Mechanism of Confinement of Quarks

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ABSTRACT: From Londons' equation the potential arising exponentially has been introduced which is responsible for the confiment of quarks. It has been proved that quark-gluon soup presents superfluidity, using the conception of lattices and very deep homology between phenomena: superfluidity and superconductivity, has been proved. It permits to use Londons' equation for the description quark-gluon soup. Next the structure and dynamics of lattice has been analysed and the possibility of the existence of sublattices has been proved.

I The Londons' equation

1.1 Lately a few conceptions of confinement of quarks have appeared. The conception of fibres is specially interesting. The gluon-electric field flux fibres expands between quarks and theirs antiparticles. This fibre has finite energy for the unit of lenght. In so way we obtain the interquark potential arising linearly with the distance [1].

The other conception is the sack model. The quarks are free inside sack hadrons but they can not abandon them. Trying to obtain the single quark from hadron, we take out long, thin sack with glueelectric field between quarks and the rest of components of hadron [2].

The teory of strong interactions with nonabelian calibration has been formulated on space-time lattice [3]. This attitude has inspirated this article, two lattices has been introduced: 3-dimentional - whole analogy of cristal lattice and 4-dimentional one with generalization to 8 dimention, taking under consideration $v > c$ [4].

1.2 Let's analyse Londons' equation [5]

$$\frac{mc^2}{4\pi ne^2}\nabla^2 H = H \qquad (1)$$

so $\alpha\nabla^2 H = H$

Particularly one of its solutions is:

$$H = H_o e^{kx} \qquad (2)$$

We will prove that the solution with shape (2), generally rejected, can be used to the explanation of the confinement of quarks.

1.3. At the beginning we have to see, in what way the magnetic field intensity is connected with bound- potential.

$$\vec{\nabla}\times\vec{A} = \vec{e}_1\left(\frac{\partial A_3}{\partial x_2} - \frac{\partial A_2}{\partial x_3}\right) + \vec{e}_2\left(\frac{\partial A_1}{\partial x_3} - \frac{\partial A_3}{\partial x_1}\right) + \vec{e}_3\left(\frac{\partial A_2}{\partial x_1} - \frac{\partial A_1}{\partial x_2}\right) \qquad (3)$$

Let's analyse the case:

$$A_1 = A_x(y)$$
$$A_2 = A_y(z)$$
$$A_3 = A_z(x) \qquad (4)$$
$$\vec{B} = \vec{\nabla}\times\vec{A} \qquad (5)$$

From (3) and (5) we obtain:

$$B_z = -\frac{\partial A_x}{\partial y} \qquad A_x = -\int B_z\,dy$$

$$B_y = -\frac{\partial A_z}{\partial x} \qquad A_z = -\int B_y\,dx$$

$$B_x = -\frac{\partial A_y}{\partial z} \qquad A_y = -\int B_x\,dz \qquad (6)$$

$$\vec{B} = \mu\vec{H}$$

The formula (2) may be written for each coordinate:

$H_x = e^{ky}$, $H_y = e^{kz}$, $H_z = e^{kx}$

Let's analyse the hamiltonian in the shape [6]

$$H = c\bar{\alpha}\bar{p} + \beta mc^2 + V$$

V-interaction potential.

The first term obtains the form $\alpha_{nk}p_i$ and in the case of momentum it can be written $p_i \rightarrow p_i - \frac{e}{c}A_i$; and this way vector potential A_i is added to the interaction potential.

1.4 The integral (2) may be created in the form of series. The integral of exponence is expenence, too:

$$A = A_o\left(\sum_{n=0}^{\infty}\frac{(kx)^n}{n!}\right)$$

and we may cut on the linear terms, which can be made for the distances comparable with the size of hadron. The linear bounding potential arises and is calculated here from the centre of the coordinate system and not from the other quark.

1.5 An equation (1) has next solutions (besides solution (2) :

$$H = H_o \sin kx \quad \text{and} \quad H = H_o \cos kx \; ; \; \alpha < 0$$

$$k = \frac{2\pi}{a} \quad a - \text{constant lattice}$$

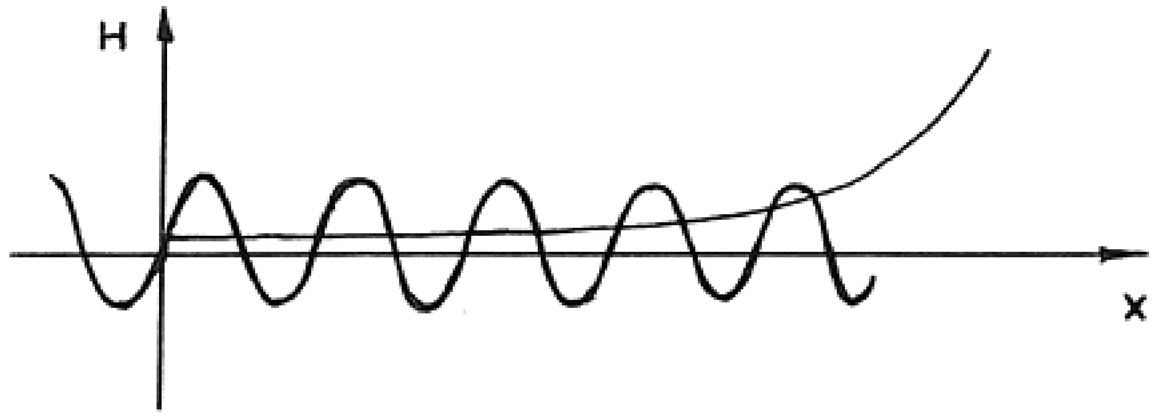


figure 1.

It means the existence of periodic potential becouse of (6). The periodic potential means that quarks exist in this periodic potential created by the lattice and tunnel through maxima of potential, so they are quasi - free like common electrons in solid body.

The confinement of them is connected with potential (2). The quarks with $H > H_o$ are bound too, but they don't tunnel inside the quark. They can't tunnel from the quark. The centre of coordinate system is free and it can move. This movement corresponds with the movement of quark as the whole. The lattice, besides the periodic potential, creates the exponence potential. For x negative, the bounding potential is $A = A_o e^{-kx}$ arising to ∞ at $-\infty$. The quanta of oscilation of this lattice are quarks.

1.6 Let's analyse the general potential of lattice:

$H = H_{0A}\sin kx + H_{0B}\cos kx$

$\nabla^2 H = -k^2 H_{0A}\sin kx - k^2 H_{0B}\cos kx$

$A = kH_{0A}\cos kx - kH_{0B}\sin kx$

We have next:

$\alpha\nabla^2 H = H$

$\alpha(-k^2)H = H$

$\alpha = -\frac{1}{k^2}$ so $\alpha < 0$

but $\alpha = \frac{mc^2}{4\pi ne^2}$ so $m < 0$

$m < 0$ corresponds with the position below energetic gap. In analogy with superconductivity and Dirac's unempty vacuum it corresponds with carriers with negative mass placed below energetic gap.

$m < 0$ refers only to these objects, which are responsable for creation of periodic potential.

For the solution $A = A_0 e^{kx}$ $\alpha > 0$ and $m > 0$ occur.
It may be thought that the object creating an infinite potential exists over energetic gap. In the case of confinement of quark $\Delta \to \infty$ but $A \to \infty$ and $A - \Delta$ is an indeterminate symbol which may achieve any value so different from zero too.
It may be assumed that mass of quarks is bigger than zero although they are confined but aren't responsible for potential and in their case the quotient $\frac{e}{m}$ is important [7].

1.7 We have two solutions describing potential:

$$A_1 = A_0 e^{kx} \tag{8}$$

$$A_2 = \sum_{n,m} \left[A_n \sin\left(\frac{2\pi}{an} x\right) + A_m \cos\left(\frac{2\pi}{am} x\right)\right]$$

Let's analyse the region $x > 0$.
$A_3 = \max \{A_n, A_m\}$, x_0 is the most distant common point of A_1 and A_2 – exponence cuts every trigonometric function with the exeption of solution when it starts below and $A_0 < 0$.
For $E > A_3$ hadron is in excited state. For every x such, that $E > A_3$ nucleon is persistently excited although the quark can't tunnel in excited state.

The oscilating potential with period equal to multiplication factor of constant lattice are added inside the hadrons till the point at which they cut an arising exponence.

Naturally the confinement in three dimensions means that potentials (8) and (9) exist in the case of any coordinate, so:

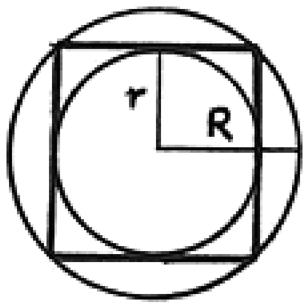
$$A_1 = A_{1x} + A_{1y} + A_{1z}$$

$$A_2 = A_{2x} + A_{2y} + A_{2z}$$

II The loop mechanism of superconductivity.

2.1 The superconductivity effect of Hall's quantum phenomenon [2] leading to fractional charges, testimonies that quark-gluon soup (in which the quarks have fractional charges, too) superconducts, too. The superconductivity of nucleons is characterised by an infinite energetic gap. In nucleons three quarks have half spin so they can not be subject to Bose-Einstein condensation. The superconductivity of quark-gluon soup is created by 3-and 8-dimensional lattices. The 3-dimensional lattice corresponds with 3 sorts of quarks and 8-dimensional lattice corresponds with 8 sorts of gluons.

2.2 The lattice may be made of deformed to quasi square loop creating the wall of cube. Three groups of such loops in the planes xy, yz, xz create the lattice made of cubes. It is easy seen that square loop superconducts



$R = \sqrt{2}r$

Figure 2

If the circle loop superconducts circle loop circumscribed about a square and circle loop inscribed of a square superconduct too. If $r \rightarrow R \rightarrow 0$ which is fulfilled in the microworld the square loop must superconduct.

2.3 The unempty vaccum superconducts [9] , becouse it is woven from Ashtekar's loop which are the subject of the superfluidity, analogically to rotons loop in Landau's superfluidity theory. The rotons loops are necessary to explain the phenomenon of superfluidity. (The rotons in solid phase are subjects to loop motion).
Similarly in superconductivity the loop exist, around which an electric field is quanted. An integral around the circle in superfluidity describes roton too.

An existence of whirls of electric field in superconductivity

$$\oint \vec{E}d\vec{l} = const$$

corresponds with existence of rotons in superfluidity and this similarity is a proof of affinity of these phenomena - the bridge binding these both phenomena.
We introduce field of roton and the principle of conservation of roton for rotons creating layer (plane) of cristal lattice.

$$\oint \vec{R}d\vec{l} = const$$

These both equations unify superconductivity and superfluidity.

2.4 The quark-gluon soup is in the state being superposition of superconductivity and superfluidity.
8 gluons in different charge state create clusters called rotons.
The quarks are in superconductivity potential $A = A_o e^{kx}$.
The superconductivity is a result of existence of lattice which shields like in cristal.
8 charges of gluons correspond with 8 corners of cube.
In each corner there is different charge of gluon. Such cubes strech lattice. This lattice makes the superconductivity possible. Each wall of the cube is one loop and each cube is one generalized three-dimensional loop.
There are two kinds of lattices in hadron. The quanta of oscillations of the second lattice are 8 kinds of gluons. Quark is quantum of oscilation of three-dimensional lattice. (Three dimensions - three quarks, quark as the wave).
Along each dimension there are condensed superconducting loops. Additionally the condensation of 8 such perpendicular systems of superconducting loops exists.
The superconducting system composed of 8 systems of superconducting loops exists.

2.5 From the preceding consideration we have:

$$V_i = \int V(x)\,dx$$

$$V_i = V(x) + \text{const}$$

Let's analyse a few cases:

1) const is real - the constant component of potential
2) const = complex = c, describes the loop structure

$$c = c_0 e^{i\varphi}$$

3) const = quaternion = c

$$c = c_0 + c_{01} e^{i\varphi_j} + c_{02} e^{i\varphi_k} + {}_{03}e^{i\varphi_l}$$

4) const = A

$$A = \prod_{j=1}^{8} e^{i\varphi_j}$$

8-dimensional loop in 8-dimensional space-time.

III Structure and dynamics of lattice

The following correspondence exists: 8 charges of gluons, 8 corners of cube of elementary cell of superfluid lattice and 8 relativistic dimendions. The gluons creating 3-dimensional lattice correspond with standing wave of 8-dimensional lattice.

The gluons exchanged in interactions of quarks correspond with moving wave of 8 dimensional lattice. The gluons of 3-dimensional lattice exist in common part of 3-dimensional and 8-dimensional space.

One gluon is connected with oscilation along each dimensions but disturbance connected with each single gluon is propagating by right of conjunction in cristal lattice with each of the remaining 7 dimensions.

$$\psi_i = \chi_i \prod_{\substack{j=1...8 \\ j \neq i}} \varphi_j$$

χ_i - the primary function of i-gluon propagating in i-dimension

ψ_i - the disturbances propagating in remaining directions connected with i-gluon.

Two gluons of selfinteraction are time-like gluons. The time-like gluons have the shape:

$$\chi_p(t_o - t) = \Theta_1 (t_o - t) + \Theta_2 (it_o - it)$$

$$\chi_n(t_o - t) = \Theta_1 (t_o - t) - \Theta_2 (it_o - it)$$

χ_p, χ_n - the propagation forewards and backwards the time, the mixing of effects arisings from the real and complex time.

3.2 8 dimensions may be connected with 8-dimensional Einsten's equation [7] , which can be done, becouse in the case of small distances in the case of hadrons, gravitation plays great role. Becouse of electomagnetic interaction the generalized Dirac - Einstein equation ought to be used, too.

3.3 Quarks exchange phonons of oscillation of lattice. The lattice creats superconducting potential confining quarks. The line of lattice corresponds with created fibres. The line of lattice creats potential which generates fibres. The structure of fibres recreats the structure of lattice.

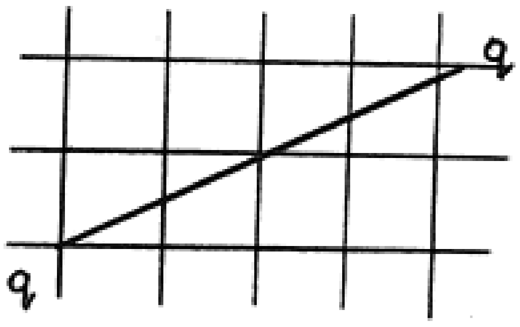


Figure 3

The fibres are so dense, that the fibre lying nearest the line binding two quarks is introduced into energe-state, when the second quark appears, which is correlated with exchange of phonon of lattice conjucted with fibres.

The interquark potential is described by the formula $V_1 = ax + b$. Potential of the second quark is given by the formula $V_2 = ax' + b = a(d-x) + b$.

The total potential $V = V_1 + V_2 = ad + 2b$

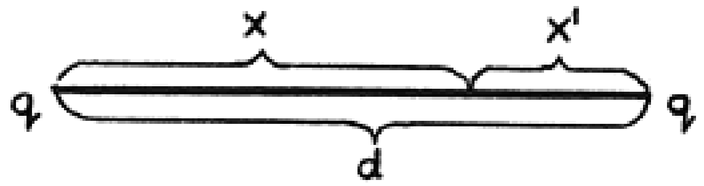


Figure 4

It is seen that the fibres are filled with energy in the homogeneous way and that this energy depends linearly on the interquarks distance in accordance with the shape of potential.

The problem is open if the constant lattice is small but different from zero or it tends to zero.

The lattice has many levels with sublattices $d = \frac{a}{2^n}$ [9] $(n \in N)$. Each such sublattice manifests the superfluidity.

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