmatrix} \tag{17}$$

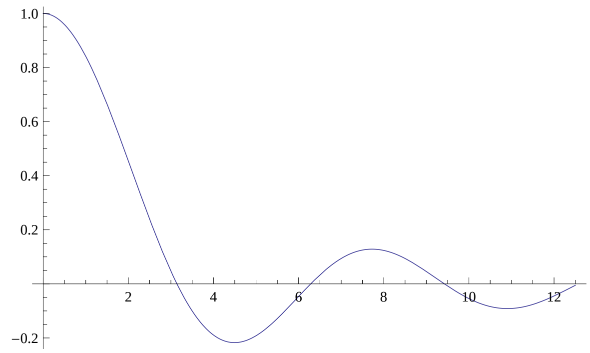

Figure 1: Real part of the function $f(x) = Re[e^{-ix}F(1,3,2ix)]$. The function is exactly similar to a spherical Bessel function of the first type.

This method satisfies all of the required properties of the superluminal Dirac equation. However, for the sake of simplicity, we mimic the former procedure for the superluminal model with imaginary mass and obtain

$$\hbar c\frac{dg(r)}{dr} + (1+\kappa)\hbar c\frac{g(r)}{r} - [E + im_\circ c^2 + \frac{Z\alpha}{r}]f(r) = 0 \tag{18}$$

$$\hbar c\frac{df(r)}{dr} + (1-\kappa)\hbar c f(r) r + [E - im_\circ c^2 + \frac{Z\alpha}{r}]g(r) = 0 \tag{19}$$

We define λ as

$$\lambda = \frac{(m_\circ^2 c^4 + E^2)^{1/2}}{\hbar c} \tag{20}$$

We solve the above equation and exactly mimic the method provided in the reference for the solution of the Coulomb potential [24]. Finally, we obtain

$$\begin{aligned} &g(r) \approx (2\lambda r)^{\gamma-1}e^{-i\lambda r} \times \\ &\left\{(\frac{(n'+\gamma)m_\circ c^2}{E} - \kappa)F(-n', 2\gamma+1; 2i\lambda r) - n'F(1-n', 2\gamma+1; 2i\lambda r)\right\} \end{aligned} \tag{21}$$

$$\begin{aligned} &f(r) \approx -(2\lambda r)^{\gamma-1}e^{-i\lambda r} \times \\ &\left\{(\frac{(n'+\gamma)m_\circ c^2}{E} - \kappa)F(-n', 2\gamma+1; 2i\lambda r) + n'F(1-n', 2\gamma+1; 2i\lambda r)\right\} \end{aligned} \tag{22}$$

In the above equations, $F(-n', 2\gamma+1; 2i\lambda r)$ is normalized for only the negative values of n' if

$$-n' < 2\gamma + 1 \tag{23}$$

For example, for $j = \frac{1}{2}$(which gives $\gamma = 1$), and $n' = -1$ we have a well-behaved wave function (figure 1). For $-n' = 2\gamma + 1$, the behavior of the wave function $F(-n', 2\gamma+1; 2i\lambda r)$ is similar to $cos(r)$. For negative n', the above hypergeometric equations are similar to the spherical Bessel function of the first type. From (21) and (22), the relation between the hypergeometric series and the Bessel functions is

$$J_\nu(x) = \frac{e^{-ix}}{\nu!}(\frac{x}{2})^\nu F(\nu + \frac{1}{2}, 2\nu + 1, 2ix) \tag{24}$$

The spherical Bessel function of the first type is defined as

$$j_\nu(x) = \sqrt{\frac{\pi}{2x}} J_{\nu+1/2}(x) \tag{25}$$

We observed that the solution for the subluminal hydrogen atom is a Laguerre polynomial. However, we see that $f(r)$ and $g(r)$ for a superluminal electron in the Coulomb potential are similar to the spherical Bessel function of the first type. The spherical Bessel functions appear in only two similar cases. The first case is a particle trapped in an infinite three-dimensional radial well potential. The solutions to this problem are spherical Bessel functions of the first type. Similarly, the solutions to the MIT bag model, which postulated the existence of an unknown pressure and the vanishing of the Dirac current outside the bag, are also spherical Bessel functions of the first type [26, 27].

although we assumed a negative $\frac{\alpha}{r}$ potential, the real shape of the strong interaction is unknown and the other potential will lead to confinement. However, even if (maybe) the force among the particles was repulsive in the above equation or its strength with respect to distance did not follow a $\frac{1}{r^2}$ law, the factor that determines whether the system is stable and whether the superluminal positron can escape the proton is the energy of the system and not the attractive or repulsive forces among the particles. Most probably the attractive force among superluminal particles is related to tachyonic field theory.

it seems from studying the shape of the inter-quark potential that, we can consider the following conjecture:

Conjecture. The strong force is simply the superluminal effect of the electromagnetic force among superluminal particles.

As an objection to the above conjecture we must ask why protons at far distance experience electromagnetic force if we consider it as accumulation of force among individual quarks of each proton.

Due to reinterpretation principle, because sign of energy of a particle is not Lorentz invariant, field vacuum state, separation of the field into positive and negative frequency parts and distinction among creation and annihilation operators are not Lorentz invariant too. If we quantize subluminal Dirac equation according to commutation relations we obtain for the energy and charge operators

$$H = \sum_{rP} E_P[N_r(P) - \overline{N}_r(P)] \tag{26}$$

$$Q = -e\sum_{rP}[N_r(P) + \overline{N}_r(P)] \tag{27}$$

Equation (27) indicates that charge of the antiparticles is similar to particles if we assume commutation relations similar to the fact that strong interaction is always attractive. If under reinterpretation principle spin is not a Lorentz invariant quantity, why we should have exclusion principle?

As we can see energy operator offer correct energy sign for antiparticle if we quantize Dirac equation according to commutation relations. Probably one method of quantization of tachyonic Dirac equation is considering null commutation relations.

$$[a(k), a^\dagger(k)] = 0 \tag{28}$$

The other modification must be the fact that applying annihilation operator on vacuum must offer a negative particle not a zero ket. From comparison with reference [28] we can see that if we use these two modifications for tachyonic field theory the vacuum will be Lorentz invariant. One consequence of this method is that fields at both time-like and space-like separation commute and do not obey micro-causality.

$$[\phi(x), \phi(y)] = 0, \qquad (x-y) < 0, \qquad (x-y) \geqslant 0 \tag{29}$$

4 Quantum Electrodynamics of Superluminal Particles

In this section, we use a heuristic approach for the calculation of cross sections in strong interactions. Although there is not yet a satisfactory theory for interacting tachyonic field theory, we seek to gain insight and a qualitative, not quantitative, sense of the calculation for the cross section of strong interactions and tachyonic particles.

In the superluminal Klein-Gordon equation, the mass term is imaginary, but all other parameters, including the Klein-Gordon current [$j^\mu = (\rho, j)$], are similar to the subluminal ones. To compute the cross sections in the subluminal Dirac and Klein-Gordon equations, we use the flux relation:

$$F = |v_A - v_B|.2E_A.2E_B = 4(|p_A|E_B + |p_B|E_A = 4((P_A.P_B)^2 - m_A^2 m_B^2)) \tag{30}$$

It can be shown that, if we use the superluminal energy-momentum relation (2) instead of (1), the above flux relation remains valid. Thus, we can conclude that the cross section formulas for superluminal and subluminal particles have similar expressions.

In the center-of-mass frame, the $AB \to CD$ process for spinless particles, has a differential cross section of

$$\frac{d\sigma}{d\Omega}|_{cm} = \frac{1}{64\pi^2 (E_A + E_B)(E_C + E_D)} \frac{p_f}{p_i} |\mathcal{M}|^2 \qquad (E_A + E_B = E_C + E_D) \tag{31}$$

where for the amplitude,

$$\mathcal{M} = (ie(p_A + p_C)^\mu)(\frac{g_{\mu\nu}}{q^2})(ie(p_B + p_D)^\nu) \tag{32}$$

In the superluminal quark model, if quarks exist at the boundary of the bag, then their speeds will approach infinity, their energies will approach zero, and their momenta will reach the minimum value $m_s c$ (non-relativistic region). In contrast, at the center of the bag, their speeds will approach the speed of light, and their energies and momenta will approach infinity (relativistic region).

In the subluminal model, the energy of the system in the denominator of (31) can never be less than the mass of the interacting particles; thus, the cross section for the minimum initial energy of the interacting particles cannot increase dramatically, but in the superluminal model, if quarks exist at the boundary of the bag (non-relativistic limit and infinite velocity, which in QCD is called a large distance), their cross sections can diverge because the energy in the denominator of the above equation (31) can approach zero. Thus, the cross section diverges at the boundary, and a quark cannot escape from the bag.

From equation (31), for the very-high-energy subluminal spinless electron muon interaction, we have

$$\frac{d\sigma}{d\Omega}|_{cm} = \frac{\alpha^2}{4(E_A+E_B)(E_C+E_D)}(\frac{3+cos\theta}{1-cos\theta})^2 \qquad e^- + \mu^- \to e^- + \mu^- \tag{33}$$

where θ is the scattering angle. To obtain this formula, we neglect the mass and equate the energy and momentum in (32). For the superluminal model, the technique is similar and produces a similar result. Thus, equation (33) is applicable to superluminal spinless particles at very high energies too. With this limit, all interactions between the quarks in hadrons, including QCD and QED interactions, are calculated using one superluminal equation (33), which is also related to the subluminal QED formula. Thus, we falsely conclude that, for short distances, the QCD running coupling constant, which is a function of the energy-momentum of the virtual gluons exchanged between quarks $(p_A - p_C)^2$, disappears. Moreover, the QCD interactions between subluminal particles are negligible, and as a result, we have only the subluminal QED result and not QCD (asymptotic freedom). However, there is no change in the running coupling constant, which can be concluded based on our conjecture.

At this stage, we study the general form of the cross sections of tachyonic spin one-half particles. The tachyonic Dirac equation can be written as

$$H_s\psi = c(\alpha.p)\psi + \beta_s m_s c^2\psi = c(\alpha.p)\psi + \beta\gamma_5 m_s c^2\psi \tag{34}$$

or, in its abbreviated form, as

$$(i\gamma^\mu\partial_\mu - \gamma^5 m)\psi(x) = 0 \tag{35}$$

The tachyonic Lagrangian and dirac current are

$$\pounds_s = i\overline{\psi}\gamma^5\gamma^\mu(\partial_\mu\psi) - m\overline{\psi}\psi \tag{36}$$

$$J^\mu = c(\overline{\psi}\gamma^\mu\gamma^5\psi) \tag{37}$$

and the tachyonic Hamiltonian is,

$$H = H_s + H_I \tag{38}$$

Its interaction Hamiltonian will be

$$H_I = J^\mu A_\mu \tag{39}$$

Because (37) is different from the subluminal current, the cross section will be different. Actually we cannot continue because there does not yet exist a successful tachyonic field theory. Nevertheless, the tachyonic propagator is written as [28]

$$S(p) = \frac{1}{\not{p} - \gamma^5(m+i\epsilon)} = \frac{\not{p} - \gamma^5 m}{p^2 + m^2 + i\epsilon} \tag{40}$$

Therefore, for quark pair production in (e^+e^-) collisions, we have

$$e^+(p) + e^-(p') \to q^+(k) + q^-(k') \tag{41}$$

Its amplitude will be

$$\mathcal{M} = ie_q e[\overline{u}(k')\gamma_\alpha\gamma_5 v(k)]_{(q)}\frac{1}{(p+p')^2}[\overline{v}(p)\gamma^\alpha u(p')]_{(e)} \tag{42}$$

We have

$$\sum_{spin}[\overline{u}(p')\gamma^\mu v(p)][\overline{u}(p')\gamma^\nu v(p)]^* = 4(p'^\mu p^\nu + p'^\nu p^\mu - (p'.p + m_e^2)g^{\mu\nu}) \tag{43}$$

The following gamma relations are useful:

$$(\gamma^5)^2 = 1 \qquad \gamma^{5\dagger} = \gamma^5 \qquad \gamma^5\gamma^\mu = -\gamma^\mu\gamma^5 \tag{44}$$

By using the above gamma relation we obtain:

$$\sum_{spin}[\overline{u}(k')\gamma_\mu\gamma_5 v(k)][\overline{u}(k')\gamma_\nu\gamma_5 v(k)]^* = 4(k'^\mu k^\nu + k'^\nu k^\mu - (k'.k - m_q^2)g_{\mu\nu}) \tag{45}$$

Therefore, the amplitude will be

$$\overline{\mathcal{M}}^2 = \frac{8e^2e_q^2}{(p+p')^4}[(k'.p')(k.p) + (k'.p)(k.p') + m_e^2 k.k' - m_q^2 p'.p - 2m_e^2 m_q^2] \tag{46}$$

This result can be compared with subluminal electron muon scattering:

$$\overline{\mathcal{M}}^2 = \frac{8e^4}{(p+p')^4}[(k'.p')(k.p) + (k'.p)(k.p') + m_e^2 k.k' + m_\mu^2 p'.p + 2m_e^2 m_\mu^2] \tag{47}$$

If the quark mass is on the order of electron mass at the extreme relativistic limit, we ignore the masses of electrons and quarks, and the cross section will be similar to the electron muon scattering cross section.

$$\frac{d\sigma}{d\Omega}|_{cm} = \frac{\alpha^2 e_q^2}{4(E_A+E_B)(E_C+E_D)e^2}\frac{p_f}{p_i}(1+\cos^2\theta) \tag{48}$$

Here, the superluminal model predicts that the total cross section is one third of the value that we obtained from the traditional QCD calculations of electron to quark annihilation, which considers the color factor. The problem can be solved by what we obtain in the next section, i.e., the fact that quarks are more massive than what traditional QCD predicts. If quark mass (up-down) is much greater than electron mass, then in the annihilation of an electron positron to quark-antiquark pair superluminal scattering, we always have $p_f = \sqrt{m_q^2 + E^2} > \sqrt{-m_e^2 + E^2} = p_i$ which increases the differential cross section in (48). Other part of the problem is probably related to the Wilson loop potential V_S that we will discuss in next sections. Thus we probably have $E_A + E_B = E_C + E_D + V_S$ that at asymptotic freedom level of cross section approaches to $E_A + E_B = E_C + E_D$ however V_S has no role in initial flux and number of final states in cross section and smaller value of $E_C + E_D$ may increase cross section.

5 Wilson loop and confinement

The Wilson loop was designed to prove confinement in Yang-Mills theory [29]. Yet, it is still an open question whether the Wilson loop in Yang-Mills theory at a finite distance offers an infinite result. Here we derive the interquark potential and contrast it with the standard QCD model and proof that both Wilson integration and interquark potential and cross section diverge beyond the hadron border. We begin with the Wilson integration

$$< e^{-ie_q\oint A_\mu dx^\mu} >= \exp[-e_q^2\oint dx^\mu \oint dy^\nu \frac{g_{\mu\nu}}{8\pi^2\varepsilon_\circ[(x-y)^2 - i\epsilon]}] \tag{49}$$

The exponent can be written as

$$
\begin{aligned}
&-2e_q^2\int_{C2} dx^\mu \int_{C4} dy^\nu \frac{g_{\mu\nu}}{8\pi^2\varepsilon_\circ[(x-y)^2-i\epsilon]} \\
&-2e_q^2\int_{C1} dx^\mu \int_{C3} dy^\nu \frac{g_{\mu\nu}}{8\pi^2\varepsilon_\circ[(x-y)^2-i\epsilon]} \\
&= -2e_q^2\int_0^T dx^0 \int_T^0 dy^0 \frac{g_{00}}{8\pi^2\varepsilon_\circ[(x^0-y^0)^2-r^2-i\epsilon]} \\
&-2e_q^2\int_0^R dx^1 \int_R^0 dy^1 \frac{g_{11}}{8\pi^2\varepsilon_\circ[(x^0-y^0)^2-r^2-i\epsilon]} \\
&\approx -\frac{e_q^2 T}{4\pi^2\varepsilon_\circ}\int_{+\infty}^{-\infty} dy^0 \frac{g_{00}}{[(x^0-y^0)^2-r^2-i\epsilon]} \\
&-\frac{e_q^2 R}{c4\pi^2\varepsilon_\circ}\int_{+\infty}^{-\infty} dy^1 \frac{g_{11}}{[(x^0-y^0)^2-r^2-i\epsilon]} \\
&= i\frac{e_q^2}{4\pi\varepsilon_\circ R}T - i\frac{e_q^2}{4\pi\varepsilon_\circ T c^2}R = -iV_s T
\end{aligned} \tag{50}
$$

where

$$
r = (x^1 - y^1) \qquad g_{00} = 1 \qquad g_{01} = g_{10} = 0 \qquad g_{11} = 1 \tag{51}
$$

and

$$
T\beta_s c = R \tag{52}
$$

In addition,from Wilson-Sommerfeld quantization; we have

$$
\frac{R m_s c \beta_s}{\sqrt{\beta_s^2 - 1}} = \hbar \tag{53}
$$

so we obtain

$$
V_S = \frac{e_q^2}{4\pi\varepsilon_\circ R}\frac{(\frac{Rmc}{\hbar})^2}{1-(\frac{Rmc}{\hbar})^2} \tag{54}
$$

The above potential indicates a strong force potential among quarks. At the boundary of the bag or hadron, both the Wilson loop integral and interquark potential diverge because in a very small time period, the quark manages to circumvent the bag and create a completely closed loop in the integration which results in confinement. Thus, quarks must be superluminal, as it is the necessary condition for confinement. The absence of a subluminal model and potential creates a true confinement and a divergence of flux and cross section beyond the hadron surface. From equations (33) or (48) and (5), we can plot the total cross section as a function of the interquark distance

$$
\sigma = \frac{\pi}{3}\frac{e^4}{16\pi^2}\frac{R^2}{\hbar^2 c^2 - m^2 c^4 R^2} \tag{55}
$$

which indicates that at the center, both potential and cross section vanish contrary to the Cornell potential, which predicts a coulombic potential at a small distance.

$$
V_{cornell} = -\frac{e_q^2}{4\pi\varepsilon_\circ R} + bR + f(R) \tag{56}
$$

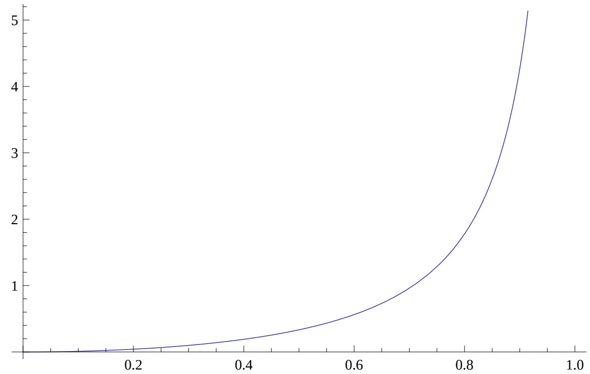

Figure 2: The graph of function $f(x) = \frac{x}{1-x^2}$. The above graph describes the interquark potential, where in approximately 1 fm (proton border), the string tension approaches infinity.

There are several differences between what we obtained here and what standard QCD predicts. As we know, the QCD coupling constant will predict approximately a Cornell potential that for a small distance behaves as a coulombic potential, but our graph (Figure 2) is different and the interquark potential will never be zero unless in the center of the bag. In addition, in QCD the flux between quarks remains constant, and at a large distance is not related to the interquark distance; but in our model in around the range of the quark Compton wavelength λ_q, both the string tension and cross section diverge completely and create confinement. If the conjecture that electromagnetic and strong interaction are the same force is true; in the superluminal model, the string tension is a function of the quarks' mass and electric charge and their distance from the center of the hadron; thus, it is different for each hadron. For a lighter quark mass, the string tension would be reduced. Yet, color factor predicts a universal string tension among all types of quarks. Because in our model, the string tension diverges completely at 1 fm, this model predicts confinement. However, in standard QCD at no distance, quarks will be confined completely and the Wilson loop fails to predict the problem of confinement although the problem of quark confinement at finite distance in Yang-Mills theory and resulting mass gap is still an open question [30].

For the hydrogen atom we have a fine structure constant

$$\alpha = \frac{e^2}{4\pi\varepsilon_\circ \hbar c} \tag{57}$$

The electron reduced Compton wavelength is $\bar{\lambda}_e$ and the electron distance from the nucleus is

$$r_n = n^2 r_\circ = n^2 \frac{\bar{\lambda}_e}{\alpha} = n^2 \frac{\lambda_e}{2\pi\alpha} \tag{58}$$

where $r_\circ$ is the Bohr radius. The electron energy is

$$E_n = \frac{m_e c^2 \alpha^2}{2n^2} \tag{59}$$

We want to create a similar equation for quarks. The quark Compton wavelength is λ_q. We know that in nucleons (for up and down quarks) the strong interaction strength is approximately $(\frac{1}{\alpha})$ times greater than the electromagnetic strength so if in equation (54) we choose

$$\frac{V_S(R = R_\circ)}{V_E} = \frac{1}{\alpha} \tag{60}$$

where

$$V_E = \frac{e_q^2}{4\pi\varepsilon_\circ R} \tag{61}$$

then we obtain

$$R_\circ = \frac{1}{\sqrt{1+\alpha}}\lambda_q = \frac{1}{\sqrt{1+\alpha}}\frac{\hbar}{m_q c} \tag{62}$$

and $R_\circ$ is a true hadron boundary. if in (54) the quark moves beyond $R_\circ$ we have a confinement

$$V_S(R = \lambda_q = \frac{\hbar}{m_q c}) = \infty \tag{63}$$

in addition,

$$V_S(R = R_\circ) = \sqrt{\alpha+1}m_q c^2(\frac{e_q^2}{e^2}) \tag{64}$$

Because a strong force is actually an electromagnetic force between tachyons, we cannot define the V_E between superluminal particles, but we can say

$$V_E(R = R_\circ) = \alpha\sqrt{\alpha+1}m_q c^2(\frac{e_q^2}{e^2}) \tag{65}$$

and from (5) we have

$$E(R = R_\circ) = \sqrt{\alpha}m_q c^2 \approx 0.085 m_q c^2 \tag{66}$$

Thus, the quark momentum is

$$p(R = R_\circ) = \sqrt{1+\alpha}m_q c \tag{67}$$

and its velocity is

$$v(R = R_\circ) = c\sqrt{1+\frac{1}{\alpha}} \tag{68}$$

Equation (62) indicates that the radius of the bag is approximately the Compton wavelength of the quark. In addition, (66) indicates that the energy of quarks is very small in comparison with their mass. As well, quarks are very heavy particles. This fact and superluminal motion may affect quark magnetic moment (probably $\mu = \frac{e_q c^2 \hbar}{E}$ in Bohr model). There is a strange point in the above derivation. It seems that in equation (64) the V_S which is the total energy derived from the strong interaction is proportional to the quark momentum |p| (equation(67)) and is much greater than the total energy of the quark (66)

$$V_S(R = R_\circ) = |p(R = R_\circ)|c\frac{e_q^2}{e^2} >> E(R = R_\circ) \tag{69}$$

It is not clear whether we must consider the mass of the hadron as proportional to its strong interaction potential V_S or the quark total energy E and probably both factors contribute to hadron mass. In addition, if we suppose that the mass of the hadrons in first quark generation depends more on V_S, we can see that in a stable hadron like any stable system, the quarks have a very small relativistic energy (66) and the quarks' mass (up and down) is much greater than what we obtained from a non-abelian formulation of quantum chromodynamics. Actually, equation (64) indicates that quark mass is on the order of hadron mass (see (55) too).

6 Possible experimental results

Local strong parity violation in heavy-ion collision: Superluminal motion of quarks must be detectable in their interactions with background magnetic field. Apart from effect of huge quark (up and down) mass and superluminal motion on quark magnetic moment because $v > c$ quarks must interact much stronger than what is expected with magnetic field. The strong magnetic field that may be produced in noncentral heavy ion collision leads to chiral magnetic effect [31, 32], i.e., creation of a parallel or anti-parallel electric current of quarks to the magnetic field. As a result of this magnetic field there will be a parity violation. Such a asymmetry is detected by STAR Collaboration and other groups[33, 34, 35] but it is estimated that the predicted asymmetry must be several order of magnitude smaller than observed signal in STAR experiment[36, 37].

Angular distribution of two jet events: If quarks (up and down) are extremely massive, we cannot easily apply equation (48) as an approximation. the extended result is

$$\frac{d\sigma}{d\Omega}|_{cm} = \frac{\alpha^2 e_q^2}{4(E_A+E_B)(E_C+E_D)e^2}\frac{p_f}{p_i}(1-\frac{m_q^2}{E^2}+(1+\frac{m_q^2}{E^2})\cos^2\theta) \tag{70}$$

The rates of variation of the above differential cross sections with respect to the scattering angle θ, i.e., $1+\lambda cos^2\theta$ are different and must affect experimental results of two jet events. At low energy $E_{cm} \leqslant 4.8$ Gev there is higher sphericity and less jet like behavior but it seems that λ is very small [38, 39]. At $E_{cm} = 7.4 \frac{Gev}{c^2}$ the observed jet axis indicated $\lambda = 0.45$ and $\lambda = 0.50$ but SLAC-LBL Collaboration used Monte Carlo simulation to get higher values $\lambda = 0.78$, $\lambda = 0.97$ [40, 41]. Even small difference of λ from 1 creates great mass. For $\lambda = 0.78$ at $E_{cm} = 7.4$ Gev we obtain $| < m_q > | = 1.3$ Gev. Justifying two jet events on the base of perturbative standard QCD for massive quarks contradicts asymptotic freedom, however only measurement of λ at different energies can reveal its true nature. PLUTO Collaboration obtained $\lambda = 0.76$ and $\lambda = 1.63$ at $E_{cm} = 7.7$ and upsilon resonance $E_{cm} = 9.4$ respectively [42]. The rapid change of λ at upsilon resonance indicates that λ is related to (bottom) quark mass in differential cross section resonance. However at $E_{cm} = 13$ and $E_{cm} = 17$ Gev again the value of $\lambda = 1.7$ was suggested by TASSO Collaboration [43]. Finally $\lambda \neq 1$ is observed in drell yan angular distribution too but QCD usually offers more justifications for this anomaly in drell yan process [44]. Usually $\lambda < 1$ in drell yan process but at bjorken scalling $x = 1$ fast decrese of λ happens. The argument that offered in reference regarding bound state effect or V_S can be correct for large bjorken scaling but another reason for $\lambda \neq 1$ is due to huge quark mass. In fact V_S has different rule in cross section from amplitude or angular distribution. However at $x = 1$ in drell yan process we have an increase in p_i of (70) and we expect that cross section fall at $x = 1$ in bjorken scaling [45, 46, 47].

It seems that naive applying concept of antiparticles for quarks contradicts experimental results $\lambda < 1$ of two jet event. Change of sign of m^2 in (46) is vulnerable to both $m \to im$ and $v(k) \to u(k)$ or $v(k) \to v(-k)$. Maybe it is related to the fact that we have only attractive strong force and we must be careful in using notation of antiparticle in calculating cross sections. Probably a similar scenario may affect noncentral collision and it tests hybrid of chromomagnetic and magnetic effects simultaneously[48]. Put in other words, for deriving equation (70) from (46) we assumed that electron and positron pair with energy momentum $p = (E, P)$, $p' = (E, -P)$ were annihilated to quark anti-quark pair with energy momentum $k = (E, K)$ and $k' = (E, -K)$ that move in opposite directions. However from reinterpretation principle anti-quark must have negative energy and also negative momentum in the direction of its velocity. As a result we would have $k = (E, K)$ and $k' = (-E, K)$ for quark anti-quark pair respectively. This modification fixes the result $\lambda < 1$ of two jet event. But we will lose the conservation of energy momentum in this process unless a third particle i.e., a gluon save it. In fact it is observed that above $E_{cm} = 13\ \frac{Gev}{c^2}$, the result of electron positron annihilation to hadrons is a planar three jet events that consist of a slim and a fat jet not naive two jet events [49, 50]. The fat jet itself contains two collinear jets. Yet, QCD predicts that such a gluon jet is very difficult to detect if it exist due to the fact that it spread much more and less jetlike than a quark jet[51].

Cherenkov radiation: As we can see Cherenkov radiation increases V_S in (54) and seems to be forbidden. In addition due to increase in V_S momentum can not decrease below a limit and tachyonic condensation seems to be forbidden too. Nevertheless tachyonic condensation is more related to scalar fields with imaginary mass. Unlike predictions [52, 53], no Cherenkov radiation is observed in hadrons. However at high energy for partons like deep inelastic electron proton scattering we must have gluon radiation. In fact there exist some types of Cherenkov gluons radiation in quark-gluon plasma and heavy ion collisions but nuclear index of refraction and other justifications are assumed to be responsible for observed radiation[54, 55, 56, 57]. In superluminal model $n = 1$ Cherenkov angle can be estimated as

$$\cos\theta \approx \frac{1}{\beta n} = \frac{1}{\sqrt{1 + \frac{m_s^2 c^4}{E^2}}} \tag{71}$$

One can interpret β as index of refraction in subluminal model. Similar behavior of dispersion relations has obtained in references. However the Cherenkov energy loss rate from dielectric models seems to be in contradiction with experiments.

From relativistic addition of velocity, if two particle move at speeds of $10c$ and $-10c$ and boosted at 0.99 speed of light, they will have velocities of $1.008c$ and $1.012c$ respectively. We can see how superluminal quarks at positive or negative velocity in boosted proton approximately have same velocity and Cherenkov radiation angle. Thus all random emission of quarks at different angles will be directed at Cherenkov radiation angle.

Hadron mass gap: As another sign in favor of the superluminal model for quarks, we can consider the great difference between the mass of vector mesons and of pseudoscalar mesons. For instance $\pi^+(u\bar{d}) = 140$, $\rho^+(u\bar{d}) = 775$, $K^+(u\bar{s}) = 493$, $K^{*+}(u\bar{s}) = 892\ \frac{Mev}{c^2}$. In the subluminal model, spin interaction (fine structure splitting) can be considered a perturbation (order of α^2) to the principal Hamiltonian (because electron speed is of order $\frac{v}{c} = \alpha$) . Yet the fact that the mass of vector mesons is much greater than that of the pseudoscalar mesons with the same quark contents can be justified only by the superluminal motion of quarks and its effect on the quarks' spin-spin interaction. In fact spin-spin coupling energy is of order of strong interaction and greater than electromagnetic potential $\frac{V_B}{V_E} \approx \frac{v^2}{c^2}$. Logically, the Thomas precession and subluminal motion of electric charges cannot account for such a great Hamiltonian and the energy difference due to the different quark's spin state in vector and pseudoscalar mesons. Note that for great quark masses which can be concluded from angular distribution of two jet event, Chromomagnetic Mass Splitting fails to predict meson mass gap.

On the other hand for next generation of quarks, the ratio of mass gap to meson mass among pseudoscalar and vector meson is very smaller (for instance $B_s^0(s\bar{b}) = 5366$, $B_s^{*0}(s\bar{b}) = 5415$, $\frac{\Delta E}{E} = 0.01$). Maybe this means that the speed of next generation of quarks in the bag is considerably different (slower) from first generation. Does jump in the angular distribution at upsion resonance indicates that buttom quark has a tiny mass in contrast to upsilon mass? If that guess is true heavy mesons made of next generation quarks have more energetic quarks (thus less stable system apart from effects of CKM matrix) and V_S is not the main indicator of their mass. Why we have a large top quark yukawa coupling? It seems that what in non abelian model is called QCD binding energy or gluon binding energy is actually Wilson loop potential V_S in the superluminal model and what QCD considers as the mass of quarks is actually relativistic energy of quarks E in the superluminal model (equation (5)).

There is a similar question about meson mass; if quark mass up and down are negligible why we must observe different masses among chiral partners? For example $J^{PC} = 1^{--}$ has mass of m_ρ=770 Mev while 1^{++} has mass of m_{a1}=1260 Mev [58]. In the superluminal model a_1 has angular momentum of 1 while ρ has angular momentum of 0 and this fact necessarily must affect mass of hadrons composed of tachyonic quarks. Is chiral symmetry breaking a good excuse for explaining huge hadron mass composed of up and down quark?

Effect of superluminal motion on quark helicity, Nucleon spin crisis: What about proton spin crisis? In an experiment first conducted by European Muon Collaboration and later by other groups they suggested that quarks spin contribution cannot account for observed proton spin and quarks carry only a small part of the proton spin[59, 60, 61]. In some papers[62, 63] it is argued that relativistic motion of the valence quarks and interplay of spin and orbital angular momentum in the proton and the one-gluon-exchange hyperfine spin-spin Interaction in the frame work of QCD and bag model can be responsible for missing spin produced by quarks in proton. However some of these corrections are not large enough to resolve the crisis. Certainly superluminal motion of quarks can extensively affect their relativistic corrections in proton, especially it casts doubt on the helicity of quarks in experienment. The intresting point from proton experiement is that for small bjorken scaling x, there is small expected asymmetry A_1 and more randomness but as x increase A_1 approaches unity. Ie there exist more spin crisis at smaller x. In addition for fixed x the asymmetry is not strongly Q^2 dependent. It seems that spin crisis is only related to struck quark energy momentum in contrast to that of the proton and at lower momentum in reference frame of proton there is more randomness. It is evident that superluminal motion of quarks in polarized nucleon create more randomness in their helicity. But again situation can be affected more if helicity of superluminal quarks like chirality remains a lorentz invariant specification. Due to reinterpretation principle spin of superluminal particles is not a Lorentz invariant quantity but its projection onto the direction of its velocity will remain Lorentz invariant in all reference frame.

***CP* violation in standard model:** Due to reinterpretation principle, superluminal antiparticles must have negative energy. This means that mesons and baryons that made from tachyonic quarks differ from their antiparticles that has opposite quark contents and *CP*-symmetry is not the exact symmetry of hadrons. If internal energy of quarks affect decay of hadrons then hadrons are not completely similar to their antiparticles and *CP* violation may be detectable in their decays. Not only an internal energy difference exist among decaying particles from their antiparticles but also it exist among decaying products from their antiparticles and as a result *CP* violation can be observed in hadrons due to asymmetry in decay[64]. *CP* violation is observed in all neutral mesons including $K^0(d\bar{s})$[65], $B^0_s(s\bar{b})$[66], $D^0(c\bar{u})$[67, 68] and $B^0(d\bar{b})$[69, 70]. Because energy of quarks in contrast to confinement potential is small *CP* violation must be difficult to detect especially in experiment of baryons that baryon number must be conserved. However due to huge energy of bottom quark, decay asymmetry in baryons made from combination of third generation and first generation of quark must be detectable. *CP* violation is observed in $\Lambda^0_b(udb)$[71]. It has also been observed in $B^+(u\bar{b})$[72, 73]. Thus we expect that hadrons containing bottom quarks or even charm quarks show higher degree of asymmetry in *CP* conservation. *CP* violation has no explanation in standard model except as input parameters of CKM matrix[74].

If energy of quarks differs from anti-quarks there must be a mass difference among mesons and their anti particles. Result of CPT invariance is equality of mass and lifetime among particle and anti-particle. No strong evidence for CPT violation exist in hadrons which means that mass of hadrons and their antiparticle are the same with good approximation[75]. This is a paradoxical issue here because although CP is violated in hadrons but CPT has not. At least two scenarios exist.

In first scenario because quark and anti-quark in meson must have opposite velocity thus they must have same sign momentum. A gluon is needed with opposite momentum in contrast to quarks momentum for conservation of momentum in hadron reference frame. Probably this gluon has energy too. If the gluon is space like and it is confined thus it can have negative energy in some Lorentz transformed reference frame and obey reinterpretation principle like all tachyons. When we interchange a hadron with anti hadron and its quark contents with their anti quark reasonably a gluon that has positive (negative) energy must be interchanged with a gluon that has negative (positive) energy. If we assume that mass of hadron is determined from V_S, energy of quarks and gluon energy then we can assume that V_S for hadron and anti hadron is the same however quarks and gluon energy must reverse sign. Thus mass of a meson and its antiparticle are equal if and only if summation of the energy of the gluon and quarks is zero or very close to zero in such a way that CPT is undetectable in mesons. This is weird because although summation of three momentum is zero but no reason exist that gluon energy be exactly as much as difference between quark and anti quark in a meson such as Kaon $K^0(d\bar{s})$. This scenario express that mass of all mesons exactly is determined from V_S.

Second scenario says that mass of hadrons made from confined quarks are determined from momentum of quarks not V_S and not quarks energies. Although internal quark energies play rule in their decays and CP violation but hadrons have similar mass to their antiparticles. From comparing mass of pseudoscalar with their vector meson for mesons containing bottom or charm quarks we can see that bottom and charm quarks have speed near the speed of light and these quarks are extremely relativistic. If speed of quarks is near the speed of light then from Wilson loop integration, V_S is very small in contrast to quarks mass. It is near zero as can be seen from equation (50). If we assume that meson mass is merely determined from Wilson loop potential V_S, that means that bottom and charm quark are extremely much massive than even QCD predicts. This is problematic. On the other hand Energy of bottom or charm quark must be even very greater than quark mass. As a result CP violation in these mesons must be very stronger than what is observed in experiments. If Meson mass is proportional to quark momentum such problems do not exist. A small mass is needed for bottom and charm quarks. Thus maybe this option is better choice although it sounds strange that mass of hadrons is proportional to confined quarks momentum.

We can assume that only the gluon that has positive energy will accompany the anti-quark with negative energy and this scenario do not happens for quarks with positive energy. In addition the both energy and momentum of this gluon always must be twice the energy and momentum of anti-quark in such a way that a meson should have equal mass with its anti-particle. But in this picture the gluon that exist in the specific meson such as Kaon $K^0(d\bar{s})$ and probably accompany $\bar{s}$ anti-quark must be different from the gluon that accompany $\bar{d}$ in $\overline{K^0}(\bar{d}s)$. Thus we lose the symmetry in this case. Another question is that why gluons accompany an anti baryons made from three anti-quark but no gluon exist in a baryon made from three quarks. In any scenario we must be careful that do not neutralize CP violation while preserve CPT symmetry.

One conclusion from principle of equivalence and particles with negative energy is interesting. It seems that principle of equivalence makes some discrimination among gravitational mass of a particle and its relativistic energy or mass. If principle of equivalence is valid, it means that probably there exist a geometric model of gravitation in such a way that trajectory of test particles is independent of their mass and merely is determined from their direction of motion and magnitude of their velocities in space-time. Thus we expect that geometric model does not discriminate among a quark with positive energy that has a specific trajectory at microscopic level with its anti-quark if it has same trajectory and speed but with negative energy. Thus from a geometric model seemingly anti-quarks must experience attractive (or repulsive) gravitation in the same manner that quarks experience. This picture probably is in contradiction with Newton third law because we expect that anti-quark with negative energy create a gravitational field with negative sign in contrast to gravitational field produced by a quark. Probably tachyonic field theory creates some problems, although merit of these problems is that they appear at fundamental level and issue in nuclear physics and may help to underestimating of problems in other fields.

7 Discussion and conclusion

As we know, lattice gauge theory is the ideal tool for performing precise calculations on a low energy scale in quantum chromodynamics. On the other hand, performing exact calculations with a minimum lattice distance requires supercomputing power, while in the above, we obtained the interquark potential in a simple manner. For larger couplings, smaller spacing and more powerful computers are needed which means computers never manage to solve QCD at singular values. A theory should be perfect (for example contrast Geocentric model with Copernican heliocentrism model or relativity with Aether theories). In other words, intuitively, if a theory is formulated correctly using appropriate and correct assumptions and formulas, that theory should never need the calculational power of such strong machines. If a theory requires such high-caliber equipment, beyond the scope of paper and pencil, this only means that the formulation of the theory is incorrect and inappropriate. Our formula should provide maximum information but minimum complication regarding our system. If we consider a tachyonic model of strong interactions instead of the traditional non-abelian theory, we obtain the ability to calculate and depict all quark-quark interactions such as interquark potentials with maximum precision. This is similar to the case in quantum electrodynamics where all types of cross sections can be calculated in principle without the help of a computer; thus, we can perform similar calculations for strong interactions.

Some scientists such as Einstein considered quantum mechanics to be an incomplete and raw picture of physics because it did not provide the exact and maximum information that its predecessor, classical mechanics, could provide [76, 77]. In another example, we would point out the large discrepancy in gravitational theory-between what our theory, i.e., general relativity predicts, and what our data indicates, e.g., in rotation galaxy curves and the cosmological constant problem-which seeks to fix the error by introducing hypothetical yet unobserved phenomena such as dark mass and dark energy.

An important point regarding strong interaction is the fact that there is no gluon-gluon interaction term and no non-abelian behavior. Thus, strong interaction is a linear theory in principle and the superluminal motion of quarks creates strange specifications of strong force. Therefore, among the three interactions, only gravitation seemingly has a non-abelian behavior and graviton-graviton interaction. In any theory, a non-abelian characteristic creates a singularity in the theory for which we cannot perform calculations at the singular point. The singularity in QCD is the low energy region of interaction. If we consider the superluminal model, we are able to predict all phenomena at the singular point. A similar point in Einstein's field equations is that they are nonlinear partial differential equations too. Non-linear partial differential equations have non-exact solutions. Furthermore, the theory has singularity in the Schwarzschild radius and we hope the theory of quantum gravity provides a solution at this scale. Most probably in physics, singularities are result of inappropriate formulation of the system and all singular points must be, in principle, calculable at any given precision. Here, another question arises. If we consider quantum mechanics as an inappropriate formulation of reality, is the uncertainty principle (resulted from un commutative relation) its singularity?

Theory	Incalculable singularity
QCD SU(3)	Low energy limit
General Relativity	Schwarzschild radius
Quantum mechanics	Uncertainty principle

At this point, we consider other facts regarding the immature and raw formulation of tachyonic dynamics. Unlike the process in the Higgs mechanism that creates real mass from the positive unstable potential term in the Lagrangian, tachyonic condensation is not observed in hadrons and hadrons are stable composites. Is there a theoretical reason for suppression of tachyonic condensation and cherenkov radiation? Quarks do not obey the Pauli exclusion principle, which is a fact that is not predicted in the tachyonic field theory of spin one-half particles. Generally speaking, superluminal particles do not obey the traditional laws of quantum mechanics. We do not know why the electromagnetic field among superluminal particles is always attractive and why the net charge of hadrons must be an integer. Is attractive force related to spin statistic of tachyons? Tacyonic field theory must explain why we do not have a single tachyon. Quantum field theory for superluminal particles needs significant review. An appropriate tachyonic field theory must explain the observed phenomena in hadrons not neutrinos. As we can see due to specification of superluminal velocity, velocity of quarks, direction of their motion, negative or positive energy of quarks and their spin play key rules in quarks interactions. It is interesting that why nuclear force has a tensor component. Unlike subliminal case, what can be the effect of relative direction of motion of two adjacent quarks from two nucleon on the positive or repulsive sign of force among two quarks?

In spite of the troublesome nature of tachyonic field theory, the superluminal model offers a united model for strong interaction, but the SU(3) model does not have this advantage. In other words in standard QCD, we have different models and effective theories to justify a specific result and usually each model offers appropriate predictions for a specific spectrum of experimental results; and in the range of energies where we can simultaneously use other models, we usually face contradictory results which means that the foundations of our models are inappropriate. For example, we know that the QCD sum rules are tools to deal with hadrons at non perturbative region. In addition, we know that the MIT bag model is created on the assumptions of both the subluminality of Dirac current and the confinement of this current. Yet, on the other hand, the predicted results and parameters, such as vacuum energy and pressure of hadrons from these two theories, are contradictory to each other. In addition, due to the fact that rigid boundary condition can leads to spurious quark motions, the MIT bag model is not Lorentz invariant[78]. Other nucleon and bag models are not ideal models too. We offer different models at different energies and seek to close the gap between them, and we are faced with contradiction. The reason is that no subluminal model can create true confinement and an appropriate model of strong interaction. Thus, we logically face several errors in the results derived from these different methods designed to solve the system. Simply speaking nonabelian model and its potential contradict Wilson-Sommerfeld quantization and quantum mechanics because we consider a classical potential for our system without notice. Only coulombic potential agree with the structure of quantum mechanics. We should not use classical justification to express why electrons do not fall into the nucleus. SU(3) model naively express that at finite distance due to huge potential we have zero kinetic energy and thus zero momentum but this picture contradict quantum mechanics and Wilson-Sommerfeld quantization. Another question about the SU(3) model is that if this model is the true model of confinement, why has no glue-ball yet been observed? However, we have achieved energies in the range of a hypothetical glue ball and only weak possible candidates exist[79, 80]. Thus, although the SU(3) model offers some approximations of true strong interactions and mimics the superluminal model, there is no strong experimental evidence to confirm the color concept.

It is interesting that we use bulk of corrections in Phenomenology to justify data in QCD while such asymmetries do not exist in QED to adjust experimental results with theory. The fact that first generation quark mass is imaginary and is much greater than what the SU(3) model predicts must be detectable in all types of scatterings, decays and cross section formulations (provided we develop a successful interacting tachyonic field theory). Although non abelian and superluminal model resemble each others at high energies but they differ at low energy values. If further experiments on cross sections prove that SU(3) is inappropriate model for strong interaction, it would seem that we must review other concepts such as the unsolved strong CP problem, axions, and other concepts that QCD and grand unified theories predict such as proton mass decay. Up to this time, no direct evidence for axion and proton mass decay has been observed and possible detections rely on interpreting astronomical observations[81, 82, 83]. Even if superluminal model is an incorrect model of strong interaction it is very suspicious that it offers similar results to those of QCD. Why nature is hypocritical? If quarks are really superluminal and we ignore it, physics is doomed to remain in trap of QCD and deadend of unifications for centuries. The problem is not merely quantum mechanics mystery and unification of forces; after so many decades we are still unable to achieve fusion energy.

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