

Implications of Complex Mass

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ABSTRACT

The features of object characterized by complex mass, energy and momentum (signalled in many articles) have been analysed.

It has been stated, that complex mass object must move with velocity bigger than limit velocity c , or even with complex velocity according to Special Relativity.

In such cases, complex space-time coordinates occur.

It has been stated, that complex mass arises as the result of interaction with unempty vacuum, like effective mass in solid body arises as the result of interaction with crystal lattice, especially that effective mass may be expressed by complex mass, too.

The discrepancies, which led to rejection of Dirac's unempty vacuum, have been removed.

The conception of two coupled Dirac's seas connected with particle and antiparticle has been introduced, and the superconducting or superfluid character of Dirac's sea has been postulated.

It has been proved that the unempty vacuum conception is not discrepant with (Special) Relativity, but on the contrary, it implicates Lorentz's transformation and further consequences.

The dependence of mass upon velocity has been interpreted as the effect of interaction with unempty vacuum.

1.1.1.

Introduction

Complex mass occurs in many works written by known and famous physicists, what is very important and interesting fact. So it is the fact worth consideration, especially, that complex mass was analysed in various contexts, which implies the possibility that this phenomenon has great consequences and is very universal.

For the first time complex mass appeared in the work by J. Goldstone [1] but Author didn't analyse its consequences unfortunately.

In the famous monography by E. Leader and E. Predazzi [2] the equation arises:

$$m_H = \sqrt{-\mu^2}$$

where: m_H - Higgs' bosons mass

μ - mass of bare quantum of field

It is obvious that either m_H or μ is complex mass.

In this case $\mu^2 < 0$.

The same situation appears in the same work by J. Goldstone. [1] In the other work by J. Goldstone, concerning 26 dimensions [3] the equation occurs:

$$\left(\frac{\partial x}{\partial t}\right)^2 + \frac{1}{(2\pi E)^2} \left(\frac{\partial x}{\partial \sigma}\right)^2 = 0$$

Again it is obvious that either energy or coordinate is expressed by complex number.

In the equation in the work by A. M. Polyakov [4] the factor m^4 exists:

$$F''(u) + \left(\frac{1}{2}u\right) F'(u) + m^4 F(u) = 0$$

Even if m^4 is real number and $m^4 > 0$,

then $m^2 > 0$ or $m^2 < 0$ and m may be expressed by complex number.

Analogically in the work by E. Cremmer [5] arises the possibility that $m^2 < 0$.

Very interesting case exists in the work by J. Bars and D. Nemsechanskoy [6] where we have $M^2 = -p^2$.

Both possible cases $M^2 < 0$ or $p^2 < 0$ are useful for further considerations.

Complex energy is introduced into propagator in purpose to avoid singularity by calculation of integral [7].

Complex mass occurs in conception of tachyon, too. [8]
This conception is still current notwithstanding the difficulties in experimental supporting [9].

There are many experiments however, for explanation of results of which, complex mass is needed. These experiments proved the real existence of complex mass.

J. Bernstein, N. Cabbibo and T.D. Lee [10] have introduced the functions

$$\eta = \frac{1}{2\gamma} \left[(m_1 + m_2) - \frac{1}{2} i (\Gamma_1 + \Gamma_2) \right]$$

$$\xi = \frac{1}{2\gamma} \left[(m_1 - m_2) - \frac{1}{2} i (\Gamma_1 - \Gamma_2) \right]$$

for explanation of the result of experiment concerning K_2^0 decay.

It is obvious, that in the square brackets complex mass occurs.

The review of experiment, for explanation of result of which the transfer of negative quadrmomentum is needed, is included in the works by B. Badežek and others [11,12].

The complex effective mass in solid body corresponds with complex mass analysed hitherto.

E. Kane [13] describes the complex wave vector of electron in electron band, which corresponds with complex energy. Analogical situation occurs in the work by J. Pendry [14] and by Y. Chang and J.N. Schulman [15].

G.D. Mahan [16] describes many cases of complex energy in solid body, for example the complex self-energy of electron or complex energy of interaction electron-polaron.

Effective mass in solid body may obtain all values, it means complex or even negative; compare D.L. Smith, C. Mailhiot [17].

Matrix of effective mass exists too, but matrix of mass occurs not only in physics of solid state.

The mass matrix occurs in the work by J. Goldstone, A. Salam and S. Weinberg [18]. It is moreover complex mass matrix 4×4 , which fully documents all analogies.

J. Bernstein, N. Cabibbo, T.D. Lee [10] consider complex mass matrix 2×2 .

In the work by E. Cremmer [19] antisymmetric mass matrix 8×8 occurs. Analogically in the work by E. Kane symmetric energy matrix 8×8 occurs. This case considers solid body.

The complex mass matrix (3×3) occurs again in the work by K.T. Mahanthappa and L. Maiani [20] .

The complex mass, mass matrix and square of mass occur in the work by L. Brink and others. [21]

M.J. Duff [22] describes Einstein's tensor with complex components, so energy momentum tensor must have complex components, too.

It corresponds with very interesting cases of complex momentum described by P. Bowcock and R. Gregory [23] .

M.J. Duff [24] describes the case when $\text{mass}^2 = x^2$, so $\text{mass} = \pm |x|$ but the most interesting facts presented in that work are complex coordinates in the more than 4 dimensional space. This fact is strictly connected with complex mass, what will be described in chapter III.

Complex coordinates occur in the work by M.J. Duff.

Callan and Friedan describe complex superspace coordinate. Then J. Ellis [27] considers cyclic Green's function on the complex plane.

Time may be expressed by complex number, too.

It occurs in the works by S.W. Hawking [28] and by J. Bars and K. Sfetsos [29] .

The existence of complex mass, complex energy, complex momentum, complex coordinates (and even complex time) in so many works by so many authors, and at so many various problems, can not be only an accident.

It manifests, that complex numbers describe deeper reality and are not mathematical trick only. One should analyse the features of objects described by complex numbers.

II

The Complex Mass Particles

2.1.1.

It has been obtained from the theoretical analysis of experimental data, that in process of interaction and self-interaction take part particles, which are called virtual particles. The name 'virtual particles' means that energy of these particles and their lifetime are connected by Heisenberg's uncertainty principle. The traditional particle is surrounded by a cloud of virtual particles. It is known from calculations, that the mass of such virtual particle is given by the complex number.

Let's contemplate properties of these untypical objects. We can assume that the Special Relativity Theory may be used for description of particles, mass of which is expressed by the complex number, because Special Relativity [SR] is one of the most fundamental theories and a deviation from this theory haven't been observed.

According to Special Relativity Theory, the dependence of the mass of the particle on its velocity is expressed by the formula:

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (1)$$

- m - mass of the particle
- m_0 - rest mass of the particle
- v - velocity of the particle
- c - limit velocity

If the mass of the particle is expressed by the complex number, then, according to (1), its velocity must be bigger than c !

So we expect, that the particles, masses of which are expressed by the complex numbers, move with velocity bigger than c .

This fact can be proved on the ground of Special Relativity.

We see from (1), that if $v > c$, then the mass is given by the complex number and vice versa: if the mass given by the complex number then $v > c$, but under condition that the rest mass m_0 is given by the real number.

Because of the formal point of view, we can't eliminate the possibility, that the rest mass may be given by the complex number. We have to consider this possibility.

2.1.2

We have to prove that the formula (1) may be used in case when $v > c$.

This fact is obvious.

This equation may be generalized to the case $v > c$, because in none place of Special Relativity the assumption that $v < c$ does occur. (Especially by eduction of formula (1).)

So there are no physical reasons for introduction of limit velocity in Relativity.

The next argument for applicability of formula (1) in the range: $v > c$ is the fact that this equation may be applied even at the point of singularity $v = c$.

We have then:

$$m \rightarrow \frac{0}{0} \rightarrow \frac{h\nu}{c^2} \quad \nu - \text{any real number}$$

and the case of photon.

The third argument is that there is no limit of velocity in quantum mechanics.

So there shouldn't be such limit in Special Relativity either especially, that an electron moving with velocity $0,99 c$ may be described both by quantum mechanics and Special Relativity and such description must be compact.

2.1.3

It follows from SR, that the particle moving with velocity $v > c$ must have the mass expressed by the complex number. We will prove, that the particle, mass of which is expressed by the complex number, moves with velocity $v > c$.

We define machyon as an object, mass of which is given by the complex number. We assume, that the rest mass of the

We assume, that the rest mass of the machyon is given by the complex number. We will see in § 1.3.1 that it is in general property of machyons.

Tachyon is the special case of machyon - see § 2.2.3.

2.1.4

It is obvious, that when $v > c$, then m is a complex number (formula (1)).

We will present this proof in the opposite direction. Let's imagine that m is expressed by complex number $m = m_a + im_b$, and an object moves with velocity $v < c$. Let's make easy calculation:

$$\vec{p} = (m_A + im_B) \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix} = (M_A + iM_B) \begin{bmatrix} (a+ib) \dot{x} \\ (a+ib) \dot{y} \\ (a+ib) \dot{z} \end{bmatrix} = (M_A + iM_B) \begin{bmatrix} \dot{x}_A + i\dot{x}_B \\ \dot{y}_A + i\dot{y}_B \\ \dot{z}_A + i\dot{z}_B \end{bmatrix} \quad (2)$$

p is momentum in LAB

We have presented the complex as a product of two complex numbers (what is always possible) and one of them has the sense of mass.

$$(m_A + im_B) = (M_A + iM_B) (a + ib)$$

So we have the complex coordinates of velocity and position which is characteristic feature of object moving with velocity $v > c$ (Lemat).

So we assumed that we have complex mass and motion with velocity $v < c$ (and v - real number) and we obtained that this motion is equivalent to the motion velocity $v > c$ or even v complex.

Let's notice how deep consequences has the fact, that both product of two complex numbers, and product of complex number and real number, are complex numbers.

We will prove now Lemat.

Let's write the Lorentz's transformation in its general form [30] .

$$\bar{r}' = \bar{r} + \frac{\gamma-1}{\beta^2} (\bar{\beta} \cdot \bar{r}) \bar{\beta} - \gamma \bar{\beta} t \quad (3)$$

So we have:

$$x' = f \left(x, y, z, t, \sqrt{1 - \frac{v^2}{c^2}} \right) \quad (4)$$

$$y' = g \left(x, y, z, t, \sqrt{1 - \frac{v^2}{c^2}} \right) \quad (5)$$

$$z' = h \left(x, y, z, t, \sqrt{1 - \frac{v^2}{c^2}} \right) \quad (6)$$

$$t' = \frac{t - \frac{\bar{v} \cdot \bar{r}}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (7)$$

x, y, z, t are coordinates in LAB, so they are real numbers. x', y', z', t' are complex numbers then and only then, when $v > c$, or when v is complex number.

We will developpe this argumentation further.

Let's transform to the coordinate system, in which the complex mass particle rests.

In this coordinate system:

$$v = \begin{bmatrix} \dot{x}_A + i\dot{x}_B \\ \dot{y}_A + i\dot{y}_B \\ \dot{z}_A + i\dot{z}_B \end{bmatrix} \quad \text{and} \quad \bar{v} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

so $\bar{r} = \int \bar{v} dt \neq 0$ in general case

So we have z

$$\bar{x} = \int (\dot{x}_A + i\dot{x}_B) dt = \int x_A dt + i \int x_B dt = c_1 + ic_2$$

and analogically:

$$\bar{y} = D_1 + iD_2$$

$$\bar{z} = E_1 + iE_2$$

When $v^2 > c^2$, v^2 is real number

and

x', y', z' are (purely) complex numbers

what means that $C_1 = D_1 = E_1 = 0$.

when v^2 is complex number, x', y', z' are meaningly complex numbers.

It is impossible that $C_2 = D_2 = E_2$, because of (4) ÷ (6).

2.1.5

Let's notice that both v and v^2 may be expressed by complex numbers.

The 4-vector in 4 dimensional space-time is defined:

$$\bar{R} = [cdt, idx_1, idx_2, idx_3]$$

then space-time interval is equal:

$$\bar{R}^2 = ds^2 = c^2dt^2 - dx_1^2 - dx_2^2 - dx_3^2$$

The 4-vector of velocity is defined:

$$v = \left[\text{const}, i \frac{dx_1}{dt}, i \frac{dx_2}{dt}, i \frac{dx_3}{dt} \right]$$

and then

$$v^2 = \text{const}^2 - v_1^2 - v_2^2 - v_3^2$$

Let's put $\text{const} = c$.

2. 1. 6

Now we will present the proof of the fact, that when complex mass has imaginary component only, velocity is bigger than $(v > c)$.

The indirect proof. Let's imagine that the situation is different.

So we have the assumption that: x, t, v are real. Next:

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$t' = \frac{t - vx}{\sqrt{1 - \frac{v^2}{c^2}}}$$

So velocity in the 'prim' coordinate system has the value:

$$w = \frac{x'}{t'} = -v \in \mathbb{R}.$$

But

$$p = mw = i|m|w = mi(w)$$

But it is implicated (from the definition of momentum and the elementary features of multiplication) that velocity has imaginary component only. So this is discrepancy.

We have proved the thesis in the case of noncurved spacetime. Such spacetimes can exist in the Nature at least locally, so we have proved the fact, that $v > c$ occurs in certain conditions at least.

2.1.7

The equations (4) - (9) implicate that the coordinates x, y, z, t are expressed by complex number in general case. So we need 8 real numbers to describe the space-time. This 8-dimensional space-time corresponds with numerous cases of multidimensional spaces [31 - 45], for example:

- 11 or 10 dimensions, E.Witten
- 11 dimensions, M.J.Duff
- 26 dimensions, J.Goldstone

This 8 dimensional space may be the subspace of those spaces.

Let's notice that time is complex too.

It corresponds with the idea of complex time, introduced earlier by S.Hawking.

The Heisenberg's uncertainty principle may be written now with the shape:

$$|\Delta x| |\Delta t| \geq \hbar$$

or

$$|\Delta E| |\Delta t| \geq \hbar$$

2.1.8

Let's call as W the system coordinate, in which machyon rests. Let's consider the system coordinate W', which moves towards LAB with velocity w, $w > c$, and which machyon moves in (compare with figure 1).

According to (4), (5), (6), position of machyon in this reference system has three complex components:

$$(y_{1r} + iy_{1u}, y_{2r} + iy_{2u}, y_{3r} + iy_{3u})$$

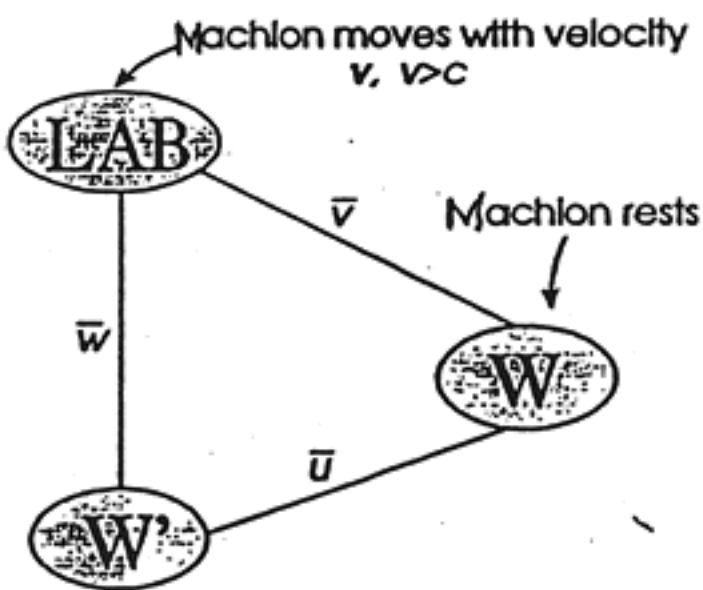


Figure 1. Machyon moves with velocity $u, u > c$. System W' moves towards LAB with velocity w . W moves towards LAB with velocity v .

or six real components:

$$(y_{1r}, y_{1u}, y_{2r}, y_{2u}, y_{3r}, y_{3u})$$

Its time is expressed by the complex number too:

$$t' = t_r + it_u$$

(t_r, t_u are real numbers)

Machyon moves in reference system W'. Components of its velocity in this system we can write, using the formula

$$\left[\frac{d(y_{1r} + iy_{1u})}{d(t_r + it_u)}, \frac{d(y_{2r} + iy_{2u})}{d(t_r + it_u)}, \frac{d(y_{3r} + iy_{3u})}{d(t_r + it_u)} \right] =$$

$$= (z_{1r} + iz_u, z_{2r} + iz_{2u}, z_{3r} + iz_{3u})$$

where: $z_{1r}, z_{1u}, z_{2r}, z_{2u}, z_{3r}, z_{3u}$ are real numbers.

Such derivative is well defined.

We use the fact that the quotient of two complex numbers is a complex number too.

Mass of machyon is expressed by the complex number:

$$m = m_r + im_u$$

m_r, m_u are real numbers.

The momentum of machyon in this system can be expressed by equation:

$$\bar{p} = m \bar{u} = (m_r + im_u) \begin{bmatrix} z_{1r} + iz_{1u} \\ z_{2r} + iz_{2u} \\ z_{3r} + iz_{3u} \end{bmatrix} = \begin{bmatrix} p_{1r} + ip_{1u} \\ p_{2r} + ip_{2u} \\ p_{3r} + ip_{3u} \end{bmatrix}$$

where: $p_{1r}, p_{1u}, p_{2r}, p_{2u}, p_{3r}, p_{3u}$ are real numbers.

The product of two real numbers is a complex number.

Machyon is described in reference system, in which it rests, by six real components of position, and in other reference system moving towards LAB with velocity w ; $w > c$, in which machyon moves - by six real components of position and six real components of momentum.

Let's comment on it more precisely. In coordinate system moving towards LAB with velocity w , $w < c$, both position and momentum of machyons are expressed by three real components (there are only three axis in such system).

It results from Lorentz's transformation.

2.2.1

We proved that complex mass particle moves with velocity v , $v > c$. This fact isn't discrepant with SR, but is implicated by this theory.

Machyon has six real components (or three complex components) of position, velocity and momentum in the coordinate system moving towards LAB with velocity w , $w > c$, but in LAB machyon has three real components of position, velocity and momentum.

The dependence of energy of machyon on its mass is expressed by the equation:

$$E = m c^2 \quad (8)$$

where:

$$m = m_x + im_y \quad ; \quad (m_x, m_y \text{ are real numbers})$$

On the other hand:

$$E = \frac{m_0 v^2}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (9)$$

where: m_0 - rest mass of machyon
 v - its velocity in LAB (expressed by real number)

From (8) and (9) we obtain:

$$m_0^2 = (m_x^2 - m_y^2 + 2im_x m_y) \left(1 - \frac{v^2}{c^2}\right) \quad (10)$$

The right member of equation (10) is expressed by complex number, so m_0 is expressed by complex number too.

The left member is expressed by complex number. We get the next property of machyon. Its rest mass is a complex number.

2.2.2

The physical nature of complex mass is a very interesting problem.

The complex mass is an equivalent of effective mass in solid body.

The conception of complex mass needs correlation with conceptions of unempty vacuum (see caapter III).

The complex mass arises as the result of interaction with unempty vacuum in the same way as effective mass of electron in solid body as the result of interaction of electron with cristal lattice.

The next argument supporting this mechanism of arising of complex mass is the theoretical conception [46, 47] treating space-time as cristal lattice with constant lattice tending to zero.

We have to add, that the particle in this attitude is understood as maximum of spectral density. This conception include both 'traditional' particle like proton, photon, electron, positron, pion... and particles characterising solid body, as hole, phonon, plasmon, exciton and quarks existing in nucleon without possibility of going out, and cloud-like surrounding another objects) virtual particles with complex mass. (Virtual particle means that its energy and lifetime are connected with Heisenberg's uncertainty principle.)

2.2.3

The effective mass in solid body may have meaningly complex values too [13-17] what means that $m = m_x + im_y$; $m_x \neq 0$, $m_y \neq 0$.

The condition $m_x \neq 0$ corresponds with general formula of mass of machyon.

The compactness of idea of complex mass implies the necessity of generalisation of tachyon and introduction of machyon with not only $\text{Im } m \neq 0$, but $\text{Re } m \neq 0$, either. The matrices of mass [18-21] exist in the same way the matrices of effective mass, what supports our considerations. There are bands with solid body with meaningly complex wave vector

$$k = k_x + ik_y, \quad k_x \neq 0, \quad k_y \neq 0 \quad (11)$$

Such complex wave vector corresponds with complex energy $E = \hbar k = \hbar (k_x + ik_y)$, and further with complex mass

$$m = \frac{E}{c^2} = \frac{\hbar}{c^2} (k_x + ik_y) \quad (11a)$$

because of equivalence of mass and energy.

So the complex wave vector means complex energy and complex mass.

Consequently, machyons arise in proces of tunneling and decay.

The arising of complex wave vector in proces of tunneling was described earlier by P.Bowcock and R.Gregory [23] where the by complex number expressed wave-vector has even far more complicated shape than (11).

2.2.4

The conception of complex mass creates a new problem. When the complex mass arise, then the probability of existence of particle in whole space is not equal 1. [48]

If

$$\int dV \left(\sum_{i=1}^N \psi_i^* \psi_i \right) < 1 \quad (12)$$

then it may be explained by the possibility, that in complicated processes of interaction, decay or tunneling not all members of series of wave function have been taken under consideration, so some positive members on the left side of (12) have not occurred, so this side is less than 1.

The totally different attempt is needed when

$$\int dV \left(\sum_{i=1}^N \psi_i^* \psi_i \right) > 1 \quad (13)$$

because the module of complex number is real, bigger or equal zero.

This case may be explained using the fact that a kind of numbers called generalized quaternions has norm, values of which may be both positive and negative.

(Generalized quaternions ought to be treated separately to quaternions, norm of which has only values bigger or equal zero, as in the case of complex numbers.)

The norm $N(x)$ (in the linear, algebraic space)

$$H(n, m) = \langle 1, e_1, e_2, e_3 \rangle Q; \quad n$$

of generalized quaternion:

$$x = x_0 + x_1 e_1 + x_2 e_2 + x_3 e_3$$

has the value:

$$N(x) = x_0^2 - n x_1^2 - m x_2^2 + x_3^2 n m \quad (14)$$

n, m : Integer

and has the sense of square of module because there are the squares of coordinates x_0, x_1, x_2, x_3 in equation (14).

The mathematical shape of (14) implicates that in the case of some $x_0, x_1, x_2, x_3 \in R$ and $n, m \in J$, $N(x)$ may have negative value.

So defined norm may reduce the probability bigger than 1 to value 1, which is expressed by the equation:

$$\int dV \left[\sum_{i=1}^N |\psi_i|^2 + \sum_{j=1}^M N(\chi_j(x)) \right] = 1$$

$\chi(x)$ is wave function with values from the set of generalized quaternions.

$\chi(x)$ is naturally solution of Schrödinger's or Dirac's equation.

The consequence of this fact is that in the processes of interaction, selfinteraction, tunneling, decay, the objects take part, which are characterized by wave function with values from the set of generalized quaternions.

The real mass and complex wave function has been considered hitherto only.

The enlargement of class of numbers describing mass, to complex numbers, makes possible or even implies necessity of enlargement of class of numbers being values of wave function. There are generalized quaternions in this case, but quaternions may be naturally too.

There are more informations about generalized quaternions in the Appendix A.

It is no matter if the second power of wave function module

is described by the quadratic form $F = p^2 + q^2$, resulting

from complex number $x = p + qi$

or by the quadratic form $F = p^2 - nq^2 - mr^2 + nms^2$ resulting

from generalized quaternion $x = pe_1 + qe_2 + re_3 + se_4$.

This, what is important, is that the whole space integral of density of probability is equal 1.

The following facts can be reasons of "disconservation of probability":

- The spacetime is four dimensionlike, so $dv = dx \, dy \, dz \, dt$.

When we don't take this fact under consideration we obtain false integral and false result.

- If $v > c$, the spacetime is eight dimensionlike and then

$$dv = dx_1 \, dx_2 \, dy_1 \, dy_2 \, dz_1 \, dz_2 \, dt_1 \, dt_2 .$$

- There are spaces $D = 10, 11, 26$ dimensionlike and the element of volume in the integral must reflect this fact.

- There are parallel Universes conjugated by black holes (according to S.W. Hawking). The wave function of a particle may have the non-zero values partially in this Universe and partially in another, and then even a correct one Universe volume integral may be false.

The history of "paradoxes" is instructive.

The opponents of the sphericity of the Earth used the argument, that if it were a sphere, these who lived on the opposite side of the globe would have failed down.

What's more, Copernicus, who didn't know the law of gravitation, wasn't able to abolish this "paradox". And now it is

obvious what is in the reality.

The antagonists of Relativity advances so called "paradox of simultaneosity". Nevertheless, it appeared that the idea of simultaneosity wasn't precise, and not Relativity "Paradox of disconservation of probability" in the case of complex mass appeared to be the result of blanks in the mathematical knowledge of certain physicists, what the author has proved in § 2. 2. 4 and in the Appendix A.

2.3.1

The trajectory of machyon is always curved. It is easy to notice. Let's imagine, that trajectory of machyon is straight line and vector of velocity is parallel to this line.

The momentum of such machyon is equal

$$\vec{p} = (m_x + im_y) \vec{v}$$

From the geometric interpretation of complex number we obtain that momentum has component perpendicular to trajectory. So there is the component of vector of velocity parallel to trajectory, but in this way we obtain discrepancy with the assumption.

Let's support it with easy calculation

$$\begin{aligned} \vec{p} &= (m_x + im_y) \vec{v} = (M_x + iM_y) (a + bi) \vec{v} = \\ &= (M_x + iM_y) (a\vec{v} + ib\vec{v}) \end{aligned}$$

and we obtain two perpendicular components of vector of velocity.

The objects called ghosts are characterized by closed loop trajectory [49, 52] in the microscopic scale. So their trajectory must be curved, which is the feature of machyons. So ghosts ought to be treated as real existing kind of machyon. In such attempt ghosts are part of cloud surrounding the traditional particle.

2.3.2

Because of analogy cristal lattice - vacuum, we may suspect, that the equivalent of ghosts exists in solid body and surround such particles as, for example, electrons.

The phase velocity always bigger than c is a candidate for velocity of such ghosts in solid body.

The phase velocity is in such attempt velocity of really existing, virtual objects surrounding particle in solid body.

The ghosts in solid body do not transfer energy, because their trajectory is closed loop in microscopic scale.

2.4.1

We will discuss problem of interactions of machyons with particles whose masses are real numbers. Such interaction must occur, in other case we couldn't be able to observe the existence of the complex mass particles (compare § 2.1.1). We will analyse mathematically this interaction which means the change of momentum and energy of both objects.

Let's assume that both particles move towards a is z . We will prove, that in this case the interaction occurs. Let's define the mass of machyon before interaction as $m_x + im_y$; after interaction as $m'_x + im'_y$; its velocity before and after collision as v_z and v'_z .

Analogically: m, m', v, v' mean one after another: the real mass of particle before, after interaction and its velocity before and after interaction.

From the principle of conservation of energy and principle of conservation of momentum, we obtain two equations:

$$(m_x + im_y)c^2 + mc^2 = (m'_x + im'_y)c^2 + m'c^2 \quad (15)$$

$$(m_x + im_y)v_z + mv = (m'_x + im'_y)v'_z + m'v' \quad (16)$$

We have to take into account the dependence of masses of particles on their velocities. This dependence is expressed by equation (1) or by equivalent 'Pythagoras theorem'.*

We obtain two next equations for both particles:

$$(m_x + im_y)^2 c^4 - (m_x + im_y)^2 v_z^2 c^2 = (m'_x + im'_y)^2 c^4 - (m'_x + im'_y)^2 v'_z^2 c^2 \quad (17)$$

$$m^2 c^4 - m^2 v^2 c^2 = m'^2 c^4 - m'^2 v'^2 c^2 \quad (18)$$

The complex part of right member of equation is equal with the complex part of left member of equation, and similarly: real part of right member of equation is equal with real part of left member of equation.

* This equiporance may be proved by the next transformations:

$$p^2 c^2 + m_0^2 c^4 = \frac{m_0^2 c^2 v^2}{\sqrt{1 - \frac{v^2}{c^2}}} + m_0^2 c^2 = \frac{m_0^2 c^2 v^2 + m_0^2 c^4 - m_0^2 c^2 v^2}{1 - \beta^2} = \frac{m_0^2 c^4}{1 - \beta^2} = E^2$$

From equation (1) we obtain 'Pythagoras theorem'. On the other hand 'Pythagoras theorem' and the sequence of transformations wouldn't be true without equation (1). So we proved this equiponderance.

So we obtain from (15)-(18):

$$m_y = m'_y \quad (19)$$

and then:

$$m_x + m = m'_x + m' \quad (20)$$

$$mv_z + mv = m'_x v'_z + m'v' \quad (21)$$

$$m^2(c^2 - v^2) = m'^2(c^2 - v'^2) \quad (22)$$

$$m_x(c^2 - v_z^2) = m'_x(c^2 - v_z'^2) \quad (23)$$

$$(m_x^2 - m_y^2)(c^2 - v_z^2) = (m_x'^2 - m_y'^2)(c^2 - v_z'^2) \quad (24)$$

If m_x, m_y, m, v_x, v are known, and m'_x, m', v_x, v' unknown, then we have the system of five equations and four unknown numbers. Generally such system of equations can't be solved.

If m_x, m, v_x, v are known, and m'_x, m', m_y, v_x', v' unknown, then we have the system of five equations (20)-(24) and five unknown numbers, which can be solved.

Necessity of inclusion of m_y into unknown numbers is caused by the equation (19). The solvability of system of five equations is a mathematical proof that the interaction of complex mass particle with real mass particle is possible.

The real component of mass of machyon doesn't change during described process, because the real and complex components of energy and momentum are conserved separately. Nevertheless the complex mass influences the process of interaction. By fixed values of m_x, m, v_x and v the collision is possible only then, when m_y is equal the value, which is obtained from the system of equations (20)-(24). The complex mass is an important parameter of collision process.

When v'_x and v' are complex numbers, we obtain two unknown parameters and two equations more, so nothing changes.

The interaction of machyon with the particle, whose mass is real and unequal zero, is possible. It means, that the

complex component of machyon can't change during the interaction. We obtained this result earlier (compare with equation (22)). We can analyse the motion and real mass particles when their velocities have three components (connected with motion towards axes x,y,z). We have then more complicated system of equations, but it gives nothing more.

The complex component can change only in interaction of machyons. The complex mass particles take part in all kind of interactions, what will be described [53].

2.4.2

It is known, that photon moves temporarily with velocity $v > c$ and temporarily with velocity $v < c$, but its average velocity is equal $v=c$ [54]. This fact can be explained, when we assume the existence of particles with complex masses and with velocities bigger than c . The conception of complex mass particle with velocity bigger than c is needed for explanation of oscilation of velocity of photon around value c . Let's analyse this problem nearer.

a)

$$m_1 + im_2 \quad \frac{h\nu}{c^2}$$

a) photon, whose mass is equal $h\nu/c^2$ aggregates temporarily with machyon, whose mass is equal $m_1 + im_2$ (see figure 2a).

It isn't discrepant with law of conservation of quadrmomentum. The rest mass of photon is equal zero ($m_0=0$) so the square of this quadrmomentum is equal zero. because:

$$p^2 = E^2 - p^2 c^2 = m_0^2 c^4 = 0$$

So its quadrmomentum is equal zero, too, and so it can be added to quadrmomentum of another particle without changing it. After aggregation of photon, the quadrmomentum of machyon doesn't change. (photon can be absorbed - for example by an atom - and it is normal situation.)

b)

$$m_1 + im_2 \quad \frac{h\nu}{c^2} \quad m_1 - im_2$$

c)

$$\frac{h\nu}{c^2} \quad m_1 - im_2$$

d)

$$m_1 + im_2 \quad \frac{h\nu}{c^2} \quad m_1 - im_2$$

Figure 2.

The mass of object is equal:

$$m = \left(\frac{h\nu}{c^2} + m_1 \right) + im_2$$

According to earlier discussion, its velocity v is bigger than c .

b) The machyon, whose mass is equal $m_1 + im_2$ and photon (with mass $h\nu/c^2$) - see figure 2b. The mass of this object is equal:

$$m = \frac{h\nu}{c^2} + m_1 + im_2 + m_1 - im_2 = \frac{h\nu}{c^2} + 2m_1$$

This mass is expressed by real number, so this object moves with velocity $v < c$. This process can be treated as aggregation of photon with conservation of quadrmomentum (compare a)). We can treat it as an annihilation of complex mass, which is analogical to the process of annihilation of real mass (for example annihilation of electron and positron with emission of photon). In our case we would have the emission of quasi-photon with rest mass zero and mass

$$m = 2 im_2 c^2$$

Such process must be possible because of symmetry of nature.

c) Machyon with mass $m_1 + im_2$ comes off; a cluster is created only by machyon with mass $m_1 - im_2$ and by photon with mass $\frac{h\nu}{c^2}$.

The mass of such object is expressed by the equation:

$$m = \left(\frac{h\nu}{c^2} + m_1 \right) - im_2$$

and velocity v is bigger than c (compare figure 2c).

d) Machyon with mass $m_1 + im_2$ associates again (compare figure 2d). Such situation was discussed in point b.

Photon is surrounded by the machyon cloud, which it interacts with.

There is a possibility of creation of bound systems photon-machyon, photon-two machyons, and so on. The emission of quasi photons can accompany this aggregation (compare

point b). The mass of system machyon-photon is complex and therefore this system moves with velocity $v > c$. This means, that faster particle binds with a slower particle and a created cluster moves faster than the slower particle.

The binding of photon and two machyons, whose masses are expressed by conjugate complex numbers, causes that photon behaves as if it were aggregated with a real mass particle.

According to it, velocity of this object is less than c .

The fluctuations of velocity of photon around the value $v=c$ can be explained in the following terms:

- Photon interacts with the cloud of surrounding machyons; there is the possibility of creation of the particle composed of photon and one more machyon.
- Photon is bound with machyons most of time. There is the most probable situation, when photon is bound with one machyon (then the mass of cluster is complex and velocity $v > c$) or when photon is bound with two machyons, whose masses are described by two conjugate complex numbers (then the mass of cluster is real and its velocity $v < c$). We don't observe photon itself, we observe cluster of photon and machyons and its fluctuating velocity.
- Photon creates with machyon the binding states described by sequection from figure 2. The lifetimes of all binding states are equal.
- The binding states don't have to arise in such order as in figure 2, but the clusters with complex mass have to arise as often as the clusters with real mass.

2.4.3

The existence of particle moving with velocity $v > c$ isn't discrepant with SR, but on the contrary, is implicated by this theory.

It is known, that using the conception of machyons with complex mass, we are able to explain the fluctuations of velocity of photon around the limit velocity c .

It is succes of this approach.

Necessary condition of motion of real mass particle with velocity $v > c$ is absorption of machyon with complex mass.

The absorption of complex mass particle by the real mass particle is possible on the same way, as the fusion is possible, and this fact isn't discrepant with law of conservation of quadrmomentum.

The fusion isn't discrepant with law of conservation of quadrmomentum in such a case when isn't discrepant with law of conservation of energy and law of conservation of momentum. The absorption of something is a kind of fusion yet.

We have the equation:

$$p^2 = E^2 - p^2 c^2 = m_0^2 c^4$$

what means that quadrmomentum of particle is defined by the rest mass of particle, and when the fusion occurs, the new particle arises with different (in general) rest mass.

The possibility of fusion, as far as the relativistic point of view is concerned, is determined by the law of conservation of energy, the law of conservation of momentum, and the relativistic dependence of mass of particle on its velocity.

So the law of conservation of quadrmomentum doesn't forbid the fusion of machyon with real rest mass particle.

It is the argument for the fact, that virtual particle creating a cloud, must have complex mass.

This means it would cause that the real mass particle would create the cluster with machyon and this cluster would move with velocity $v > c$ because of its complex mass.

Such situation isn't observed not because of law of conservation of quadrmomentum, but because of other reason. The particle is surrounded by the cloud of machyons and interacts simultaneously with great number of machyons situated in various places in space and these interactions are mutually compensated and the fusion doesn't occur.

2.5.1

The tachyons, special case of machyon, described by $\text{Im } m \neq 0$ and $\text{Re } m = 0$ had been investigated theoretically [8]. They were looked experimentally for, but without result [9].

The shock wave connected with tachyon has not been discovered.

This fact can be explained.

The complex mass particles are short living virtual particles. It implicates, that the shock wave is far weaker than has been seemed, and arises very insignificantly over the background of radiation of others living tachyons. Such wave is attenuated before arising.

2.5.2

In the processes of inelastic electron (muon) - nucleon scattering are characterised by Q^2 , which is the negative of the square of the four-momentum transferred by the lepton to nucleon. [11-12]

Q^2 describes the real experimental effects.

We have:

$$Q^2 = -q^2 \quad (q - \text{four-momentum})$$

Because $Q^2 > 0$

then q is complex number.

So it is the next proof for existence of complex mass particles.

The transfer of momentum is described by the exchange of a particle with appropriate quantum number.

In my opinion these particles are really existing objects with complex mass discovered in experiment, to description of result of which they had been needed.

Regge pole exchange is a generalization of a single-particle exchange. Regge poles are characterized by quantum numbers too.

Formally the Regge pole corresponds to a pole of the t-channel partial wave amplitude in the complex angular momentum plane.

2.5.3

The assumption of quantum emission and absorption of electromagnetic radiation was needed for explanation of dependence of black body on wavelength.

Such assumption turned out to be physical truth.

Now we have the same situation.

We need an assumption of existence of complex mass for explanation of the dependence of cross section on wavelength.

So in both cases the assumptions present physical truth;

it is the next argument for real existence of complex mass.

2.5.4

The mass of the particle moving with velocity $v > c$ is expressed by complex number - it is a consequence of SR. It was considered till now, that complex mass particles are only mathematical trick.

It hasn't been known, how to interpret and classify them. Therefore they have been called virtual particles and haven't been treated as real existing objects.

However such phenomena like: quantum character of emission and absorption of electromagnetic radiation, postulated by Planck ; de Broglie's matter waves ; or existence of quarks foreseen by Gellmann and Zweig, which were treated at first only as mathematical assumptions, are really existing in Nature.

If de Broglie hadn't invented the conception of matter waves, electron diffraction discovered by Davisson and Germer would have been called: quasi-diffraction or pseudodiffraction...

There is a similar situation as far as the complex mass particles are concerned. They really exist in Nature. Their properties ought to be analyzed on the ground of SR. There is no reason why this fundamental theory couldn't be confronted with these particles.

The consequence of this fact is existence of machyons, which are moving towards LAB with velocity $v > c$. We shall see in the next chapters, that complex mass particles are deeply rooted in the structure of physics.

III

The Unempty Vacuum

3.1.1.

The complex mass particle moves towards LAB with velocity $v > c$, and its rest mass is expressed by complex number. In this moment we should understand what means the fact of existence of complex mass particles.

We will use in our analysis the conception of effective

mass of electron in the solid body.

Electron in solid body interacts with other electrons and crystal lattice. It introduces effective mass for description of this interaction. It means, that electron in solid body behaves so, as if it had different mass than electron in vacuum. It is a similar situation to the motion of air bubble in liquid. The bubble is moving slowly, although the buoyancy acts, because the force of internal friction acts too. It can be told differently, that the bubble moves slowly, because it has a huge effective mass, which is caused by interaction with other particles in liquid.

The effective mass of electron in the solid body is a long step towards complex mass, because the values of effective mass may be negative and complex too. In order to explain conception of complex mass we will adduce the conception of unempty vacuum.

We assume that this, what we call vacuum, has its inside structure.

The complex mass of machyons is resulted from their interaction with objects creating structure of unempty vacuum. Interaction of machyons with unempty vacuum leads to existence of complex mass just as interaction of electron with other electrons and crystal lattice leads to existence of effective mass.

3.1.2 Experiment suggested by Aharonov and Bohm [55] and then many times realized and repeated [56-58] proves, that vector potential really exists in Nature and isn't, as it had been thought earlier, only element of mathematical formalism.

It has been proved that the field exists really, whose perturbations are observed as the constant electric field or constant magnetic field or electromagnetic wave.

Aharonov's and Bohm's experiment supported Maxwell's prevision concerning existence of oscillating environment filling the space.

The other case for existence of unempty vacuum are all results of experiments, which can't be interpreted without introduction of complex mass particle conception. [11-12] The complex mass characterizing these objects manifests existence of interaction of these objects with unempty vacuum similar to interaction of electron with crystal lattice and other electrons, which leads to existence of effective mass of electron.

The existence of complex mass manifests possibility of motion with velocity $v > c$ and the existence of unempty vacuum. The first fact isn't discrepant with SR. We proved it in chapter II. The consistency of the second fact with SR we will prove in § 3.2.1.

3.2.1

Dirac postulated manifestly existence of unempty vacuum. Let's analyze Dirac's vacuum filled by electrons, which occupy the electron states, whose energy is negative and less or equal $E = -m_0 c^2$ (m_0 - rest mass of electron). The observed electrons are excited states of vacuum, which arise when electron is knock out of the negative energy state and occupies the positive energy state, whose energy is bigger or equal $E_0 = m_0 c^2$.

The hole, which arises after such excitation of electron was identified by Dirac with the positive charge (equal $+e$), whose rest mass is equal with rest mass of electron. Such particle was discovered by Anderson and called positron.

We ought to put some obvious questions.

- Why don't we feel the huge charge of vacuum?
- Why don't we feel the huge gravitation resulted from huge mass of vacuum?
- Why doesn't resistance to motion exist, which would be caused by unempty vacuum?
- Why is there unnatural asymmetry in Dirac's approach?

Dirac assumed, that positron is the hole in electron sea. There is unnatural and groundless asymmetry. Why positron could be hole in electron sea, and electron couldn't be hole in positron sea?

3.2.2

The latest doubt can be easily eliminated and it is the step leading at once to elimination of other doubts.

The discrepancies - because of which the Dirac's conception of unempty vacuum and particles understood as the excited states of vacuum and hole as antiparticles, was rejected - are removed in this work.

It was noticed, that if the equation

$$\left(i\hbar \gamma^\mu \partial_\mu - \beta m c \right) \psi = 0$$

corresponds with the situation when particle is the excited state of vacuum and antiparticle - the unpopulated state, then the equivalent equation

$$-\left(i\hbar \gamma^\mu \partial_\mu - \beta m c \right) \psi = 0$$

corresponds with the situation when antiparticle is the excited state of vacuum and antiparticle is unpopulated state.

Because the Dirac's equation is implicated by the equation:

$$i\hbar \partial_t \psi(\vec{r}, t) = E \psi(\vec{r}, t) = c \sqrt{m^2 c^2 - \hbar^2 \nabla^2} \psi(\vec{r}, t)$$

and the change of the sign means the change of sense of axis of energy.

Let's assume that both sea of electrons and sea of positrons exist. We eliminate the problem of asymmetry. Both beings: electron and positron are totally symmetrical. The signs of charges of electron and positron are opposite, so there are electromagnetic attractive forces between them and the electron pairs come into existence. Vacuum is filled with pairs composed of opposite charges, so it is neutral. The local fluctuations of dipole electric moment are possible only. If we excite one particle from electron-positron pair (for example electron) - it means that we set it outside the pair - then free electron originates and its empty room remains (the hole - in other words), and free positron originates too (compare figure 3b).

We remove the first particle and become the second particle and the hole, which can be interpreted as this second particle.

The elimination of one electron outside electron sea, causes

automatically the elimination of positron outside positron sea, and hole originates.

Vice versa: elimination of one positron outside positron sea causes automatically the elimination of electron outside electron sea and origination of hole (in the sea of electrons). Both seas are con

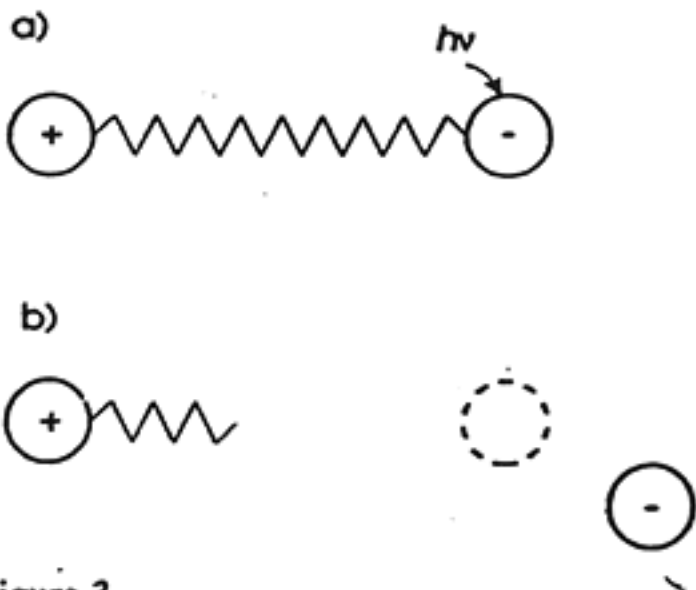


Figure 3.

nected because of existence of electron-positron pairs. Both descriptions (Dirac's and this) are complementary.

3.2.3

Superconductors, semiconductors and Dirac's unempty vacuum are described by model of energy bands and energy gaps between them. Electron in conduction band in semiconductor moves influenced by electric field. Its empty room in valency band moves then in opposite direction and has the properties of particles (so called holes).

Negative energy band in superconductor is filled with electrons creating Cooper's pairs. These electrons superconduct.

There is a similar situation in case of Dirac's vacuum. Electrons and positrons create pair. Free electron and positron means, that one pair from Dirac's sea has absorbed photon and has been burst (compare figure 3).

Annihilation of electron and positron means creation of electron-positron pair 'under the surface' of Dirac's sea, which is accompanied with emission of photon. The electron-positron pairs are parallel to Cooper's pairs in semiconductor. The charges creating pair are in this situation opposite, but the difference isn't so much as it could seem.

Let's imagine, that electron and positron bring nearer one to another because of attractive force between them. The observer connected for example with positron may tell that two charges are opposite and they bring nearer, but he may interpret this situation in different way. He may tell, that the signs of charges are the same, but the time in system connected with positron is negative - it means that time goes in opposite direction. (We have analogous situation when we project film, starting from the end.)

The electron-positron pairs filling Dirac's unempty vacuum cause the superconducting character of Dirac's sea. The unempty vacuum is a superconductor or something very similar. It is a postulate, but very logical and attractive idea.

The running friction in vacuum doesn't exist because of the same reasons which are responsible for non-existence of crystal lattice dissipation of Cooper's pair in semiconductors.

3.2.4

We don't feel the huge gravitational forces generated by the huge mass of Dirac's sea, because forces generated by all surrounding us from all sides particles are countermanded themselves mutually. We can't forget, that our dimensions are remissingly small, point like as a matter of fact, in comparison with the distances in cosmic scale. This situation is analogous to molecules in the liquid.

The molecule inside the liquid is acted by the resultant intermolecular force equal zero, because all forces generated by neighbouring, surrounding molecules are countermanded mutually. There is a different situation in case of surface molecules, because the forces generated by neighbouring molecules aren't countermanded.

The vector of resultant force is turned inside the liquid. It is the cause of surface tension. There is a similar situation as far as nucleus is concerned. The nucleon inside the nucleus composed of great number of nucleons is acted by the resultant force equal zero, and the surface nucleons are acted by the nonzero resultant force turned inside the nucleons.

3.2.5

The vacuum has very rich structure, because two united Dirac's seas exist in case of all types of particle-antiparticle pair.

3.3.1

The next argument supporting the existence of unempty vacuum is fact, that both velocity of electron in vacuum and velocity of electron in solid state depend on the vector of electron wave (compare figures 4a and 4b).

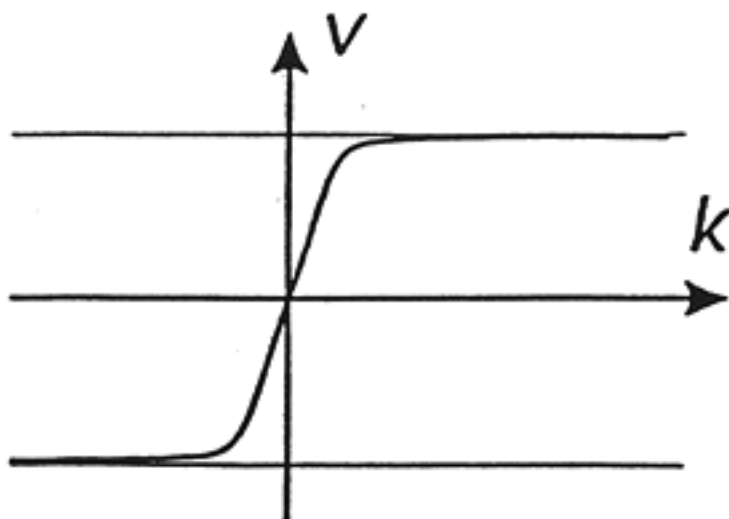


Fig 4a. Dependence $v(k)$ for electron in vacuum
 $k = 2\pi/T = 2\pi p/h = 2\pi m_0 v/h \sqrt{1-(v^2/c^2)}$

The next analogy leads to similar conclusion: both creation of electron-hole pair in semiconductor accompanied by emission of quantum of crystal lattice oscillation-phonon, and creation of electron-positron pair in vacuum accompanied by emission of quantum of vacuum oscillations, are described by the

same creation-annihilation operator formalism. This fact suggests, that vacuum can have inside structure. In theoretical research of quarks imprisonment is used the mathematical trick consisting in introduction of lattice in spacetime and then approaching the limit of lattice constant equal zero. [46-47]

This lattice, which is treated by theorists only as a mathematical trick seems to be analogue of crystal lattice in solid body. It corresponds with complex effective mass and complex band structure [13-17].

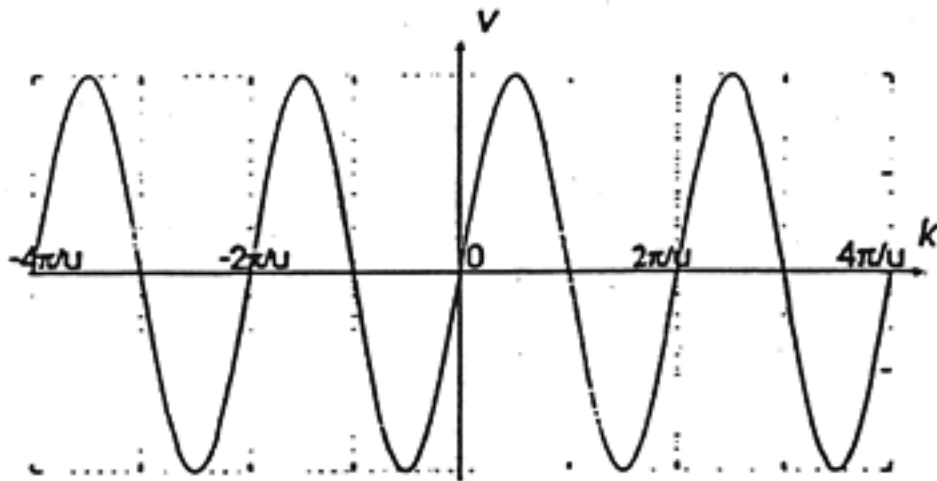


Fig. 4b $v(k)$ for electron in solid state, u is lattice constant, k is value of wave vector - solution of Schrödinger's equation

These analogies are so numerous that they can't be only coincidence, all the more so as there are experimental facts which evidence the existence of unempty vacuum (compare § 3.1.2.).

3.3.2

The existence of unempty vacuum is proved experimentally and we shouldn't be afraid of the fact that we don't see it.

The ground of the surrounding us reality, is quantum, and the observed classical world is only limiting case of quantum world. There are such situations in quantum world, when we don't see something, although it really exists.

The crystal of semiconductor illuminated by electromagnetic radiation at its plasma frequency behaves like vacuum. It means that oscillations induced by the outside electromagnetic field are creating such an electromagnetic field, that the same field and deformed outside electromagnetic field are so, as if the outside electromagnetic field weren't deformed and as if it were only field propagating in vacuum. We don't see the crystal in such conditions.

There is a similar situation in case of Ramsauer-Townsen effect. The electrons at energies about 1 eV see the argon atom as the whole, but at energies about 0,7 eV the scattering cross section is so little, that this gas is for electrons nearly transparent. [59]

We shouldn't be afraid of it either, that both vector potential as well as its derivatives expressed by the fundamental equations of electromagnetics, have the physical meaning. There is a similar situation in case of Nuclear Magnetic Resonance, in which both electric field E and its gradient ($\text{grad } E$) play the role [60].

IV

The Conception of Unempty Vacuum and Special Relativity Theory

4.1.1

The results of Aharonov and Bohm evidence explicitly the existence of environment, whose perturbation is observed as electromagnetic field.

The conception of ether is renewed, but the experimental facts can't be turned down because they don't appeal to us. From the other side, SR is a very deep, beautiful and experimentally testified theory.

It leads to supposition that the conception of ether isn't discrepant with SR.

4.1.2

We will prove that the existence of ether isn't discrepant with SR.

The space is homogeneous and isotopic, so ether filling the universe is homogeneous and isotopic. We know, that ether has a superconducting character (compare § 3.2.4).



Figure.5

Negative result of M.M. experiment is a consequence of the fact, that the motion towards something can't be discovered, when this something is homogeneous and isotropic and doesn't resist to uniform motion because of its superconducting character. All points of ether are identical and their surroundings are identical, so the observer at point A (see figure 5) isn't able

to state if he has translocated to the identical point B or if he hasn't translocated; all the more so as he doesn't feel the resistance to motion, which could evidence this motion.

The motion towards local heterogeneities like for example electrons, protons or others elementary particles or their agglomerations like for example atoms, planets can be only observed. We aren't able to state, if we move towards vacuum and it means that the motion has relative character.

It isn't possible to observe the motion towards the medium which is homogeneous in global scale, isotropic and superconducting, which means that it doesn't resist to uniform motion.

It is the reason of negative result of Michelson's and Morley's experiment (although the ether exists) and it implies SR. Negative result of M. and M. experiment doesn't evidence the nonexistence of ether, but it evidences only the impossibility of observation of motion towards ether!

The existence of ether has been however experimentally discovered by Aharonov and Bohm. The Special Relativity Theory isn't discrepant with the conception of ether, but on the contrary, it is implicated by this conception. The results of Michelson's and Morley's experiment, which implies SR, are conditioned by the properties of ether.

The homogeneity, isotropy and superconducting character of ether create the essentials of Special Relative Theory!

4.1.3

The Lorentz's transformation results from postulate of identical shape of Maxwell's equation in all inertial systems.

The rightness of this postulate is self-evident: if it is impossible to observe motion towards unempty vacuum, then all inertial systems are equipollent and as a consequence the shapes of fundamental Maxwell's equations in each inertial system must be identical. Also in this case SR results indirectly from the impossibility of observation of motion towards ether.

It is widely known that Einstein has repudiated the conception of ether because he has admitted it to be unnecessary. The equations (1)-(7) and others equations of SR can be actually considered, separating the character of vacuum. The existence of unempty vacuum isn't necessary for deduction of equations (1)-(7) and foreseeing their consequences. SR results however from the existence of unempty vacuum, which has been evidenced in § 4.1.2, although SR can be formulated without adduction.

of unempty vacuum. (The motion of planets around the Sun is caused by the gravitational force although the acceptance of this fact hasn't been necessary for formulation of heliocentric system.)

It seems to be paradox, but the deepest ground of SR is conception of unempty vacuum (or ether), which has been experimentally testified.

4.2.1

We can explain qualitatively the dependence of mass of the particle on its velocity, using the conception of unempty, superconducting vacuum.

The particle, whose velocity increases in LAB, began to interact with unempty vacuum more intensively. The growth of intensity of interaction with unempty vacuum leads to growth of mass. If the velocity of object is bigger than c which is limit velocity, then the interaction of this particle with vacuum leads to arising of complex mass (compare chapter I).

The mechanism of change of mass with change of velocity is analogous to mechanism causing the arising of effective mass of electron in solid body.

Let's consider this problem on the other way. Vacuum doesn't hamper the constant motion because of the same reason which causes, that the electrons in superconducting state aren't hampered by crystal lattice. The growth of velocity corresponds with growth of interaction with unempty vacuum and connected with it change of masses with possibility of arising of complex mass when $v > c$.

The increase of velocity (acceleration) corresponds with perturbation of ordered superconducting state, which leads to increase of intensity of interaction and to increase of mass on this way too. The growth of mass difficults further growth of velocity and further deformation of superconducting state.

System: particle - unempty vacuum aims at conservation of superconducting state, whose results are increase of mass upon velocity, and arising of complex mass when $v > c$.

The tendency of conservation of superconducting state is realized by negative feedback:

- growth of velocity
- perturbation of superconducting state

- growth of interaction unempty vacuum - particle
- growth of mass
- difficulty of further increase of velocity

The observer in coordinate system connected with himself can't observe the constant motion if he doesn't see other reference system because the motion is relative. He can't observe the motion towards vacuum, because both his and all masses in this system (and the reference mass equal, for example, 1 kilogram) increase in the same way. It means that all these masses are multiplied by the same factor:

$$\left(\sqrt{1 - \frac{v^2}{c^2}} \right)^{-1}$$

The observer can observe only the accelerated motion (without other reference system) because of the force of inertia. The forces of inertia are caused by acceleration, which is created by others forces which are created by others objects.

The friction (in sense of loss of energy caused by interaction with environment) is purely classical idea. Energy isn't necessary for keeping the object moving in case of quantum objects like superconduction of motion, or motion of helium II up the wall of the vessel.

The unempty vacuum has a quantum character, so energy isn't needed for keeping the constant motion (towards some reference system). The energy of constant motion can be lost because of interaction with heterogeneities, which are the excited states of vacuum like for example electrons, or clusters of such excited states like for example planets, rough surfaces.

4.3.1

Einstein has analysed such problem. He has considered the particle composed of two protons. If this particle is desseved then according to the principle of conservation of momentum, both protons are moving in opposite directions (along the same axis) with the same value of velocity. If we measure the position of the first proton, we know the position of the second proton without measurement. It is said to be discrepant with quantum mechanics. This problem can be explained on the ground of results obtained in this work.

Both moving protons interact mutually exchanging particles whose masses are expressed by complex numbers.

There is a cloud composed of machyons between two moving protons. Machyons inside the cloud can travel any distance in freely short time because there is not upper limit for velocity of complex mass particle.*

It means that there is always such machyon, whose velocity is enough huge, that it travels the distance between both protons in freely short time Δt .

The vacuum moreover doesn't resist to constant motion. This fact implicates that both protons create the bound system, even when they are very far one from another. The machyons are responsible for creation of bond between protons, similarly electrons are responsible for creation of bond between two nuclei in diatomic molecule.

If we treat protons like points, than we have a bound system, whose position is described by six coordinates: three coordinates of current position of the first proton and three coordinates of current position of the second proton, or three coordinates of current position of one proton and three coordinates of position of start point (or centre of mass of the system).

We don't know naturally the position of one proton and position of centre of mass before measurement, but there isn't discrepancy with quantum mechanics when we are able to know the position of the second proton without measurement, but only on the grounds of two earlier measurements.

There is no discrepancy in this problem. It hasn't been known earlier about existence of machyons, which are responsible for creation of weak, but really existing bond between even very distant protons, which causes bound system. It is the only reason of misunderstanding.

4.4.1

We proved in this part of work, that the existence of unempty

* The limit velocity c is upper limit velocity of real mass particles and a lower limit for velocity of complex mass particles (compare chapter I). The upper limit for velocity of complex mass particle doesn't exist.

vacuum isn't discrepant with SR. This theory is implicated by this conception, although SR can be formulated without adduction this fact.

The existence of unempty vacuum throws moreover light on a matter of some facts of SR; it makes possible for example to understand better the physical sense of equation (1) (see § 4.2.1).

The unempty vacuum is really existing being!

Its existence is experimentally confirmed fact.

The conception of unempty vacuum makes possible to explain the origin of complex mass and to present de Broglie's wave as the wave of Dirac's sea.

So this conception is useful and needed.

4.4.2

The idea of unempty vacuum throws light on a matter of wave-particle duality. This phenomenon stops to be so mysterious. The excited electron moves in the sea of unexcited particles surrounding it from all sides.

The particle goes across the environment and it causes, that wave accompanying particle comes into being. In ones phenomena the particle is exposed and in another phenomena the by particle created wave is exposed. The similar conception has been postulated by Bohm. Bohm explained the wave-particle duality, assuming that particle is accompanied by so called piloting wave, which is the solution of Schrödinger's equation. [61]

My conception is similar, the only difference is qualitatively explained origin of this wave.

4.4.3

The de Broglie's wave exists really, because the diffraction and interference of wave of elementary particles on the crystal lattice are observed.

From the other side in the case of refraction on the board of phases, the part of wave is reflected and other part is refracted, which means that it goes into the other phase. But it is known that elementary particle accompanied by this wave, either goes into the second phase or stays in the first phase.

This fact is described by Born's interpretation of wave function, which treats wave function as something, whose second power of

module, gives the density of probability of finding of elementary particles.

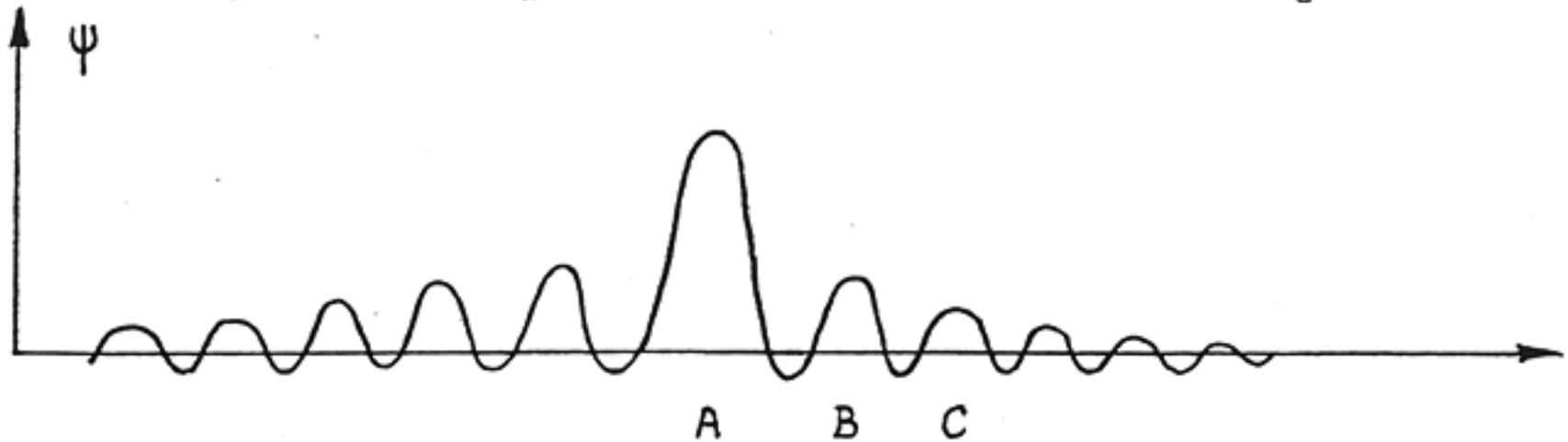
In the Bohm's conception both particle and piloting wave occur.

Both interpretations are complementary.

Let's analyse the particle excited from Dirac's sea.

This particle moving in Dirac's sea creates the wave, which is accompanying it.

In this way we obtain particle-wave dualism of de Broglie.



Let's analyse the wave function ψ as at the figure.

The wave function is expanded in the whole space, but the particle is in the same, concrete place (for example at points A or B or C). The probability of the fact that particle exists at point B is bigger than that it exists at point C, because the wave created by the existence of particle has (at this point B) bigger amplitude; and the biggest probability is at point A, because wave created by the existence of particle has at this point the biggest amplitude.

It is the generalization of the conception of piloting wave of Bohm, and unification with Born's conception.

So both de Broglie's wave exists and its amplitude (the second power of its module) is measure of probability of finding of elementary particle.

We have both real wave in Dirac's sea (Bohm's interpretation) and density of probability (Born's interpretation).

At the board of phases de Broglie's wave partially reflects and partially refracts.

The Dirac's sea behaves like waving medium.

The particle either comes to the other phase or does not, but de Broglie's wave, created by the particle in Dirac's sea, determines the probability of both these events.

We observe the diffraction of de Broglie's wave on the crystal lattice and its interference, too.

So there is the complementarity of these two interpretations of de Broglie's wave, and not contradiction.

4.4.4

The Dirac's equation describes only the fermions with spin $1/2$, but the implicated by it theory of particles and holes is more extensive and contains the bosons and other fermions, too. The fact of the unhomogeneous population of energetic levels of Dirac's sea is not important.

The fact which is important, is the existence of two Dirac's seas - sea of particles and sea of antiparticles, creating pairs coupled by interaction, in the case of bosons too.

The absorption of photon causes the destruction of the pair and the creation of free particle and free antiparticle and empty places in the space (called holes) in which there had been particle and antiparticle when they had created the pair. (The excited objects - particle and antiparticle - can move to other places, because the vacuum doesn't attenuate the motion.) The mechanism of creation of the particle-antiparticle pair and the effects of destruction of such pair are the same both in case of fermions and in the case of bosons.

It suggests the possibility of generalization of Dirac's equations for the case of others spins than $1/2$, which will be done in the work [53] .

V

Recapitulation

5.1.1

It was stated in this work, that the motion with velocity $v > c$ towards LAB (c is limit velocity) is possible and isn't discrepant with SR, but on the contrary it is implicated by this theory. The particle moving with velocity $v > c$ according to SR must have complex mass and complex rest mass.

The existence of complex mass particle has been postulated in order to explain results of some experiment in elementary particle physics. These objects have been called not existing

particles because of their untypical character and difficulties with location in the structure of physics. In this work the complex mass particles were bound to SR and it was stated that according to this theory they must move towards LAB with velocity $v > c$.

The experiments in quantum optics suggest that some kind of interaction between two objects is propagating with velocity $v > c$ [62]. This effect can be explained at once, when we assume the existence of machyons, which are responsible for delivery of signal. These experiments are actually the next proof of the existence of machyons.

The argumentation, that relativity theory is theory qualitatively different from quantum mechanics doesn't stand the test of criticism. There are some analogies between classical and quantum mechanics: the classical mechanics is the limitary case of quantum mechanics which corresponds to the situation when the quantum numbers are great. From the other hand the mathematical identity of Fermat variational principle (for electromagnetic wave) and Jacobi's variational principle (for particle) inspired de Broglie to formulate the idea of wave particle dualism.

We can start from quantum mechanics and come to classical mechanics and vice versa, so the argumentation that these theories are qualitatively different and quantum effects in optics can't have something common with SR, doesn't stand the test of criticism.

5.1.2

In order to deepen explanation of character of the complex mass particle, the conception of unempty vacuum is resumed using the analogy with effective mass of electron in solid body caused by the interaction of electron with others electrons and crystal lattice.

It was stated, that results of Aharonov's and Bohm's experiment are irrefutable argument for existence of unempty vacuum. It was referred to earlier theoretical conceptions by Maxwell, de Broglie, Dirac and Bohm connected directly or indirectly with this idea.

The discrepancies and un consequences of Dirac's approach which called in question his extremely deep and original conception of Dirac's sea, were removed.

It was stated, that unempty vacuum has very rich inside structure, and is homogeneous, isotropic and superconducting, which explains its unexpected properties. Homogeneity, isotropy and postulated superconducting character of unempty vacuum cause that SR is implicated just by this idea.

These properties of unempty vacuum imply that motion towards vacuum can't be observed. It means, that Michelson's and Morley's experiment must give negative result, which implies the whole SR. However the unempty vacuum can be observed in experiment suggested by Aharonov and Bohm, and realised many times. The unempty vacuum conception permits to understand better qualitatively the physical sense of the dependence of mass on velocity in SR.

One ought to remark, that idea of unempty vacuum isn't discrepant with field theory. Each particle is a source of field and the part of energy of system is connected in each moment with the field. The principle of equipollence of mass and energy implies that at all points of field, at which energy is nonzero, there is nonzero mass too, what leads directly to conception of unempty vacuum.

5.2.1

Four mutually bound notions:

complex mass

motion with velocity $v > c$

unempty vacuum

compactness of unempty vacuum with Relativity

aren't discrepant with most important theories of modern physics and make possible to explain many doubts, paradoxes and facts connected with SR and quantum mechanics. The interpretation of phase velocity, ghosts and introduction of equivalent of ghosts in solid body makes this picture totally compact.

These notions together with results of Aharonov's and Bohm's experiment create the compact set of ideas and facts, which are well placed in the structure of physics.

They are implicated by experimental facts and earlier theoretical conceptions and throw some light on the established results, so they can't be ignored.

Acknowledgements

I am very grateful to Professor G.Białkowski of blessed memory Who called my attention to the most fundamental problems of modern physics and inspired me to write this work.

Appendix A

Generalized quaternions are expressed by equation:

$$x = x_0 + x_1 e_1 + x_2 e_2 + x_3 e_3 ; \quad x_0, x_1, x_2, x_3 \text{ are real}$$

and the rules of multiplication are determined by multiplication table:

1	1	e_1	e_2	e_3
1	1	e_1	e_2	e_3
e_1	e_1	n	e_3	ne_2
e_2	e_2	$-e_3$	m	$-me_1$
e_3	e_3	$-ne_2$	me_1	$-nm$

$n, m \in \mathbb{J} ; n, m \neq 0$. The structure of associative algebra with $\mathbb{1}$ is introduced in the four dimensional algebraic linear space $H(n, m) = \langle 1, e_1, e_2, e_3 \rangle \mathbb{Q}$ by this table. [Certain Russian book]

Next the representation is introduced:

$$x = x_0 + x_1 e_1 + x_2 e_2 + x_3 e_3 \rightarrow A_x = \begin{vmatrix} x_0 + x_1 \sqrt{n} & x_2 \sqrt{m} + x_3 \sqrt{nm} \\ x_2 \sqrt{m} - x_3 \sqrt{nm} & x_0 - x_1 \sqrt{n} \end{vmatrix}$$

Determinant $\det A_x = x_0^2 - x_1^2 n - x_2^2 m + x_3^2 nm = N(x)$

has the sense of the norm of element x .

Norme $N(x)$ depends on square of x_0, x_1, x_2, x_3 , so it is an analog of square of module of complex number and it is obvious that for certain x_0, x_1, x_2, x_3, n, m $N(x)$ may obtain negative values.

The generalized quaternions must be distinguished from quaternions, which have not negative norm.

Quaternion is expressed by the formula:

$$x = x_0 + x_1 i + x_2 j + x_3 k$$

x_0, x_1, x_2, x_3 are real, but now multiplication table is easier.

$$i^2 = j^2 = l^2 = -1, \quad ij = -ji = k, \quad jk = -kj = i,$$

$$ki = -ik = j.$$

$$\text{Then } x^* = x_0 - x_1 i - x_2 j - x_3 k$$

and norm is equal:

$$N(x) = xx^* = x_0^2 + x_1^2 + x_2^2 + x_3^2 \geq 0$$

Appendix B

$$p = m v$$

p is complex no matter if m is complex or if v is complex.

Let's analyse energy:

$$E^2 = \sqrt{m_0^2 c^4 + p^2 c^2} = \sqrt{m_0^2 c^4 + \frac{m_0^2 v^2 c^2}{1 - \frac{v^2}{c^2}}} = \sqrt{\frac{m_0^2 c^4}{1 - \frac{v^2}{c^2}}}$$

If m_0 is complex (and $v \in \mathbb{R}$ and $v < c$) then m_0^2 is negative and E is complex.

If $m_0 \in \mathbb{R}$ and v is complex ($|v| > c$) then E is complex too.

So E and p are complex no matter if m_0 or v is complex.

We obtained that in the case of canonically conjugated quantities E, p and t, x the complex numbers appear if $v > c$; and in both cases the assumption that m is complex and $v < c$ ($v \in \mathbb{R}$) leads to discrepancy.

Appendix C

The complex potential $U = V + iW$ V, W - real numbers means really the appearance of particle with complex mass. Though the complex potential describes the process of absorption of quantum wave (it has been introduced in this way) and complex mass particle describe processes of decay and fision (absorption).

The procedure of quantisation of potential U would lead to the state with complex energy and complex mass; it is seen on the example when V and W are harmonic potentials.

Then naturally $E_u = \left[\left(n + \frac{1}{2} \right) + i \left(m + \frac{1}{2} \right) \right] \hbar \omega$. $n, m \in \mathbb{N} \cup \{0\}$.

Moreover we have in the case of complex mass

$$m = m_x + im_y ; m_x, m_y \in \mathbb{R}$$

so

$$E = E_x + iE_y ; m_x, m_y \in \mathbb{R}$$

and next

$$\Psi = A e^{i/\hbar(Et)}$$

so

$$\Psi = A e^{i/\hbar(E_x + iE_y)t} = A e^{-\frac{E_y}{\hbar}t} \cdot e^{i/\hbar E_x t}$$

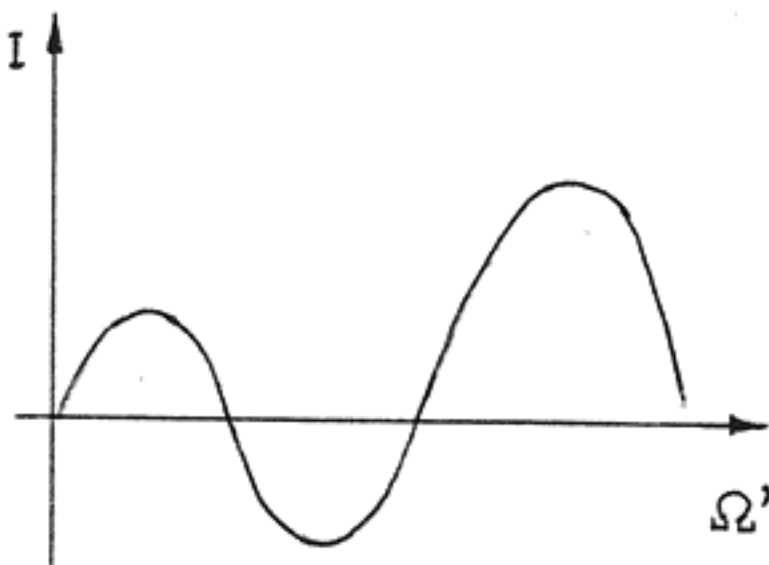
It is a formula describing oscillating decay or absorption, as it has been stated previously.

Appendix D

The probability of finding of ghosts is negative. It means only that integral

$$I = \int_{\Omega} \Psi \Psi^* dV$$

is locally smaller than zero although the integral runs the whole system and must be equal 1.



The fact that in the case of ghosts the integral is smaller than zero means only that ghosts are inseparable of certain bigger system. It corresponds with the fact that ghosts as objects moving along closed curve, must be machyon with complex mass; and this (according to appendix C) means that they exist in the con-

densation which appears in the process of oscillating decay and simultaneous arising of another object or in the process of absorption and so on, for example in the cloud surrounding the particle.

Naturally the product $\Psi\Psi^*$ is bigger or equal zero in the case of complex numbers and quaternions but in the case of generalized quaternions, the product $\Psi\Psi^*$ may obtain both positive and negative values.

Appendix E

It isn't truth that the introduction of the conception of unempty vacuum introduces certain distinguished coordinate system. In unempty vacuum there are the layers of particles moving with different velocities in any coordinate system. Each value of velocity is obtained by certain group of particles. If we want to introduce the distinguished reference system, we would have to choose certain layer of particles, and there is not any physical reason to do it.

It isn't truth, either, that one can discover unempty vacuum making a research in which it swims round the bodies with different shapes.

Naturally there isn't any friction of bodies with unempty vacuum. But unempty vacuum, meeting the transverse surface doesn't swim it round but comes through it like the neutrinos through the Earth.

It concerns all bodies having an inside structure and I am convinced that all bodies have such structure.

Appendix F

The particle knocked out from the Dirac sea comes through it creating the wave. On the other hand it doesn't feel friction because of effects analogical to superfluidity or superconduction.

The problem arises if it isn't discrepancy.

The motion of a particle in the Dirac sea is described by the Dirac equation.

$$i\hbar (\gamma^\mu \delta_\mu - m) \psi = 0 \quad (25)$$

The superconduction is described by the London equation

$$\frac{m c^2}{4\pi n e^2} \Delta H = H \quad (26)$$

The mass from the London equation may be put into the Dirac equation

$$i\hbar \left(\gamma^\mu \delta_\mu - \frac{4\pi n e^2}{c^2} \frac{H}{\Delta H} \right) \psi = 0 \quad (27)$$

It is the most general equation of superconduction described by the equation (27) equivalent to the equations (25) and (26).

It is clear that this same Dirac's equation describes both the motion of a particle in the Dirac sea and superconduction, so they are analogical effects. By this means the potential discrepancy has been eliminated.

Appendix G

In this work it has been proved that the complex mass implicates the curve of the route. But there is problem if the particle move along a straight line.

We have

$$\vec{p} = m \vec{v} \quad , \quad m \text{ complex}$$

$$\vec{F} = \frac{d\vec{p}}{dt}$$

$F = 0$ the condition of non-curve of the route.

$$\vec{p} = \vec{\text{const}}$$

so $\vec{v} = \vec{\text{const}}$

The particles with complex mass moving with constant velocity have the chance to move along a straight line. It corresponds with the $R = \infty$.

Appendix H

When something passes from one reference system to another, the forces of inertia are active. These forces are the result of interaction with unempty vacuum, just as the change of superconducting state in consequence of the momentary voltage is caused by the interaction of electrons with crystal lattice.

Simply, there aren't sourceless forces. The "sourceless" forces are the result of interaction with unempty vacuum and a proof for its existence.

Appendix I

It isn't true that it is possible to discover a distinguished coordinate system analysing the differences of flowing of a body by ether thanks to the differences of the shapes of the body, because ether not only flows the body but it passes through it.

There is only the problem if each physical body has any inside structure [63].

Appendix J

In this work the Relativity has been generalised. It has been proved that this theory doesn't forbid the motion

with velocity bigger than the limit velocity c , called the velocity of light. It has been proved, too, that the conception of Dirac's unempty vacuum - simply speaking: ether - does not introduce any differentiated coordinate system, so it isn't discrepant from the Relativity.

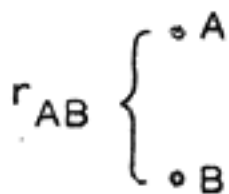
These both conceptions are connected with the idea of complex mass which removes Einstein's reservation that the conception of ether isn't necessary.

In this work the Dirac's sea conception has been improved with the introduction of two seas and two systems: particle and antiparticle adequately for both of them.

This work presents a new vision of physics but it is strongly based on the foundations created by predecessors and it is implicated by them in the strict and logical way.

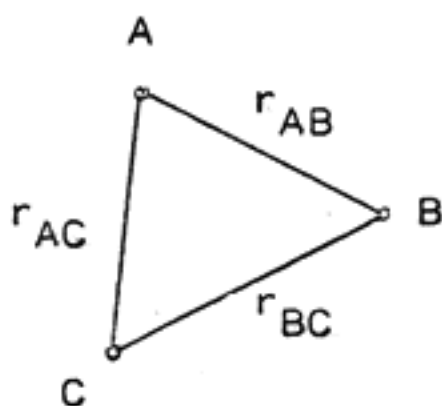
Appendix K

Quantum mechanics doesn't forbid the motion with velocity bigger than limit velocity $v > c$.



Let's assume that in the distance of time dt we have measured the particles, once at the point A and then at the point B with the distance r_{AB} .

There is no condition $c dt > r_{AB}$.



Considering the fact that the particles of the same sort aren't possible to be distinguished, we can assume that the particle from the point C moved after certain time dt to the point B, and at the same time the particle from the point A moved to the point C.

There are not the dependences

$$c dt > r_{BC} \quad \text{and} \quad c dt > r_{AC}.$$

What's more, the procedure of Dirac's linearisation of the root in so called Pitagoras theorem eliminates the limit of velocity.

Appendix L

We have

$$\vec{E} = -\vec{\nabla}\varphi - \frac{\partial \vec{A}}{\partial t}$$

$$\vec{B} = \vec{\nabla} \times \vec{A}$$

Since A is a real, existing field, so the existence of ether is a fact; and φ is a real, existing field, too.

The influence of the static gravitational field on the electromagnetic field is analogical to the influence of a medium whose electric and magnetic permeability are equal:

$$\epsilon = \mu' = \frac{1}{\sqrt{h}} \quad [64].$$

The problem arises if the unempty and curved space must have an inside structure. For a one-dimensional line the answer is negative. The case of more dimensional structures will be discussed.

Appendix M

We have the dependence

$$v_f \cdot v_g = c^2$$

So, if $v_g < c$ then $v_f > c$.

This feature of phase velocity is the next proof that velocity can be bigger than c .

The interpretation of phase velocity is easy. The cloud of tachyons is always bound with a real mass particle.

Appendix N

It is not true that during first small split second after the Big Bang the laws of physics weren't satis-

fied, because the velocity would be bigger than c ($v > c$). The situation is opposite. The velocity $v > c$ isn't discrepant from the Relativity.

Appendix O

The existence of much amount of trajectories binding the same two points may be result both of interaction and of the fact that the particle propagating from x_0 to x feels what happens at distant points of space and the topology of this space. It is the proof of the existence of machyons (tachyons) carrying information.

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