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ON QUARKS, PARTONS AND A POSSIBLE GLOBAL BOOTSTRAP

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О кварках, партонах и возможном глобальном бутстрапе

Возможные в рамках обшей теории относительности частицы максимально больших масс ($\sim 10^{-5}$ гр) и размеров $\sim 10^{-32}$ см (максимоны) могут быть использованы в моделях адронов, допускаюших тяжелые кварки. Обсуждаются квантовые аспекты теории максимонов.

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Markov M.A. **E2 - 8572**

On Quarks, Partons and a Possible Global Bootstrap

The values of the charges of various vector fields (electric charge e, specific charges of ρ, ϕ and ω meson fields g_ρ, g_ϕ and g_ω) as well as the values of the gravitational constant κ, the Planck constant $\hbar$ and the light velocity constant c can be used to construct a number of quantities of masses near $10^{-5} - 10^{-6}$ gr

$$\left(\frac{e}{\sqrt{\kappa}} \sim 10^{-6} \text{ gr}, \frac{g}{\sqrt{\kappa}} \sim 10^{-5} \text{ gr}, \sqrt{\frac{\hbar c}{\kappa}} \sim 10^{-5} \text{ gr}\right).$$

Within the framework of general relativity the appropriate particles ("maximons") are naturally interpreted as elementary, as black holes of dimensions $r_0 \sim 10^{-32} - 10^{-33}$ cm, or as objects with internal static metric described by the Papapetrou model. In the hadron models admitting arbitrary heavy quarks account should be taken of a possible existence of particles (stable or unstable) like maximons. The quantum aspect of maximon theory is discussed.

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In a number of papers there are arguments in favour of the fact that, at least theoretically, hadrons can be built out of more elementary, but very heavy particles, even of particles of infinitely heavy masses /1,2,3/. Leaving the discussion of the suggested theories aside it is worth speaking of a number of pretenders to the role of such particles of large but finite masses, and what is the main, of very small sizes. The attractive feature of these objects consists in that they are not specially conceived but are described with the well-known solutions within the framework of general relativity. It is important that the objects, which will be discussed below, can, in principle, exist in nature independently or whether these particles form hadrons or whether they bear no relation to this problem.

There is a number of constants which characterize the charges of the known vector fields:

e - the electric charge,
g_ρ - the charge of ρ-meson vector field,
g_ϕ - the charge of ϕ-meson vector field, and
g_ω - the charge of ω-meson vector field

($\hbar$ - the Planck constant, c - the light velocity). On the basis of the gravitational constant κ it is possible to obtain the following values for the masses

$$m_e = \frac{e}{\sqrt{\kappa}} \sim 10^{-6} \text{ gr}.$$

$$m_{g_\rho} = \frac{g_\rho}{\sqrt{\kappa}} \sim 10^{-5} \text{ gr}.$$

$$m_{g_\phi} = \frac{g_\phi}{\sqrt{\kappa}} \sim 10^{-5} \text{gr.}$$

$$m_{g_\omega} = \frac{g_\omega}{\sqrt{\kappa}} \sim 10^{-5} \text{gr.}$$

$$m_\hbar = \sqrt{\frac{\hbar c}{\kappa}} \sim 10^{-5} \text{gr.}$$

$m_\hbar$ is the commonly known Planck mass. It is quite possible that all these values are the upper limits of possible masses of microparticles. In refs./4,5/ they are given the common name "maximons", that is, possible elementary particles of the largest but finite mass. It is interesting that all the masses of maximons lie within the limits 10^{-6} - 10^{-5} gr. though they slightly differ from one another by the values of the constants of specific charges.

It is essential that maximons are natural objects of the theory of general relativity. The first of these particles can be realized in nature as an electrically charged black hole of extremely small sizes /6/ with external Nordström-Reissner metric. In other words, this is an elementary electrically charged black hole*. The internal region of this objects can be described as follows: If the Friedmann closed world, which is by definition electrically neutral and, due to the huge gravitational mass defect, possesses zero total mass, is "damaged" by the introduction of the

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*An elementary analysis (JETP 64, 1105 (1973)) shows that in the calculation of, e.g., the electron proper energy by perturbation theory there arise intermediate states (for $E_{\text{interm}} > \sqrt{\frac{\hbar c}{\kappa}}\, c^2$)) of the type of the black hole when, according to the Heisenberg uncertainty relation, the energy of the intermediate state is inevitably localized inside the appropriate Schwarzschild sphere.

only electron (more rightly, the only electric charge), then the world will turn out to be open/5,6/ with the following dimensions for an external observer *

$$r_0^e \approx \frac{e\sqrt{\kappa}}{c^2} \sim 10^{-33} \text{ cm}$$

and the total mass

$$m_e \sim \frac{e}{\sqrt{\kappa}} \sim 10^{-6} \text{ gr.}$$

It is remarkable that this result is independent of how many nucleons and other particles (in total, electrically neutral matter) are contained inside such a system. Moreover, we can surely say, in spite of the fact that at the first glance this assertion seems to be paradoxial, that this result is also independent of how many galaxies and possible civilisations exist on the celestial bodies inside this system. All these differencies in the internal structure of such systems are not detectable for the external observer: they are hidden from him behind the Schwarzschild sphere. In spite of these possible differences, all these systems are identical for the external observer since these objects for him are characterized only by the total mass and total electric charge. The internal region of the systems, with the exception of the small region near its very boundary, can be described by the Friedmann metric/5,6/. This object was called "friedmon"/7/. When the charge $\epsilon \to 0$, the system turns to a closed Friedmann world. The spin of this object is zero. Another type of the elementary black hole can be constructed by using the Kerr metric. In the list of maximons such a particle

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* Strictly speaking, such a classical (nonquantum) consideration is valid for objects with charge $10\,e$, mass larger than 10^{-5} g and of sizes larger than 10^{-32} cm/13/.

could be represented by a particle with mass $m_{\hbar} = \sqrt{\frac{\hbar c}{\kappa}}$.

This electrically neutral particle with spin (the minimum spin is naturally $\hbar/2$) could, in principle, carry an electric charge (ϵ) too. In the latter case its mass will be somewhat larger: $m^e_{\hbar} \sim \sqrt{\frac{\hbar c + \epsilon^2}{\kappa}}$. The sizes are $r^e_{\hbar} \sim \frac{\sqrt{\hbar c}\sqrt{\kappa}}{c^2} \sim 10^{-33}$ cm, provided that $\epsilon < \sqrt{\hbar c}$. The existence of a particle with mass $\sqrt{\frac{\hbar c}{\kappa}}$ (the Planck mass) was discussed by a number of authors /4,5,8/. It was given various names. However, it is natural to refer to the mass of this maximon as the Planck mass and if, in addition, the particle is assigned a nonzero spin and the external metric is identified with the Kerr metric then these particles could be named "kerron". Such particles should be thought of, on the one hand, as microworld objects, especially if they may be considered as pretenders to the structural particles composing hadrons /4,5,8/. On the other hand, these particles themselves consist of hadrons. There thus arises a peculiar, so to say, "generalized or global" bootstrap which makes naturally the idea of "truly elementary particles" and the dreams of such particles meaningless. In the authors opinion, this is just the attractive feature of the model suggested /9/.

For the sources of vector fields, systems with the same masses (for example $m_e = \frac{e}{\sqrt{\kappa}}$) and the same (within the limit $m_e \to \frac{e}{\sqrt{\kappa}}$) external metric* but, contrary to the

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* $ds^2 = \Phi dt^2 - \Phi^{-1} dr^2 - r^2 (d\theta^2 + \sin^2\theta \, d\phi^2)$, where $\Phi = (1 - \frac{e\sqrt{\kappa}}{c^2 r})^2$. For a detailed comparison of these metrics see also ref. /10/.

previous example, with static internal metric can, in principle, be realized /10,14/. We imply here the well-known Papapetrou model the external metric of which was discussed by him as long ago as in 1945 /11/. The Papapetrou model may classically be interpreted as a system in which gravitational attraction is equilibrated by, e.g., electrostatic repulsion forces

$$\frac{\kappa m_e^2}{r} = \frac{e^2}{r},$$

from where it follows immediately

$$m_e = \frac{e}{\sqrt{\kappa}}.$$

The Papapetrou system is not a black hole. Sewing of the appropriate external (in vacuum) solutions together with the internal solutions (in the domain occupied by matter) results in that not all the matter is found to be localized under the Schwarzschild sphere, but it can come anyhow nearer from without to this sphere /10/.

So, the particle thus composed may be called "papapetron". Contrary to friedmons and kerrons, no cosmological objects can, in principle, be inside papapetrons. Here there is no internal huge gravitational mass defect* but the number of nucleons capable of forming an electrostatic papapetron is nevertheless large $n = \frac{m_e}{m_n} \sim 10^{18}$.

In this sence, the idea of a global bootstrap may be kept in this case too if papapetrons will serve as structural elements of hadrons.

The latter remarks are interesting in the sence that, according to a number of well-known theorems, macroscopic black holes, at least, cannot have external (meson,

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* We mean classical consideration only. In the frame of quantum theory it is necessary to take into account the quantum oscillations of the medium and the corresponding gravitational mass defect of the total energy.

neutrino, etc.) fields, with the exception of electromagnetic and gravitational ones /12/.

This situation was figuratively defined by Wheeler as follows. ''A black hole has no hair''. It is quite possible that only for particles like $m_e = \frac{e}{\sqrt{\kappa}}$ and $m_h = \sqrt{\frac{\hbar c+\epsilon^2}{\kappa}}$ black holes may serve as models.

Though, there are considerations that the Wheeler's statement may be invalid for maximons as far as maximons are essentially objects of the quantum physics rather than the classic one /14/. However, in any case, particles like papapetrons ($m_{g_\rho}, m_{g_\phi}, m_{g_\omega}$) might exist in nature. Maximum sizes of these papapetrons would be defined by the radius of action of the appropriate forces, that is, by the masses of ρ, ϕ and ω mesons, $r_{max} \sim 10^{-13}$cm. Minimum sizes of papapetrons are close to their gravitational radii

$$r_{min} \sim \frac{g\sqrt{\kappa}}{c^2} \sim 10^{-33} \text{ cm.}$$

If the papapetron model is considered without recourse to quantum theory then the equality of the gravitational attraction forces and the vector repulsion forces holds, roughly speaking, for any sizes of the system in the limit from $r_{min.}$ to $r_{max.}$.

Papapetrons may be supposed to have in the bound state minimum sizes, since in this case the gravitational mass defect of the system is maximum, i.e., the system is at the lowest energy level. In other words, the sizes of the whole set of maximons may be supposed to be close to their gravitational radii. If one dares to consider a semi-classic system consisting of two maximons (for example, $m_\hbar \sim \sqrt{\frac{\hbar c}{\kappa}}$) and estimate its radius (the Bohr radius) following the Heisenberg relations then the Bohr radius for the lowest state takes the form

$$r_B \sim \frac{\hbar^2}{m_\hbar^3 \kappa} = \frac{\sqrt{\hbar c}\ \sqrt{\kappa}}{c^2} \sim r_\hbar \sim \frac{m_\hbar \kappa}{c^2}, \qquad (2)$$

i.e., it turns out to be equal to the same gravitational radius of the maximon. If one dares to calculate in a classic (in a nonquantum) way the gravitational mass defect of these systems, it turns out to be of the order of the total mass of the particles composing the system /5/

$$\Delta m \sim \frac{\kappa\, m_\hbar^2}{r_\hbar c^2} \sim m_\hbar \;. \qquad (3)$$

It is natural that all these estimates are invalid: they are too classic but may be of a certain heuristic value.

The matter is that in many quark or parton models of hadrons (in the case of large quark masses) a new class of fields, a new class of interactions between these particles resulting in a necessary mass defect is needed.

It was great advantage of the theory if the gravitational forces existing in nature would be used for this purpose. The list of papapetrons and, consequently, maximons can be extended by assigning all or some of them elementary rotational moments (spin). Unfortunately, these considerations in their essential part are still of purely platonic character since we are dealing with such space dimensions of particles (10^{-33} cm) for which quantum fluctuation of the metric is of importance /13/. We do not know, for example, to what extent the macroscopic characteristics of black holes are violated by quantum effects /14/.

The properties of black holes of dimension in question (elementary black holes) can essentially be modified by quantum effects.

The particles under discussion can be divertified by introducing antiparticles and other specific charges. A very important part can be assigned to specific charges, the sources of the scalar meson field which leads to attraction. At a large scalar meson field constant G these fields can play at small distances the role of an analogous ''strong gravitation''.

In this case the maximon masses might be essentially smaller (in principle, arbitrary small), namely /15/

$$m_m \sim \sqrt{\frac{\hbar c - G^2}{\kappa}}\,; \; = \sqrt{\frac{g^2 - G^2}{\kappa}} \tag{4}$$

and might be G-dependent.

The latter remarks are of interest in connection with the idea about a possible unified theory of weak and electromagnetic interactions in some versions of which hypothesis scalar mesons play an important, but still auxiliary, role.

At present there are many papers devoted to various quark-parton models of hadrons. Side by side with any widely extended activities, there also appear, according to the Parkinson laws, wide activities which provide a theoretical service for just the former ones. This implies that different theories (which are, of course, not all realizable in nature) have their own difficulties which are more or less successfully overcome with great persistency and sometimes with a wit. Now we are aware of a great number of various models and difficulties embeded in them* . In realistic models there are difficulties due to the absence of free quarks in nature and experiment. This problem is essentially solved by a possible large mass of quarks ** .

There are also difficulties with the Fermi statistic, there is a necessity of either introducing a parastatistic or increasing the number of quarks (introducing color quarks), etc. Here a general remark is worth making. The models we are dealing with /1, 2, 3/ are described within the framework of quantum theory where, in particular, the usual space-time description is valid.

If we are concerned with the objects such as maximons, the space regions, where quantum fluctuation of the metric is essential, it is doubtful whether it is possible to require for the Pauli principle to be strictly fulfilled. Generally, the usual quantum description of such models may turn out to be invalid, and then the whole formalism of the theory should be modified in an appropriate manner.

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*See Moscow Seminar "Quarks and Partons", July 25-28, 1974.

**It is possible that all the free maximons are unstable too /14/.

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