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ELEMENTARY PARTICLES OF THE LARGEST MASSES

(quarks, maximons)

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Быть может эти электроны -
Миры, где пять материков,
Искусства, знанья, войны, троны
И память сорока веков!
Ещё быть может каждый атом-
Вселенная, где сто планет.
Там все, что здесь, в объеме сжатом,
Но также то, чего здесь нет.
/В.Брюсов./

Over the last decades a new idea has appeared in our concepts of the structure of the matter, the idea of composing relatively small masses from fundamental particles of large mass.(Fermi-Yang et al.).

In the quark model the mass of the fundamental particles is supposed to be larger than several nucleon masses.The masses of newly discovered particles (Ω^- -hyperon, resonances) gradually increase. It is natural to assume that the upper limit of the elementary particle masses must be determined by some fundamental properties of the matter.

In the framework of the modern theory it is possible to indicate several quantities of the mass dimensionality which could claim to play the role of the largest masses of the fundamental particles concerned.

The length closest to the baryon ones and the mass related to it is the weak interaction length

$\ell = \sqrt{\frac{G}{\hbar c}} \sim 0.7 \ 10^{-16}$ cm and the corresponding mass $M \sim 300$ GeV.

Taking into account the gravitational field larger values of the maximum possible masses can be indicated and the latter seem to have a more universal meaning.

Indeed, using the gravitational constant and other universal constants two expressions of the mass dimensionality can be derived

$$m_1 = \frac{e}{\sqrt{\varkappa}} \sim 10^{-6} gr \quad ; \quad m_0 = \sqrt{\frac{\hbar c}{\varkappa}} \sim 10^{-5} gr , \qquad (1)$$

e is the electric charge.

The masses of eq.(I) are unusually large as compared with the elementary particle masses which experimental physics is dealing with.

But it should be borne in mind that we mean the maximum large masses of elementary particles.

From this point of view the value of the mass $m_1 = \frac{e}{\sqrt{\varkappa}}$ is, at least, in classical (non-quantum) physics the maximum one of the physical mass of a point particle carrying the electric charge e for any bare mass M_0 of the bare particles.

The expression for the physical mass m, of charge e localized with density ρ in the sphere of r -radius is defined in the general theory of relativity as [I]

$$m = M_0 + \frac{1}{2}\frac{e^2}{\varkappa} - \frac{\varkappa}{2}\frac{m^2}{r}, \quad r \to 0 \quad . \qquad (2)$$

Here $M_0 = \int_{V_0} \rho dv$ is the bare mass of the system, i.e. the mass density ρ, integrated over the volume of the curved space V_0.

In the corresponding linear theory the last term $-\frac{\varkappa}{2}\frac{m^2}{r}$ is replaced by $-\frac{\varkappa}{2}\frac{M_0^2}{r}$. In the linear theory the value of m diverges at $r \to 0$. In the general theory of relativity eq.(2) gives for m

$$m = \varkappa^{-1}\left\{-r + \left[r^2 + 2M_0\varkappa r + e^2\varkappa\right]^{\frac{1}{2}}\right\} . \qquad (3)$$

From where

$$m_{(r\to 0)} \to \frac{e}{\sqrt{\varkappa}}$$

for any value of the bare mass M_0 .

If in the case of electrically charged particle mass one can strictly formulate the purely static Schwarzschield problem (the Papapetrou model) which was thoroughly studied by Bonnor [2], then the case of electrically neutral gravitating dust is a non-static problem. The three-dimensional sphere of the radius r with a uniform density of the dust-like matter is a part of the Friedman Universe.

The possibility of sewing together *) the internal solution for the

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*) The radius of the sewing sphere depends upon the time.

corresponding Einstein gravitational equation with the Schwarzschield external solution ($g_{00}=1-\frac{2\varkappa m}{c^2 r}$; $g_{11}=\ \dots$ and so on) was indicated by Tolman [3].

Over the last years this problem was considered by Klein [4], Zeldovich[5] and more thoroughly by Novikov [6].

As is known, in the closed world of radius a the distance can be given as $r=a\sin\chi$ (where $0<\chi<\pi$). The surface of the three-dimensional sphere cut from this world is expressed as

$$S^2=4\pi a^2 \sin^2\chi . \tag{5}$$

The surface of the sphere (5) at $\chi=\frac{\pi}{2}$ is maximum and with further increase of χ it reduces to a point at $\chi=\pi$. When $\chi=\pi$ - the gravitational self-energy completely compensates the bare mass M_0 and m appears to be equal to zero as it should be for the closed Universe *).

Thus, if one considers the Friedman Universe which is slightly non-closed in this sense ($\chi=\pi-\delta$ where δ is small) so that the mass of the "whole Universe" is close or equal to the mass of the neutron, for example, then for the Schwarzschield's observer localized in a free space outside the considered sphere the behaviour of the whole Universe under the action of forces does not differ from the behaviour of the particle with mass equal to that of the neutron or electron.

I am far from suggesting that inside a neutron or an electron another conference on High-Energy Nuclear Physics is now taking place but I would like to stress that our modern understanding of the elementary particles may be very far from what they really are and that the gap between "the cosmic -large" and the "micro-small" can be not so great as it seems from the first sight.

Now turn to the quantum expression of another claimer to the possible maximum mass of the elementary particle $m_0=\sqrt{\frac{\hbar c}{\varkappa}}$.

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*) In the above model of the point charged particle with radius tending to zero the negative gravitational self-energy cancels any value of the bare mass.

Further we shall oall the particle of largest mass m_0 "quantum maximon" [8], and m_1 "classical maximon".

By the values of their masses these particles are suprisingly close to eaoh other

$$\frac{m_1}{m_0} = \sqrt{\frac{e^2}{\hbar c}} = \alpha^{1/2}. \qquad (6)$$

The mass $m_0 = \sqrt{\frac{\hbar c}{\varkappa}}$ and, especially, the related length $\ell_0 = \sqrt{\frac{\varkappa \hbar}{c^3}} \sim 10^{-33}\,cm$ were often discussed in the framework of the general theory of relativity (Wheeller, Regge,Blokhintsev et al.)

Regrets have been expressed that the mass $m_0 = \sqrt{\frac{\hbar c}{\varkappa}}$ does not coincide with the mass of the eleotron or proton, for example, and sometimes assumptions were made that the consequent quantum theory of gravitation could signifioantly change the situation.

However the recent tendency to increase the elementary particle masses permits to consider the large mass m_0 as a hint on the existenoe of partioles with the value of this largest mass rather than a trouble. For such a particle to be stable it is necessary that its total mass be concentrated in a region of corresponding elementary length $\ell_0 = \sqrt{\frac{\hbar \varkappa}{c^3}}$. The length ℓ_0, in fact, ooincides with the partiole gravitational radius

$$r_{gr} = \frac{2 m_0 \varkappa}{c^2} = 2\ell_0 \quad . \qquad (7)$$

It is noteworthy that two maximons of mass m_0 interaot aooording to the law

$$\frac{\varkappa m_0^2}{r} = \frac{\hbar c}{r} . \qquad (8)$$

In other words, the interaction of the two maximons is strong.

Probably the most interesting thing is that the purely gravitational interaotion of such particles whose mass is distributed over the small volume with large density results in a collapse in the system of two maximons leading to systems of arbitrarily small masses as compared to the maximon mass.

The attention to the possibility of the small-mass oollapse was first paid by Ya.B.Zeldovich [7]. According to his estimate the system of N neutrons can collapse if the necessary contraction energy is

$$E \sim N^{2/3} \left(\frac{\hbar c}{\varkappa}\right)^{1/2} c^2 .$$

Thus, the energy $\sim \left(\frac{\hbar c}{\varkappa}\right)^{1/2} c^2$ should be added to each neutron to overpass the energy barrier which leads to collapse. But $\left(\frac{\hbar c}{\varkappa}\right)^{1/2}$ is just the mass of the maximon localized in the region of its gravitational radius.

Hence, there is no energy barrier for the collapse of two maximons of mass m_0. We are led to the conclusion that in the maximon physics a mechanism leading to the formation of the system of arbitrarily small masses appears.

The question arises whether the maximons could be the quarks out of which strongly interacting particles are attempted to be constructed.

In the quark theory the existence of unknown forces uniting quarks into the small system is assumed. In the maximon physics the appearance of a specific mechanism of the small mass formation out of maximon large masses is natural and inevitable *). Even the appearance of the fractional charges can be due to the specific nature of maximons.

In any case, when in the physics of the discussed particles such small lengths are involved, there appears a mechanism (polarization) which can change the value of the bare electric charge. One can even assume that the combination of constants $\hbar c = e_0^2$ is a fundamental constant rather than the e equal to the electron charge and that only the vacuum polarization effect reduces the values of the bare charge to the observables.

From the first sight the gravitational forces acting similarly on particles and antiparticles seem to be incompatible with the quark concept according to which only quarks and antiquarks can be grouped into a close system, for example, meson. However at small distances the value of the bare electric charges becomes involved too, and there appears the possibility of a sharp difference between the charged maximon system consisting

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*) It should be noted that the classical concepts are involved in our consideration, the quantum theory can introduce significant modifications.

either of two particles [ж)] or a particle and antiparticle.

It may seem that the maximons have nothing to do with quarks and are independent of the latter.

The collapse of the small masses which tempts to identify maximons and quarks appears within the framework of the non-quantum theory. There is no quantum theory for the collapse of small masses. We do not know whether the system can be in the state of arbitrarily small mass due to quantum collapse, whether the desired discrete spectrum is observed in quantum field instead of the continuous mass spectrum or as a result of quantum collapse the system are necessary to arise which are only comparable with the masses of the initial maximons. Unfortunately all these questions remain still open.

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[ж)] For instance,the mass of a system of two electrically charged particles-maximons may be of the order of the mass of the same maximon.