The Substantive Model of the Proton According to J. Wheeler's Geometrodynamic Concept

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The review article presents the proton structure in accordance with the model based on a mechanistic interpretation of Wheeler's geometrodynamics. It is shown that this model gives a physically justified interpretation of the concepts introduced in quantum chromodynamics, such as "quark", "color", and also excludes the problem of confinement and others. The main parameters of the proton are calculated, namely: its mass, magnetic moment, lifetime, the proton-neutron mass difference, and also an analytical formula for its radius is derived. Typical lifetimes for various classes of elementary particles have been determined. Successful usage of the model gives reason to assume the model can be used for development a more rational theory of strong interactions instead of QCD.

1 Introduction

The internal structure of elementary particles, in particular of the proton, and their interactions with each other are considered in the theory of strong interactions (quantum chromodynamics). In QCD, there are no complete substantive models of the physical systems under consideration; instead, idealized virtual particles and quasiparticles (quarks, gluons) are introduced, as well as the concepts of an abstract image ("color") are appealed. QCD is based only on the observed properties of hadrons. It is assumed, that in hadrons interaction processes the numerous laws of conservation and redistribution (the amount of matter, energy, momentum, angular momentum, electric charge, magnetic flux and others) must simultaneously be fulfilled and various conditions must be observed.

In the absence of essential real models of elementary particles, the standard theory uses the approach of quantum mechanics: the properties of quarks and hadrons are simply described using wave functions and unitary symmetry combinatorics. The combination rules has formally been derived using the mathematical apparatus of quantum field theory and confirmed by experiments (there are 17 parameters that cannot be derived from the theory). However, it is not known why their physical nature is exactly this. In particular, it is not known why quarks can exist only in a bound state ("confinement"), which is recognized as one of the seven problems of the millennium.

This article shows the possibility of replacing the abstract QCD concepts applied to elementary particles with the particles real physical parameters. In contrast to the quantum theory, which states that micro-phenomena cannot be understood in any way from the point of view of our world scale, the mechanistic interpretation of Wheeler's idea first of all presupposes the presence of uniform or similar natural laws that are reproduced at different scale levels of matter. These laws, or at least their macroanalogues, are revealed in the structure of elementary particles. Therefore, there is reason to believe that the model based on Wheeler's idea can be used to construct a more rational theory of strong interactions instead of QCD.

2 On the macroanalogues

According to Wheeler's concept charges are considered as singular points on a three-dimensional surface, connected by a "wormhole" or vortex current tubes of the drain-source type, forming a generally closed contour, which a physical vacuum or some medium circulates along. From a purely mechanistic viewpoint the charge is proportional to the momentum of this medium in its motion along the vortex current tube contour, the spin, respectively, is proportional to the angular momentum of this medium relative to the contour longitudinal axis, while the magnetic interaction of the conductors is analogous to the forces acting between the current tubes.

The work [1] shows the possibility and expediency of introducing the "Coulombless" system of units and replacing the Coulomb with momentum. This approach allows using of well-known physical macroanalogues. The space and medium unit elements in the model are: an element with an electron mass m_e and size r_e and a vortex tube with a linear density $\varepsilon_0 = m_e/r_e$.

Microparticles are likened to vortex formations in an ideal liquid, where a vortex funnel (conditionally it is a surface X) is a *fermion analogue* with mass m_x, and a vortex thread in depth below the surface (conditionally it is a region Y) is a *boson analogue* with mass m_y, length l_y, radius r, and peripheral speed v. The vortex thread, in turn, is capable of twisting into a spiral forming subsequent structures (current tubes). In a real medium, these structures oscillate, transforming into each other (oscillation of oscillators); it is assumed that this is accompanied by the "packing" of the bosonic thread into a fermionic form. Apparently, fermion particles retain the bosonic part with half spin, which determines their magnetic and spin properties, and in the bosonic form the spin is restored to an integer value.

By the well-known physical analogy, the vortex tube of a contour, crossing over the surface of a liquid, creates ring waves or *contours of the next order*. Thus, interconnected contours are formed. Therefore, any particle seems to have two quantum numbers, depending on how one consider it: as a fermion (the analog of the proton being part of the greater contour of the subsequent family of particles) or as a boson (the mass of the contour of the previous family of particles). Thus, three generations of elementary particles as shown in [2] to form and there cannot be more. The microparticle itself is no longer considered as a point object and is characterized by the parameters of its own contour with a quantum number n.

The parameters of a bosonic vortex thread (or a contour with mass M) are determined in dimensionless units: in the fractions of the electron mass m_e, its classical radius r_e, and the speed of light c:

$$m_y = l_y = (an)^2, \tag{1}$$

$$v = \frac{c_0^{1/3}}{(an)^2}\,, \tag{2}$$

$$r = \frac{c_0^{2/3}}{(an)^4}\,, \tag{3}$$

where a is the inverse fine structure constant, c_0 is the dimensionless light velocity $c/[\mathrm{m/sec}]$.

In [3] a closed proton-electron contour is considered. From the condition of equality of the medium motion energy along the contour Mv^2 and the ultimate electron energy m_ec^2 the charge numerical value as the vortex current tube momentum and the projection angle value are determined. The projection angle value turned out to be complementary to the Weinberg angle $q_w \approx 28.7°$. Such a contour is "standard" and has parameters: the main quantum number $n = c_0^{1/3}/a = 4.884$, mass $M = c_0^{2/3} = 4.48\times10^5$, and the charge value (momentum)

$$e_0 = m_e c_0^{4/3}\cos q_w \times [\mathrm{m/sec}] = 1.602\times10^{-19}\ \mathrm{kg}\times\mathrm{m/sec}. \tag{4}$$

One can state therefore that the vortex current tube is formed by three vortex threads rotating around the common longitudinal axis. These threads are finite structures. They possess, by necessity, the right and left rotation; the last thread (it is evidently double one) possesses summary null rotation. These threads can be associated with vector bosons W^+, W^-, Z^0.

For the rotating unidirectional currents vortex threads with the condition of the magnetic and inertial (centrifugal) forces equilibrium their peripheral velocity v_0 is derived. If there are unit parameters, then it is true [2]:

$$v_0 = \frac{r_e}{(2\pi)^{1/2}\times[\mathrm{sec}]} = 1.124\times10^{-15}\ \mathrm{m/sec}. \tag{5}$$

This speed does not depend on the vortex threads length and on the distance between them. Thus, having some definite mass and length, bosonic vortex tubes *do not have a certain configuration and shape*. The latter indicates the difference between bosonic vortex tubes and their physical analogue; this is also the physical reason for their difference from fermions in that bosons do not obey the Pauli exclusion principle.

3 The proton and its parameters

With the extremely dense packing of a bosonic thread into a fermionic form, as shown in [2], the proton and electron own quantum numbers have the following values:

$$n_p = \left(\frac{2c_0}{a^5}\right)^{1/4} = 0.3338\,, \tag{6}$$

$$n_e = \left(\frac{2c_0}{a^5}\right)^{1/8} = 0.5777\,. \tag{7}$$

It was found that the relative mass of any fermion m_x with an arbitrary quantum number n_x is determined by the ratio:

$$m_x = \left(\frac{n_e}{n_x}\right)^{14}. \tag{8}$$

For a proton, as it turned out (with slight simplifications), its fermionic and boson masses are equal, $m_x = m_y = 2090$, which is the reason for its minimum baryon mass and its stability. When corrected by the Weinberg angle cosine, the proton relative mass is determined quite accurately, i.e. $m_p = 2090\times\cos q_w = 1836$.

The charged particle included in a circulation contour is the place where a medium flow intersects the boundary between X- and Y-regions; there occurs a phase transformation. In this case, the fermionic and boson densities become equal, and the parameters of the medium acquire density and velocity *critical values*. The values of these critical parameters can be attributed to some quasiparticle — a *quark* that exists only in the phase transition region, which in fact is the part of the proton mass obtaining critical parameters. Moreover, in order to comply with the critical parameters at the standard contour energy m_ec^2, it is necessary to split the general contour current in the proton region into three parts (calculated value is 3.2). Under these conditions, the total quark mass m_k is 12.9. At the same time, as shown in [2] and [4], this mass depends on the interaction conditions and can take a minimum value equal to the electron mass.

In addition, the conditions for the flow continuity and charge constancy in any cross section of the contour (there must be three current lines) require the *reverse circulation currents* in the proton region to arise, which can be interpreted as the presence of zones with different charge signs in the proton. Using the minimal number of non-recurrent force current lines, one can schematically express current lines in a

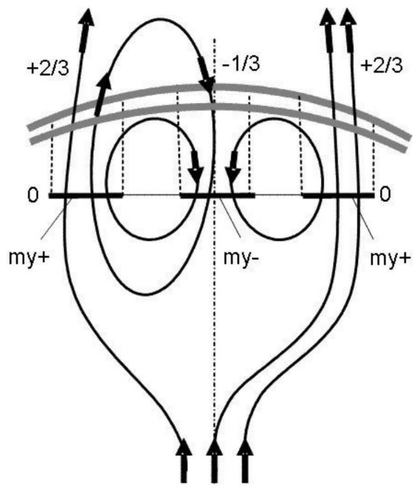

Fig. 1: A scheme of the proton: distribution of the current lines inside the proton.

proton in an unique way, as shown the Fig. 1. As seen, there exist two critical sections with a conditionally plus current (on the scheme up) and one section with a conditionally minus current (on the scheme down), where three current lines correspond to a general current in the scheme. Consequently, the proton fermionic surface for an external observer is as follows: the regions where force lines intersect the critical sections on the line 0–0 inside a proton will be projected onto the proton surface in the form of +2/3, +2/3, −1/3 of the total charge in according to the number and direction of the force lines crossing this surface. It would be more correct to associate quarks not with critical sections, but with stable ring currents containing, as follows from the diagram, one or two closed unit contours intersecting the critical sections.

Obviously, the proton parts in the critical sections have the velocity c and radius r_e, and they must have the bosonic vortex tubes of such length l_y that their own momentum would be equal to the momentum (charge) of an electron e_0. Assuming that the vortex tube linear density for critical conditions is proportional to the average quark mass $\frac{1}{3}\, m_k$, we can write:

$$\frac{1}{3}\, m_k\, \frac{m_e}{r_e}\, l_y r_e c = e_0\,. \tag{9}$$

Bearing in mind that in a "Coulombless" system the charge has the dimension of momentum and substituting the known parameter values, we find $l_y = 136.4$. Thus, the relative bosonic part length is actually equal to a, its unexcited mass is am_e, respectively, the vortex tube angular momentum (spin) is equal to $am_e c r_e = h/2\pi = \hbar$. Thus, the structures inside the proton are found with the relative length l_y and boson mass m_y, numerically equal to a, and the spin, equal to $\hbar$. Apparently, there are pairs of such boson tubes with the mass equal to that of a pion and with the counter-directional rotation that compensates for the spin. Depending on the currents impulse direction, they can form the pions family or be part of other mesons, which are supposed to exist in the close environment of protons in the form of a virtual meson "coat".

The *magnetic moment of the proton* μ_p in this model is calculated in accordance with its definition, where μ_p is the product (charge × velocity × path) and is determined by the bosonic configuration of the proton. The peripheral speed of the vortex threads relative to the Y-axis is υ, the path is πr. Revealing υ and r through (2) and (3), we finally get:

$$\mu_p = \frac{\pi c_0 e_0 c r_e}{(an_p)^6} = 1.39 \times 10^{-26}\ \mathrm{Am}^2. \tag{10}$$

For an electron, the path is the Bohr radius, and (10) takes the form:

$$\mu_e = \frac{\pi c_0 e_0 c R_B}{(an_e)^6} = 9.30 \times 10^{-24}\ \mathrm{Am}^2. \tag{11}$$

Only closed current lines remain in the neutron. The magnetic moment of the neutron equals two thirds of the proton's magnetic moment, i.e. proportional to the number of intersections of the critical sections by current lines (six instead of nine, existing in a proton, see Fig. 1) and is equal to -0.92×10^{-26} Am^2. Naturally, the magnetic moment sign changes in addition, because three positive open current lines are removed. The obtained values differ slightly from the actual ones, since the parameters n_p and n_e are determined with some simplifications.

The *neutron-proton mass difference* arises due to the acquisition of additional mass-energy by the neutron when the proton absorbs the electron. In [2] it was assumed that in the proton-neutron transition state one of the quark contours is located at the intersection of X–Y regions, and, becoming axisymmetric, increases itself to the maximum value m_{max}. In this case, keeping in mind (1) and (3), its parameters are $l_y = r = c_0^{2/9} = m_{max} = 76.5$. The difference between the kinetic energies of rotation of the excited contour and the initial quark contour with an average mass $\frac{1}{2}\, m_k$ should correspond (when corrected by the cosine of the Weinberg angle) to the proton-neutron mass difference Δm:

$$\left(m_{max}\upsilon_{max}^2 - \frac{1}{2}\, m_k \upsilon_k^2 \right) \cos q_w = \Delta m. \tag{12}$$

Indeed, proceeding from their relative masses 76.5 and 12.9/2 and calculating their quantum numbers and velocities by (8) and (2), as a result, after substituting all quantities in (12), we find $\Delta m = 2.51$, which coincides with the actual value (2.53).

The exact *size of the proton* was determined in recent experiments [5]. It is significant that within the framework of this model, which does not use a complex mathematical apparatus and, in fact, is not a physical and mathematical model, but rather is a physical and logical one, it was possible to obtain an analytical formula for the proton size, proceeding from general laws only.

So, in [6] it was found that a single contour or a vortex tube having the momentum equivalent to the electron charge contains $n_i = 3$ single vortex threads, and the formula is obtained:

$$n_i = \frac{\left\{\left(m_e c_0^{2/3} r_e\right) / \left((2\pi)^{1/2} \times [\mathrm{sec}^2]\right)\right\}^{1/3}}{\{(2\pi)^{1/2} \gamma m_e^2 / r_e^2\}^{1/3}} = 2.973 \approx 3. \quad (13)$$

The formula is the cubic root of the ratio of the inertial forces, arising during the acceleration of the standard boson contour mass and acting towards the periphery (the value $r_e / \left((2\pi)^{1/2} \times [\mathrm{sec}]\right)$ is the rotation speed of the vortex threads relative to the contour longitudinal axis), to the gravity forces acting between masses of the size m_e at the distance r_e. The numerator is a constant value, so the formula depends only on the gravity forces, that is, on the interacting masses and the distance between them. It was shown in [4] that this ratio (or its modification for arbitrary m and r) can serve as a *coupling constant* equivalent, since it indicates the strength of bonds between the proton structure elements (quarks).

Moreover, it is the equality of these forces that determines the proton radius r_p and makes it possible to obtain an exact analytical formula under the condition $m_k = m_e$. Let us specify formula (13) under the assumption that the quarks are located at the corners of a regular triangle and that each of them is affected by the sum of two projections of forces, and also take into account that r_p is the size of the circumscribed circle. Then the formula is written in the form of equality of the dynamic and gravitational forces:

$$\frac{m_e c_0^{2/3} r_e}{2\pi \times [\mathrm{sec}^2]} = \frac{2 \sin 60^\circ \gamma m_e^2}{(r_p \sin 60^\circ)^2}\,, \quad (14)$$

whence we get:

$$r_p = \frac{(8\pi\gamma\varepsilon_0)^{1/2} \times [\mathrm{sec}]}{3^{1/4} c_0^{1/3}} = 0.836 \times 10^{-15}\ \mathrm{m}, \quad (15)$$

which exactly coincides with the proton charge radius value obtained in the recent experiments (0.833 femtometers, with an uncertainty of ±0.010 femtometers [5]). Thus, the boson mass of the standard contour, which is in the Y region and is, as it were, hidden, having the value $m_e c_0^{2/3}$, determines not only the proton charge and spin, but also its radius. Note that this radius is determined for the proton in the hydrogen composition, but not for a single proton, where it can have a greater value. It is important that the formula (15) contains the gravitational constant; in papers [2, 7, 8] the necessity of introducing gravity into the microcosm is shown, in particular, to determine the neutrino mass.

Thus, there is a sufficient set of parameters for the proton internal structure to describe the strong interaction. The concepts of fractional charge, quarks and color find here their physical representation. Indeed, there are two different ring currents or circuits (quarks u and d), the force lines of which are projected onto the proton outer surface in the form of fractional charges, and three different critical sections ("colored" quarks). Moreover, as the contour currents can be directed in the opposite direction, forming antiquarks, so the vortex tubes in the critical sections can have the opposite direction of rotation, creating an "anticolor". It is obvious that the proposed proton structure in the form of a field lines unique configuration no longer requires the confinement existence and, consequently, the filling of the proton region with the "sea" of virtual quarks and gluons.

In fact, the concept originating from the hydrodynamics of a continuous inviscid media is proposed here and this analogy turned out to be correct. Moreover, it has been established that the light velocity can be calculated by the equation describing the wave propagation on a liquid surface [9].

4 On the elementary particles lifetime

The microparticles decay probability and their lifetimes depend on many factors. The most important of them is the type of interaction (electromagnetic, weak, strong), which is responsible for the decay that occurs. The lifetimes of elementary particles differ extremely strongly: $10^{-6} \ldots 10^{-25}$ seconds, at that most of them are grouped according to their lifetimes in rather narrow intervals. This model has objective parameters that allow one to estimate the microparticle various classes lifetime. Further there are calculated values, in general, corresponding to the average lifetimes for these classes.

The *microparticle lifetime* t (except for resonances and W, Z bosons) can be estimated as the time it takes to run around with a velocity v over the entire "stretched" contour length [7]:

$$t = \frac{a^8 n^8}{c_0} \frac{r_e}{c}\,. \quad (16)$$

But W, Z bosons and resonances decay even before the final spiral structure is formed, i.e. they are, as it were, not completely particles. W, Z bosons have the shortest decay time, and it is determined by the time it takes to run with the speed of light around the electron vortex tube with the radius r. Bearing in mind (3),

$$t_{min} = \pi \frac{r_e}{c} \frac{c_0^{2/3}}{(a n_e)^4} = 3.4 \times 10^{-25}\ \mathrm{sec}. \quad (17)$$

For numerous resonances the lifetime correlates well with the run time with the light velocity of the contour radius $l_y/2\pi$. Since $l_y = m_y$, then

$$t = \frac{m_y r_e}{2\pi c}\,. \quad (18)$$

For example, for Y, J/Ψ, η-particles with masses $m_y = 19700, 6056, 1074$ values $t = 2.95 \times 10^{-20}$, 0.91×10^{-20}, 0.30×10^{-20} seconds.

In the group of heavy hadrons, particles contain unstable heavy quarks, and they decay through rapid weak decays. Then, in formula (16) for a weak decay n must be minimal, i.e. equal to 1.643 [7], and $t = 2.1 \times 10^{-13}$ seconds.

Light and "strange" hadrons are more stable, and in formula (16) the parameter n should have the value of its own Y-contour [4]. For a group, on average, $n \approx 3.5$, and $t \approx 10^{-10}$ seconds.

Particles that decay due to strong interaction, for example η and π^0-particles, live only within the proton or electron own contours. Therefore, for them, when substituting the values of n_p and n_e in (16), the values of t is about 6×10^{-19} and 5×10^{-17} seconds.

Finally, during the electromagnetic decay of light charged particles (pions, kaons) the contour with large n and, accordingly, with the largest value of t manages to form.

As for the *neutron lifetime*, it is assumed [2] that the neutron loses the acquired mass-energy Δmc^2 gradually with fractions of $m_e v^2 c^2$ for a time per each fraction equal to the vortex threads rotation period inside the current tube r_e/v_0. Bearing in mind (2) and (5), we obtain the duration of the total energy dissipation by the neutron:

$$t = (2\pi)^{1/2}\,\frac{\Delta m}{\cos q_w}\,\frac{a^4 n_e^4}{c_0^{2/3}} \times [\text{sec}] = 629 \text{ sec}. \qquad (19)$$

The same duration is determined by the time constant - the return duration of the excited axisymmetric contour with the total length $\pi c_0^{2/9}$ to its initial state due to its constituent current lines rotation with the speed v_0:

$$t = \frac{\pi c_0^{2/9} r_e}{v_0} = 604 \text{ sec}. \qquad (20)$$

The neutron half-life is about 609 seconds. Thus, the consistency of formulas (12), (19), (20) with each other and their results with the actual values of the neutron lifetime and the neutron-proton mass difference confirm the accepted model of proton-neutron transitions.

5 Conclusion

In the articles concerning the microworld and, in particular, the proton properties, it has been established that there are only three generations of elementary particles. The parameters of the proton (mass, magnetic moment, charge radius, proton lifetime, neutron-proton mass difference) are determined. A physical explanation is proposed for such abstract images as quarks and their confinement, "color", pions "coat", etc. The results were obtained within the framework of the elementary model based on the mechanistic interpretation of Wheeler's geometrodynamics. Wherein the balances between the main interactions and general patterns were only used, moreover, without adding any empirical coefficients.

The model can be used as a basis for constructing the theory of strong interactions, which can be an alternative for QCD. In a possible new theory, the interpretation of the concepts and results obtained, which form the model basis, can be performed in some terms of electrodynamics (or some other) on the basis of a suitable mathematical apparatus.

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