On the Problem of the Existence of Stable Particles in the Metagalaxy

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Abstract: In this paper, originally written in 1965, Kyril P. Stanyukovich introduces *planckeons* — fundamental particles, whose characteristics are based on the fundamental mass, length, and time introduced earlier by Max Planck (the Planck mass, the Planck length, and the Planck time). Moses A. Markov defined such particles in 1965 independently from Stanyukovich, and called them *maximons*. Originally published in Russian as: Stanyukovich K. P. K voprosy o suschetvovanii ustoychivykh chastiz v metagalaktike. *Problemy Teorii Gravitazii i Elementarnykh Chastiz*, vol. 1, Atomizdat, Moscow, 1966, 267–279. Translated from the Russian manuscript of 1965 by Dmitri Rabounski, 2008. The translator thanks Andrew K. Stanyukovich, Russia, for permission to reproduce the original version of this paper, and also William C. Daywitt, USA, for assistance.

In our Metagalaxy the following physically reasonable condition, which is obvious and well-verified by observations, is true: the radius of the Metagalaxy, $r_{_M}$, corresponds to its gravitational radius $r_{_{M_g}}$ and its curvature radius a, i.e.

$$r_{_M} = r_{_{M_g}} = \frac{GM_0}{c^2} = \left(\frac{G\delta_{_M}}{c^2}\right)^{-1/2}, \tag{1}$$

where $M_0 \approx \delta_{_M} r_{_M}^3$ is the mass of the Metagalaxy.

The relations in (1) can be compared to the contracted Einstein equation

$$R = \frac{const}{a^2} = -\varkappa T = \frac{8\pi G\delta_{_M}}{c^2}, \tag{2}$$

where R is the scalar curvature, $T = -\delta_{_M} c^2$ is the trace of the energy-momentum tensor, and $\delta_{_M} \approx M_0/r_{_M}^3$ is the density of the Metagalaxy. From here it follows that

$$\frac{GM_0}{c^2} = \frac{c^2 r_{_M}^2}{GM_0}. \tag{3}$$

This formula is an identity. In other words, the radius of the internal curvature of an object, which equals its gravitational radius, always equals the size L of the object.

Let us try to answer the following question: can the Metagalaxy contain objects which are analogous, in the sense of self-closure or selfcontainment, to the Metagalaxy itself, i.e. objects whose characteristics are

$$L = r_g = a\,, \tag{4}$$

where L is the size of such an object?

J. Oppenheimer and G. Volkoff [1], and also L. D. Landau [2] working independently, showed that, given a star whose mass is larger than $100M_{\odot} = 10^{35}$ g, such a star experiences rapid compression (collapse) so that its radius shrinks to its gravitational radius, or even smaller. It is likely that a reverse process, an anti-collapse process, is also possible that may explain many of the "enigmatic" bulky explosions of star-like objects in the universe.

As M. Planck has shown, the quantities $\hbar$, G, and c (here $\hbar$ is Planck's constant, G is the gravitational constant, c is the velocity of light) provide a base for the construction of the following quantities

$$\left.\begin{aligned} L &= \sqrt{\frac{\hbar G}{c^3}} = 1.6\times10^{-33}\ \text{cm} \\ m_L &= \frac{1}{2}\sqrt{\frac{c\hbar}{G}} = \frac{\hbar}{2cL} = 1.1\times10^{-5}\ \text{g} \\ \tau_L &= \frac{L}{c} = 10^{-43}\ \text{sec} \end{aligned}\right\}. \tag{5}$$

Note that in such a case, according to [3],

$$L = \frac{2Gm_L}{c^2} = r_g\,, \tag{6}$$

where r_g is the gravitational radius specific to the mass m_L.

The density of a "particle" whose mass is m_L is [5, Part II]

$$\delta_L = \frac{3m_L}{4\pi L^3} = \frac{3}{4\pi}\,\frac{c^5}{2\hbar G^2} \approx 10^{95}\ \text{g/cm}^3. \tag{7}$$

As a matter of fact, the curvature radius of the internal gravitational field of such a "particle", a_L, is L. The scalar curvature is then

$$R = const\times\frac{6}{a_L^2} = -\varkappa T = \frac{8\pi G\delta_L}{c^2} = \frac{8\pi\times3c^3}{2\times4\pi\hbar G} = \frac{3}{L^2}\,, \tag{8}$$

from which we obtain $a_L = L$ (here the $const = 1/2$).

It should be noted that, inside such a particle, we have an "Einstein universe" with variable curvature, or, more precisely, an internal Schwarzschild field [6]. Thus the size of such a quasi-particle is the same as its gravitational radius and its internal curvature radius, and, at the same time, its size satisfies the uncertainty principle.

Being born as a result of random fluctuations of energy, or in the initial stage of expansion of the Friedmann universe, such particles should be stable and neutral to any external radiation (both electromagnetic and gravitational). Such particles, in contrast to unstable geons assumed by Wheeler, should be stable, self-contained Einstein micro-universes. The charge of such a particle is of the order of $e_L = \sqrt{\hbar c} = \sqrt{137}\, e$, the internal field stress being $E \simeq H \simeq \frac{e_L}{L^2} \approx 10^{57}$ Oersteds, while the total energy of such particle corresponds to a rest-mass 10^{-5} g. The "Bohr radius" for such a particle is

$$r_B = \frac{\hbar^2}{e_L^2 m_L} = \frac{\hbar^2}{137\, e^2 m_L} \approx L\,.$$

Because the quantities L and m_L are connected to fluctuations of gravitational fields (gravitons), we are allowed to assume the number of such particles to be $N_L = N_g^{1/2} = N_p^{3/4}$, where $N_g = 10^{120}$ and $N_p = 10^{80}$ are the numbers of gravitons and nucleons in the Metagalaxy.

Thus, $N_L = 10^{60}$. In such a case the total mass of these particles is $M_L = m_L N_L = 10^{55}$ g which is the same as the mass of the Metagalaxy. In other words, the energy of these particles is of the same order as the energy of other kinds of matter, as it should be in a homogeneous model of the universe. The number of collisions among these quasi-particles (we will refer to such particles as *planckeons*, in memory of Planck) is determined, within an order of magnitude, by the following formula per unit time per unit of volume

$$n_{col} = \pi r_0^2\, c\, n_L n_p \approx r_0^2\, c N_p^{7/4} a^{-6}, \tag{9}$$

where $n_L = N_L a^{-3}$ and $n_p = N_p a^{-3}$ are the density of planckeons and the density of nucleons respectively, where a is the radius of the Metagalaxy and r_0 is the nucleon radius.

Calculations show that $n_{col} \approx 10^{-40}\,\text{cm}^{-3}\,\text{sec}^{-1}$. The energy radiated in these collisions corresponds to a rest-mass $10^{-45}\,\text{g cm}^{-3}\,\text{sec}^{-1}$ that is the mass necessary for the generation of new nucleons according to the Dirac-Hoyle theory that the law $N_p = T_m^2$ hold (here $T_m = \omega_0 t_m$ is the dimensionless age, ω_0 is the frequency of strong interactions, t_m is the age of our universe — the Metagalaxy).

Naturally,

$$\triangle m = \frac{\triangle N_p m_p}{\triangle t\, a^3} \simeq \frac{T_m \omega_0 m_p}{a^3} \approx 10^{-45}\ \text{g cm}^{-3}\,\text{sec}^{-1}. \tag{10}$$

Formula (9) gives

$$\triangle m = n_m m_{\scriptscriptstyle L} = N_p^{7/4} r_0^2\, c\, a^{-6} \sqrt{\frac{c\hbar}{G}}\,, \tag{11}$$

because

$$\sqrt{\frac{c\hbar}{G}} = m_p T_m^{1/2} = m_p N_p^{1/4}.$$

Then, comparing (10) and (11), we obtain

$$N_p^2 r_0^2\, c\, a^{-3} = N_p^{1/2} \omega_0\,.$$

Therefore, because $r_0 \omega_0 / c \approx 1$, we have

$$N_p^{3/2} = \frac{a^3}{r_0^3}\,, \qquad \frac{a}{r_0} = N_p^{1/2},$$

that is found in nature and so proves the aforementioned claim. Thus we can easily show that $\triangle m = \alpha M_0 / a^3$, where $M_0 = N_p m_p$ is the mass of the Metagalaxy. Naturally, $\alpha \sim t^{-1} \sim \omega_0 T_m^{-1}$; therefore

$$\triangle m = \frac{\omega_0 N_p m_p}{a^3} = \omega_0 N_p^{1/2} m_p a^{-3} = \omega_0 m_p T_m a^{-3}$$

that gives equation (10) as a result.

In Hoyle's theory [7] matter is produced from "nothing", a strange assumption at best. In contrast to that assumption, I suggested the hypothesis that the replenishment of the number of particles has its origin in the gravitational background from gravitational transmutations* of "heavy gravitons" [5, Part II]. Now we see that the aforementioned views come together in part. The Hoyle "nothing" is our particles-planckeons ("heavy gravitons"), whose energy is self-contained until the moment when the planckeon, due to interaction with another particle (an elementary particle e.g.), relinquishes its energy, realizing a multiple birth of $\approx 10^{20}$ nucleons. This I assert. Hoyle, however, contradicts the law of conservation of energy, because at a given

$$G \sim T_m^{-1}$$

$m_{\scriptscriptstyle L}$ becomes

$$m_{\scriptscriptstyle L} \sim T_m^{1/2},$$

so $m_{\scriptscriptstyle L}$ is growing with time.

At present, from studies of V. A. Ambarzumian [8] and other modern astronomical observations, it is almost obvious that galaxies have an

*The term "gravitational transmutations" here is intended in the sense according to D. D. Ivanenko.

explosive origin similar to the origin of superstars, quasars, and several other objects in the Metagalaxy. My view on the origin of these objects is [5, Part II] that different kinds of super-dense particles of very small size, which were born and are still being born in interactions within the evolving Metagalaxy, can give birth to superstars and galaxies (meaning that superstars are galaxies in the process of being born). In this process, not only is matter evolving, but also the so-called universal-constants (such as $\hbar$, G, m_p, e) specific to the "universes" where the matter evolves. And now I will justify this view on more solid ground.

Having assumed that

$$G \simeq T_m\,, \qquad \hbar \sim m_p \sim e^2 \sim T_m^{-2},$$
$$c = const, \quad r_0 = const, \quad \omega_0 = const,$$

all conservation laws will be true, and also the relations

$$a = ct_m \sim T_m\,, \qquad \frac{Gm_p^2}{e^2} \simeq T_m^{-1}, \qquad N_p = T_m^2.$$

In such a case, m_L is large for small T_m. Naturally,

$$m_L = \sqrt{\frac{c\hbar}{G}} = \sqrt{\frac{c\hbar_0}{G_0}}\; T_m^{-3/2} = M_0\, T_m^{-3/2}\,. \tag{12}$$

For instance, given $T_m = 10^8$ we obtain $m_L = 10^{44}$ g as the mass of the Metagalaxy. Several of these particles still remain non-interacting, so they replenish the galaxy "reserve". Interactions of these particles with nucleons of that epoch ($m_p = 10^{40}$ g), in large groups, are able to give birth to galaxies. As these particles age, galaxies of smaller size, constellations, and stars of some classes are born. According to the hypothesis suggested by I. D. Novikov [9], super-stars represent the late explosion of a part of the "Friedmann super-dense substance", which was delayed while the main mass of the Metagalaxy evolved. My views [5, Part II], independent of his, are close to his nevertheless, but the mechanism delaying the evolution of the Friedmann substance, as I suggested (the density of this substance coincides with the initial density of the Metagalaxy, $\delta = 10^{95}\ \text{g/cm}^3 = const$), is more specifically developed and reasonable. With this mechanism new developments in the theory of the explosive origin of galaxies and stars are possible [5, Part II].

The likely existence of planckeons suggests that the Metagalaxy itself may be only a "particle" in a complicated structure of a countably-dimensional hierarchy of "particles" in an infinite universe. In other systems similar to our Metagalaxy, other energy stores, light velocities, and particle sizes (on a relative scale of values) are possible. Such systems can be born as a result of interactions (collisions) among "particles", or as a result of fluctuations of other structural systems larger than our Metagalaxy. The "death" of such structural systems can be found in their expansion or compression, or absorption by external sources.

Aside from planckeons, other "self-contained" particles can exist in the Metagalaxy. The main parameters of several classes of such particles are given in the Table.

A few classes of "self-contained" particles can exist between the classes $n=4$ and $n=5$.

In the Table: N is the total number of "elementary" particles whose fluctuations give birth to $N_F=\sqrt{N}$ stable fundamental particles; m, L, and δ are the mass, size, and density of fundamental particles; $\hbar_n/\hbar_4$ is the effective magnitude of the "Planck constants" for these particles (the Table also shows the evolution of $\hbar_n/\hbar_4$ with time for particles of each class); and ν/a^3 is the relative volume "lost" in the self-contained particles.

It is interesting to note from the Table that the probability of large objects (such as galactic clusters and galaxies) emerging from particles whose N is large decreases. In other words, the probabilities of stellar-like objects emerging from particles whose N is small increases. At $n=4$ we have planckeons ($\hbar_4=\hbar$).

Such stable particles can be called *fundamental particles* and, as a result of interactions (for the most part between particles of neighboring classes), can give birth to different "elementary" quasi-stable particles of stars, i.e. nucleons and leptons. In this process, 10^{-45} g cm^{-3} sec^{-1} of "new" substance is born, on the average, in the Metagalaxy.

M. A. Markov [10] suggests that planckeons ($n=4$ in our Table), referred by him as *maximons*, are quarks. I think however that quarks are particles with $n=5$. I suggest the following scheme of interaction between elementary particles and fundamental particles: fundamental particles can be born due to fluctuations of the fields of elementary particles; then the fundamental particles, in their interaction with the elementary particles and with each other, give birth to other elementary particles.

Because we assume that particles "age" (including the so-called elementary particles), i.e. their energy decreases with time, we should clearly determine how this happens. For particles which are in the quantum ground state, quantum mechanics prohibits both electromagnetic wave radiation and "corpuscular radiation". Quantum mechanics and the quantum field theory assume that such stationary states exist

n	N	$N_F = \sqrt{N}$	m, g	L, cm	δ, g/cm^3	$\hbar_n/\hbar_4$	ν/a^3
1	1	1	10^{55}	$10^{28} \sim T_m$	$10^{-28} \sim T_m^{-3}$	$10^{120} \sim T_m^3$	1
2	$10^{40} \sim T_m$	$10^{20} \sim T_m^{1/2}$	$10^{35} \sim T_m^{-1/2}$	$10^{7} \sim T_m^{1/2}$	$10^{14} \sim T_m^{-2}$	$10^{80} \sim T_m^2$	$10^{-40} \sim T_m^{-1}$
3	$10^{80} \sim T_m^2$	$10^{40} \sim T_m$	$10^{15} \sim T_m^{-1}$	10^{-13}	$10^{-54} \sim T_m^{-1}$	$10^{40} \sim T_m$	$10^{-80} \sim T_m^{-2}$
4	$10^{120} \sim T_m^3$	$10^{60} \sim T_m^{3/2}$	$10^{-5} \sim T_m^{-3/2}$	$10^{-33} \sim T_m^{-1/2}$	10^{95}	1	$10^{-120} \sim T_m^{-3}$
...	......	......	......	......	......	......	......
5	$10^{160} \sim T_m^4$	$10^{80} \sim T_m^2$	$10^{-24} \sim T_m^{-2}$	$10^{-52} \sim T_m^{-1}$	$10^{135} \sim T_m$	$10^{-40} \sim T_m^{-1}$	$10^{-160} \sim T_m^{-4}$

Table: The classes of “self-contained” particles, which are possible in the Metagalaxy.

for a particle in its minimum energy state. This assumption follows from the supposition that a particle can be absolutely isolated (or "shielded") from other particles and fields. Because this is true except for gravitational fields, the modern theories of quantum mechanics and the quantum field theory are theories working in a flat space-time (Minkowski's space), so they don't take into account interactions with the universal gravitational field which, according to the General Theory of Relativity, cannot be "shielded". Experiments of the last decades show that this is true to a measurement precision of at least 10^{-12}. Thus isolating particles from gravitational fields contradicts not only the General Theory of Relativity, but also the experimental evidence.

As an example, a single proton, shielded from all other fields, is a stationary superposition (in the quantum mechanics sense) of the states of a so-called "naked" proton (neutron + meson, etc.; such a proton is also known as "physical proton"). The stationary superposition is spherically symmetric (as it should be for a particle whose spin is 1/2) and, hence, such particles cannot produce radiation; so they remain in their stationary ground states.

If a proton is in the presence of another proton somewhere else in the universe, the impossibility of shielding their gravitational fields destroys the spherically symmetric superpositions of their virtual states due to the tidal forces which perturb their spherical meson shells.

The periodic order of the proton states during the deformation of their spherically symmetric forms results in the braking of the strong stationary states, and leads to the periodic processes of radiation and absorption of the gravitational field energy.

In the case of the gravitational interaction among many moving particles, the perturbation of the surface of each particle is depending on the perturbation or fluctuation of the space metric. The magnitude of such a metric perturbation is known from [1, 2], and is

$$L = \sqrt{\frac{G\hbar}{c^3}} = r_0\, T_m^{-1/2} = 10^{-33}\ \text{cm}. \tag{13}$$

Elementary particles are oscillators whose frequency is of the order of $\omega_0 = c/r_0 = 10^{23}\,\text{sec}^{-1}$. We therefore should consider the probability of various possible quantum transitions of these oscillators, which are due to the action of the fluctuating gravitational fields. Because the perturbations of the fields are small in magnitude, the respective solution of Schrödinger's equation leads to the formula

$$W_{0k} = \frac{\xi_0^{2k}}{2^k k!}\, \mathrm{e}^{-\xi_0^2/2}, \tag{14}$$

where W_{0k} is the transition probability from the stationary ground state to an excited state of level k, and where

$$\xi_0 = \chi_0 \sqrt{\frac{m\omega}{\hbar}}\,, \tag{15}$$

where $\chi_0 = L$, $\omega = \omega_0$, $m = m_p$.

Because

$$\xi_0 = 10^{-33} \sqrt{\frac{10^{-24}\,10^{23}}{10^{-27}}} = 10^{-20},$$

we obtain

$$W_{0k} = \frac{10^{-40k}}{2^k k!}\, e^{-\frac{1}{2}10^{-4}} = \frac{10^{-40k}}{2^k k!}\,. \tag{16}$$

In the transition to a minimally excited state ($k = 1$), we have

$$W_{0k} = \frac{1}{2}\, 10^{-40}\,.$$

The average numerical value $\bar{k} = \frac{\xi_0^2}{2} = \frac{1}{2}\, 10^{-40} \approx 10^{-40}$. Therefore the radiation of energy is characterized by the value $\bar{k} = 10^{-40}$, which corresponds, for a nucleon, to the gravitational field energy relative to the energy of the strong interactions. We can also arrive at the same value from the following formula [11]

$$W = \bar{k}\, \frac{\triangle E}{E_0} = \left(\frac{E_g}{E_0}\right)^2. \tag{17}$$

Assuming the "naked" nucleon is not a point-mass, but a continuous particle whose size is $r = L = 10^{-33}$ cm [12], we have

$$E_g = \frac{G m_p^2}{L} = 10^{-20}\, m_p L^2 = 10^{-20}\, E \text{ cm}, \tag{18}$$

with the same result $W \simeq 10^{-40}$ obtained above.

The probability of radiation due to the action of an external field is always larger than the probability of absorption. The remainder of these probabilities, i.e. the probability of excess radiation, is of the order of these probabilities, and is proportional to them.

Because the energy density of such an external gravitational field decreases with time, the relative density of the field energy decreases with time for the time $\triangle\varepsilon_g/\varepsilon_g = 10^{-40} \sim T_m^{-1}$ during a single fluctuation or pulsation of the nucleon. Thus the probability of radiation exceeds the probability of absorption, and leads to a change in the relative energy of the particle.

The method of adiabatic invariants, applied to slow transitions due to adiabatic perturbations, leads naturally to the formula

$$W_{12} = \mathrm{e}^{-2T_m} \int\limits_{t_0}^{t} \omega_{21}(t)\, dt \,, \tag{19}$$

where $\omega_{21} = \frac{E_2 - E_1}{\hbar}$, $t = t_1$ is the current time, t_0 is the initial time, W_{12} is the probability of the particle (system) being in the state characterized by the wave function ψ_2 when $t \to \infty$ under the condition that this particle (system) was in the state ψ_1 as $t \to -\infty$. For the problem at hand, we will assume that $E_1 = E_2 = E_0$ at time $t = t_0$ and that $E_1 = E$ at $t = t_1$.

Let $\omega_{21} = \alpha = \frac{1}{2t}$, and the imaginary part of the complex "time" be $t_1 = t_0 = t = 10^{17}$ sec. In such a case, $E_0 - E_1 = 10^{-44}$ ergs corresponding to a mass $m_g = \frac{E_0 - E_1}{c^2} = 10^{-65}$ g, which is the actual mass of a graviton.

We approximate W_{12} by the equation

$$W_{12} \;=\; \mathrm{e}^{2} \int\limits_{t_1}^{t_0} \alpha\, dt \;=\; \mathrm{e}^{\int_{t_1}^{t_0} \frac{dt}{t}} = \frac{t_0}{t_1}\,. \tag{20}$$

For $t_1 = t_0 + \triangle t$ we have

$$W_{12} = 1 - \frac{\triangle t}{t_0} = 1 - 10^{-17} \triangle t\,.$$

While a single pulsation of a nucleon takes $\triangle t = 10^{-23}$ sec, we have $W_{12} = 1 - 10^{-40}$. Thus the change of the probability of the nucleon state in a single pulsation is

$$W = 1 - W_{12} = 1 - \frac{t_0}{t} \simeq \frac{\triangle t}{t} = 10^{-40}$$

which corresponds to the above conclusion arrived at in a different way.

These quantum transitions take place only if the frequency of the particle (oscillator) equals the frequency of the external field.

Because the displacement of such an oscillator is $x_0 = F/m\omega^2$, where F is an external force perturbing the oscillator, we arrive at

$$F = m_p\, \omega_0^2\, L = m_p\, \omega_0^2\, r_0\, \frac{L}{r_0} = \frac{L}{r_0} \times 10^{-10} = 10^{10}. \tag{21}$$

On the other hand, the force of the gravitational field acting on the nucleon (oscillator) is

$$F = m_g^* c\, \omega = m_g\, c\, \omega\, \frac{m_g^*}{m_g} = 10^{-30}\, \frac{m_g^*}{m_g}\,, \tag{22}$$

where the mass of a quantum of the gravitational field at a distance L from the center of the nucleon is

$$m_g^* = \frac{G m_p^2}{c^2 L}\,, \qquad m_g = \frac{G m_p^2}{c^2 r_0}\,, \tag{23}$$

wherefrom we obtain

$$\frac{m_g^*}{m_g} = \frac{r_0}{L} = 10^{20}, \qquad F = 10^{10},$$

that coincides with the magnitude of F found in equation (21).

Comparing (21) and (22) in their general form, we obtain

$$L^2 = \frac{G m_p}{c\,\omega_0} = \frac{G m_p r_0}{c^2} = r_0 r_g\,, \tag{24}$$

which is true in general as borne out by experiment.

So, our speculations and calculations show that a particle in a gravitational field (ignoring that field is unrealistic) cannot be in a stationary ground state. The term "stationary state" itself contradicts the covariant laws of the General Theory of Relativity which treats gravitation as a universal disturbance leading to changes in the space metric, i.e. to changes in the geometry of space and any sources located therein. Because a system of bodies interacting through the gravitation field cannot be at rest, the space metric changes with time and forces the bodies to radiate. This radiation is electromagnetic dipole, four-gravitational quadruple radiation.

An opposing view to that taken above would appear to contradict the principles of General Relativity which are well-verified by experiment.

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