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ELEMENTARY PARTICLES OF MAXIMUM LARGE MASSES

(quarks, maximons)

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In the well-known paper by Fermi and Yang[1] an idea was first proposed to consider the π-meson as a system consisting of a nucleon and an antinucleon with mass defects by an order of magnitude higher than that of the resulting system (of the π-meson).

Though the modern theory is actually incapable of describing such systems in a relativistically consistent way, the above idea has attracted attention of many physicists and has been widely utilized in various models[2] of strongly interacting particles.

As these representations developed, the mass of fundamental particles in composite models first increased up to hyperon masses and recently, as the concept of quarks appeared, the fundamental particle masses by one more order of magnitude higher are discussed.

The latter values of the fundamental particle masses are most likely considered as an experimental lower limit since, as is known, it is impossible to indicate in the range of these masses any theoretical limits (any fundamental lengths).[x]

Yet, using the general theory of relativity (gravitation) two expressions of the mass dimensionality can be deduced from the universal constants. One of them is characteristic of the quantum theory

$$m_0 = \left(\frac{hc}{\kappa}\right)^{1/2} \approx 10^{-5}\,\mathrm{gr}. \qquad (1)$$

where h is the Planck's constant, κ the gravitational constant, c the velocity of light. The other expression relates to the classical theory

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[x] The nearest length which could be considered is the weak interaction length:

$$\ell = \sqrt{G/hc} \approx 0.7 \cdot 10^{-16}\,\mathrm{cm}.$$

However, as is seen from the following there may be much smaller length, the smallest of them being in its sense, the most universal.

$$m_1 = \frac{e}{\sqrt{\kappa}} \approx 10^{-6} \text{ gr} . \qquad (2)$$

e is the electric charge.

As is seen from the following it is interesting to consider eqs. (1) and (2) as claimants on the role of the mass of a fundamental particle of "quark type". In paper/3/ these particles of maximum masses are called maximons in contrast to quarks from which the former can, generally speaking, differ by some properties (see paragraphs 3 and 4).

§ 1. $m_0 = \left(\frac{hc}{\kappa}\right)^{1/2}$

It may be assumed that the appearance in theory of eq.(1) and the related length

$$\frac{h}{m_0 c} = \ell_0 = \left(\frac{h\kappa}{c^3}\right)^{1/2} \approx 10^{-33} \text{cm} . \qquad (3)$$

is far from being occasional. The length ℓ_0 may be put to be the really fundamental length since distances shorter than ℓ_0 lose their physical meaning due to the quantum fluctuations of the metric. Thus, m_0 may be, in fact, considered as the upper limit for a possible value of the fundamental mass we are dealing with ($m_0 > m_1$).

Perhaps the most essential is the fact that at this value of the mass localized in the range of the fundamental length ℓ_0 an entirely new mechanism begins to act which is capable of providing the resulting system of an arbitrary small mass consisting of maximons. By this we mean the gravitational collapse (§ 2) which may take place for small masses of large densities.

A particle of mass m_0, localized in the range of ℓ_0 possesses some peculiar properties/3/.

Two maximons of mass m_0 interact gravitationally as

$$\kappa \frac{m_0^2}{r} = \frac{hc}{r} . \qquad (4)$$

This means that the gravitational interaction of two maximons is $\frac{hc}{\epsilon}$ times larger than their Coulomb interaction when the electric charge is ϵ.

Thus, the two maximons with electric charge $\epsilon < (hc)^{1/2}$ may form a bound system.

The "Bohr gravitational radius" of this system estimated from the Heisenberg uncertainty relations turns out to be

$$r_0 \approx \frac{h^2}{\kappa m_0^3} = \ell_0 . \qquad (5)$$

The estimate (5) shows that the size of the considered systems is such that the corresponding gravitational effect must be of the order of the maximons masses:

$$\Delta m c^2 \approx \kappa \frac{m_0^2}{\ell_0} \approx \left(\frac{hc}{\kappa}\right)^{1/2} c^2 \approx m_0 c^2 . \qquad (6)$$

The estimate (6) is qualitative, i.e. it points only to a very large mass defect necessarily arising in such systems.

This estimate is inaccurate in many respects.

Firstly, in the systems of particles interacting according to the law

$$\frac{hc}{r} \approx 137 \frac{e^2}{r} \qquad (7)$$

there are no stationary bound states, i.e. the corresponding relativistic functions have a pole at zero $\Psi_{r\to 0} \approx r^{\sqrt{1-\left(\frac{Ze^2}{hc}\right)}-1} \approx r^{-1}$. In other words, under the effect of the gravitational interaction maximons must "fall" on the centre of gravity. The main thing is that the gravitation interaction inevitably leads to the gravitational collapse of the system.

§ 2. Gravitational Collapse of Small Masses

When the collapse takes place the whole energy is closed within the range of radius

$$r_{gr} = \frac{2\kappa m}{c^2} ,$$

with the mean mass density

$$\rho \geq \frac{m}{4/3\, \pi r_{gr}^3} = \frac{3}{32\pi} \frac{c^6}{\kappa^3 m^2} . \qquad (8)$$

Thus, the smaller is the mass, the larger the mass density is needed to realize a collapsing state.

The collapsing system consisting of two maximons ($m = 2m_0 = 2\left(\frac{hc}{\kappa}\right)^{1/2}$) must have the mean mass density $\rho \geq \frac{3}{32\pi}\frac{c^5}{4\kappa^2 h}$. But according to eqs.(6) and (7) the system under consideration must have the size $\leq \ell_0$ i.e. the density $\rho = \frac{3c^5}{2\pi\kappa^2 h}$ and the system consisting of two maximons must be in a collapsing state. The latter circumstance adds nothing new to the arguments of the previous paragraph. But for further considerations it is essential that the collapsing system can possesses an arbitrary small mass.

J.B. Zeldovich has considered the case of the ultra-relativistic gas when the particle density (n) and the density (ρ) of the matter being at rest at the initial moment are connected by the relation

$$\rho = \tfrac{3}{4} h (3\pi)^{1/3} \frac{1}{c} n^{4/3} . \tag{9}$$

For the mass of this system (M) and the total number of particles (N) we have respectively

$$M = 4\pi \int_0^R \rho(r) r^2 dr \tag{10}$$

$$N = 4\pi \int_0^R n dV = 4\pi \int_0^R n(r) e^{\lambda/2} r^2 dr \tag{11}$$

The invariant volume $dV = 4\pi e^{\lambda/2} r^2 dr$. The distribution of the density ρ is chosen so that

$$\rho = \frac{a}{r^2}, \quad r < R; \quad \rho = 0, \quad r > R . \tag{12}$$

where a is an arbitrary constant. Using eqs. (9), (10) and (12) we have for M

$$M = \mathrm{const}\, N^{2/3} (ha)^{1/2} \left(1 - \frac{8\pi\kappa}{c^2} a\right) \tag{13}$$

for $a \to \frac{c^2}{8\pi\kappa}$, $M \to 0$ for any given N.

It is essential that there is a configuration of particles such that their total mass approaches zero independently of the number of particles. In order to bring an ordinary matter, say neutrons, to such a state it is necessary to spend a great amount of energy for contracting the matter up to required densities. This energy barrier separating the equilibrium state from the collapsing one is estimated by Zeldovich as

$$M_{max} \approx N^{2/3} \left(\frac{hc}{\kappa}\right)^{1/2} . \qquad (14)$$

According to eq. (1) the latter expression can be rewritten in the form

$$M_{max} \approx N^{2/3} m_0 . \qquad (15)$$

This means that to bring the system consisting of small number of neutrons into the collapsing state it is necessary to spend for each neutron an energy of the order of the maximon self-energy $\left(\frac{hc}{\kappa}\right)^{1/2}$.

This also means that for particles of mass $m_0 = \left(\frac{hc}{\kappa}\right)^{1/2}$ (maximons) there exists no energy barrier for the transition of the system of maximons to the collapsing state.

We see that indeed when the mass $m = \left(\frac{hc}{\kappa}\right)^{1/2}$ there arises naturally a peculiar mechanism in the system of these particles which is able in principle to form a resulting system of arbitrarily small mass.

The above consideration has one more serious disadvantage, namely eqs. (1) and (3) are due to the Planck's constant and the collapse of the systems sampled in the range of the quantum fluctuations of the metrics is considered by us according to the classical theory. And the main thing is that the possible states of the resulting system are also considered according to the classical theory. At present the quantum theory of the small mass collapse is not constructed yet. It may be expected that, e.g., the final states of the systems consisting of maximons will turn out to have discrete values of the masses. It may be naturally assumed that the entire process of the quantum mass collapse will be treated as quantum transitions to these discrete states.

As is known, the realistic quark model of strongly interacting particles suggests the existence of a still unknown type of forces which ensure the formation of the systems representing baryons, π - mesons and other quanta of nuclear fields out of quarks (i.e. particles with large, but still unknown masses $m_q > m_N$) The question arises to what extent maximons could claim to the role of quarks and the above considered mechanism (collapse) could play the role of mechanism which combines maximons into the known particles.

§ 3. Maximons, Quarks and the Hierarchy of Particles

As is seen from the foregoing, the idea of maximons, in contrast to the idea of quarks, is not associated with any group- symmetry considerations.

The maximum heavy fundamental particles of the considered type must naturally appear in any matter being in the superdense state.

Such superdense state of the matter is supposed in the initial stage of the evolution of the Universe according to the Friedmann model which appears to be the most suitable in the light of the present-day astrophysical and astronomical data. If we accept this model of the Universe and admit that at the initial moment the matter of the Universe was of an arbitrarily large density (more exactly, of densities close to $\rho \approx \frac{c^5}{\kappa^2 h}$) the formation of maximons should be inevitable. The situations should be inevitable when the matter in the space with size ℓ_0 and the substance density $\approx \frac{m_0}{\ell_0^3}$ is gravitationally closed into maximons.

Since maximons as collapsing bunches could be produced out of any matter then, in principle, they could possess various properties, e.g. be strongly interacting or not, have weak interactions or not, be electrically charged or neutral etc.[x]

Hence, the hypothesis of the form of the matter at the initial stage of the evolution of the Universe seems to be essential for discussing the properties of maximons and their possible role in the hierarchy of particles.

It may, of course, be assumed (as it is often done) that at the initial stage of the evolution of the Universe the properties of the matter did not differ radically from those of the well-known forms of the matter possessing strong, weak and electromagnetic interactions.

It is also possible to assume that the matter of the Universe in the very beginning of its evolution possessed more elementary properties. If we should attempt to express the considerations leading to the idea of maximons in the strict language of theoretical physics then we should start from the Einstein equation

$$R_\mu^\nu - \tfrac{1}{2} g_\mu^\nu R = -\kappa T_\mu^\nu \qquad (1)$$

which describes the gravitational field created by the matter. In this equation the matter is represented by the tensor T_μ^ν . T_μ^ν is a function of the fields ψ_1 , ... , ψ_n which describe the matter filling the Universe. If following Heisenberg or simply choosing the most elementary example we restrict ourselves to the Universe filled, for the sake of simplicity to one spinor ψ field then the Dirac equation written for this field in a curved space

$$D\Psi = 0 \qquad (II)$$

[x] Although, it should not be ruled out that certain properties could disappear under such a state of the matter.

together with the Einstein equation forms a complete set of equations desçribing the given physical world. By eliminating from these two equations the gravitational field $g_{\mu\nu}$ we expect to obtain for the ψ -field a strongly nonlinear equation. According to the above arguments this equation is expected to have particle-like solutions of the maximon character x/.

Further the question is how many particle-like solutions exist which describe the systems consisting of maximons and what relation exists between these systems and the really existing elementary particles xx/.

Unfortunately at the given stage of a purely qualitative approach to the problem of the possible existence of the maximon structure, e.g. for strongly interacting elementary particles, there are only some arguments pro and con.

In particular it may be indicated in what properties maximons must differ from quarks.

At the given stage of the consideration of the maximon properties we have no arguments in favor of that the nucleons should necessarily be constructed out of three electrically charged maximons.

Such a possibility may be only required. At the given stage of the discussion there is no objections that maximons would have gravitational and electromagnetic interactions. But there arise some difficulties if we ascribe to maximons the properties of particles interacting via the nuclear forces.

Here we imply that the properties of maximons essentially differ from those of quarks for which the presence of nuclear forces is supposed.

The arguments which underlie the previous statement are the following:

In electrodynamics very small fundamental lengths are allowable. The applicability of electrodynamics up to the lengths of the order of ℓ_0 does not lead to any contradictions (weak logarithmic divergences).

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x/ In a rough classical approximation such a solution can be visually represented in the form, e.g. of the limiting state of the wave packet consisting of convergent spherical waves with the wave length $\lambda \approx \ell_0$ at $t \to \infty$. We bear in mind a packet whose energy is gravitaionally closed within ℓ_0 .

But the neglect of the quantum nature of the maximon makes such rather classical representations illegal.

Moreover the question is open to what extent the discussed particle-like solution in classical physics is stable. (See the Papapetrou's theorem. A.Papapetrou und Treder, Ann. der Physik 3 (1959), 345.

xx/ Such a world may be rather poor but it is of interest as a model.

Complicating the problem one could introduce several kinds of primary fields ascribing to them some features characteristic, e.g. of the quark symmetry. It should be stressed that in this case we bear in mind the nonlinearity of the equation for ψ -fild which naturally appear in strong gravitational fields.

At the first stages of the consideration it is advisable to do without the nonlinearity of the field itself (e.g. nonlinearity introduced by Heisenberg) i.e. investigate the role and the possibilities of the natural nonlinearity induced by strong gravitation.

The situation is quite different if the nuclear forces act at the lengths ℓ_0 as well, without changing their strong functional dependence on distances.

Such small lengths are known to be incompatible with the theory of strongly interacting fields. If maximons have no nuclear interactions then such a situation means: either

a) Strongly interacting particles are not constructed out of maximons. Maximons exist as elementary particles along with other elementary particles, in particular, with quarks.

or

b) Strongly-interacting particles (say, nucleons) are built up out of the system of maximons, namely while the process of the gravitational collapse which has been discussed above.

The latter hypothesis would mean that the nuclear forces arise only in complicated systems of maximons (like the Van der Waal's forces in molecules).

This would mean that nuclear forces, in contrast to gravitational ones, and perhaps to electromagnetic forces are not fundamental ones.

But, how can characteristic nuclear lengths ($h / M_n c$), in principle, arise in the system of particles with size ℓ_0 in their collapse[x/] ?

The appearance of nuclear forces can be illustrated in the following way.

The appearance of a particle, for example, claiming to the name of nucleon[xx/] in the system of maximons which are assumed to have no nuclear interactions must be, in particular, accompanied by the appearance of a π -meson field around such a particle (the bare nucleon should be "dressed").

Such a field could automatically arise accompanied by the appearance of nucleons, if, e.g. π -mesons are systems formed out of bare nucleons and antinucleons.

But then the lengths which naturally follow from the structures of π , K and of other quanta of strongly interacting fields may turn out to be characteristic of physical (dressed) baryons since for the small (by definition) bare mass of a bare nucleon the properties of the physical nucleon are determined by just these fields.

[x/] It is worthnoting here that we do not know what is the quantum collapse: the space-time characteristics of the final states of quantum systems may essentially differ from the classical ones.

[xx/] We bear in mind, so to say, "bare" nucleon, i.e. a system of maximons of mass $m \ll m_0$.

In a consistent mathematical theory of elementary particles this situation could become such that just the same non-linear equation which leads to the baryon wave function should give also non-linear interactions between baryons (many-fermion interactions) producing π-mesons and other quanta of strongly interacting fields.

The question remains open how well these considerations may be proved by the analysis of the corresponding equations even if using the models.

If, indeed, the gravitational collapse of maximons or quarks is a mechanism by means of which nucleons are built up then the attempts to describe the properties of composite particles by potential wells of different kinds may turn out to be far from the situation which is really in the collapse.

If maximons possess gravitational and electromagnetic properties and can strongly interact in complicated systems only, then the corresponding properties may be essential and more clearly expressed only in the region of electromagnetic effects.

§ 4. $m_1 = \frac{e}{\sqrt{\kappa}}$

Using the e-electric charge constant and the gravitational one we can construct a quantity of mass dimensionality

$$m_1 = \frac{e}{\sqrt{\kappa}}$$

In classical physics the particle of mass m_1 is represented by the model consisting of an electrically charged matter in which the gravitational attraction is equilibrated by the electrostatic repulsion. In the framework of the general theory of relativity this model was considered by Papapetrou /6/ and, in a more detailed manner, by Bonnor, and especially by Arnowitt, Deser and Misner /7/.

The corresponding metric is

$$ds^2 = (1 + \frac{m_1}{r})^{-2} dt^2 - (1 + \frac{m_1}{r})^2 (dr^2 + r^2 d\theta^2 + r^2 \sin^2\theta\, d\phi^2).$$

The mass of such a system can be estimated from simple equilibrium conditions:

$$\kappa \frac{m_1^2}{r} = \frac{e^2}{r}, \quad \text{i.e} \quad m_1 = \frac{e}{\sqrt{\kappa}} = 10^{-6}\,\text{gr}. \qquad (16)$$

The ratio of the mass of the "classical" maximon to that of the quantum one (1) is

$$\frac{m_1}{m_0} = \sqrt{\frac{e^2}{hc}} = \frac{1}{10} . \tag{17}$$

It is interesting that for the charge e there is one and only one value for the mass in the statical model of the particle.

The gravitational and electrostatic equilibrium appears to be violated when two classical maximons having the relative kinetic energy such that $M > \frac{2e}{\sqrt{\kappa}}$ (M is the total mass of the system) interact[x/].

From the classical point of view a particle of charge $\epsilon < \sqrt{hc}$ and of mass m_0 equal to the mass of the quantum maximon is not a statical system. This system becomes statical when $\epsilon = \sqrt{hc}$. In other words, there may exist, in principle, maximons with different charges up to the charge[xx/] $\epsilon = \sqrt{hc}$. Some further arguments may be indicated in virtue of which quantum maximons can not possess some properties of quarks.

The quantum maximon is a matter which is gravitationally closed in a region of radius which is smaller than its gravitational radius. Any radiation from within this region is impossible.

In particular, the quantum maximon can decay neither in a strong nor in a weak way. In the quark model of particles λ -quark is known to be heavier than other quarks and λ -quark must decay by a pair of leptons. The classical maximon, in contrast to the quantum one, is not a system in the collapse state. The classical maximon, in contrast to the quantum one, is necessarily electrically charged. Possessing a large mass it should be fast decayed if some special forbiddennesses (e.g. fractional electric charges are not assumed). In other words, classical maximons might not exist in a free state without special forbiddennesses. Yet, in the latter case too this maximon (possessing an integral, e.g. electric charge) could play the role of structure units in systems with enormous mass defects representing available elementary particles.

[x/] In the quantum field, even when $M = \frac{2e}{\sqrt{\kappa}}$ two classical maximons could form a collapsing system "penetrating" throughout the energy barrier which is not so high.

[xx/] Here we bear in mind the charge (ϵ) of the "bare" particle in classical physics. In quantum theory the physical charge (e) may be equal to the electron or quark charge independently on the "bare" particle charge ($\epsilon > e$) . This result is achieved by the vacuum polarization effect strongly screening (at small distances $\approx \ell_0$) the "bare" particle electric charge.

The "bare" particle electric charge may assumed to be universal and equal to $\epsilon^2 = hc$.

From this point of view the constant e is not a fundamental constant of the theory .

The distictive feature of maximons consists in that there naturally arises a peculiar mechanism of formation of a small mass out of the system of maximons.

But the qualitative characteristics of these forces differs at the first glance from that needed for the SU_3 symmetry to be possible in the range of strongly interacting particles: one would think that the gravitational forces should be the same for particles and antiparticles.

In other words, while maximons-quarks may be used to construct, e.g. baryons, according to the above-mentioned, π -mesons should be constructed directly out of baryons and antibaryons as it was supposed in the prequark models of composite particles, i.e. dynamics may essentially change the quark symmetry[x/].

More definite (positive or negative) answers should be expected after the analysis of nonlinear equations of the above type under different assumptions (under the condition of a superhigh energy density) about the fields which formed tensor T_μ^ν . The discussion of the possible existence of maximons and their possible role in the hierarchy of particles is an attempt to predict some qualitative peculiar features of a nonlinear physics which arises in the gravitational fields induced by the superdense state of one or another (perhaps simple) kind of the matter. If the account of the quantum character of the maximon collapse conserves the possibility of forming resulting systems of arbitrarily small masses then it would be difficult to think that these systems exist as particles in addition to the experimentally available particles.

If in a consistent quantum theory such a possibility will turn out to be forbidden[xx/] then maximons must, in principle, exist as particles side by side with other ones and, may be, side by side with quarks.

By the way, the widely used here relation $\ell_0 = (\frac{h\kappa}{c^3})^{1/2}$ connects the universe constants. It is not decided yet which constants are fundamental and which are derivative. We may, e.g. assume that

$$h = \frac{\ell_0^2 c^3}{\kappa} \qquad (18)$$

i.e. the length is a fundamental constant and the Planck's constant - a consequence of the existence of the fundamental length.

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x/ Let us assume that e.g. the systems are not constructed out of a free quark and a free antiquark, more strictly their lifetime is close to zero.

xx/ For example, two maximons turn necessarily into one maximon by emmiting in some form a redundant mass of the system.

Relation (18) would be interesting if it was possible to construct a theory in which the quantum effects would be a consequence of the fundamental length ℓ_0 .

§ 5. Behavior of Maximons in Matter

Since maximons can be created out of particles of energy $\approx 10^{28}$ eV then the creation of maximons even on accelerators in distant future is exclúded.

But it may be assumed that the matter of the Universe at the initial stage of its evolution mainly consisted of maximons.

Assuming that due to the collapse mechanism first existing maximons turned partially into the well-known matter nevertheless a fraction of original maximons could remain up to the present x/ .

By the way it is easily seen that at present a significant part of the whole matter might be in a maximon state so that to ensure a closed character of our Universe.

Indeed the critical density of the matter providing a closed Universe is $\rho_c \approx 10^{-29} \frac{gr}{cm^3}$. This means that for maximon mass 10^{-5} gr the maximon density xx/

$$\approx 10^{-24} \frac{\text{particles}}{\text{cm}^3} \tag{19}$$

is sufficient for the Universe to be closed. The corresponding fluxes of particles might be

$$N \lesssim 10^{-24} c \approx 10^{-14} \frac{\text{particles}}{\text{cm}^2 \text{sec}} \tag{20}$$

The upper limit of the flux (N) in the Universe can be estimated from the data on the Earth temperature. The energy released by the maximon flux must not exceed the heat balance of the Earth which is available from the geophysical data.

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x/ We do not analyse the mechanism of degeneration of maximons at the first stage of the evolution of the Universe. The matter being in a superdense state may possess properties which can not be foreseen for the time being. We do not know which statistics should obey maximons in a superdense state (Bose, Fermi statistics or even parastatistics).

xx/ This means that there are only 10^{-19} maximons per one nucleon in the Universe (the nucleon density is $\approx 10^{-5}$ nucl/cm).

According to the geophysical data [5] the heat per 1 cm^3/ sec of the Earth is about $H = 2.10^5$ eV.

If the Earth temperature is in the equilibrium state and if maximons give the whole energy to the Earth then the incident flux (N) of maximons should not exceded

$$N \leq \frac{RH}{3m_0} \quad (4\pi R^2 N m_0 = \frac{4}{3}\pi R^3 H), \tag{21}$$

where R is the Earth radius. For N we get[x]

$$N \leq 10^{-14} \frac{\text{particles}}{\text{cm}^2 \text{ sec}} . \tag{22}$$

The numbers of (20) and (22) do not contradict each other since in fact it is very likely that the mean velocity of maximons is smaller than c. It is just the velocity that the particle obtains in the gravitational field of celestial bodies, i.e. $10^6 - 10^7$ cm/sec. In other words, under the condition (19) the flux of maximons on the surface of the Earth might be of the order of

$$10^{-14} \leq N \geq 10^{-18} - 10^{-17} \frac{\text{particles}}{\text{cm}^2 \text{ sec}} . \tag{23}$$

It is interesting to consider the behavior of maximons in matter at velocities which they obtain in the fields of gravitation of celestial bodies, e.g. when they fall on the Earth.

For such relatively small velocities (10^6 - 10^7 cm/sec) maximons must have an enormous kinetic energy:

$$E = \frac{m_0 v^2}{2} \approx 10^{20} \text{ eV} . \tag{24}$$

But, having such a large kinetic energy charged maximons can not produce ionization traces. Indeed, the maximum energy which can be transferred to an electron while colliding with a maximon is

$$T_{max} = 2 m_{el} v^2 < 0{,}01 \text{ eV} . \tag{25}$$

if $v = 10^6 \frac{\text{cm}}{\text{sec}}$. In nucleon collision the transferred energy increases up to 10 ev per collision act.

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[x] In order that the energy balance of the Sun should be essentially determined by incident maximons it is necessary that $N \approx 10^{-8}$ partecles/ cm^2 sec. Generally speaking, near massive celestial bodies the maximon atmosphere might be more dense.

If the cross section for such collisions is assumed to be of the order of atomic one ($10^{-16}cm^2$) then the energy losses per metre of the maximon path in matter are

$$\Delta E \lessapprox \sigma \cdot n \frac{\text{atoms}}{\text{cm}} \cdot 1\,\text{m} \cdot 10\,\text{eV} \leq 10^{10}\,\text{eV} . \tag{26}$$

what is negligibly small as compared to the kinetic energy obtained by a maximon when falling on the Earth ($\approx 10^{20}$eV). Even for the energy losses of the order of (26) maximon can pass $> 10^7$km in a solid matter. In other words, maximons would be capable to move during a long time along the orbits inside or Planet. Slowly losing the energy maximons must be accumulated in the centre of the Earth forming an ordinary matter releasing an enormous amount of energy, rising the temperature of the central regions of the Earth,

If the flux of such particles was not by far smaller than 10^{-14}part/ cm^2.sec then one such particle would pass through the area of 1000 m^2 during a year. But if these particles, even if charged, have velocities 10^6 cm/ sec then it is probably impossible to give a direct method of detection.

As was said, they can not be observed by the ionizing capacity. They can not probably be observed in a calorimetric way, their energy losses are of the order of the ionization losses of charged penetrating cosmic rays ($<10^7$eV/ cm)

The transition electromagnetic radiation is very small in its absolute magnitude though it is independent of the mass of an emitting particle /7/.

In principle, such particle must cause mecanical vibrations in a solid matter, i.e. it must sound, but the "whine" of such a particle (according to a rough energy estimate) is more than 10^7 times weaker than the whine of a bullet x/.

On the surface of the Earth the action of the force of gravity on a maximon is expressed as

$$mg \approx 10^{-2}\ \text{dyn} .$$

This means that on the intermolecular distances $\approx 10^{-7}$ cm can obtain the energy

$$mgh \approx 10^{-9}\ \text{erg} \approx 10^{3}\ \text{eV} .$$

This apparently means that in no one place on the surface of the Earth one can discover these particles. Under the action of the forces of gravity they fall on the center of the Planet. However under some favor sircumstances indirect evi-

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x/ The kinetic energy of a bullet (of the weight of about 5 gr) is of the same order (10^{22} eV), it is lost at the distance of about 1 km while maximon loses the same energy at the distance $\gtrapprox 10^7$ km.

dence for the existence of such a particle could be obtained in an underground neutrino experiment.

Indeed, if in the center of the Earth maximons emit their energy turning into the ordinary matter then in a particle shower of energy $\approx 10^{28}$eV there might arise a relatively large and intensive flux of electrons, μ – mesons and, may be, even of neutrinos e.g. of energy $10^{25}-10^{15}$eV.

At high energies electrons and even μ -mesons ($E_{\mu} \gtrsim 10^{12}$ eV) spend their energy for the production of gamma quanta when slowing down in the Coulomb field of nuclei. But at still higher energies the radiation losses in dense matter decrease again (the Landau-Pomerancuk effect[12]: the Bethe-Heitler cross section $\frac{d\nu}{\nu}$ transforms into $\frac{d\nu}{\sqrt{E_0 \nu}}$ in dense matter). For example, the bremsstrahlung of an electron of energy $E_0 \approx 10^{17}$ eV decreases by about two orders as compared to the corresponding Bethe-Heitler one/13/ x/.

At these energies electron becomes a penetrating particle. For the energies ($10^{20}-10^{25}$eV) discussed the paths of electrons and μ -mesons in ground may apper to be comparable with the Earth's radius.

Thus, in the underground neutrino experiment one might observe correlated simultaneous "neutrino events", i.e. the showers of penetrating particles (electrons and mesons) going "upwards".This happens only if physicists are lucky, i.e. several conditions are fulfilled xx/.

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x/ It was G.T.Zatzepin who pointed to the Pomansky's estimates/13/. I am grateful to him also for discussing the problem.

xx/ The discussed possibility has meaning only if a gamma quantum is produced in the center of the earth (while maximon collapse) which is by a few orders smaller than the maximon mass. This quantum initiates a very large cascade shower.

Such a possibility is well justified if maximon has no nuclear interactions.

A narrow shower cone of particles is one more characteristic feature of high-energy physics.

For example, a pair of electrons produced by a photon of energy $E_{\gamma} \approx 10^{20}$eV on the path equal to the Earth radius ($\approx 10^{9}$cm) will be separated (in vacuum) by the distance ($\theta \approx m_e c^2/E_{\gamma}$) $d \approx 10^{-5}$ cm.

If weak inelastic processes increase linearly with energy then at the above energies these processes would play an essential role for producing high-energy neutinos. $\mu + N \to N' + \nu_{\mu} + n\pi$; $e + N \to N' + \nu_e + n\pi$.

$$E_a \approx 10^{20} \text{ eV} , \quad \sigma_{e \to \nu_e} \approx 10^{-27} \text{ cm}^2 .$$

At

At $E_{\nu} \approx 10^{15}$eV the cross section for a neutrino event $\sigma_{e \to \nu_e} \approx 10^{-32}$ cm^2 i.e. the path of a neutrino of such energy keeps within the Planet. Some other mechanisms for the high-energy neutrino production (bremsstrahlung of neutrino pairs by μ -mesons, etc.) are possible.

Collecting maximons by means of gravitational forces celestial bodies (starting with small meteorites) might serve as a source of cosmic rays and, may be, well determine the very upper region of the energy spectrum.

Thus, this region might consist not only of protons but also of electrons and gamma quanta.

Since maximons can appear only in a superdense matter then the discovery of maximons (which may be only relictive particles) would be a decisive experimental evidence in favor of the Friedmann Universe and prove that indeed while evoluting the Universe was in a state of a superdense matter.

In other cosmological models where this initial superdense matter is excluded there must be no free maximons.

A widely spread sceptical attitude to a possible role of gravitational effects in elementary particle theory is based on a "dread" of small lengths which are characteristic of gravitation. This sceptical attitude is supported by the consideration that lengths of the order of the nucleon ones ($\approx 10^{-14}$ cm) seem also to be necessary.

But firstly, there exists the most developed field theory (electrodynamics) where such small lengths $\approx \ell_0$ are acceptable/9/. Secondly, together with the hierarchy of particles the above discussed hierarchy of interactions is also conceivable.

In particular, the treatment of the nuclear forces as nonfundamental ones, as forces arising in relatively complicated systems, at relatively large distances is not yet absurd.

It may turn out to be heuristically valuable in searching for a consistent field theory. As a paradox, it is worth noting that the most sceptically thinking physicists of the twentieth century Pauli and Landau are in favor of the possible fundamental role of gravitation in elementary particle physics/10,11/.

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