MAGNETISM AS MANIFESTATION OF GRAVITATION

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ABSTRACT

Defining the center of self gravity (or gravitation; both expressions are equivalent in the present-day usage) as the point at which the Earth's gravitational field is zero, and using that center of the self gravity of the Earth as the coordinate origin of the geophysical coordinate system, not the center of mass as used erroneously so far, the motion of a suspended or pivoted needle made of any non-ferromagnetic material is analyzed by applying strictly the classical Newtonian mechanics, which results in a new gravitational theory of the origin of the conventional Earth's magnetic field. A gravitational experiment with a pivoted thin bronze needle is described in the attached appendix. That needle assumes after the very slow rotation the North-South direction identical to the N-S direction of an ordinary magnetic compass. All known facts about the planetary and solar large-scale magnetic fields are compared how they fit into this gravitational model of the Earth's magnetic field and into the dynamo theory of the origin of the Earth's magnetic field, which theory appears to fail in some instances, namely connected with the reversal of the Earth's magnetic field and with the large-scale magnetic field of the Sun and of the planet Mercury.

INTRODUCTION

The large-scale Earth's magnetic field was recognized very long time ago and utilized for navigation for centuries, but its origin remains still a mystery. The Earth was considered to be a large permanent magnet, but that view had to be abandoned after the experiments in 1895 by Pierre Curie, see [1] and [2] for more details. The present day view is that the Earth's magnetic field is due to a dynamo action inside the Earth, see [2].

It is strange to realize that the gravitation was never attempted to account for the Earth's magnetic field. The explanation for this strange fact is that the two important points inside any celestial body, including the Earth, were never strictly distinguished, often erroneously interchanged and even considered as one single point, which is totally wrong. These two points are the center of self gravity and the center of mass. The center of self gravity is defined as the point inside the mass distribution of a celestial body at which the self gravity is zero. It is a unique point inside any mass distribution. The center of mass of a mass distribution is the point inside that mass distribution with respect to which the first mass dipole moment of that mass distribution is zero by definition. It is also a unique point under the same assumptions. It is easy to see that these two points never coincide for any real celestial body, unless that celestial body is perfectly symmetrical, which never occurs in nature. It will be shown that with these two points clearly distinguished and properly utilized, it is possible to form applying strictly the classical Newtonian mechanics a consistent, strict and logical model to account for the large-scale magnetic field and the regional ferromagnetism, if present, of any celestial body exclusively by gravitation without any need for the electrical currents, although they may be present especially in the case of the extremely hot celestial bodies like the Sun and the stars. Magnetism appears to be a manifestation of gravitation.

EARTH'S GRAVITATIONAL FIELD

The Earth's gravitational field is an old established subject dating back to Sir Isaac Newton, who in his famous Principia published in 1687 established the foundation of modern physics. The Earth's gravitational field in the accepted present day formalism and notation is the solution of the differential equation

$$\nabla \cdot \vec{g}_e = 4\pi G \rho_{me} , \quad (1)$$

where ρ_{me} is the specified mass distribution per volume of the Earth, and G is the universal gravitational constant, whose value in the MKS system of units is $G = 6.67 \times 10^{-11} kg^{-1} m^3 s^{-2}$. By definition, the test point mass m experiences the force in the Earth's gravitational field $\vec{g}_e$ given by

$$\vec{F} = m\vec{a}\,' = -m\vec{g}_e , \quad (2)$$

where $\vec{a}\,'$ is the acceleration of that point mass m with respect to the coordinate system which does not rotate with the Earth. Let $\vec{a}$ denote the acceleration of that test point mass in the coordinate system which rotates with the Earth with the constant angular velocity $\vec{\omega}$ with the common coordinate origin for both coordinate systems, then

$$m\vec{a} = -m\vec{g}_e - m\vec{\omega} \times (\vec{\omega} \times \vec{r}) - 2m\vec{\omega} \times \vec{v}, \quad (3)$$

where $\vec{r}$ is the position vector of that test point mass and $\vec{v}$ is its velocity in that rotating coordinate system. The Equation (3) can be found in any comprehensive modern textbook of classical Newtonian mechanics. The second term in (3) is the centrifugal acceleration, while the third term is the Coriolis acceleration.

The solution of the Equation (1) for the specified mass distribution ρ_{me} at the point of observation defined by the position vector $\vec{r}$ is given by

$$\vec{g}_e = G \int \frac{\rho_{me} (\vec{r} - \vec{r}\,') dV\,'}{\left| \vec{r} - \vec{r}\,' \right|^3} = -\nabla U_e . \quad (4)$$

The scalar gravitational potential U_e of the Earth is given by

$$U_e = G \int \frac{\rho_{me} dV\,'}{\left| \vec{r} - \vec{r}\,' \right|} . \quad (5)$$

The point of observation as specified by the position vector $\vec{r}$ can be inside as well as outside the mass distribution, and the integrals in (4) and (5) are well defined under some very broad conditions.

For the points of observation outside the mass distribution and on the surface of the Earth, the potential U_e is now developed into the Taylor series

$$U_e = \frac{G}{|\vec{r}|}\int \rho_{me} dV' + \frac{G}{|\vec{r}|^3}\int \vec{r}\cdot\vec{r}\,'\rho_{me} dV' + \dots \quad . \tag{6}$$

The total mass M_e of the Earth is

$$M_e = \int \rho_{me} dV' \quad , \tag{7}$$

and $\vec{M}_{1e}$ is the first mass dipole moment of the Earth

$$\vec{M}_{1e} = \int \vec{r}\,'\rho_{me} dV' \quad . \tag{8}$$

Retaining only the monopolar term and the dipolar term as the first approximation, the Equation (6) is written in the form

$$U_e = \frac{GM_e}{|\vec{r}|} + \frac{G\vec{M}_{1e}\cdot\vec{r}}{|\vec{r}|^3} = U_{0e} + U_{1e} \quad . \tag{9}$$

To repeat once more, all these expressions can be found in any comprehensive modern textbook of classical Newtonian mechanics and the potential theory.

There are obviously the two physically very important points for any mass distribution, including, of course, the Earth. Using the Equation (8) the center of mass of the Earth is defined by

$$\vec{r}_{cme} = \frac{1}{M_e}\int \vec{r}\,'\rho_{me} dV' \quad , \tag{10}$$

where M_e is the total mass of the Earth given by (7). The other important point is the center of self gravity of the Earth, i.e., the point at which $\vec{g}_e$ given by (4) is equal to zero. Let $\vec{r}_{cge}$ be the position vector of the center of self gravity of the Earth, then by definition

$$\vec{g}_e(\vec{r}_{cge}) = G\int \frac{\rho_{me}(\vec{r}_{cge} - \vec{r}\,')dV'}{|\vec{r}_{cge} - \vec{r}\,'|^3} = 0 \quad . \tag{11}$$

It is obvious from the definitions (10) and (11) that these two points can never coincide for the Earth, or any real celestial body, except in the case of the perfect symmetry of a celestial body, which never occurs in nature. Clearly, all above definitions can be applied to any material body, as well as for any elementary particle.

The center of self gravity must be used as the natural coordinate origin in the calculation of the gravity in order to obtain the best approximation for the gravity, including the very important dipolar term. The first mass dipolar moment with respect to the center of self gravity is defined as the intrinsic first mass dipolar moment of the observed mass distribution. A body acts with its self gravity from its center of self gravity upon the center of mass of the other body as the first approximation. And vice versa, the other body reciprocates in the same manner upon the first body. There is a very important moment of force between the two gravitationally interacting bodies which is obvious, if those bodies are approximated as point masses and point intrinsic mass dipolar moments as the first approximation in the calculation of the gravitational interaction. A serious error is made if the center of mass is used as the origin of the coordinate system of reference in the calculation of the gravity. The dipolar term disappears as the consequence from the gravity expansion formula (9) by definition with the consequential serious error in the calculation from the point of view of the theory of approximation.

Also, as the consequence, the body appears only as a point mass, thus loosing the character of a body. A celestial body, or any material body regardless of its size, is properly and best characterized and represented in the first approximation by its point mass, i.e., its total mass and its intrinsic point–like first mass dipolar moment, thus retaining the essential quality of a material body through its physically very important two centers of mass and self gravity. It must be emphasized that these two characteristic quantities of a mass distribution, i.e., its total mass and its intrinsic first mass dipolar moment are independent of the choice of the coordinate system. They are the two intrinsic invariants of a mass distribution, but obviously subject to variation if the mass distribution is varying.

INTERNATIONAL GRAVITY FORMULA

Using the experimental data about the Earth and assuming the center of mass as the origin of the coordinate system of reference, i.e., only the monopolar term is used as the consequence, the International Gravity Formula is obtained for the stationary test point mass, i.e., the Coriolis acceleration is dropped since the test point mass is at rest, in the following form (see [3], p. 79)

$$g = 9.780490(1 + 0.0052884\sin^2\lambda - 0.0000059\sin^2 2\lambda) \quad m/s^2 \ , \tag{12}$$

where λ is the geographic latitude. The second term in the parenthesis is due to the rotation of the Earth, while the third term is assumed for fitting and has no physical meaning.

This Formula (12) does not show explicitly the dependence on r and φ, but the flattening $f^{-1} = 298.5$ must be used for the northern hemisphere, and the flattening $f^{-1} = 297.3$ for the southern hemisphere (see p. 79, [3]). This fact suggests that the dipolar term should be present in the correct Earth's gravity formula. The dipolar term is not present in the IGF (12), which is a serious error from the point of view of the theory of approximation in the numerical calculations, unless the center of mass and the center of self gravity of the Earth coincide, which is physically impossible in view of the fact that the real Earth is far from being perfectly symmetrical. Even the sea level, which is the reference for the IGF (12), is relative and questionable for the real Earth and subject to various changes. So it is quite natural that the actual Earth's gravity measurements exhibit many noticeable deviations and anomalies with reference to the IGF (12), which is obviously inadequate.

GRAVITATIONAL DIPOLE-DIPOLE INTERACTION

The International Gravity Formula (12) is obviously inadequate, but it is not the purpose of this paper to propose a new Earth's gravity formula. That task should be undertaken only after many additional geophysical measurements. But this paper will show that the absence of the dipolar term in the Earth's gravity formulas so far, i.e., the erroneous and inappropriate choice of the center of mass of the Earth as the origin of the geophysical coordinate system of reference, and the error and the delusion about the center of mass and the center of self gravity of the Earth are responsible that an obvious mathematical model, namely, the gravitational dipole-dipole interaction was never conceived so far and considered and analyzed as a possible mathematical model based on gravitation to account for geomagnetism and planetary, solar and stellar large-scale magnetic fields.

The Equation (9), which is repeated here for convenience

$$U_e = \frac{GM_e}{|\vec{r}|} + \frac{G\vec{M}_{1e} \cdot \vec{r}}{|\vec{r}|^3} = U_{0e} + U_{1e} \tag{9}$$

is the first approximation for the potential of the Earth's gravity field, excluding the centrifugal and the Coriolis acceleration, for the observation points on the surface of the Earth and all outside points. This Equation (9) means that as the first approximation, the Earth's gravitational field is the superposition of the two gravitational fields, one due to a point mass monopole and the other due to a point mass dipole. The point mass dipole may be formally represented by two point masses, one positive and the other negative, which coincide with each other as the limiting case. This formal representation is not necessary. The only quantity which is important is the intrinsic first mass dipolar moment $\vec{M}_{1e}$ given by the Equation (8), which is calculated by definition with respect to the center of self gravity of the Earth.

The test object for the detection and the observation of the Earth's gravitational field as used so far from Galileo and Newton till the present days is a small sphere-like object, the legendary apple, small enough compared to the Earth to be considered as a point mass. That is how the point mass model came to be used on the Earth and within the planetary system as the presumably logical extension. But the Equation (9) shows unmistakably that the Earth's gravity is better approximated as a point mass and a point mass dipole. In order to preserve the consistency and logic, it is appropriate to define and to use as a test object for the observation of the Earth's gravitational field an object which is formally similar to the Earth, but very, very much smaller compared to the Earth, a point "Earth" so to speak of the molecular or even atomic size. That test object is defined by its point mass m, i.e., its total mass m, which is a scalar, and its point intrinsic mass dipolar moment $\vec{m}_1$, which is a vector by definition. But from the practical point of view, that test object is in reality, say, a very tiny rod-like or needle-like object whose non-magnetic mass is distributed non-uniformly along its length, so that for that test object its center of self gravity and its center of mass are clearly distinguished and defined with its intrinsic first mass dipolar moment $\vec{m}_1$ along its length strictly defined. Such a test object is especially very important to observe its interaction with the Earth's gravitational field, when that test object is suspended or pivoted at a point on the surface of the Earth.

Assume now that the above defined test object with its point mass m and its intrinsic first mass dipolar moment $\vec{m}_1$ is suspended or pivoted on the surface of the Earth about its center of mass, so that it can rotate in the horizontal as well as the vertical plane. The point of suspension P_s is defined by the position vector $\vec{r}_s$ from the center of self gravity of the Earth. Thus the Earth's gravity is balanced by the contact force of the suspended system, but the rotation is freely possible. Friction is assumed to be negligible.

Let ρ_{m1} be the volume mass distribution of that test suspended object. By definition the torque exerted only by the Earth's gravitational field $\vec{g}_e = -\nabla U_e$, Equation (9) for U_e, is

$$\vec{T} = \int \vec{r}\,' \times (-\rho_{m1} \vec{g}_e dV') , \tag{13}$$

where $\vec{r}\,'$ is the position vector of integration from the suspension point P_s. It is obvious that if $\vec{g}_e$ is uniform, so that it can be brought before the integral sign, the result is zero, i.e.

$$\vec{T} = \vec{g}_e \times \int \rho_{m1} \vec{r}\,' dV' = 0 \tag{14}$$

in view of the assumption about the suspension point. The conclusion is that only due to the non-uniformity of $\vec{g}_e$ the torque (13) can yield a non-zero value.

Introducing the proper expressions for $\vec{g}_e = -\nabla U_e$, U_e given by (9), we obtain

$$\vec{T} = \int \rho_{m1} \frac{GM_e(\vec{r}_s + \vec{r}\,') \times \vec{r}\,'}{\left|\vec{r}_s + \vec{r}\,'\right|^3} dV' - \int \rho_{m1} \frac{G\vec{M}_{1e} \times \vec{r}\,'}{\left|\vec{r}_s + \vec{r}\,'\right|^3} dV' +$$
$$+ \int \rho_{m1} \frac{3G[\vec{M}_{1e} \cdot (\vec{r}_s + \vec{r}\,')](\vec{r}_s + \vec{r}\,') \times \vec{r}\,'}{\left|\vec{r}_s + \vec{r}\,'\right|^5} dV' \quad ,$$

or, after some obvious simplifications and since $\left|\vec{r}_s\right| >> \left|\vec{r}\,'\right|$, approximately

$$\vec{T} \approx GM_e \vec{r}_s \times \int \frac{\vec{r}\,' \rho_{m1} dV'}{\left|\vec{r}_s + \vec{r}\,'\right|^3} - G\vec{M}_{1e} \times \int \frac{\vec{r}\,' \rho_{m1} dV'}{\left|\vec{r}_s + \vec{r}\,'\right|^3} + \tag{15}$$
$$+ 3G(\vec{M}_{1e} \cdot \vec{r}_s)\vec{r}_s \times \int \frac{\vec{r}\,' \rho_{m1} dV'}{\left|\vec{r}_s + \vec{r}\,'\right|^5} \quad .$$

The suspended object was assumed to be rod-like, i.e., cylindrical with the axis well defined and its intrinsic first mass dipolar moment $\vec{m}_1$ directed along this axis. It is concluded that the two integrals in (15) must be the vector quantities along the same axis, i.e., proportional to $\vec{m}_1$, especially if the axial symmetry of that test object is assumed. Thus

$$\int \frac{\vec{r}\,' \rho_{m1} dV'}{\left|\vec{r}_s + \vec{r}\,'\right|^3} = k_3 \vec{m}_1 \quad , \tag{16}$$

and

$$\int \frac{\vec{r}\,' \rho_{m1} dV'}{\left|\vec{r}_s + \vec{r}\,'\right|^5} = k_5 \vec{m}_1 \quad , \tag{17}$$

where k_3 and k_5 are the scalar quantities which depend on the geometry of that test object and its non-homogeneous mass distribution. Hence

$$\vec{T} = GM_e k_3 \vec{r}_s \times \vec{m}_1 - Gk_3 \vec{M}_{1e} \times \vec{m}_1 + 3Gk_5 (\vec{M}_{1e} \cdot \vec{r}_s)\vec{r}_s \times \vec{m}_1 \quad . \tag{18}$$

This is an interesting result. Note that the vector $\vec{M}_{1e}$ generally has a component along $\vec{r}_s$, which is practically the vertical direction, as well as a component normal to that direction, i.e., in the horizontal plane. Thus, the torque (18) tends to align $\vec{m}_1$ with the vertical direction and also in the direction of the horizontal component of the vector $\vec{M}_{1e}$. The balancing direction of the vector $\vec{m}_1$, i.e., of the rod-like or needle-like suspended object, depends on many factors, but mainly on the position of the suspension point along that suspended rod-like object, since the center of mass, which is assumed to be the suspension point, may be very difficult to be determined in practice, i.e., always in the non-uniform gravitational field. Nevertheless, the suspended rod-like object with the non-homogeneous mass distribution along its length must assume an angle with respect to the vertical direction, and an angle measured in the horizontal plane from the North, which angle depends only on the vector $\vec{M}_{1e}$, which is, to repeat once more, the intrinsic first mass dipolar moment of the Earth. These angles may be referred to as the inclination and the declination respectively, to use the terminology associated with the magnetic compass. In view of the geophysical data, $\vec{M}_{1e}$ is directed from the southern to the northern hemisphere of the Earth. It must be determined experimentally.

In principle it is always possible to slightly move the suspension point and find such a point of suspension for which the first term, the third term and the appropriate portion of the second term in the Equation (18) cancel each other, which is written mathematically

$$\left\{GM_e k_3 \vec{r}_s - Gk_3 \vec{M}_{1ev} + 3Gk_5 (\vec{M}_{1e} \cdot \vec{r}_s)\vec{r}_s\right\} \times \vec{m}_1 = 0 ,$$

i.e.,

$$M_e k_3 \vec{r}_s - k_3 \vec{M}_{1ev} + 3k_5 (\vec{M}_{1e} \cdot \vec{r}_s)\vec{r}_s = 0 , \tag{19}$$

where $\vec{M}_{1ev}$ is the vertical component of $\vec{M}_{1e}$.

Thus, the Equation (18) reduces to

$$\vec{T} = -Gk_3 \vec{M}_{1eh} \times \vec{m}_1 \quad . \tag{20}$$

This formula (20) defines mathematically the gravitational dipole-dipole interaction subject to all above stated assumptions. Note that $\vec{M}_{1eh}$ is the horizontal component of the vector $\vec{M}_{1e}$. This gravitational dipole-dipole interaction has been derived applying strictly the laws and the rules of the classical Newtonian mechanics. This is mathematically identical to the magnetic needle in the conventional Earth's magnetic field. It must be emphasized that this mathematical model collapses totally and is not possible to be recognized, if the origin of the geophysical coordinate system is moved from the center of self gravity of the Earth to the center of mass of the Earth. Thus, it appears that this mathematical model bears some resemblance to the heliocentric theory of Mikolaj Kopernik, or of his forerunner and harbinger Aristarchos of Samos some 18 centuries earlier, since in the both cases, the correct choice of the proper coordinate system leads to truth and solution.

It is easy to show that the centrifugal acceleration $\vec{a}_c$ (the second term in the Equation (3)) does not exert a noticeable torque on the suspended rod-like object subject to all previous assumptions and approximations used in the derivation of (15). Namely,

$$\begin{aligned} \vec{T}_c &= \int \vec{r}\,' \times \rho_{m1} \vec{a}_c dV' = -\int \vec{r}\,' \times \rho_{m1} \{\vec{\omega} \times [\vec{\omega} \times (\vec{r}_s + \vec{r}\,')]\} dV' \approx \\ &\approx -|\vec{\omega}|^2 \vec{r}_s \times \int \rho_{m1} \vec{r}\,' dV' + (\vec{\omega} \cdot \vec{r}_s)\vec{\omega} \times \int \vec{r}\,' \rho_{m1} dV' \quad . \end{aligned} \tag{21}$$

This torque $\vec{T}_c$ is zero if the suspension point of the suspended rod-like object is at its center of mass as it was assumed. But when the suspension point is moved along the rod-like suspended test object, then this torque $\vec{T}_c$ must, in principle, modify somewhat the effect of the torque $\vec{T}$ (18), but by no means substantially, since the centrifugal acceleration due to the rotation of the Earth is only about 0.5 per cent of the Earth's gravity on the equator and zero on the poles. $\vec{\omega}$ is the vector from the South to the North along the axis of rotation of the Earth by definition for the right-hand coordinate system, which is, roughly, also the general direction of $\vec{M}_{1e}$, which is due probably mainly to the Earth's flattening The Coriolis acceleration is of no consequence, since the suspended test rod-like object is at rest when the balance is achieved.

The test rod-like object was introduced as an analogy to the Earth, a very tiny almost a point "Earth" so to speak with its point mass and its point mass dipolar moment. It is a fact that the mass distribution per volume ρ_{me} is not sufficient to define and describe the actual Earth at all its points. Some regions of the actual Earth are better described and defined as the conglomeration of the mass points, molecules or atoms, which are accompanied by the intrinsic point mass dipolar moments, which may be in some regions or domains aligned totally or partially, i.e., gravitationalized, or, shall we say, polarized or magnetized, which word was derived from the word magnet, i.e., the stone, a piece of the Earth from Magnesia, a region of Thesally in northern Greece, see Webster's Dictionary, College Edition. Designating by $\vec{M}_1$ the distribution of the intrinsic first mass dipolar moments per volume within a mass object, the gravitational potential due to such a distribution by generalization and analogy with U_{1e} in (9) is written in the form

$$U_d = G\int \frac{\vec{M}_1 \cdot (\vec{r} - \vec{r}\,')dV'}{\left|\vec{r} - \vec{r}\,'\right|^3} \quad . \tag{22}$$

It is obvious that this generalization introduces a new concept in the classical gravitational theory that various materials in nature are no longer defined only by their mass distribution functions, but also by their intrinsic mass dipolar moment distributions. Care must be taken to distinguish properly the macroscopic and the microscopic properties of the polarized or magnetized materials in order to fit the experimental data in the proper way. For instance, a rod may have the microscopic distribution of the mass dipolar moments, but it may also possess the macroscopic intrinsic dipolar mass moment, or it may be pivoted so to have the macroscopic mass moment with respect to the pivot point. The vector $\vec{M}_1$ in (22) is obviously defined with reference to the microscopic region. The analogy with the Earth's magnetic field is obvious. Note that $\vec{M}_1$ interacts only with the dipolar portion of the Earth's gravitational field in the case of the suspended or pivoted test rod. But obviously, if an object is falling freely in the Earth's gravitational field, it practically does not matter whether it possesses the microscopic mass dipolar moments or not, i.e., whether it is conventionally magnetized or not. The interaction with the Earth's magnetic field, i.e., the dipolar portion of the Earth's gravitational field according to this model, and of the magnetization of that falling object is practically negligible.

At the end of this paragraph the question must be asked and answered, why the effects of the torque given by (18), or (20) were never detected so far. The probable answer is that that torque (20) is very weak, and nobody was looking for it for reasons stated and discussed above in this paper. But that torque (20) must be present under the defined conditions, since otherwise, the classical Newtonian mechanics breaks down in this case, which is absurd from the logical point of view. The determination of the center of mass of the test rod-like object made of the non-homogeneous material in the non-uniform gravitational field is a very serious problem, whose exact solution may prove to be impossible. A pivoted needle made of the polarized or, shall we say, magnetized material, as such material was defined above, must certainly enhance the torque defined by (20), since that is a well-known magnetic compass needle, whose total first mass dipolar moment $\vec{M}_1 V_1$ interacts with the dipolar portion of the Earth's gravitational field in accordance with (20). V_1 is the volume of that needle whose $\vec{M}_1$ is assumed to be uniform along that needle. In that respect, it should be mentioned that the needle of an ordinary magnetic compass is slightly asymmetrical, with one leg slightly longer to offset the inevitable inclination by the obvious mass moment interacting with the Earth's gravitational field macroscopically with respect to the pivot point. This is essentially analogous to the mathematical condition of the Equation (19). Thus, it appears that the first intrinsic mass dipolar moment $\vec{M}_{1e}$ of the Earth multiplied by a suitable constant is the conventional Earth's magnetic dipole moment with some probably very minor influence, if any, of the Earth's angular velocity.

As the first approximation, the conventional Earth's magnetic field is $\vec{B}_{earth} = -\nabla U_{mage}$, where U_{mage} is the Earth's magnetic scalar potential given by (see [1])

$$U_{mage} = \frac{\mu_0}{4\pi} \frac{\vec{m} \cdot \vec{r}}{|\vec{r}|^3} \quad , \tag{23}$$

where $\vec{m}$ is the magnetic dipole moment of the Earth. From the above derived mathematical model it appears that that magnetic scalar potential of the Earth is, as the first approximation, directly proportional to the dipolar term U_{1e} of the Earth's gravitational potential given by the Equation (9) with the suitable constant of proportionality n_2 which must be determined experimentally. Thus,

$$n_2 U_{1e} = n_2 \frac{G\vec{M}_{1e} \cdot \vec{r}}{|\vec{r}|^3} = U_{mage} = \frac{\mu_0}{4\pi} \frac{\vec{m} \cdot \vec{r}}{|\vec{r}|^3} \quad . \tag{24}$$

According to the Equation (10), $\vec{M}_{1e} = \vec{r}_{cme} M_e$, where $\vec{r}_{cme}$ is the vector of the center of mass of the Earth with respect to the Earth's center of self gravity. Using numerical values for the Earth

$$M_e = 5.975 \times 10^{24} kg, \qquad |\vec{m}| = 8 \times 10^{22} Am^2 \quad ,$$

and the universal constants

$$G = 6.67 \times 10^{-11} \ kg^{-1} m^3 s^{-2} \ \text{and} \ \mu_0 = 4\pi \times 10^{-7} \ H/m \quad ,$$

the Equation (24) yields

$$n_2 |\vec{r}_{cme}| \approx 20 \quad . \tag{25}$$

Both these two quantities n_2 and $|\vec{r}_{cme}|$ must be determined experimentally.

It must be emphasized that the above approximation of the conventional Earth's magnetic field by one singe term U_{1e} is very crude. Namely, the Earth's magnetic scalar potential given by (23) contains roughly the influence of the ferromagnetic materials on and inside the Earth, wherever present, while U_{1e} is obviously only global. In order to add the influence of the ferromagnetic materials on and inside the Earth, the additional term U_d as defined by (22) must be added to the main term U_{1e} with the integration for the experimentally measured and specified $\vec{M}_1$ throughout the Earth. But that should be the separate task and the subject for another paper after many additional geophysical measurements.

Hence, the above analysis shows unmistakably that an "elementary magnet", i.e., a portion of the magnetic domain of a highly complex, non-linear ferromagnetic material which even partially memorizes its previous state and the field to which it was subjected, appears to be properly definable as a point mass m with an intrinsic point mass dipolar moment $\vec{m}_1$, which, when suspended or pivoted at the point defined by the position vector $\vec{r}$ on the surface in the Earth's gravitational field with its potential defined by the Equation (9), experiences a torque

$$\vec{T} = \vec{m}_1 \times (-\nabla U_{1e}) = -\vec{m}_1 \times \nabla \frac{G\vec{M}_{1e} \cdot \vec{r}}{|\vec{r}|^3}. \qquad (26)$$

This is a generalization of the Equation (20). In fact, it should be considered as the definition of the interaction between the two gravitational intrinsic point dipoles in the situation as considered in this paper. Note that this Equation (26) defines the inclination, i.e., the interaction-rotation in the vertical plane, as well as the declination, i.e., the interaction-rotation in the horizontal plane, while the Equation (20) defines only the interaction-rotation in the horizontal plane. That means that for the "elementary magnet", the condition expressed by the Equation (19) must be somewhat modified together with the obligatory inclusion of the centrifugal acceleration, which may be rather important in this case of the rather small quantities involved in this Equation (19). The more detailed model of the "elementary magnet" remains as a subject of the future research. The expression (26) is essentially identical to the corresponding expression in the conventional theory of geomagnetism.

CONCLUSION

It is obvious that the above mathematical model of the gravitational dipole-dipole interaction, which was derived by the application only of the laws and the rules of the classical Newtonian mechanics, can be consistently applied to the Earth’s magnetic field, whose origin is still a mystery, cf. [1] and [2]. The natural magnet, which word magnet was derived from Magnesia, since it is a stone, i.e., a piece of the Earth from Magnesia, a district of Thessaly in northern Greece (see Webster's Dictionary, College Edition), appears to be an object with the distribution of the quite small internal portions, called domains, which consist of the almost point structures with the intrinsic first mass dipolar moments with, of course, the inevitable mass points. The density of gravitization or “magnetization” is $\vec{M}_1$, i.e., the volume distribution of the intrinsic first mass dipolar moments $\vec{m}_1$. Note that $\vec{M}_1$, in view of the Equation (24), must be multiplied by the constant $4\pi n_2 G / \mu_0$ to be converted dimensionally and numerically into the conventional magnetization density per volume as defined in the classical electromagnetic field theory. Thus, this mathematical - gravitational model fits consistently, logically and easily into the existing theory of magnetism, which should be somewhat modified by this model.

This mathematical model shows that the Earth's magnetic field appears to be only a special manifestation of the Earth's gravitational field with its essential dipolar term, but the angular velocity of the Earth may have some minor influence. Of course, the influence of ferromagnetism is defined by the density of gravitization or "magnetization" as stated earlier above. This model is consistent with all experimental facts about geomagnetism, cf. [1]. The variations due to the Moon, the Sun, the planets, the continental drift, the earthquakes and the reversal of the Earth's magnetic field are the obvious straightforward consequences of this mathematical model. This model resolves completely and logically the enigma of the "missing magnetic monopoles", which turn out to be the ubiquitous mass monopoles. Also, this model eliminates totally the fictitious sheet-surface electrical currents associated with the permanent magnets by the conventional theory of magnetism. This model represents the true origin of the conventional Earth's magnetic field, or otherwise this model would represent the breakdown of the classical Newtonian mechanics.

The geological data show that the warm periods of the Earth with the melting of its polar ice caps were accompanied by the <u>increase</u> of the level of the oceans and the seas up to few meters - the floods as mentioned in the various legends, and by the <u>decrease</u> of the intensity of the conventional Earth's magnetic field, while the ice periods of the Earth were accompanied by the formation of the substantial polar ice caps with the <u>increase</u> of the intensity of the conventional Earth's magnetic field. These facts about those variations of the intensity of the conventional Earth's magnetic field are impossible to comprehend if the dynamo theory of the origin of the Earth's magnetic field is assumed. On the other hand, it is obvious that the melting of the Earth's polar ice caps with the <u>increase</u> of the ocean - see level must result in the <u>decrease</u> of the Earth's intrinsic dipolar mass moment, since the Earth becomes more spherical so to speak, and that means the decrease of the intensity of the Earth's magnetic field according to the mathematical-gravitational model as exposed in this paper, while the formation of the substantial Earth's polar ice caps during the ice ages - periods of the Earth must result in the <u>increase</u> of the intrinsic Earth's dipolar mass moment, i.e., in the <u>increase</u> of the intensity of the Earth's magnetic field according to this mathematical-gravitational model. The agreement of this model with the mentioned geological facts is obvious. The change of the Earth's warm and ice periods, i.e., the climatic variation of the Earth is presumably periodic and due to the variations of the direction of the Earth's axis of rotation according to the theory of Milankovic [4]. It appears at this moment that the Earth is approaching the warm period, but it is quite probable that due to the excessive fuel consumption of our civilization with the inevitable increase of the carbon dioxide, the warming of the Earth may be accelerated as the recent geophysical data about the increase of the temperature of Greenland indicate. Anyway, monitoring of the intensity of the Earth's magnetic field is obviously called for. The observed reported decrease of the intensity of the Earth's magnetic field of about 10-15 percent, see [5], is interpreted by some researchers as a beginning of the reversal of the Earth's magnetic field, and a cause for that reversal is as mysterious as the origin of that field so far. But according to the mathematical-gravitational model as developed in this paper, it appears that that decrease together with the floodings of many sand beaches as widely reported in newspapers and elsewhere are the signs of the approaching warm period of the Earth, and also possibly but not very probably the signs of the beginning of the reversal of the Earth's magnetic field, and both conclusions are in full accordance with this model.

It is concluded from this model that all celestial bodies, which are all somewhat asymmetrical due to the inevitable external gravitational fields, must possess the conventional large-scale magnetic fields with possible some regions of the enhanced magnetization, i.e., some regions of the distributed intrinsic first mass dipolar moments associated with the ferromagnetic materials. The planet Mercury should be mentioned particularly, since its magnetic dipole field detection and measurement by the Mariner 10 was unexpected and was a great surprise, see [6] in view of the dynamo theory of the origin of the Earth's magnetic field, which is based on the conversion of the heat energy of the Earth's core in the electrical current which creates the Earth's magnetic field. However, the planet Mercury does not have a heated molten core, so it should not possess a magnetic field according to the dynamo theory, i.e., the dynamo theory fails in this case. But that magnetic field of the planet Mercury is quite natural and expected according to this model. The conventional large-scale magnetic fields of the celestial bodies are in the first approximation due to the intrinsic first mass dipolar moments with respect to their centers of self gravity. Of course, this model does not exclude in any way the electric currents as the additional sources of the magnetic field. This mathematical model only shows that the origin of the planetary magnetism as observed in the stones from Magnesia in northern Greece can be consistently and completely accounted for as the manifestation of gravitation without any reference to any electric currents which are obviously not observed macroscopically in the stones from Magnesia, i.e., the natural magnets.

It should be mentioned that the dynamo theory is essentially thermodynamical, and It may be argued that it violates the second law of thermodynamics, which law may be interpreted differently, not at all uniquely.

As the immediate application and the check of this gravitational model, let us consider the Sun's conventional large scale magnetic field whose magnetic dipole was observed to be practically normal to the axis of rotation of the Sun, i.e., practically within the ecliptic plane, see [7]. This fact is impossible to comprehend and account for by the assumed dynamo theory of the origin of that field. But the above mathematical model suggests that the Sun, essentially plasma, is stretched by the planets revolving around the Sun very approximately in the ecliptic plane and pulling the Sun's center of mass from the Sun's center of self gravity, thus creating the Sun's first intrinsic mass dipolar moment, i.e., the Sun's magnetic dipole as observed in the ecliptic plane and normal to the axis of rotation of the Sun. The dominant effect is due to the planet Jupiter, which is by far the largest planet, but the influences of the other planets cannot be neglected. The solar cycle of about 11 years of the Sun's spots is consequently largely determined by the planet Jupiter, whose period of revolution around the Sun is 11.86 years. This mathematical model appears to be reasonably in agreement with the observed facts about the solar cycle. This mathematical model can be also applied to the so-called non-Newtonian forces, which were observed and widely reported during 1980's, but more research is necessary. The dynamo theory obviously fails completely in this case.

The Earth's gravitational field inside the Earth and close to its center of self gravity is approximately the linear function of r and quite weak and of the order of $10^{-5}\ m/s^2$ or less at the distance of about $10\ m$ from the Earth's center of self gravity, assuming that the mass density in the core of the Earth is of the order of, or probably less than $10^5\ kg/m^3$, which is only a guess. Nevertheless, even such a very weak gravitational field, which acts against the internal elastic forces, may, in the long run, pull the center of mass towards the center of self gravity with the inevitable consequence for the Earth's magnetic field, which may change drastically and even pass through zero. However, in view of the fact that all the planets revolve around the Sun very approximately in the same ecliptic plane, which cannot possibly be a simple chance, it is reasonable to assume that there must be a component of a gravitational field from some very distant matter, say dark matter, etc. which is normal to the ecliptic plane and which keeps all the planets to revolve around the Sun very approximately in the same ecliptic plane. That same gravitational field together with the Earth's internal elastic forces can keep the Earth's center of mass away from the Earth's center of self gravity, thus keeping the Earth's magnetic field more or less constant, but always subject to some drifting and disturbances, which is a well-known fact and observed for centuries. It is also easy and tempting with this gravitational-mathematical model to visualize and to model the reversal of the Earth's conventional large scale magnetic field by and under some circumstances which depend on some causes outside our solar-planetary system from the very distant matter as our solar-planetary system is speeding through the Universe perhaps approaching that matter, but more research is obviously necessary. It must be emphasized that the Earth's magnetic field during the reversal passes through its reported interim phase with its interim magnetic dipole 90 degrees from its original direction just before the reversal, which is easily understood and modeled by this gravitational mathematical model. However, the reversal of the conventional Earth's magnetic field with its interim magnetic dipole 90 degrees from its original direction, i.e., normal to its original direction before the actual reversal, is almost impossible to comprehend, particularly the interim dipole, if the dynamo theory is assumed as the origin of the conventional Earth's magnetic field. The astonishingly rapid change of the Earth's magnetic field of up to 6 degrees per day during a reversal (see [8]) significantly challenges that dynamo theory, while it is easily modeled and understood within this gravitational model of the origin of the conventional Earth's magnetic field.

This mathematical-gravitational model confirms completely the conclusions of many researchers, who although using quite different approaches and presumably the Schuster-Wilson-Blackett so-called "effect", found (see for instance [9]) that the cosmic magnetic fields pervade the Universe, just like the gravitational fields obviously do pervade the Universe, whose manifestations those cosmic magnetic fields certainly appear to be according to this model.

The reported beneficial effects of disk magnets placed at various points around the human body of the patients, particularly around the spine, are easily understood with this gravitational model. Those disk magnets are the sources of the rather weak gravitational fields, which act on the surrounding tissues to modify appropriately and beneficially the strong Earth's gravitational field.

It is a well-known fact that some animal species, homing pigeons especially, some insects and some sea animals, are capable to detect the conventional Earth's magnetic field, which is easy to comprehend with this mathematical model. It appears that those animals, hovering and floating in their natural media air and water, thus mastering "the surly bonds of Earth" as a poet put it, i.e., mastering the Earth's gravity, are capable to detect even the minimal, slightest variations of the Earth's gravitational field.

APPENDIX ABOUT THE NECESSARY EXPERIMENTS

The Equation (20) defines the gravitational dipole-dipole interaction. It was derived by the strict application of the rules and the laws of the classical Newtonian mechanics using the geophysical coordinate system with its origin at the Earth's center of self gravity. That torque (20) cannot be recognized, if the origin of the geophysical coordinate system is moved to the center of mass of the Earth, in which coordinate system that torque (20) is zero by definition. Therefore, it is obvious that the experimental detection of that torque (20) and its measurement is absolutely necessary, but strictly with respect to the geophysical coordinate system with its origin at the center of self gravity of the Earth. Note that the absence of that torque (20) would mean the breakdown of the classical Newtonian mechanics, which is absurd from the logical point of view.

In order to obtain even a very rough estimate of the order of magnitude of that torque (20), it is assumed that the factor n_2 in the Equation (25) is equal to 1 (one) in the MKS system of units, so that $|\vec{r}_{cme}|$=20 m according to that Equation (25), which value appears to be reasonable. Since the numerical value of the Earth's magnetic field depending on location in the MKS system of units is about 5×10^{-5} T (0.5 Gauss), it follows from the Equation (24) that the order of magnitude of the horizontal component of the dipolar portion of the Earth's gravitational field is 5×10^{-5} m/s^2=5 milliGals, with n_2=1 in the MKS system of units. On the other hand, the order of magnitude of the horizontal component of the dipolar portion of the Earth's gravitational field is approximately equal to 9.81 m/s^2 multiplied by $|\vec{r}_{cme}|/|\vec{r}_e|$, where $|\vec{r}_e|$=6.37×10^6 m is the so-called Earth's radius, which yields 3×10^{-5} m/s^2=3 milliGals. This is the same order of magnitude as the above value obtained from the experimental value of the Earth's magnetic field.

Assume now that the rod-like or needle-like test object as defined in this paper is 0.1 m in length with the copper mass of 0.01 kg non-uniformly distributed along its length. The estimated obtainable intrinsic first mass dipolar moment of that test object $|\vec{m}_1|$ is of the order of 10^{-4} kgm. Hence, the estimated value of the torque defined by the Equation (20) is of the order of 3×10^{-9} Nm, or thereabouts. Of course, the quantity $|Gk_3\vec{M}_{1eh}|$ in that Equation (20) is the horizontal component of the dipolar portion of the Earth's gravitational field by definition with its estimated value quoted above. This estimated value of the torque is very small, whose detection and measurement with respect to the direction of the Earth's self gravity center is a very serious task, complicated even more by the inevitable friction in the suspension system or the pivot system. It is obvious that the increase of the mass and the length of that test object may be helpful to offset friction, but there is a limit in that approach. The locations for such experiments should be a number of different flat land sites around the Earth sufficiently far away from any ferromagnetic substances, any mountains, any buildings and other tall objects, including trees in order to avoid the possible interference of any horizontal components of the gravitational fields of the mentioned objects. These experiments will have to prove the existence of the torque (20), or its nonexistence with the consequential breakdown of the classical Newtonian mechanics, which is, to repeat once more, absurd from the logical point of view.

The preliminary but inadequate experiments by this author in his apartment in a high-rise apartment building just below the Terazije plateau in the center of old Belgrade do corroborate the existence of the torque given by the Equation (20), but the strictly supervised experiments as outlined above are absolutely necessary.

P.S.

After this paper was written, the author completed a wide range of experiments which are reported in three papers entitled: "GRAVITATIONAL EXPERIMENT", "EXPERIMENT IN EARTH'S GRAVITATIONAL FIELD" and "EXPERIMENTAL CONNECTION OF MAGNETISM WITH GRAVITATION". This last third paper is available in the pdf format on the Internet Site of this author http://jovandjuric.tripod.com

These three papers confirm fully the theoretical results obtained in this paper. The short paper "GRAVITATIONAL EXPERIMENT" is attached at the end of this paper as **APPENDIX 2 .**

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APPENDIX 2

GRAVITATIONAL EXPERIMENT

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ABSTRACT

A gravitational experiment with an elongated triangularly shaped thin horizontal needle made of thin bronze and pivoted at its presumed center of mass so to rotate freely in the Earth's gravitational field is described. The experiment shows that after some oscillations, that needle assumes the North-South direction identical to the N-S direction of an ordinary magnetic compass. The same experiment was performed using needles made of wood, aluminum and brass with the identical results. These experimental results prove that the quark hypothesis is absolutely unnecessary. Quark appears to be only a dogmatic fiction.

The Earth's gravitational field has been extensively analyzed experimentally using a ball small enough compared to the Earth to be considered as a point mass with the well-known results. But the experiments with the triangular thin needle made of bronze and pivoted at its presumed center of mass to be horizontal and able to rotate freely in the horizontal plane in the Earth's gravitational field, yield some very interesting results, which are not mentioned in the literature so far.

An equilateral elongated triangle with the base of 9 mm and height of about 100 mm was cut from a bronze sheet of 0.16 mm thickness, and then shortened to 90 mm to form an elongated trapezoid with the upper side of approximately 1 mm whose mass was measured to be 0.8 grams. Using a steel ball of the diameter of 0.5 mm , a semispherical cavity – dent was made very carefully by an appropriate tool at the approximate center of mass (or weight) of that needle. An aluminum pedestal, to which a brass cylinder of diameter 2 mm was attached to be strictly vertical and carrying coaxially fitted the balance wheel axle-shaft of the smallest mechanical watch, was used as a pivot. The diameter of that balance wheel axle is about 75 microns, whose tip is actually a calotte, semispherical. On that pivot tip, the above described bronze needle was placed at its semispherical cavity. Since the semispherical cavity - dent was formed approximately, the needle is normally not horizontal, but can be made to be strictly horizontal by filing it very carefully around its sides. Everything is now ready for the experiment. It should be mentioned that the ruby bearings for the balance wheels of small watches introduced more friction than the said dents.

The aluminum pedestal with the described bronze needle freely rotating in the horizontal plane was placed on an electrically grounded horizontal aluminum plate about 1 mm thick in author's tightly closed living room without any heating element to avoid any movement of air, and the rotation of the bronze needle was observed. It was observed that that needle oscillated quite slowly reaching finally the balance direction which was found to be the North-South direction of an ordinary magnetic compass, with the sharp end of that bronze needle pointing towards the North. That bronze needle remained in that balance direction indefinitely, until disturbed by the obvious air movement due to the movement of the experimenter (author), or if the door of that living room was suddenly opened, causing the strong air movement. It was observed that after such air disturbance, the bronze needle oscillated slowly around the magnetic N-S direction and stopped, assuming again that N-S balance direction and remaining there indefinitely, provided that no further air disturbance was allowed to occur. This experiment was repeated at another location in Belgrade under the identical circumstances with the identical results. The externally applied magnetic fields caused some movement of the described bronze needle, which should be investigated separately.

This experiment was also performed with the similarly constructed needles made of brass, aluminum and wood, except that in the case of the wooden needles, the suitably attached brass piece was used to create the semispherical cavity – dent for pivoting. The wooden material exhibits too strong friction with the described pivoting tip. That attached brass piece for the semispherical cavity – dent for pivoting secured freer rotation of the wooden needle. The observed results were identical as obtained and described for the bronze needle above. These results prove the axial property of the Earth's gravitational field due to the Earth's flattening. These results were demonstrated during this author's seminar lecture on November 22, 2007 at the Faculty (College) of Mechanical Engineering, University of Belgrade in Belgrade.

The explanation of the obtained results is beyond the scope of this paper, which is written with the only purpose to report this experiment with the sufficient details, so that anybody who is interested, can repeat such an experiment. This author is very interested to learn about the results of such experiments at other locations around the world. It is obvious that the centrifugal acceleration due to the Earth's rotation is ruled out for the explanation of the results of this experiment, since the bronze needle, being horizontal, is pivoted at its presumed center of mass. Also, diamagnetism and paramagnetism of the said needles cannot explain the obtained results of these experiments. It is described in the literature, that the needles made of diamagnetic and paramagnetic materials may rotate in strong nonuniform magnetic fields, but the Earth's rather weak magnetic field is practically uniform within a room of the ordinary apartment buildings in Belgrade, in which these experiments were performed. The well-known International Gravity Formula does not give any clue for the explanation of the obtained results. Due to the very strict grounding, electrical charge is also ruled out, but in fact, the careful removal of the electrical grounding caused no difference of the observed results.

It appears to this author that the observed results of these experiments in the

Earth's gravitational field are very interesting and very important, since they show undoubtedly a very intimate relationship between the conventional Earth's magnetic field and the Earth's gravitational field, particularly the Earth's flattening. These experiments can and certainly should be performed at various locations around the world, South as well as North of the equator. This author considers that they prove his unified field theory as presented on http://jovandjuric.tripod.com and also briefly outlined in his Fifth Award winning essay "Gravitation and Electromagnetism" in the 1963 Competition of Essays on Gravity of the Gravity Research Foundation. These experimental results are fully in agreement with the theoretical results in this author's paper MAGNETISM AS MANIFESTATION OF GRAVITATION which is available in the pdf format on the above mentioned Internet Site of this author, in which the analysis is done using strictly the classical Newton's theory of gravity, but the coordinate origin of the geophysical coordinate system is moved from the center of mass of the Earth to the center of gravitation of the Earth, at which point the Earth's gravitational field is zero. It is concluded in that paper that the error in considering the center of mass of the Earth as the center of gravitation of the Earth concealed the fact that the planetary magnetism is the manifestation of gravitation.

The results of the above described experiments prove that the intrinsic mass moment of a mass distribution, as calculated by definition with respect to the center of gravitation of that mass distribution, must be considered as the conventional magnetic moment of that mass distribution with the factor of proportionality which depends on the units and the material property of that mass distribution. The center of gravitation of a mass distribution is the point where the gravitational field of that mass distribution is zero, to repeat again. This fact also holds for **any elementary particle**, which **must possess** its center of mass and its center of gravitation as the two distinctly different points due to the ever-present external gravitational field, and consequently, **its intrinsic mass moment, i.e., its magnetic moment, i.e., the evident asymmetry of that particle. The deviation from the perfect symmetry of some subatomic particles was actually observed and reported. Thus, the quark hypothesis is absolutely unnecessary.** As it is known, some outstanding scientists, Heisenberg, Chew and others, disapproved of the quark hypothesis. The hypothetical particle *quark* appears to be only a dogmatic and unnecessary fiction.

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