The upper limit of the mass and energy of the relativistic particles

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It is shown that a relativistic particle has an upper limit of the mass and energy when it is accelerated to the speed of light. Now we can calculate the limiting parameters of the relativistic particles by the use of the normalized relativistic factor in Einstein's relativistic equations. For example, the maximum mass of the relativistic proton is a limited number of $1.1 \cdot 10^{12}$ kg. The state of the relativistic particle is described by a mass balance and an energy balance. The energy balance includes the maximum energy of a relativistic particle and her real energy and her hidden energy.

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Accelerating to relativistic speeds of the elementary particles leads to an unlimited increase of the mass m and energy W at increase of their speed close to the speed of light [1]

$$m = m_0\gamma \tag{1}$$

$$W = W_0\gamma \tag{2}$$

where m_0 is rest mass; W_0 is rest energy; γ is relativistic factor:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{C_0^2}}} \tag{3}$$

The relativistic mass of an elementary particle can't be greater than the mass of the Universe. Therefore, the real relativistic mass should have a limit. This problem is solved by the introduction of the complex speed of light ($C_0e^{i\theta}$), where $i = \sqrt{-1}$, e=2.71…, θ is argument of a complex number, $\varphi=Gm_0/r$ is Newton's gravitational potential [2]:

$$C_0e^{i\theta} = C + i\sqrt{\varphi} \tag{4}$$

$$\theta = arcsin\frac{\sqrt{\varphi}}{C_0} \tag{5}$$

$$C = C_0\sqrt{1-\frac{\varphi}{C_0^2}} \tag{6}$$

Analysis (4, 5, 6) shows that at $\theta = \pi/2 \rightarrow \varphi = C_0^2$ the speed of light is equal to zero, $C = 0$. This is possible only on the black hole's surface where the light stops. However the black holes it are big cosmological objects. Then we can estimate the limiting mass m_{max} of the relativistic particles in assuming that its radius R_S is the gravitational radius (without the multiplier 2):

$$R_S = \frac{Gm_{max}}{C_0^2} \tag{7}$$

From (7) we find the limiting (maximum) mass m_{max} of the relativistic particle:

$$m_{max} = \frac{C_0^2}{G}R_S \tag{8}$$

Obvious, that the relativistic mass $m = m_0\gamma$ (1) of the particle cannot be greater than her limiting mass m_{max} (8). This condition can be satisfied if we make the renormalization of the relativistic factor γ (3). For this purpose we enter into (3) limiting coefficient k_0 and we call a new factor as the normalized relativistic factor γ_n:

$$\gamma_n = \frac{1}{\sqrt{1-k_0\frac{v^2}{C_0^2}}} \tag{9}$$

Now we need to find the coefficient k_0 in (9). We write a new condition for (1) under which the relativistic particle acquires the limiting mass m_{max} (8) at the speed of light $v = C_0$:

$$m_0\gamma_n = m_{max} \tag{10}$$

$$\frac{m_0}{\sqrt{1-k_0}} = \frac{C_0^2}{G}R_S \tag{11}$$

From (11) we find k_0 taking into account of the gravitational radius $Rg = Gm_0/C_0^2$

$$k_0 = 1 - \frac{G^2m_0^2}{C_0^4R_S^2} = 1 - \frac{R_g^2}{R_S^2} \tag{12}$$

Then we substitute (12) in (9), and we find the normalized relativistic factor γ_n:

$$\gamma_n = \frac{1}{\sqrt{1-\left(1-\frac{R_g^2}{R_S^2}\right)\frac{v^2}{C_0^2}}} \tag{13}$$

Introduction of the normalized relativistic factor γ_n (13) in (1) and (2) allows excluding unlimited value of mass and energy of the relativistic particles at the speed of light:

$$m = m_0\gamma_n \tag{14}$$

$$W = W_0\gamma_n \tag{15}$$

Let's consider practical application of the formulas (14) and (15):

1. Limit the mass and energy of the proton. In [3], there is a forecast that the relativistic micro black holes can be obtained artificially using the Large Hadrons Collider (LHC). To estimate reliability of this forecast we will use formulas (14) and (15) for the calculation of the limiting parameters of the proton. The rest mass m_{p0} of the proton is known m_{p0} = $1.67 \cdot 10^{-27}$ kg. Radius of a proton has no exact value [4, 5]. Therefore we will use the minimum radius of the proton in calculations R_S = 0.84 femtometer.

Now we define the limiting mass m_{pmax} (14) proton under the condition $v = C_0$:

$$m_{pmax} = m_{p0}\gamma_n = \frac{m_{p0}}{\sqrt{1-\left(1-\frac{R_g^2}{R_S^2}\right)\frac{v^2}{C_0^2}}} = \qquad (16)$$

$$= \frac{C_0^2}{G} R_S = 1.1 \cdot 10^{12} kg$$

As can be seen, the limiting mass of a proton $m_{pmax} = 1.1 \cdot 10^{12} kg$ (16) has a finite value at a speed of light. It's the limiting mass is very large, but it is not infinite and corresponds to the mass of an iron asteroid with a diameter of 700 meters.

And at last we define the limiting energy W_{pmax} (15) proton under the condition $v = C_0$:

$$W_{pmax} = m_{p0} C_0^2 \gamma_n = \frac{m_{p0} C_0^2}{\sqrt{1-\left(1-\frac{R_g^2}{R_S^2}\right)\frac{v^2}{C_0^2}}} = \qquad (17)$$

$$= \frac{C_0^4}{G} R_S = 6.4 \cdot 10^{35} TeV$$

The Large Hadrons Collider (LHC) can accelerate the protons to energy of 7 TeV. This is 35 orders of magnitude less energy is needed for the conversion of a proton in a micro black hole. Therefore, experiments at the LHC present no danger to the Earth.

2. Hidden mass. The square of the module speed of light C_0^2 in (4) represents the gravitational potentials balance in the perturbed by gravitation the four-dimensional space-time in a statics [2].

$$C_0^2 = C^2 + \varphi_n \qquad (18)$$

The gravitational potentials balance (18) in the dynamics should be written taking into account of the normalized relativistic factor γ_n (13):

$$C_0^2 = C^2 + \varphi_n \gamma_n \qquad (19)$$

The gravitational potentials balance (19) is multiplied by the R_S/G (10) at $r = R_S$ and we find the dynamic mass balance m of a relativistic particle in the full range of speeds:

$$m_{max} = m_0 \gamma_n + m_s \qquad (20)$$

The mass balance (20) includes the hidden mass m_S of the particle as a real component of the four-dimensional space-time:

$$m_s = m_{max} - m_0\gamma_n = C^2 R_s / G \qquad (21)$$

The relativistic mass m (14) of a particle increases by reducing of the hidden mass m_S (21) providing mass balance with increasing speed of the particle:

$$m = m_{max} - m_s = m_0 \gamma_n \qquad (22)$$

3. Hidden energy. The dynamic mass balance (20) is multiplied by the C_0^2, and we find the dynamic energy balance W_{max} of a relativistic particle in the full range of speeds:

$$W_{max} = W_0 \gamma_n + W_s \qquad (23)$$

The energy balance (20) includes the hidden energy W_S of the particle as a real component of the four-dimensional space-time:

$$W_s = W_{max} - m_0 C_0^2 \gamma_n = C_0^2 C^2 R_s / G \qquad (24)$$

The relativistic energy W (15) of a particle increases by reducing of the hidden energy W_S (24), providing the energy balance at increase in speed of a particle:

$$W = W_{max} - W_s = m_0 C_0^2 \gamma_n \qquad (25)$$

It is necessary to remind that in the theory of Superunification the four-dimensional space-time is the carrier of the superstrong electromagnetic interaction (SEI) [6] which provides the energy exchange between the relativistic energy W and the hidden energy W_S.

Thus, the introduction of the normalized relativistic factor γ_n (13) eliminates the infinite values of the mass and energy with increasing speed of the relativistic particle to the speed of light. The dynamic mass balance (20) and the dynamic energy balance (23) includes the hidden mass m_S and the hidden energy W_S providing the energy exchange with the superstrong electromagnetic interaction (SEI) inside of the four-dimensional space-time [6]. The hidden mass and the hidden energy is more correct characteristics of the four-dimensional space time, than the terms "dark matter and dark energy" [2].

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