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On the Relation of the Methagalaxy Mass to the Gravitation Constant. 1. From Einstein's Theory to the Einstein–Cartan Theory

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Abstract— The notion of the dimensionless gravitational charge defined through the Planck mass and the fundamental constants specifying this mass itself is introduced. The Big Bang is related to the unified physical interaction decay and the drop of Newton's gravitational constant by 40.67 orders of magnitude in comparison with the electromagnetic constant taken as unity. This causes an increase in the Metagalaxy curvature radius by the same value and a decrease in the average density of space–time curvature sources by 122 orders of magnitude: from the maximum allowable Planck density to the observed critical density. The microphysics appears naturally related to cosmology.

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According to the concepts of modern physics, all physical interactions (strong, electroweak, and gravitational) arose during the decay of the unified physical interaction in the Big Bang epoch given rise to Universe expansion 13.7 billions years ago. For example, within the primary unified interaction, gravitation was stronger than current gravitation by 41 orders of magnitude (a small reduction of the electrical interaction from the constant 1/40 to 1/137 will not give significant corrections where orders of magnitude are first of all important). Accordingly, the gravitational constant was higher than its current value approximately by 41 orders of magnitude. The current gravitational constant is equal (when taking the Planck constant and speed of light as unities) to the squared Planck length which can be naturally called the Planck area.

The Planck length is necessary for describing microphysics, Newton's constant is required for describing cosmology. The question arises about the relation of microphysics with cosmology. The objective of this paper is to point to this possible relation. It is easy to detect this relation by relating the mass of Metagalaxy, Universum ($M_U \cong 2 \cdot 10^{56}$ g) with fundamental physical constants (FPCs).

Let us remind the known fundamental constants. Newton's gravitational constant $G = 6.6745(8) \times 10^{-8}\,\text{cm}^3/\text{g}{\cdot}\text{s}^2 = 2.612 \cdot 10^{-66}\,\text{cm}^2$, the electric charge $e = 4.8 \cdot 10^{-10}\,(\text{g}{\cdot}\text{cm}^3/\text{s}^2)^{1/2} = 1.381 \cdot 10^{-34}$ cm, the Planck length $l_{pl} = (hG/2\pi c^3)^{1/2} = 1.616 \cdot 10^{-33}$ cm, the Planck mass $m_{pl} = (hc/2\pi G)^{1/2} = 2.177 \cdot 10^{-5}$ g, the reduced Planck constant $h/2\pi = 10^{-27}\,\text{g}{\cdot}\text{cm}^2/\text{s} = 1$, and speed of light $c = 3 \cdot 10^{10}\,\text{cm/s} = 1$. When a body is compressed to its gravitational radius, the speed of separation from it becomes the light speed. In this case, the body itself becomes a black hole (or a white hole with changing the time sign). However, in this case, the body does not collapse into a point with infinite density, since the Planck density $5.157 \cdot 10^{93}\,\text{g/cm}^3$ is the limit density.

To estimate the Universe mass, we take into account that the volume of its 3-sphere of the curvature radius a with the matter of critical density gives the following value

$$M_U = 2\pi^2 a^3 \rho_{cr} = 2\pi^2 (0.7 \cdot 10^{28}\,\text{cm})^3 \cdot 0.6 \cdot 10^{-29}\,\text{g/cm}^3 = 2 \cdot 10^{56}\,\text{g} = 10^{61} m_{pl}.$$

An imagined particle of Planck mass (we refer it to as the planckeon) can be considered simply as a black hole of Planck density and Planck size. It is natural to consider the cube of the Planck length as a three-dimensional planckeon volume and *the Planck volume*. When the gravitational constant before the unified interaction decay was larger by 40.67 orders of magnitude (we take this value to obtain the above estimate of the total Universe mass with three-dimensional space: $40 + 2/3$ to the power $3/2$ yields

61), the Planck volume was larger by 61 orders of magnitude. Increasing accordingly the planckeon mass, we obtain the mass $\sim 2 \cdot 10^{56}$ g which we take as the Metagalaxy mass. Our hypothesis consists in the feet that this possibility of obtaining the relation between small and large values is not accidental.

Let us introduce the notion of the dimensionless *gravitational charge* m/m_{pl} for a particle of mass m. Then it is similar to the dimensionless electric charge which indicates simply a number of elementary electric charges of a charged body, although the size of $1.38 \cdot 10^{-34}$ cm is usually assigned to the charge of the electron as an energy carrier. This size is smaller than the Compton electron wavelength $\lambda/2\pi = h/2\pi m_e c = 3.86 \cdot 10^{-11}$ cm. The planckeon mass in reduced units is equal to the inverse Planck length; therefore, by definition, the planckeon gravitational charge is dimensionless unity (and is independent, among others, on Newton's gravitation constant).

Before decaying the unified interaction into the strong, electroweak, and gravitational interactions, there was only one fundamental constant. *We put forward the hypothesis that the speed of light, the Planck constant, and the dimensionless gravitational charge of the planckeon, independent of the gravitation constant, remained unchanged during the unified interaction decay.* This means that the dimensional Planck mass increased by $20 + 1/3$ orders of magnitude during the initial strong gravity reduction by $40 + 2/3$ orders of magnitude; accordingly, the three-dimensional volume of the planckeon before the Big Bang was larger than the current value by 61 orders of magnitude. Multiplying this value by the dimensional (in grams) current Planck mass, we do obtain the dimensional Metagalaxy mass of $2 \cdot 10^{56}$ g. And multiplying the current Planck length by 61 orders of magnitude, we obtain (in centimeters) the gravitational diameter (the doubled curvature radius of 3-space) of the Metagalaxy of $1.6 \cdot 10^{28}$ cm. This value exactly corresponds to the doubled radius of the event horizon radius of the expanding Metagalaxy within observational cosmology. However, the Planck mass is expressed in terms of three basic fundamental physical constants. Thus, the total Metagalaxy mass also appears related to them.

It is reasonable to consider the total compensation of this mass by the negative potential gravitational energy. Intuitively, we got used to consider the mass as that enclosed into the infinite flat Minkowski word, i.e., in the spirit of the island physical system with the Schwarzschild geometry. However, according to Hilbert [4], actual infinity does not exist in nature, and a homogeneous space geometry in the form of the de Sitter three-dimensional sphere with its equivalent forming points and with a cosmological term as a curvature source in the world of events seems more physical.

The expanding Universe asymptotics is the world described by the one-sheet de Sitter hyperboloid with the neck radius of $\sim 1.6 \cdot 10^{28}$ cm. To what particle this de Sitter vacuum can be related? Let us draw an analogy to the Sun parameters. Its mass is close to the mass of a black hole with a gravitational radius of 3 km. The main contribution to the solar mass is made by nucleons with the size of the order of their Compton wavelength of $\sim 1.93 \cdot 10^{-14}$ cm. This size can approximately be obtained from the relation $3 \cdot 10^5\,\mathrm{cm} \cdot 1.616 \cdot 10^{-33}\,\mathrm{cm} = (2.2 \cdot 10^{-14}\,\mathrm{cm})^2$. That is the product of the gravitational solar radius and the planckeon size (Planck length) is approximately equal to the squared size of the particle forming a star. This size is larger than the Planck length by 19 orders of magnitude, and the particle mass is accordingly smaller than the planckeon mass by 19 orders of magnitude; note that the planckeon itself is a black a hole. Hence, dense linear packing of 10^{19} nucleons and cubic packing of $(10^{19})^3 = 10^{57}$ nucleons are required to compose a black hole. Multiplying this number by the nucleon mass of $1.67 \cdot 10^{-24}$ g, we do obtain the approximate mass of the Sun as an average stable star (every second loss of four megatons of the solar mass for radiation created and supporting the Earth biosphere is insignificant).

For the system size of the order of the radius of the event horizon of the Metagalaxy, we obtain $16 \cdot 10^{27}\,\mathrm{cm} \cdot 1.6 \cdot 10^{-33}\,\mathrm{cm} = (5 \cdot 10^{-3}\,\mathrm{cm})^2$. We call a particle $5 \cdot 10^{-3}$ cm in size with a corresponding mass of $4 \cdot 10^{-36}$ g as the *zeron* (from *zero*), as though a zero particle. After matter scattering until reaching de Sitter vacuum in the asymptotic, the Metagalaxy will probably consist of zerons.

Observational cosmology proves the Universe expansion fact. The rate of distance increase, unlike the propagation velocity of physical interactions, can be arbitrarily high. The expansion began after the Big Bang 13.7 billion years ago. It is reasonable to assume that the primary state was a three-dimensional sphere with a limit Planck density $5 \cdot 10^{93}$ g/cm^3 of matter and with a curvature radius of $\sim 1.25 \times 10^{-13}$ cm. The increase in the curvature radius by 40.67 orders of magnitude corresponded to reduction of primary strong gravity as a unified interaction by these 40.67 orders of magnitude. After the unified interaction splitting into the strong, electroweak, and gravitational, the electroweak interaction was further split into the electromagnetic and weak ones.

The interaction constants depend on energy. For energies of 0.01, 0.1, 1, and 100 in the units of GeV, the strong interaction constants sequentially take the values of 10, 1, 0.40, and 0.12; the electromagnetic interaction constants are $1/137$, $1/135$, $1/133$, and $1/128$; the weak interaction constants are $1/26$, $1/27$, $1/28$, and $1/36$. A decrease in the strong interaction constant α_s is caused by strong (color) charge antiscreening.

The values inverse to the interaction constants depend on energy logarithmically and converge to the inverse constant of the unified interaction $1/\alpha_{GU} = 40$ at the energy of 10^{16} GeV which does not reach the Planck energy 10^{19} GeV. In this case, the constant $(3/8)(1/\alpha_e)$ was taken for the electromagnetic interaction, where the factor $3/8$ is associated with the weak mixing angle (Weinberg angle). According to the Grand unification theory, $\sin^2\theta_W = 3/8$ at the energy of 10^{16} GeV (the experimental value is 0.231 for 91 GeV). At this energy, the unified interaction arise (except for the gravitational one), corresponding to the special (with a unit matrix determinant) unitary (the matrix unitarity means that its transpose is equal to the inverse matrix) 5-dimensional symmetry group $SU(5)$.

To clarify the role of symmetry, it should be said that the Lagrangian of the electromagnetic interaction $\Psi\bar{\Psi}$ is invariant with respect to multiplying the wave function by the unit complex vector $\exp[i\varphi(x)]$; however, the Dirac equation for the electron–positron pair remains valid when substituting the partial derivative $\partial_\mu = \partial/\partial x^\mu$ with the covariant $D_\mu = \partial_\mu - ieA_\mu$ one introducing the electromagnetic field vector potential A_μ satisfying Maxwell's equations (in this sense, the electromagnetic field is the calibration and compensating one retaining the Dirac equation with including the electromagnetic interaction). But while imaginary exponents correspond to the one-dimensional commutative symmetry group $U(1)$, multidimensional symmetry groups $SU(n)$ are already non-commutative; therefore, strong-interaction gluons (and weak interaction bosons related accordingly to symmetry groups $SU(3)$, $SU(2)$) interact with each other. In this case $SU(2)\times U(1) = U(2)$ and subgroup-factors have here different physical meaning, being combined into a more general group, which intuitively points to the internal unity of all physical interactions, not existing without each other.

Strong and electromagnetic interaction symmetries are exact, and the weak interaction symmetry mixes fermions of various generations and corresponds to symmetry breaking, which leads to instability of corresponding particles (except for the easiest ones), CP-invariance breaking, and neutrino oscillation (periodic alteration of its types). This was discovered in 1957 by physicist B. M. Pontekorvo (incidentally, at an appropriate time he came to the Moscow State University; I saw him, being studying at the Faculty of Mechanics and Mathematics and the postgraduate school of the Faculty of Physics (1955–1963)). Quarks interacting via gluon exchange and electrons interacting via photon (electrically uncharged) exchange are stable, whereas vector W^+, W^-, Z^0 bosons the exchange with which implements the weak interaction are unstable. Fundamental fermions of this model are 6 quarks and 6 leptons. Their interaction is implemented by an exchange, along with the indicated bosons and gluons, by bosons X, Y of spin 1 with charges $4e/3$ and $e/3$. For not yet been discovered symmetries, the roles of stable and unstable particles change places.

The strong interaction binds neutrons and protons into atomic nuclei contrary to the electromagnetic relatively weak repulsion of atoms. The neutron–proton collision can produce deuterium (synthesis of hydrogen atoms is performed in the hydrogen bomb), and excitation of massive uranium nucleus in which the strong interaction of nucleons weakens (due to forced removal of some of them from each other and in comparison with electromagnetic repulsion) can cause its decay (this causes the chain reaction in the atomic bomb). The strong interaction is defined by the Yukawa potential $U(r) = -(k/r)\exp(-r/r_0)$, where $k = 1$, $r_0 \cong 10^{-13}$ cm are constants. The quantitative theory of the strong interaction was developed by Yukawa in 1935. The Fermi momentum calculation for the helium atom shows that the proton velocity in the nucleus is about a quarter of the speed of light, so that the nucleon motion in the nucleus is relativistic and slightly increases the nucleon motion mass in comparison with the nucleon rest mass (by a factor of $4/\sqrt{15}$).

Nucleons consist of quark triplets bound by eight gluons. The quark has an internal quantum number called the color, as well as spin, electric charge, and momentum. Its state is described by the vector in the three-dimensional complex color space. It is invariant with respect to unitary rotations with symmetry group $SU(3)$. Quarks and antiquarks can be used to construct colorless combinations which do not interact with gluons in the long-wavelength approximation. Asymptotic freedom of quarks is caused by their charge antiscreening. The quark confinement is caused by the fact that they cannot move apart to a distance longer than 1 fm (10^{-13} cm). They are bound by gluons as if an elastic band: its stretching means mass-energy expenditure so that a quark pair breaking produces two such pairs. Therefore, we do not observe free quarks. The characteristic binding energy of quarks is 1 GeV which is approximately equal to the nucleon mass-energy. Colorless states of quarks are called the hadrons which interact via exchange by other hadrons (mesons of the quark-antiquark pair) bonding hadrons into atomic nuclei. Atoms form molecules involved in chemical reactions with electron shell rearrangement.

According to Democritus, the world is atoms and emptiness; from the viewpoint of chemistry, the life is chemical process of an organism with local expulsion of entropy at the expense of its general increase, with hereditary code self-correction under the condition of free energy inflow [1, 2] (the reason with its understanding and desirability naturally arises as a further means for energy saving in comparison with purely instinctive behavior of living organisms). As for the “emptinesses”, it is most likely everything than nothing: its macroscopic dimension is three (and it is the topological invariant of the group of homeomorphisms, i.e., one-to-one mappings of a set of point elements). The Universe before the Big Bang and the asymptotic state of the Metagalaxy (with receding Galaxies, rapidly diluting radiation, and a decreasing matter density) are two different states of physical vacuum with nonzero mass-energy density in the form of a cosmological term of the gravity equations. The elementary particles are vacuum excitation quanta. The particle quantization arises due to the survival of only resonances, as in the case of a sounding string: non-resonant excitations compensate for each other in the Feynman integral over the paths of all possible evolutions of the physical system. In this case, the action (integral of the density of the system Lagrangian over the space volume) reaches an extremum which dictates the form of all equations of system dynamics. Thus the nature feels for its evolution laws, and bifurcations give rise to the world as an ocean of branching possibilities. In this case, only probabilities are determinate (in particular, the choice of a man imposes the responsibility for his choice; in all the determination of the behavior by various factors and circumstances).

The weak interaction is responsible for the neutron beta decay. The neutron and proton consist of three top and bottom quarks: $n = (uud)$, $p = (udd)$. The neutron decay produces a proton and an intermediate electrically charged W-boson which then decays into an electron and an electron antineutrino (or a muon and a muon antineutrino, or a tau-lepton and a tau-lepton antineutrino). Quarks can be of six types: top, bottom, charmed, strange, truth, and beauty ones. These types form a $3{\times}3$ Cabibbo—Kobayashi—Maskawa matrix which is parametrized by three angles and a phase factor. In the Weinberg—Salam theory, the electroweak interaction is the quantum theory with calibration group $SU(2) \times U(1)$. This symmetry is spontaneously broken by the Higgs boson action. This boson was discovered on July 4, 2012 at the Large Hadron Collider of the CERN; its mass-energy is of the order of 125 GeV. Its spin, electric and color charges are zero. It is produced by fusion of two gluons, charged W-bosons, or neutral Z-bosons, and decays into a particle—antiparticle pair, where the particle is a photon, b-quark, electron, muon, or neutrino.

The Higgs boson gives rise to the rest masses of elementary particles. Since the eigenvalue of the quantum velocity operator is only the plus-minus speed of light, all particles are produced in the light state with 4-momentum of zero length (its square is equal to the difference of the squared time component and 3-momentum: the time is the imaginary spatial coordinate, which is its difference from the spatial dimension). At the quantum level, the time can be considered as enumeration of spatial “frames” replacing each other with Planck frequency of about $1.85 \cdot 10^{43}$ times per second, obtained by combining three fundamental physical constants (Newton’s constant G, Planck constant h, and speed of light c). Due to the systematic interaction of the particle with the Higgs boson, the 3-momentum reverses its direction, and this light jitter of the particle seems on average as hanging around in one place with nonzero “rest” mass.

The weak and electromagnetic interactions arose with the decay of the unified electroweak interaction with decreasing interaction energy. The electromagnetic interaction is caused by the exchange of electric charges by virtual photons appearing during symmetry localization, $U(1) = \{\exp(i\varphi(x)\}$, i.e., when introducing the dependence of the phase φ on the world point coordinate (a spatial point taken at one time point).

The electromagnetic interaction force, in contrast to the strong interaction, obeys the law of inverse squares, as well as the gravitational interaction. But for all that, the electrical interaction force, e.g., of electron and positron, is stronger than their gravitational interaction by 41 orders of magnitude. In the string theory, while the photon of spin 1 is a string with open ends, the graviton of spin 2, transferring the gravitational interaction, is a closed loop. All elementary particles are various states of one of them, various modes of string oscillations (in such a way the modern physics combines the unity and diversity of our world).

As noted above, observational cosmology discovered the Universe expansion (Hubble, 1929) theoretically predicted by A. A. Fridmann (St.Petersburg, 1922; incidentally, in 1918–1920 he lived at Kolchak in Perm at the 2nd floor of a small two-storeyed house, Siberian street 19, in which then was an author's favorite bookshop). The equation of physical vacuum state (the pressure is equal to the minus vacuum density) shows that the negative pressure causes accelerated divergence of test particles. Galaxies are not test particles, but they resulted from the Big Bang when ultradense vacuum gave almost all its mass-energy to matter and radiation. The total mass M of the Metagalaxy is $2 \cdot 10^{56}$ g: this is of the order of 100 billions of Galaxies with 100 billion stars with an average mass of more than 10^{33} g plus dark matter and dark vacuum energy, which increase the total mass by a factor of $\sim$20. Initially (before the formation of gravity matter slightly retarding expansion), the Metagalaxy evolution corresponded to the three-dimensional de Sitter sphere (expanding one-sheet hyperboloid mentally enclosed into the 5-dimensional flat Minkowski world with $(- + + + +)$ space-time signature) initially compressed to the limit Planck density of $\rho_{pl} = 5 \cdot 10^{93}$ grams per cubic centimeter. The curvature radius a of the de Sitter 3-sphere is related to the primary vacuum mass of the Metagalaxy by the formula $M = 2\pi^2 a^3 \rho_{pl}$, where $a = 0.75 \cdot 10^{-13}$ cm. The decay of the primary unified physical interaction into the strong, electroweak, and gravitational interactions caused a gravity reduction almost by 41 orders of magnitude.

We note that the expanding Universe is not a black hole, but it is a white hole produced from the black hole by changing the time sign. In this case, we proceeded from the de Sitter solution for both the initial state and for the final asymptotic state of the Metagalaxy, when entire matter decays and forms new de Sitter vacuum in which the matter energy–momentum tensor is reduced to the cosmological term. In this case, as is known, the entropy is equal to a quarter of the event horizon area. Since test particles behind the event horizon move away from us with a superlight speed, they are unobservable and become a virtual reality in this sense: arcs of their world lines are spacelike for our speculation; i.e., they become a flashing and immediately extinguishing spatial interval for a certain imagined observer.

Strong interactions operate only at short distances, opposite-sign electric charges on average compensate for each other, and the weakest (no longer vectorial, but tensorial) gravitational interaction controls the Metagalaxy dynamics on cosmological scale. We note that the Maxwell's equations can be written in the following form: *the codifferential of the differential of the vector potential is equal to the self-sustaining electric current*, and Einstein's gravitational equations with a lambda-term can be written in a similar form: *the codifferential of the differential of the tetradic potential is equal to the self-sustaining tetradic current* [3] (here the codifferential is a covariant divergence of the form with a minus sign with respect to its first coordinate index; the exterior differential conventionally affects the form, i.e., the tensor with only antisymmetric coordinate indices; for the tetradic current, one index is coordinate, and one index is Lorentzian involved in Lorentz rotations of the tetrad field controlling the metric, the curvature in Einstein's general relativity theory (GRT) with its symmetric connectivity [3]. The introduction of the connectivity torsion generalizes the GRT to the Einstein–Cartan theory [5] with Cartan torsion fields (1922) which were not operated by Einstein (1915).

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