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**Derivations and calculations around the hypothesis explaining gravitation forces
as recoil forces of radiation**

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Abstract

The paper is a continuation of two previous papers of the author [1], [2] in which he explained the force induced by the electrostatic field on the electron as a recoil force. The derivations started with the hypothesis that in a dynamic energy equilibrium with the Quantum Vacuum (QV) the electron simultaneously absorbs and emits energy. A formula has been derived for the power of the emission. In the paper [2], the author presented similar derivations for gravitational forces. However, at that time the derivations were incomplete. This was caused by the lack of knowledge of the highest possible value of intensity of any gravitational field. Now this value has been determined using the gravitational field at the surface of a neutron star. Using a mass in the form a sphere with the uniform mass density, the radiation pattern of the emission of the energy into the vacuum with no external gravitation field has been modeled by a sphere. Such a radiation does not produce a recoil force. In presence of the external gravitational field the radiation pattern is modeled by an ellipsoid. The non-circularity of the radiation produces a recoil force. Its value is defined by the total radiation power and the eccentricity of the ellipsoid. The eccentricity has been defined by the ratio of the external gravitational field to the maximum possible gravitational field of the value $7.59 \times 10^{12} \text{ [m/s}^2\text{]}$.

1. Introduction

The Newton's law and derivations of general relativity allow very precise calculations of gravitational forces. However, the physical nature of gravity and inertia is still an unsolved problem of science. Certainly the understanding of the nature of gravity depends on progress in understanding the nature of the Quantum Vacuum (QV). Actually we know that QV is a medium of extremely high energy density. The evidence is given by the Zero Point Fluctuations (ZPF) of QV. Several phenomena, for example, the Lamb shift, the Casimir force, the behaviour of the electron on the Bohr orbit and so on confirm the existence of ZPF. In the famous Planck's formula defining the spectrum of thermal electromagnetic radiation there is a zero temperature term $0.5hf$. The spectral density of ZPF is given by $\rho(f) = (4\pi hf^3)/c^3 \text{ [Js/m}^3\text{]}$. The integration of this density from zero to $f_{\max} = \sqrt{c^2/(2hG)} = 5.8 \times 10^{42} \text{ [Hz]}$ yields a formidable value of the volume energy density of QV $E_{QV} = 5.8 \times 10^{112} \text{ [J/m}^3\text{]}$. QV is a carrier of electromagnetic and gravitational fields.

The energy density of the electrostatic field is $\rho_{elec} = 0.5\varepsilon_0 \left| \overset{\leftrightarrow}{E} \right|^2 \text{ [J/m}^3\text{]}$. This energy increases

the energy of QV and the proper notation is "Energy density" = $\rho_{QV} + 0.5\varepsilon_0 \left| \overset{\leftrightarrow}{E} \right|^2 \text{ [J/m}^3\text{]}$.

Remark: Actually effective methods of extraction the energy ρ_{QV} for commercial use are unknown. Differently to the electrostatic case the energy of the **gravitational field lowers the energy density of QV** We should write "*Energy density*" = $\rho_{QV} - 0.5\gamma \left| \overset{\leftrightarrow}{g} \right|^2$ [J/m³]. Only in the sense of this representation the energy density of the gravitational fields could be interpreted as negative (evidence see Fig.8).

In this and previous papers of the author, gravitational forces are interpreted as recoil forces of radiation. We have two kinds of forces connected with electromagnetic radiation. The first is the force of radiation pressure. For example, Japanese scientists constructed a spacecraft with the propulsion given by the radiation of the sun falling on a special wing. The second is a recoil force given by a anisotropic radiation pattern of a source of radiation. An example is the anomaly of the velocity of the Pioneer spacecraft explained by the anisotropic thermal radiation of the spacecraft of the heat produced by the isotopic energy source. We explain the gravity as a recoil force of radiation. It is assumed that particles having the property of mass exist in a **dynamic energetic equilibrium** with QV. Dynamic means that particles absorb and emit energy with zero mean balance. In the absence of an external g-field, the self field g_{self} of a spherical body is also spherical symmetric (isotropic) (see Fig.1). The energy density of the QV in the region surrounding the body is uniform. In consequence, the postulated emission pattern is isotropic. There is no recoil force. Let us recall that the external gravity field g_{ext} crosses the body with no change of sign and if the distance to the far body is large with negligible change of intensity. What happens is illustrated in Fig.2. Let us call the face of the body seeing the far body the day side and the opposite night side. At the day side the two fields have opposite directions and at the night side equal directions. In consequence the energy density of QV is higher at the day side w.r.t. the night side. We postulate that the unknown rules of the dynamic energy equilibrium enforce higher emission towards lower energy intensity in comparison to the emission towards higher energy density. This yields a recoil force towards the far body fulfilling the requirement that the bodies attract as illustrated in Fig.2. We derived the following formula defining the power of the emission

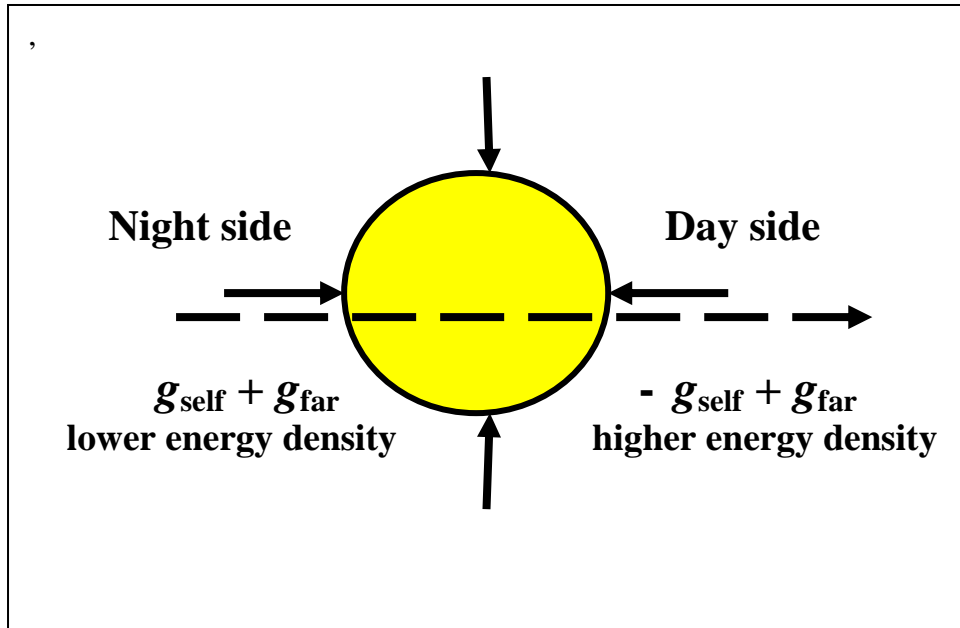


Fig. 1. Cross-section of the spherical body (yellow). The self g-field (solid arrows) is spherically symmetric. The g-field of a far body (dotted line) penetrates the body with no change of sign. Therefore at the night side we have summation and at the day side subtraction of the fields. The energy density is lower at the night side w.r.t. the day side.

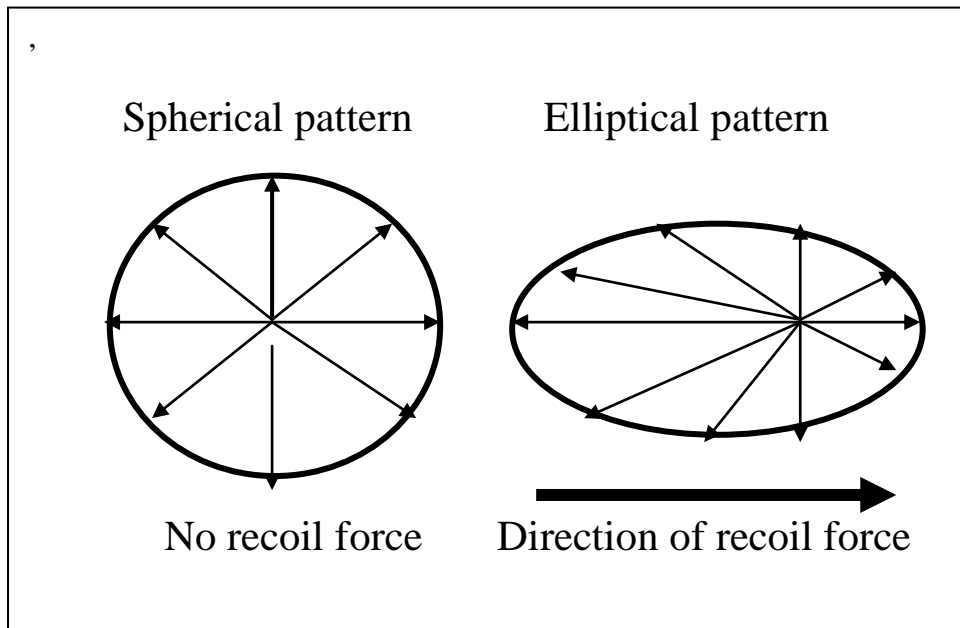


Fig.2. Left. The cross-section of a circular radiation pattern. Right. The cross-section of an elliptical radiation pattern.

$P = 3c \left| \vec{g}_{\max} \right| M = 6.82 \times 10^{21} \text{ [W]}$, c – the speed of light, $\left| \vec{g} \right|_{\max} = 7.59 \times 10^{12} \text{ [m/s}^2\text{]}$ the maximum possible intensity of any gravitational field. For the neutron we get $1.14 \times 10^{-5} \text{ [W]}$, for the Earth $4 \times 10^{46} \text{ [W]}$. With no compensation by absorption of the emitted energy the neutron would decay in about 13 microsecond. This value looks small but equals 3×10^{18} Compton periods (reciprocal of the Compton frequency of the neutron). Note that we

postulated that only the emission is anisotropic. The eventual anisotropy of absorption enforced by the higher pressure at the day side w.r.t. the night side would act as a repulsive force contradicting the physical reality.

2. Preliminaries

For convenience, let us recall some basic definitions and notations used in this paper. We apply the SI system of units. The macroscopic Newtonian law defining the force of attraction of two bodies of mass M_1 and M_2 is

$$\vec{F}_{12} = G \frac{M_1 M_2}{R_{12}^2} \quad [\text{N}] \quad (1)$$

where

$$G = 6.67384 \times 10^{-11} \left[\frac{\text{m}^3}{\text{kg s}^2} \right] \quad (2)$$

is the gravitational constant measured for the first time by Cavendish. M_1 and M_2 are masses of the bodies [kg] and R_{12} the distance between their centers of mass. In this paper we apply the reciprocal gravitational constant

$$\gamma = \frac{1}{4\pi G} = 1.92379 \times 10^9 \left[\frac{\text{kg s}^2}{\text{m}^3} \right] \quad (3)$$

having in mind the analogies between electrostatics and gravity where γ corresponds to the permittivity of free space ϵ_0 .

The gravitational field generated by a hypothetical point mass M_1 is

$$\vec{g} = \frac{\vec{F}_{12}}{M_2} = -G \frac{M_1}{R^2} \vec{r} = \frac{-1}{4\pi\gamma} \frac{M_1}{R^2} \vec{r} = \frac{-\rho_M}{\gamma} \vec{r} \left[\text{m/s}^2 \right] \text{ or } [\text{N/kg}] \quad (4)$$

is called gravitational acceleration. R is the distance from the center of mass of M_1 and \vec{r} a unit vector indicating the direction of the field. The minus sign indicates that acceleration is directed towards the center of mass. Let us remind that:

1. The gravitational field is a vector quantity.
2. Two opposite gravitational fields of the same modulus cancel.
3. Ordinary matter (baryon matter) is transparent for gravitational fields. Differently to electrostatic fields gravitational screens are unknown.
4. The energy density of the gravitational field is given by the equation

$$Ed = Ed_{QV} - 0.5\gamma |\vec{g}|^2 \left[\text{J/m}^3 \right] \text{ or } \left[\text{N/m}^2 \right] \quad (5)$$

where E_{QV} is the extremely high energy density of the quantum vacuum (see the next chapter). The energy density of the electrostatic field \vec{E} is given by the analogous equation

$$Ed_E = E_{QV} + 0.5\epsilon_0 |\vec{E}|^2 \left[\text{J/m}^3 \right] \text{ or } \left[\text{N/m}^2 \right] \quad (6)$$

Note that gravity *lowers the energy density* of the vacuum differently to the energy of electrostatic field and that energy densities and pressure have the same dimensions. In view of Eq.(5), the assumption that gravity produces negative energy density is false. It lowers the positive energy density of the vacuum (evidence in Fig.8).

3. Selected simple models of gravitational bodies

Our discussions about the nature of gravitation apply the following simple idealized models of mass bodies:

3.1 A sphere of radius R_0 filled with a uniform volume mass density (Fig. 3)

$$\rho_v = \frac{3M_1}{4\pi R_0^3} \left[\text{kg/m}_3 \right] \quad (7)$$

3.2 The above sphere can be replaced by a hollow sphere with an equivalent surface mass density (Fig. 4)

$$\rho_M = \frac{M_1}{4\pi R_0^2} \left[\text{kg/m}^2 \right] \quad (8)$$

The surface and outside g–fields of both spheres are the same. For the first the g–field is (Fig. 5)

$$\vec{g}(r) = \begin{cases} -\frac{\rho_M}{\gamma} \frac{r}{R_0} \vec{r} & r < R_0 \\ -\frac{\rho_M}{\gamma} \vec{r} & r = R_0 \\ -\frac{\rho_M}{\gamma} \frac{R_0^2}{r^2} \vec{r} & r > R_0 \end{cases} \quad (9)$$

and for the second the inside g–field equals zero.

3.3 An infinite plane covered with a surface mass density (Fig. 6).

Consider the rectangular Cartesian coordinates (x, y, z) and the plane $x = 0$. We assume that the plane is covered with a surface mass density ρ_M [kg/m²]. This unphysical body could be interpreted as a limiting case of a disc of radius R_d located between the planes $x = -\sqrt{x}/2$ and $x = \sqrt{x}/2$ filled with a volume mass density ρ_V [kg/m³] assuming $R_d \rightarrow \infty$, $\sqrt{x} \rightarrow 0$ and $\rho_V \rightarrow \infty$. The g-field of this plane is

$$\vec{g}(z) = -\frac{\rho_M}{2\gamma} \text{sgn}(x) \bar{x} \quad (10)$$

3.4 Two parallel plates of point 3.3 located at $x = -x_0$ and $x = x_0$ (Fig. 7)

The g-field is

$$\vec{g}(x) = -\frac{\rho_M}{2\gamma} [\text{sgn}(x+x_0) + \text{sgn}(x-x_0)] \bar{x} = \begin{cases} \frac{\rho_M}{\gamma} \bar{x} & x < -x_0 \\ \text{zero} & \text{in the range } (-x_0, x_0) \\ -\frac{\rho_M}{\gamma} \bar{x} & x > x_0 \end{cases} \quad (11)$$

We observe that the self fields of the plates have different signs at the left and right sides. Differently, the field generated by the opposite plane crosses the plane with no change of the sign.

3.5 A single body of any shape or an ensemble of many bodies with a center of mass at the origin

The asymptotic g-field at large distance from these bodies decays proportionally to $1/r^2$ independently of the direction.

4. The energy density of the Quantum Vacuum

Our goal is the derivation of formulae describing the gravitation force as a recoil force caused by anisotropic emission of radiation. We start with the hypothesis that baryonic matter having the property of a mass exists in a dynamic equilibrium with the Quantum Vacuum (QV). The QV is a medium with extremely high energy density. This can be shown starting with the Planck's formula

$$\rho(f, T) = \frac{8\pi f^2}{c^3} \left[\frac{hf}{\exp(hf/kT) - 1} + \frac{hf}{2} \right] \quad [\text{Js/m}^3] \quad (12)$$

which defines the frequency domain energy distribution of thermal radiation. h is the Planck constant, k – the Boltzmann constant, T – the absolute temperature and f the frequency of radiation. The term $hf/2$ represents the **zero-point fluctuations** of QV. For $T=0$, we get

$$\rho(f) = \frac{4\pi hf^3}{c^3} \quad [\text{Js/m}^3] \quad (13)$$

The total energy density in the frequency band from f_1 to f_2 is given by the integral

$$E_{(f_1, f_2)} = \int_{f_1}^{f_2} \rho(f) df = \frac{\pi h}{c^3} (f_2^4 - f_1^4) \quad [\text{J/m}^3] \quad (14)$$

Planck suggested that the highest frequency of the radiation is defined by the formula

$$f_{\max} = f_2 = \sqrt{\frac{c^5}{2hG}} \cong 5.235 \times 10^{42} \quad [\text{Hz}] \quad (15)$$

This value of f_2 with $f_1 = 0$ yields a formidable energy density of QV

$$E_{QV} = \frac{\pi h f_{\max}^4}{c^3} \cong 5.8 \times 10^{12} \quad [\text{J/m}^3] \quad (16)$$

This value applies for a pure vacuum. In case of an electrostatic and gravitational field the energy of the vacuum is given by the Eqs.(5) and (6). In the actual state of the art it is impossible to extract from the vacuum the energy E_{QV} . Of course, the energy of the electrostatic field can be used for any application. For example, charged capacitors can drive electric machines.

5. Anisotropy of energy distribution around a mass induced by an external g–field

Consider a spherical body with the g–field defined by Eq.(9) with the center at the origin of the (x,y,z) coordinates. The self g–field $\vec{g}_{self} = \left| \vec{g}_{self} \right| \times \vec{r}$ is isotropic, i.e., the magnitude is equal for all directions. In the presence of an external g–field $\vec{g}_{ext} = \left| \vec{g}_{ext} \right| \times \vec{x}$ the resulting g–field is given by the formula

$$\vec{g} = \left| \vec{g}_{ext} \right| \times \vec{x} - \left| \vec{g}_{self} \right| \times \vec{r} . \quad (17)$$

The modulus of this vector is

$$\left| \vec{g} \right|^2 = \left| \vec{g}_{self} \right|^2 + \left| \vec{g}_{ext} \right|^2 - 2 \left| \vec{g}_{self} \right| \left| \vec{g}_{ext} \right| \cos(\vec{r} \times \vec{x}) \quad (18)$$

Evidently, the energy density at the surface of the sphere is anisotropic. For example, if $\cos(\vec{r} \times \vec{x}) = +1$, we have

$$E = E_{QV} - 0.5\gamma \left(\left| \vec{g}_{self} \right| - \left| \vec{g}_{ext} \right| \right)^2 \quad (19)$$

and if $\cos(\vec{r} \times \vec{x}) = -1$

$$E = E_{QV} - 0.5\gamma \left(\left| \vec{g}_{self} \right| + \left| \vec{g}_{ext} \right| \right)^2 \quad (20)$$

This anisotropy is responsible for the existence of a recoil force.

5. Gravitational data for selected bodies

Our principal goal is the determination of the maximum possible intensity and energy density of the gravitational field. It is advisable to use data supplied by astronomy. Our choice is the neutron star PSRJ614-2230 located 3000 light years from our solar system. Its diameter is 19300 [m] and its mass equals two solar masses. Selected data for this star are presented in Table 1 and compared with data for Earth, Moon and Sun and with data for the electron (two options of the radius) and for the neutron.

TABLE 1

Body or Particle	Radius R	Mass M	Volume mass density ρ_V	Equivalent surface mass density ρ_M	Surface g-field	Energy density of the surface g-field
	[m]	[kg]	[kg/m ³]	[kg/m ²]	[m/s ²]	[J/m ³]
Moon	1.738x10 ⁶	7.3477x10 ²²	3.34x10 ³	1.9357x10 ⁹	1.623	1.57x10 ⁹
Earth	6.3471x10 ⁶	5.9736x10 ²⁴	5.51x10 ³	1.171x10 ¹⁰	9.8211	5.75x10 ¹⁰
Sun	6.96x10 ⁸	1.9891x10 ³⁰	1.48x10 ³	3.267x10 ¹¹	274.04	4.47x10 ¹³
Neutron star	19300	3.978x10 ³⁰	1.32x10 ¹⁷	8.4988x10 ²⁰	7.13x10 ¹¹	3.02x10 ³²
Electron	2.81x10 ⁻¹⁵	9.1093x10 ⁻³¹	9.80x10 ¹²	9.18x10 ⁻³	7.7x10 ⁻¹²	3.53x10 ⁻¹⁴
Electron	2.81x10 ⁻²²	9.1093x10 ⁻³¹	9.80x10 ³³	9.18x10 ¹¹	7.7x10 ²	3.53x10 ¹⁴
Neutron	8.0x10 ⁻¹⁶	1.675x10 ⁻²⁷	7.81x10 ¹⁷	2.08x10 ²	1.74x10 ⁻⁷	1.81x10 ⁻⁵

TABLE 2

Body	Schwarz- schild radius R_s	Volume mass density ρ_V	Equivalent surface mass density ρ_M	Surface g-field	Surface g-field energy density	Einstein energy density
	[m]	[kg/m ³]	[kg/m ²]	[m/s ²]	[J/m ³]	[J/m ³]
Moon	1.09×10^{-4}	1.34×10^{34}	4.904×10^{29}	1.008×10^{50}	1.008×10^{50}	1.21×10^{51}
Earth	8.87×10^{-3}	2.038×10^{30}	6.032×10^{27}	1.562×10^{46}	1.562×10^{46}	1.835×10^{47}
Sun	2.95×10^3	1.838×10^{19}	1.811×10^{22}	1.519×10^{13}	1.376×10^{35}	1.651×10^{36}
Neutron star	5911.6	4.596×10^{18}	9.058×10^{21}	7.596×10^{12}	3.44×10^{34}	4.128×10^{35}

Table 2 presents the Schwarzschild radius and selected data for the bodies of Table 1.

6. The Schwarzschild radius and the highest value of a g-field in nature

The Schwarzschild radius R_{sch} is defined as the radius of a sphere such that, if all of the mass of a body is compressed within that sphere, the escape speed from the surface of the sphere would equal the speed of light. In this paper we apply this notion to calculate the maximum value of the modulus of the g-field.

Using equations of general relativity Schwarzschild derived the following form

$$R_{sch} = \frac{2GM}{c^2} \quad [m] \quad (21)$$

For a sphere of radius R_{sch} the equivalent surface mass density $\rho_M = M / (4\pi R_{sch}^2)$. Therefore, the surface g-field is

$$\left| \vec{g} \right| = 4\pi G \rho_M = \frac{c^4}{4GM} \quad [m/s^2] \quad (22)$$

The energy density at the surface (see Eq. (5)) is

$$E_{sch} = \frac{1}{8\pi G} \left| \vec{g} \right|^2 = \frac{c^8}{128\pi G^3 M^2} \quad [J/m^3] \quad (23)$$

For comparison, let us calculate the Einstein's energy density

$$E_{ein} = \frac{Mc^2}{(4/3)\pi R_{sch}^3} = \frac{3c^8}{32\pi G^3 M^2} \quad [J/m^3] \quad (24)$$

Note that the ratio (24)/(23) equals 12.

The g -field at the surface of the neutron star displayed in Table 1 equals 7.13×10^{11} [m/s²]. We observe that the Schwarzschild radius 5911 [m] (see Table 2) is only 3.27 times smaller from the physical value 19300 [m]. A neutron star with the diameter 5911 [m] and the mass equals twice the mass of the Sun would have a g -field at the surface given by Eq. (22):

$$\left| \vec{g} \right|_{\max} = 7.59 \times 10^{12} \text{ [m/s}^2\text{]} \quad (25)$$

In this paper, we apply this value as the largest possible value of any g -field. The highest value of the g -field is defined macroscopically at the surface of a neutron star. Differently, the highest value of electrostatic field is defined microscopically at the surface of the electron.

8. Derivation of the formula for calculation of the power of the energy exchange between a mass M and the vacuum

All baryonic matter (electrons, protons, neutrons, atoms) are surrounded by extremely high energy density QV. It would be unreasonable to assume that particles are separated from QV by an “iron curtain”. We should postulate that we have continuous energy exchange between particles and the QV having a **dynamic energy equilibrium**. Particles absorb and emit the same amount of energy. In absence of external fields the absorption and emission patterns of the radiation are isotropic or circularly symmetric. There is no recoil force. Our goal is to calculate the power of the energy exchange. Our choice is a radiation pattern (power density per unit solid angle) defined the ellipsoid

$$\sigma_{\Omega} = \sigma_{\max} \frac{1 - \varepsilon^2}{1 + \varepsilon \cos(\varphi)} \text{ [W/Ster]} \quad (26)$$

where ε is the eccentricity of the ellipse. This formula uses the polar coordinates centered in the focus of the ellipsoid. The recoil force is given by the integral

$$\left| \vec{F} \right| = \frac{v}{c} \int_{4\pi} \sigma_{\Omega} \vec{n}_0 d\Omega \quad (27)$$

where v is the velocity of radiation and \vec{n}_0 a unit vector directed along the longer axis of the ellipse. The derivation in the Appendix yields the following formula

$$\left| \vec{F} \right|_{\text{recoil}} \simeq \frac{\varepsilon P}{3c} \text{ [N]} \quad (28)$$

This recoil force should be equal to the gravitation force

$$\left| \vec{F} \right|_{\text{grav}} = \left| \vec{g} \right| M \text{ [N]} \quad (29)$$

Equating the above formulae yields the power P

$$P = \frac{3c \left| \vec{g} \right| M}{\varepsilon} \quad [\text{W}] \quad (30)$$

Evidently, the calculation of the value of P requires the knowledge of the value of the eccentricity ε . Following the procedure of defining the eccentricity for electrostatic fields [2] let us define

$$\varepsilon = \frac{\left| \vec{g} \right|}{\left| \vec{g} \right|_{\max}} \quad (31)$$

where $\left| \vec{g} \right|_{\max}$ is defined by the Eq.(25). We get the following simple formula

$$P = 3c \left| \vec{g} \right|_{\max} M \approx 6.82 \times 10^{21} M \quad [\text{W}] \quad (32)$$

For the model of two parallel plates covered with a mass density $\rho_M/2$ [kg/m²], the Eq.(32) takes the form

$$P = 3c \left| \vec{g} \right|_{\max} \frac{\rho_M}{2} = 3.41 \times 10^{21} \rho_M \quad [\text{W/m}^2] \quad (33)$$

having the dimensions of the Poynting vector of electromagnetic theory. The Table 3 presents the value of P for selected bodies.

TABLE 3

Name	Mass [kg]	Power [W]
Elektron	9.109×10^{-31}	6.21×10^{-9}
Neutron	1.675×10^{-27}	1.142×10^{-5}
Autor	88	6.00×10^{23}
Earth	5.973×10^{24}	4.073×10^{46}
Moon	7.347×10^{22}	5.07×10^{44}
Sun	1.989×10^{30}	1.356×10^{52}
Planck mass	2.176×10^{-8}	1.479×10^{14}
Neutron star	3.978×10^{30}	2.713×10^{52}

9. The surface energy density of the isotropic radiation of the power P

Consider the isotropic radiation of a sphere with the total power given by the Eq. (32). The energy radiated in an elementary time dt is $E_{dt} = Pdt$ [J]. The elementary volume around the sphere is $dV = 4\pi R^2 dr = 4\pi R^2 c dt$. Therefore, the surface energy density of the isotropic radiation is

$$\sigma_P = \frac{Pdt}{4\pi R^2 c dt} = \frac{P}{4\pi R^2 c} \text{ [J/m}^3\text{]} \quad (34)$$

The insertion of (32) yields

$$\sigma_P = \frac{6.82 \times 10^{21} M}{4\pi R^2 c} = \frac{6.82 \times 10^{21} \rho_M}{c} = 2.275 \times 10^{13} \rho_M \text{ [J/m}^3\text{]} \quad (35)$$

The insertion of data for ρ_M from Table 1 yields the following values of σ_P : Neutron – 4.73×10^{15} , Earth – 2.664×10^{26} , Neutron Star – 1.933×10^{34} . For comparison the surface energy density of the gravitational field of the sphere is

$$\sigma_g = \frac{\rho_M^2}{2\gamma} \text{ [J/m}^3\text{]} \quad (36)$$

The ratio is

$$\frac{\sigma_P}{\sigma_g} = \frac{7.085 \times 10^{22}}{\rho_M} \quad (37)$$

Again using the data of Table 1 the value of this ratio is: Neutron – 3.4×10^{20} , Earth – 6.05×10^{12} , Neutron Star – 85.3.

Let us repeat the same comparison for the Einstein's energy density of sphere

$$\sigma_{Einstein} = \rho_V c^2 = \frac{3\rho_M c^2}{R_0} \text{ [J/m}^3\text{]}. \quad (38)$$

We get

$$\frac{\sigma_P}{\sigma_{Einstein}} = 8.44 \times 10^{-5} R_0 \quad (39)$$

10. The decay time of the neutron assuming lack of energy absorption from QV.

We explained the nature of gravitation assuming that particles are in a dynamic energy equilibrium with QV, i.e., are absorbing and emitting energy with zero balance. Let us calculate the time of decay of the neutron in case of the lack of absorption. Usually such a decay is exponential in time. Let us apply a simplification that the time of decay is

$$t = \frac{\text{Einsteins energy } mc^2}{\text{Power of emission}} = \frac{1.5 \times 10^{-10}}{1.142 \times 10^{-5}} = 1.3 \times 10^{-5} \text{ [s]} \approx 13 \text{ [\mu s]}$$

This value appears to be short. However it contains about 3×10^{18} Compton periods (Compton period is a reciprocal of the Compton frequency which for the neutron equals 2.27×10^{23} [Hz]). For illustration the counting of the above number of periods of a cesium atomic frequency clock (frequency 9.192... [GHz]) requires a time of about one year.

11 . A trial to estimate the frequency range of the energy exchange.

The frequency range of the isotropic energy exchange between particles and quantum vacuum can be studied using the spectral energy density of the QV defined by Eq. (13).

$$E_{(f_1, f_2)} = \frac{\pi h}{c^3} (f_2^4 - f_1^4) \text{ [J/m}^3\text{]} \quad (40)$$

Let us investigate the frequency band

$$\Delta f = f_c [(1+a) - (1-a)] \quad ; \quad a < 1 \quad (41)$$

The insertion in (40) yields

$$E_{(f_1, f_2)} = \frac{8\pi h f_c^4}{c^3} (a+a^3) \text{ [J/m}^3\text{]} \quad (42)$$

Equating this energy density with another energy density, for example given by (35) yields

$$(a+a^3) = \frac{\sigma_p c^3}{8\pi h f_c^4} \quad (43)$$

The value of the center frequency is unknown and should be *estimated* by other arguments. The value of a should be calculated numerically. For $a \ll 1$, $(a+a^3) \sim a$.

Example: For the neutron: Let us insert $f_c = 2.27 \times 10^{23}$ (Compton f.) and $\sigma_p = 4.73 \times 10^{15}$ (see data for Eq.(40)). We get $a = 2.88 \times 10^{-21}$, i.e., an extremely narrow frequency band. The choice of a lower value of f_c yields a larger value of a . In the limit for $f_c = 1.66 \times 10^{18}$ [Hz], we get $a = 1$ with a frequency band from zero to $2f_c$. The Eq.(41) defines a rectangular frequency domain window. Other windows could be applied. However, at present there is no need to apply sophisticated calculations. Concluding, for f_c equal to the Compton frequency, the radiated signal is monochromatic and for $a = 1$ it has the form of a noise signal. The calculations show that the radiation energy density is small w.r.t. the energy density of the vacuum.

12. Remarks and conclusions

The fact that the Quantum Vacuum is a medium with extremely high energy density is nowadays accepted by the scientific community. For example see references [4] and [5]. Moreover, experiments of creation particles using the energy of QV are in progress [6]. This makes the hypothesis that particles exist due to continuous energy exchange with QV in a dynamic energy equilibrium highly probable. It would be unreasonable to assume that particles are separated from the QV by “splendid isolation”. Using this hypothesis the author derived a formula for computation the power of the radiation emitted by a spherical mass. The values of this power are high, however, are not high in comparison to the extremely high energy density of the QV. The calculation was possible due to the determination of the eccentricity of the radiation pattern using the maximum possible value of any gravitational field. The derivation gave the right sign of the recoil force due to the fact that gravitation lowers the energy density of the QV. We assume that negative energy of the QV doesn't exist. At present we don't know why the gravitational field lowers the energy density of the QV. The gravitational fields reaching the Earth from far sources are of low intensity. For example, the gravitation of the Sun equals only 0.0006 of the surface gravity of Earth ($9.798 \text{ [m/s}^2\text{]}$). Due to the large distance from the Sun it is practically the same at the day and night sides. This weak field enforces a strong recoil force which keeps the Earth on Kepler's orbit. The long range weak gravitation is converted to a local strong recoil force. This could be classified as a kind of amplification.

In the model of two parallel planes the inside g-field is cancelled. This state of the vacuum differs from the state where we don't have fields of opposite direction. The evidence is given by the fact that the field generated by the plate B reappears at the outer side of the plate A. This shows that hypothetical gravitons which are flowing inside the plates in opposite directions do not collide. The volume inside the planes could be called a Lagrange volume corresponding to Lagrange points in the system Sun-Earth.

Our numerical results depend on the maximum possible value of the intensity of any gravitational field. The eventual application of another value of this constant will change only numerical results.

We are aware that the presented hypothesis about the recoil nature of gravitational forces should be verified experimentally. An indirect evidence is given by the model of

two parallel planes. Due to Eq, (7) the pressure in the outside volume is lower w.r.t the inside. This should yield a repulsive force while certainly we have attraction, Last remark: In frame of the above hypothesis anti-gravity don't exists.

References

- [1] S. Hahn, "Die Deutung der Kraft auf ein Elektron im Elektrostatischen Feld als Rückstasskraft", *Kleinheubacher Berichte*, Band 20, 1976, ss.145-149.
- [2] S.L. Hahn, „The recoil nature of electrostatic and gravitational forces“, *Bulletin of the Polish Academy of Sciences*, Technical Sciences, vol.35, No.4, 2007, pp. 405-410.
- [3] H.E. Puthoff, "Quantum Vacuum Fluctuations: A New Rosetta Stone of Physics?", <http://www.idolphin.org/zpe.html>
- [4] T. Valone, *Zero Point Energy: The Fuel of the Future*, Integrity Research Institute, 2007.
- [5] To get information about experiments of producing particles from the energy of QV click "Creation of matter by a laser beam".

Let us quote some recent papers about the nature of gravity with no comment from our side.

A.A. Larson, A Discussion on the True Nature of Gravity and Inertia, NM 2012 Proceedings of the NPA

U.W. Massie, Gravity and Zero Point Energy, *Physics Proceedia*, 18 (2012) 280-287, on line www.sciencedirect.com

M.R. Edwards, Gravity from refraction of CMB photons using the optical-mechanical analogy in general relativity, *Astroph. Space Sci.*,(2014) 351, 401-406.

M.E. McCulloch, Gravity from the uncertainty principle, *Astroph. Space Sci.*, (2014), 349, 957-959.

Appendix 1

Derivation of the recoil force for an ellipsoidal power radiation pattern

We assume that the angular power radiation pattern (power density per unit solid angle) is given by the rotation around the longer axis of the ellipse

$$\sigma_{\Omega} = \sigma_{\max} \frac{1 - \varepsilon^2}{1 + \varepsilon \cos(\varphi)} \text{ [W/Ster]} \quad (\text{A1})$$

where ε is the eccentricity of the ellipse. This formula uses polar coordinates centered in the focus of the ellipsoid. The recoil force is given by the integral

$$\vec{F} = \frac{v}{c} \int_{4\pi} \sigma_{\Omega} \vec{n}_0 d\Omega \quad (\text{A2})$$

where v is the velocity of radiation and \vec{n}_0 a unit vector directed along the longer axis of the ellipse. The insertion of (A1) and using the projection of the radius centered in the focus on the longer axis ($\cos(\varphi)$) yields

$$|\vec{F}| = \frac{v}{c^2} \int_{4\pi} \frac{(1-\varepsilon^2)\cos(\varphi)}{1+\varepsilon\cos(\varphi)} d\Omega \quad (\text{A3})$$

We get inserting $v = c$

$$|\vec{F}| = \frac{\sigma_{\max}}{c} \int_0^{2\pi} \int_0^{\pi} \frac{(1-\varepsilon^2)\cos(\varphi)\sin(\varphi)}{1+\varepsilon\cos(\varphi)} d\varphi d\psi \quad (\text{A4})$$

The evaluation of the integral yields

$$|\vec{F}| = \frac{\sigma_{\max}}{c} f_1(\varepsilon) \quad (\text{A5})$$

where

$$f_1(\varepsilon) = \left[\frac{1-\varepsilon^2}{\varepsilon} \log(1-\varepsilon^2) + (1-\varepsilon^2) \sum_{n=1}^{\infty} \frac{\varepsilon^{2n-1}}{n(2n-1)} \right] 2\pi \quad (\text{A6})$$

However, σ_{\max} should be normalized to keep the total power P independent on ε . The power gain of the ellipsoid is given by the formula

$$G = \frac{4\pi}{B} \quad (\text{A7})$$

where B is the equivalent solid angle

$$B = \int_0^{2\pi} \int_0^{\pi} \frac{1-\varepsilon^2}{1+\varepsilon\cos(\varphi)} \sin(\varphi) d\varphi d\psi = f_2(\varepsilon) \quad (\text{A8})$$

where

$$f_2(\varepsilon) = \left[(1-\varepsilon^2) \log\left(\frac{1+\varepsilon}{1-\varepsilon}\right) \right] 2\pi \quad (\text{A9})$$

Since $\sigma_{\max} = PG$, we get

$$\sigma_{\max} = \frac{P}{f_2(\varepsilon)} \quad (\text{A10})$$

The insertion of (A10) in (A5) yields

$$|\vec{F}| = \frac{P}{c} \frac{f_1(\varepsilon)}{f_2(\varepsilon)} \quad (\text{A11})$$

If $\varepsilon \ll 1$, the ratio $f_1(\varepsilon)/f_2(\varepsilon) \approx \varepsilon/3$.

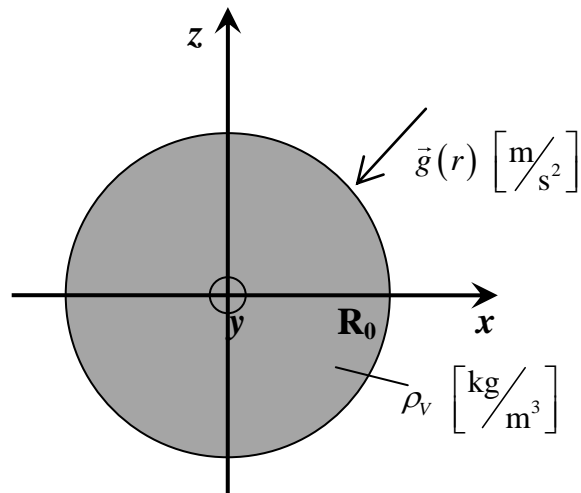


Fig.3. Cross section of a sphere with a uniform mass density ρ_v .

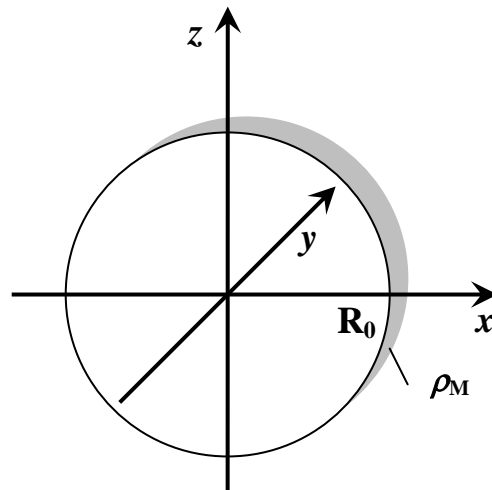


Fig.4. The cross section of a hollow sphere with a uniform surface mass density ρ_M .

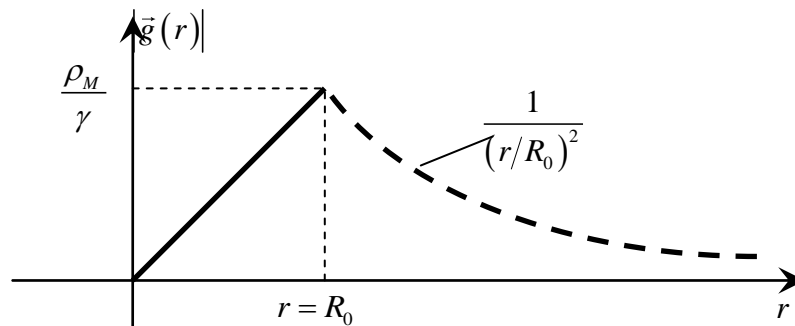


Fig. 5 The intensity of the g-field of the sphere of Fig.1 as a function of the distance r .

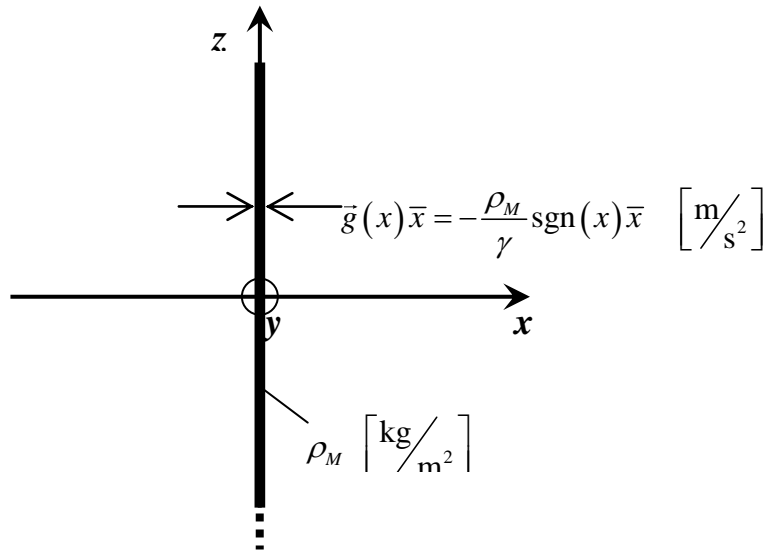


Fig.6 An infinite plane covered by a uniform surface mass density ρ_M .

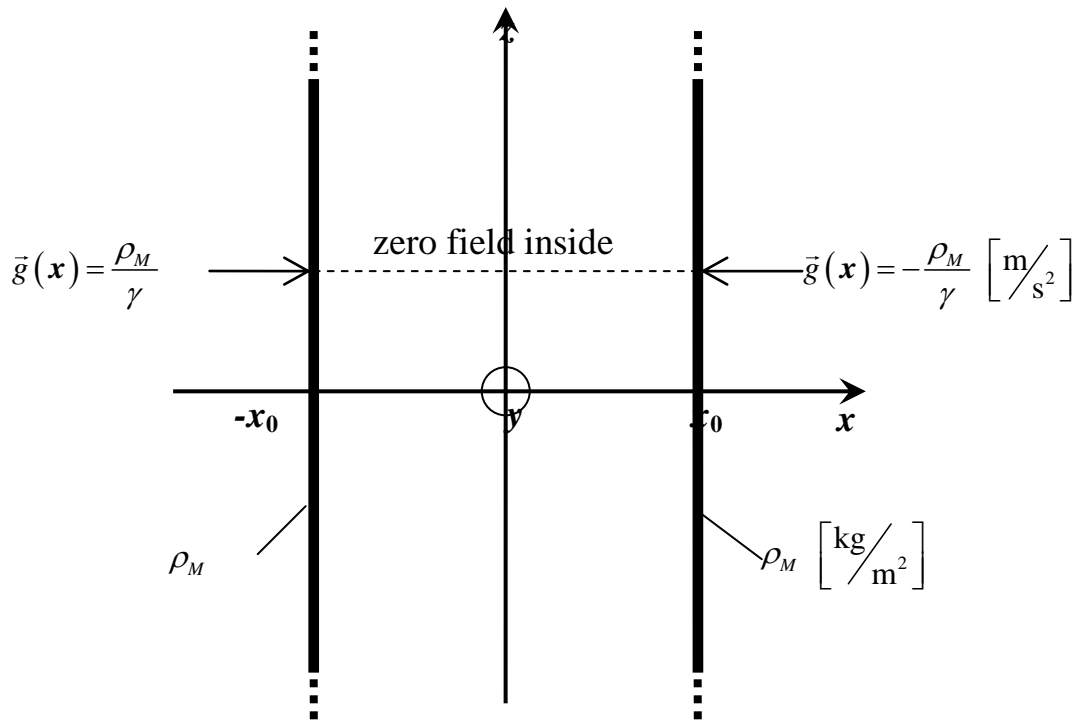


Fig.7. Two parallel planes of Fig.6.

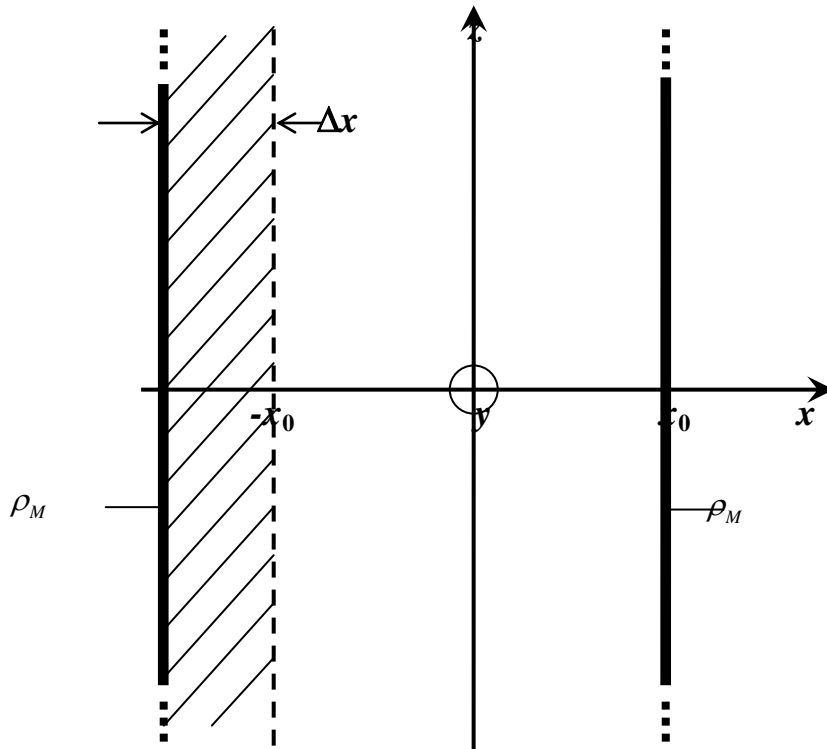


Fig. 8. The shift of the left plane enlarges the volume without the g-field. The cancellation of the g-field requires an input of positive energy since the planes attract. Therefore the energy of the cancelled field is negative. The same evidence is given by calculation of the energy of the g-field of the spherical body of Fig.3. If for a mass $2M$ this energy equals E then for two bodies of a mass M this energy for each body equals $E//4$, i.e. one half of E is cancelled. The separation of these bodies shifting one body to infinity requires an input of positive energy. Evidently the cancelled energy is negative.