Physical Consequences of Moving Faster than Light in Empty Space

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Physical phenomena caused by particle’s moving faster than light in a space with multifractal time with dimension close to integer (d_t = 1 + ε(r(t), t)), |ε| ≪ 1 - time is almost homogeneous and almost isotropic) are considered. The presence of gravitational field is taken into account. According to the results of the developed by the author theory, a particle with the rest energy E_0 would achieve the velocity of light if given the energy of about E ∼ 10^7E_0.

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I. INTRODUCTION

In [1], basing on the theory of multifractal time and space proposed in [2], the main features of relative motion of systems close to inertial (“almost” inertial systems) in the space with fractal dimension of time d_t = d_t(r(t), t) = 1 + ε, |ε| ≪ 1 were formulated, and it was shown that in such systems motion of body with any velocity (from zero up to infinite) becomes possible. For total momentum and energy of a moving object the following relations were obtained

\[ p = \beta^{α-1} m_0v = \frac{m_0v}{\sqrt{\beta^4 + 4a_0^2}}, \quad E = E_0\sqrt{\frac{v^2c^{-2}}{\beta^4 + 4a_0^2} + 1} \quad (1) \]

where \( \beta = \sqrt{1 - v^2/c^2} \), \( a_0 = \sum_{i=1}^{4} \beta_i F_{0i} \), \( F_i = dL_i/dr \) with \( L_i \) standing for Lagrangian density of ith physical field, \( t \) for time and \( \beta_i \) being dimensional factors for ith field, providing dimensionlessness of ε: \( \varepsilon = \sum_{i} \beta_i L_i \). However, the question on what new physical phenomena can be observed from the point of view of this theory if a body’s velocity exceeds that of light in empty space was temporarily put aside. The present paper is devoted to fill in this gap and deals with several consequences of the proposed multifractal concept of time [1] and relations (1), that allow for experimental verification.

II. VAVILOV-CHERENKOV-LIKE RADIATION AT V > C

According to the main statements of [1], small noninertia of moving frames of reference arising from the time being multifractal, and openness of any real system (for statistical theory of open systems see [3]) must lead to small deviations from the conservation laws. In particular, the law of energy conservation would be fulfilled only approximately. Basing on the laws of electrodynamics, which remain valid in the theory of multifractal time at any velocities, it was shown that when a body’s velocity \( v \) reaches that of light \( c \) and continue increasing, the energy of the moving body reaches its maximum value and then begins diminishing (see (1)). As this takes place, more and more energy is lost by the body in order to span the small deviation from the energy conservation will be emitted to the surrounding matter (space) through radiation. With the energy of this radiation, the energy conservation law is “almost” fulfilled

\[ E = E_0\sqrt{\frac{v^2}{c^2\beta^2} + 1} + E_{rad} \quad v > c \quad (2) \]

It can be shown that at the velocities greater than the speed of light perturbation of multifractal structure of time still remains negligibly small, just as it is the case for resting particles.

III. DOES THE CASUALITY REMAIN IN V > C REGION?

In special relativity the necessary condition of two events that take place in a fixed frame of reference in points \( x_1 \) and \( x_2 \) at times \( t_1 \) and \( t_2 \) and of the same events in a moving frame to be casually connected is the validity of the following inequalities
\[ t_2 - t_1 > 0, \quad t'_2 - t'_1 = \frac{t_2 - t_1}{\sqrt{\beta^4 + 4a_0^2}} \left(1 - \frac{v}{c^2}v_{\text{inf}} \right) > 0 \] (3)

where \( v_{\text{inf}} \) is the velocity of the influence spreading between the points \( x_1 \) and \( x_2 \). If \( v_{\text{inf}} < c^2/v \), the casual connectivity of the two events remains at any speed of motion \( v \leq \infty \). Though, when \( v = \infty \), the rate of influence must be zero. Nevertheless, if this inequality is not fulfilled \( (v_{\text{inf}}v > c^2) \), casuality does not remain. This violation of casuality for different events is one of the main arguments against the tachion theory, restricting, in particular, the free will of objects. Fortunately, in our model casuality does not break for the following reason.

Any body moving faster than light radiates energy, and the greater its speed the less its energy. Hence, motion with velocity greater than that of light is always a motion with acceleration and thus it is not "almost inertial" in our terminology. Therefore, in terms of the assumptions made, any comparison between moving with acceleration and fixed frames of reference have no physical sense.

Stress now the main differences between motion faster than light in tachion and in multifractal time models. In the tachion model the whole region of velocities consists of two separate parts, velocities greater and less than that of light in vacuum. Particles whose speed is greater than \( c \) (tachions) can not cross the barrier and move into the other region. Tachions have several peculiarities in their motion, and the principle of casuality can be violated if we are to compare events in different regions of velocities. In the model of multifractal time any particle, if supplied with sufficiently big energy, can be accelerated up to velocities greater than the speed of light, and thus found itself in the tachion region. However, in this region it will be constantly radiating energy and moving with growing velocity. In this process its energy tends to a finite value \( E \to E_0\sqrt{2} \) as \( v \to \infty \). By consuming energy it, though, can be slowed down, and, having its energy being increased up to \( E = E_0\sqrt{2a_0} \) (see (4)), can return in the region \( v < c \) and begin to radiate again, but now when being decelerated.

IV. POSSIBLE PHYSICAL PHENOMENA AT \( V > C \)

A body (with nonzero rest mass) moving with the speed of light has maximum possible energy and represents a sort of energy reservoir - if its velocity increases or decreases, the excess of energy emits through radiation. Such a body thus can serve as an energy source, since small initial (e.g., spontaneous) increasing of its velocity would lead to release of immense energy of order \( E \sim E_0\sqrt{2a_0} \). In this connection, the following possible consequences allowing for experimental observation and applications of motion faster then light can be pointed out.

a) a sudden burst of radiation can occur as a particle’s velocity increases from \( v = c \) to \( v > c \). As an example of observation of this effect we can consider a charged particle in accelerators like synchrotron. At energies much greater then the rest energy \( (v \approx c, \ v < c) \), the particle’s velocity almost does not alter while its energy can vary by orders of magnitude, with this change accompanied by considerable growth of synchrotron radiation. When velocity reaches the value \( v = c \), energy has its maximal value (see (4)). Then in the narrow region of velocities \( 0 < v^2/c^2 - 1 < 4a_0 \) the particle loses almost all its energy through Vavilov-Cherenkov-like radiation and synchrotron radiation. In this process the radius of its orbit remains almost the same (the particle’s velocity is still close \( c \)). As this occurs, the radiation power grows sharply and has the order of \( E_010^9t^{-1/2}sec^{1/2} \) (which equals to \( \sim 10^{12}t^{-1/2}eVsec^{1/2} \) for protons). This jump of radiation power can be detected by registering appearance of high-energy \( \gamma \)-quants, mesons, electron-positron pairs etc. Further increasing of velocity will result in the particle’s getting out from the stationary orbit and becoming invisible for the observer. The latter is connected with the fact that in order to reduce particle’s velocity down to \( v = c \) it is necessary to give it energy it lose through radiation \( (\sim 10^{12}eV \) during one second for proton). Such particle will move undergoing acceleration without substantial change in energy \( (E_{\min} = E_0\sqrt{2}) \). Experimental observation then becomes possible only if it collides with something that can supply it with the required for the transition in the region \( v < c \) amount of energy (another high energy particle or \( \gamma \)-quantum). In this case the particle can be detected as ordinary charged particle with very high energy, that ionizes matter and gives birth to bunches of \( \gamma \)-quants, mesons, electron-positron pairs etc.

b) Propagation of a faster-than-light particles beam in a dense media would lead to diminishing the media’s temperature due to such particles’ attaining energy while being decelerated, and this can serve as a possible method to decrease the energy of a hot dense matter (thermonuclear plasma, neutron star, nuclear power reactors etc.)

This method of cooling very hot matter with high density and high scattering crossection for faster-than-light particles may turn to be one of the most effective ways of doing that for these kinds of media because of huge amounts of energy necessary to slow down such particles.

c) Energy \( E_010^k t^{-1/2}sec^{1/2} \) released over small time intervals corresponds to the temperature of \( T \sim E_0l0^{12}t^{-1/2}sec^{1/2}K \), and perhaps can be used for initiating or controlling thermonuclear fusion in deuterium-tritium media.

d) Provided that the conditions for coherent radiation appearance are satisfied, a laser with working frequency of \( \nu \sim 10^3E_0h^{-1}t^{-1/2}sec^{1/2} \) can probably be created.
V. CONCLUSION

Investigation of relative motion in the multifractal time model for "almost inertial" systems [1] indicates of possible appearance of a number of new physical phenomena in the region of the velocities greater than the speed of light and new notions about properties of mass and energy as functions of velocity in the case of fractional corrections to the topological dimension of time being small (in particular, possibility of motion with any velocity, existence of a maximum energy for a particle and several others). The proposed model, based on the concept of time with fractional dimension, does not contradict to special relativity and is not its generalization. Indeed, all motions and frames of reference in this model are absolute. Due to the time and space inhomogeneity and openness of time-space in general, Galileee and Lorentz transformations, and conservation laws are only approximate. This does not contradict to the usually observed phenomena, since the deviations from the classical laws are very small (as it is the case with space-time curvature in general relativity). The model of relative motion in multifractal time, on which the present paper is based, hence represents a theory of relative motion in "almost inertial" frames of reference in the space of almost homogeneous time with dimension very close to integer. The theory proposed in [1] contains the special relativity as a special case, corresponding to zero fractional corrections to the dimension of time, and reduces to it if we set time dimension to be unity (then all the approximate laws named in the paper become exact). Approximate validity of the Lorentz transformations follows from the assumption about the smallness of fractional correction to the topological dimensionality of time. On the other hand, one should not be surprised by taking into account the velocity of light dependence on the Lagrangian densities of physical fields in "almost inertial" frames. For example, in general relativity it depends on gravitational potentials. As it was mentioned in [1], appearance of fractional dimensions of space and time can be interpreted in terms of Penrose’s ideas [4] concerning appearance of the equations of free physical fields as a result of deformations of certain complex manifolds (such as co-homologies of bunches with coefficients) characterizing space-time (in our case, with fractional dimension).

The main results of the model of multifractal time that disappear when we use usual concept of time are the following.

1. The possibility for any object to move faster than light (instead of the factor \( \beta = \sqrt{1 - v^2/c^2} \) of special relativity the modified factor \( \beta^* = \sqrt{\beta^4 + 4a_0^2} \) appears).

2. Total energy at \( v > c \) is determined by the expression

\[
E = \sqrt{p^2c^2 + E_0^2} = E_0\sqrt{\frac{1 + \beta^2}{\sqrt{\beta^4 + 4a_0^2}}} + 1, \quad E_0 = m_0c^2
\]

with \( \beta^2 = \frac{\beta^*}{c^2} - 1 \) which does not coincide with the relation \( E = \beta^{*^{-1}} E_0 \) valid for \( v < c \).

3. Maximal value of the total energy (mass, momentum) are bounded by the value corresponding to the motion with the velocity of light

\[
E_{\max} = m_{\max}c^2 = E_0\sqrt{2a_0}, \quad p_{\max} = m_{\max}c
\]

Both energy and momentum remain finite as \( v \to \infty \)

\[
E_\infty = E_0\sqrt{2}, \quad p_\infty = m_0c
\]

4. Existence of Vavilov-Cherenkov-like radiation not connected with deceleration processes

5. If the fractional correction \( \varepsilon \) to the time dimension is zero, our model fully reduces to the equations and conclusions of special relativity.

The energies, necessary according to our theory to accelerate the particles up to the velocity of light \((E \sim 10^{10}\mathrm{eV} \text{ for electron, } E \sim 10^{12}\mathrm{eV} \text{ for proton})\) seem to be available in the nearest decade, thus making the experimental verification of the theory of "almost inertial" frames of reference [1] possible.

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