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Recent Geodynamics

GEODYNAMIC WAVES AND GRAVITY

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Abstract: Gravity phenomena related to the Earth movements in the Solar System and through the Galaxy are reviewed. Such movements are manifested by geological processes on the Earth and correlate with geophysical fields of the Earth. It is concluded that geodynamic processes and the gravity phenomena (including those of cosmic nature) are related.

The state of the geomedium composed of blocks is determined by stresses with force moment and by slow rotational waves that are considered as a new type of movements [*Vikulin, 2008, 2010*]. It is shown that the geomedium has typical rheid properties [*Carey, 1954*], specifically an ability to flow while being in the solid state [*Leonov, 2008*]. Within the framework of the rotational model with a symmetric stress tensor, which is developed by the authors [*Vikulin, Ivanchin, 1998; Vikulin et al., 2012a, 2013*], such movement of the geomedium may explain the energy-saturated state of the geomedium and a possibility of its movements in the form of vortex geological structures [*Lee, 1928*]

The article discusses the gravity wave detection method based on the concept of interactions between gravity waves and crustal blocks [*Braginsky et al., 1985*]. It is concluded that gravity waves can be recorded by the proposed technique that detects slow rotational waves. It is shown that geo-gravitational movements can be described by both the concept of potential with account of gravitational energy of bodies [*Kondratyev, 2003*] and the nonlinear physical acoustics [*Gurbatov et al., 2008*]. Based on the combined description of geophysical and gravitational wave movements, the authors suggest a hypothesis about the nature of spin, i.e. own moment as a demonstration of the space-time 'vortex' properties.

Key words: geodynamics, force moment, rotational waves, rheid flow, gravitational waves.

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ГЕОДИНАМИЧЕСКИЕ ВОЛНЫ И ГРАВИТАЦИЯ

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Аннотация: Проводится обзор гравитационных явлений, связанных с движениями Земли в Солнечной системе и Галактике. Эти движения и их вариации отражаются в геологических процессах, происходящих в Земле, и коррелируют с ее геофизическими полями. Формулируется вывод о существовании взаимосвязи между геодинамическими процессами и гравитационными (космической природы в том числе) явлениями.

Состояние геосреды, являющейся блоковой по своему строению, определяется напряжениями с моментом силы и новым типом движений – медленными ротационными волнами [*Vikulin, 2008a, 2008b, 2010*]. Показано, что для геосреды характерны реидные [*Carey*, *1953*] свойства – способность течь в твердом состоянии [*Leonov*, *2008*]. Такое движение геосреды позволяет в рамках развиваемой авторами ротационной модели с симметричным тензором напряжений [*Vikulin, Ivanchin, 1998; Vikulin et al.*, *2012a*, *2013*] объяснить ее энергонасыщенное состояние и возможность движения в виде вихревых геологических структур [*Lee, 1928*].

Обсуждается метод регистрации гравитационных волн, в основе которого заложена идея их взаимодействия с блоками земной коры [*Braginsky et al.*, *1985*]. Формулируется вывод о том, что в рамках такой методики с использованием в качестве детектора медленных ротационных волн оказывается возможным зарегистрировать гравитационные волны. Описание геогравитационных движений возможно в рамках как теории потенциала с учетом гравитационной энергии тел [*Kondratiev*, *2003*], так и нелинейной физической акустики [*Gurbatov et al.*, *2008*]. Обобщение геофизических и гравитационных волновых движений позволило авторам предложить гипотезу о природе спина – собственного момента как проявления «вихревых» свойств пространства–времени.

Ключевые слова: геодинамика, момент силы, ротационные волны, реидное течение, гравитационные волны.

There is no 'relativity of rotation'. A rotating system is *not* an inertial frame, and the laws of physics are different.

R. Feynman [*Feynman et al.*, *1964*]

The geological time scale is close to the scale of the Universe. Geologists have a chronicle that records events of the history of Earth and the Universe.

D.V. Nalivkin [*Nalivkin*, *1969*]

1. Introduction

Abundant geological and physical data suggest a close relationship between processes that take place on Earth and in space. Indeed, Earth is a body rotating around its axis at a speed of 465 m/s at the equator and around Sun at a speed higher by an order of magnitude, about 30 km/s. Together with Sun and other planets of the solar system, it rotates around the center of our galaxy with an average speed that is also higher by an order of magnitude, 270 km/s. Parameters of all rotational movements are subject to quite specific changes in time, and all of them are reflected in the geological processes. Gravity and other influences exerted on our planet by other bodies of the solar system itself, as well as those in the more distant Universe, should be taken into account. Recently, both rotation and space factors attract wider attention of researchers as modern technical capabilities of such studies have increased immeasurably.

The generally accepted view is that global processes take place on Earth cyclically with typical periods of 10^7–10^8 years, and this is the most important scientific concept of modern geology. The idea of recurrent global cycles of the Earth development was originated by J. Hutton at the end of the 18th century. In the 19th and early 20th centuries, E. Haug, M. Bertrand, E. Suess and H. Stille were among the major advocates of Hutton's ideas, and the cyclicity concept was further developed by many geologists. Their researches have provided arguments confirming the existence of global cycles, which is now undebatable, and the focus of geological studies has shifted from detection and proof of the cycles to issues of the nature and causes of the cycles. Cyclicity is typical of almost all the processes which occur on Earth, such as glaciation, formation of rocks, erosion, sea-level changes, extinction of flora and fauna, seismicity and volcanism etc. Besides, many of these processes are confidently correlated with cycles of some astronomical phenomena [*Khain, Khalilov*, *2009*].

Through centuries, studies have been devoted to effects of the Earth rotation on processes, associated with the evolution of its interiors. Founders of Geology J. Hutton, J. Playfair and C. Lyell and astronomer W. Herschel established that differentiation of the Earth core and its crust is associated with rotation of the planet. A possible link between deformation of the Earth's crust and rotational forces of the planet was mentioned by A.P. Karpinski, D.I. Mushketov, N.S. Shatsky, B.L. Lichkov, A.L. Yanshin, V.E. Khain etc.

Our study shows that natural oscillations of the Earth reflect movements in the interior, which are considered elastic, according to earthquake records in seismograms, and gravitational at the same time, according to gravity measurements. Apparently, for this very reason, D.D. Ivanenko, who is one of the most prominent physicists conducting theoretical studies of gravity, has demonstrated a keen interest in problems of geology and gravity [*Vladimirov*, *2011*]. In January 1961, he initiated establishment of Gravity Group in Gravimetry Department of Sternberg Astronomical Institute, Moscow State University. The most prominent Russian surveyors, Corresponding Member of the USSR Academy of Sciences Y.D. Boulanger (IPE Institute) and Associate Professor of Moscow State University N.P. Grushinskiy were among the members of the Gravity Commitee of the Scientific and Technical Council of the USSR Ministry of Education. A number of symposiums on related problems of the theory of gravity, geology and gravimetry were held in Moscow. Many of the symposiums, as well as weekly workshops conducted by D.D. Ivanenko at the Physics Department of Moscow State University, were devoted to specific geological and geophysical topics, such as the Titius-Bode law (of distances between the planets and the Sun) as a manifestation of the laws of quantum mechanics across the solar system, the pear-shaped asymmetrical form of the Earth etc.

The conclusion about the existence of the relationship between the geodynamic processes and space phenomena is in full compliance with Mach's principle of the universal interconnectedness of all processes in the Universe. In such a relationship, only gravity can be viewed as a ‘cosmic’ link that unites all the parts of the universe. A ‘terrestrial’ link in the relationship between the geodynamic processes and phenomena in space may be slow geodynamic waves (their velocities are by many orders of magnitude lower than those of seismic waves) [*Bykov, 2005, 2008; Gershenzon et al., 2009*]. For the block rotating medium, i.e. geomedium, slow movements are typical in the same way, as volume elastic longitudinal (V_P) and transverse (V_S) waves [*Vikulin, 2008a, 2008b, 2010; Vikulin, Ivanchin, 2013; Vikulin et al., 2013*].

The existence of the close relationship between gravity and wave geodynamic movements as ‘a fact of the simultaneous action of potential energy and kinetic energy inside the Earth’ is discussed in [*Ferronsky V.I., Ferronsky S.V., 2007, p. 65–66*]. Searching for a common ground between concepts of geodynamics and gravity is also discussed in our publications [*Vikulin, 2010, 2011, 2012*].

2. Geodynamic rotational waves

Block structure of geomedium. The wave nature of geodynamic movements is now undoubted [*Bykov, 2005, 2008*]. It is evidenced by the so-called ‘ground waves’ propagating from foci of strong earthquakes [*Aki, Richards, 2002; Shebalin, 2003; Lomnitz, 1970; Lomnitz, Castanos, 2006; Matuzawa, 1925*], geodynamic earthquake precursors [*Mogi, 1985; Rikitake, 1976; Sobolev, 1993*] and visually observed and geodetically recorded slow motion of the Earth surface [*Karryev, 2009; Kuznetsov, 2009; Leonov, 2008, p. 5; Popkov et al., 2013*], which is observed both before and after earthquakes and without any recordable activation of seismic and volcanic activity. All the above-mentioned movements are of the single wave geodynamic nature.

The rationale of the concept of block structure of geomedium [*Pieve, 1961; Sadovsky, 1979*] is an important achievement in the Earth Sciences. Variability in time, strong non-linearity, activity, energy saturation and possible rheid movements (i.e. superplastic flow in the solid state [*Leonov, 2008; Carey, 1953*]) are fundamental properties of such a medium. All of these properties, including slow motion of the Earth surface, as part of the rotational model [*Vikulin, Ivanchin, 1998; Vikulin, 2006*], are due to geodynamic waves of a new type which are termed as ‘rotational waves’ [*Vikulin, 2008a; Vikulin et al., 2013*]. Rotational waves are typical of geomedium in the same way as elastic waves are typical of solid bodies [*Vikulin, 2010; Vikulin, Ivanchin, 2013*].

Spatial and temporal patterns of seismic and volcanic activity were studied within the three most active zones of the planet – the Pacific margin, the Alpine-Himalayan belt and the Mid-Atlantic Ridge. Mathematical simulation of their block geomedium [*Vikulin, 2012; Vikulin et al., 2012a, 2012b*] shows that migration of geodynamic activity is the wave process, which properties are determined by solutions of the sine-Gordon (SG) equation [*Vikulin, 2008a*]:

$$\frac{\partial^2\theta}{\partial\xi^2}-\frac{\partial^2\theta}{\partial\eta^2}=\sin\theta\ . \qquad (1)$$

where

$$V_{sol}\le c_0\approx\sqrt{V_S V_R}\approx(1-10)\ \text{cm/s} \qquad (2)$$

and

$$c_0<V_{ex}\le V_S\ . \qquad (3)$$

Characteristic velocities V_{sol} and c_0 define a new type of perturbations termed rotational, which is typical of the rotating block medium, i.e. geomedium – solitons (V_{sol}) and excitons (V_{ex}), respectively [*Vikulin, 2010*]. Here $\theta=\beta/2$, $\xi=k_0 z$ and $\eta=c_0 k_0 t$ are dimensionless coordinates; z is distance along the chain of blocks; and t is time. In solutions for the terminal velocity (2), it is assumed that the wave length is similar to the block size, $\lambda\approx R_0$, and the wave number equals $k_0=2\pi/R_0$, where the assumed block size is $R_0\approx 100$ km at medium density $\rho\approx 3$ g/cm^3 and its shear modulus $G\approx 10^{12}$ Dyn/cm^2; $V_S=\sqrt{G/\rho}$ is the velocity of transversal seismic waves; and $V_R=\Omega R_0$, $\Omega=7.3\cdot10^{-5}$ rad/s is the angular velocity of rotation of Earth around its axis.

Excitons, in fact, are the solutions of the linearized SG equation (see solution II in Figure 5, and solution 2 in Figure 6 in [*Vikulin, 2010*]), which degenerate into conventional seismic waves [*Davydov, 1982*].

Rotational stress of geomedium. All the space objects in the Universe, as well as other bodies and particles of micro-and macrocosm, have angular momentum. Rotation is a movement of special quality [*Feynman et al., 1964*], which cannot be confined to translational motion as the result of two rotations at the final angles is not equal to the amount of rotations and depends on the sequence of such turns. Therefore, it is not correct to apply an approximation based on Euler (D'Alembert-Euler) theorem on equivalence of translation along the surface of the sphere and the turn, which is traditionally used in solutions of tectonic problems within the framework of global tectonics [*Zonenshain, Kovaleva, 1974; Morgan, 1968*][1]. Let us approach the problem with reference to more general terms of mechanics.

The lithosphere is in constant motion, and its blocks are moving at the Earth surface in translational way. For example, a block from position M_1 moves gradually to position M_2 (Figure, a), and this defines specific rotational properties of the block lithosphere. Angular velocity Ω, with which the coordinate system rigidly associated with the body (Earth) rotates at every given moment, is completely independent of this system. At a specified moment, all such systems rotate around the axes, which are parallel to each other, at velocity Ω of the same absolute value [*Landau, Lifshitz, 1976*]. It follows that regardless of its size, each block (and / or plate) of the lithosphere is characterized by equal angular momentum *M* directed parallel to the axis of rotation of the body (i.e. Earth): $M = m \cdot \Omega$. Here *m* is momentum of inertia of block / plate, which magnitude during movement and consecutively possible deformation are changeable. Movements of the lithosphere should lead to a change in the direction of the angular momentum, $M_1 \rightarrow M_2$. However, it is impossible – the momentum should be maintained as this block has to rotate together with Earth at angular velocity Ω. This leads to momentum of force *K*, which is applied to the block by its host medium, i.e. the lithosphere (Figure, b).

A theoretical exercise to determine the value and direction of the momentum of force *K* may be as follows. First, the block (assumed to be a homogeneous ball-shaped body) is stopped in position M_2 by applying elastic stresses with momentum of force P_2. Then, the block is propelled to its initial state in position M_1 by applying elastic stresses with momentum of force P_1. Assuming that in each case, conversion of kinetic energy of block rotation into elastic stress and vice versa occurs without any energy loss, i.e. $|P_1| = |P_2| = P$, momentum of force *K* is as follows [*Vikulin, Ivanchin, 2013*]:

$$|K| = 2P\sin\beta/2\,. \tag{4}$$

Important: the elastic stresses with momentum of force *K* are applied to the block by its host medium, i.e. the lithosphere.

Thus, we obtain a model that describes the block motion in the rotating medium Ω as mechanically equivalent to the block motion in a non-rotating medium under its *intrinsic* angular momentum *M* (i.e. equivalent to rotating the block by angle β), which creates an elastic field with momentum of force (4) in the host medium around the block. The elastic stress field generated by such rotational motion of the block occurs according to the law of conservation of angular momentum.

In fact, 'internal' (or intrinsic) momentum *M* or spin has a specific feature in terms of geodynamics – it cannot be somehow 'taken away' from the lithosphere by plastic deformation of the block. Therefore, as a result of translational movement of the block (i.e. due to an increasing angle of block rotation β), rotational stresses with momentum of force (4) shall be accumulated in the lithosphere, which clearly explains such a property of geomedium as its energy saturation [*Vikulin, 2011, p. 384–394; Vikulin, Ivanchin, 2013*].

Actually, stresses with momentum of force (4) determine the form of the model equation of motion (1) or nonlinear SG and properties of its solutions corresponding to such an equation.

It is assumed that in the space around the lithospheric block turning under its intrinsic angular momentum, elastic stresses with momentum of force (4) are generated. To determine the value of elastic stresses σ generated by the ball-shape block R_0, that rotates due to its intrinsic angular momentum *K* in an infinite solid body with $r \geq R_0$, the task was set [*Vikulin, Ivanchin, 1998*] in the framework of the classical[2] theory of elasticity [*Landau, Lifshitz, 1986*]. In the spherical coordinate system (r, θ, φ) (starting $r = 0$ in the center of the block; plane θ=0 orthogonal to *K*), the solution of this task [*Vikulin, 2006; Vikulin, Ivanchin, 2013*] is as follows:

$$\sigma_{r\varphi} = \sigma_{\varphi r} = 4\Omega R_0^4 r^{-3}\sqrt{\frac{\rho G}{5\pi}}\sin\theta\sin\beta/2\,,\ r \geq R_0\,. \tag{5}$$

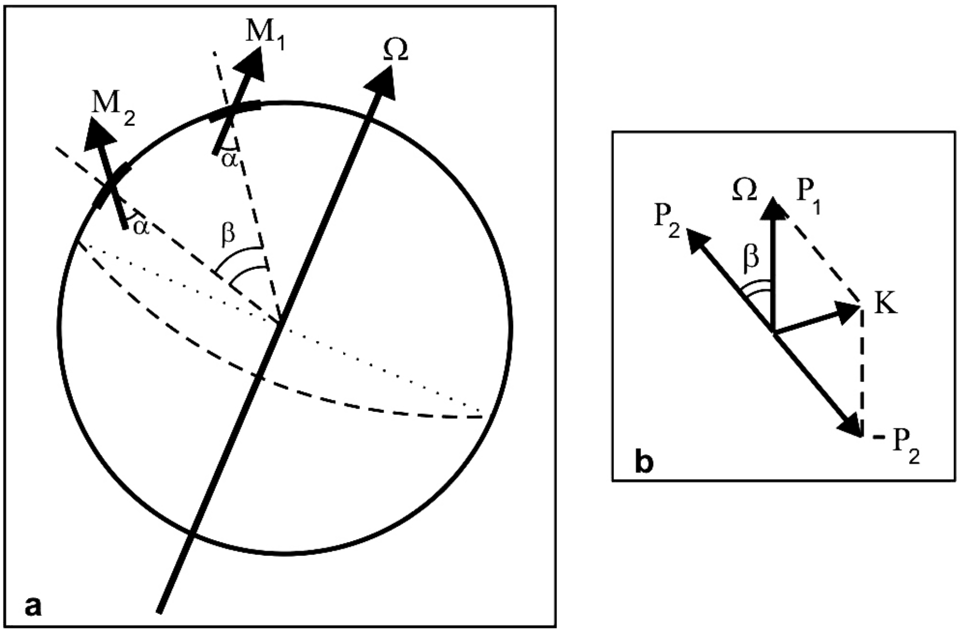
The remaining stress components are zero.

It is important that the stress field in the rotational model, according to (5), is symmetrical, which allows us not to refer to the essentially mathematical model of couple stresses, which is widely applied to solving geodynamic problems (e.g., [*Nikolaevsky, 1995, 1996*]); it is based on Cosserat mathematical continuum that has not been mathematically and physically justified [*Hirth, Lothe, 1968, p. 26*].

'Superconductivity' (rheidity) of geomedium and Chandler fluctuation. Based on the review of the evolution of

[1] Incorrect application of Euler's theorem to movements along the surface of the Earth is also tied with the absence of a fixed point on the Earth, while this is one of the requirements of the theorem.

[2] As opposed to the momentum [*Nikolaevsky, 1995*] mathematical theory of elasticity with asymmetric stress tensor (see e.g. [*Nikolaevsky, 1995*]), the theory of elasticity with symmetrical stress tensor [*Landau, Lifshitz, 1986*] is called classical here.



Movement of a block of the lithosphere from its position with angular momentum M_1 to position M_2 (the block turn at angle β) (*a*) is accompanied by 'generation' of stresses in the lithosphere with force momentum *K* (*b*), which are applied to the block by its surrounding medium. See explanations in the text.

Движение блока литосферы из положения с моментом импульса M_1 в положение M_2 (поворот блока на угол β) (*a*), сопровождающееся «генерацией» в литосфере прикладываемыми к блоку со стороны окружающей его среды напряжениями с моментом силы *K* (*b*), пояснения в тексте.

concepts of rheological properties of Earth [*Vikulin, 2009, p. 239–247*], Debye temperature θ_d for the geological medium can be given as follows [*Zharkov, 1983, p. 199*]:

$$\theta_d \approx 10^{-3}\overline{V}(H)\sqrt[3]{\rho(H)}\,, \qquad (6)$$

where $\overline{V}$ [cm/s] is average velocity of excitations in geomedium; ρ [g/cm^3] is density of the medium; H [km] is depth. At an average velocity determined by values of longitudinal and transverse seismic velocities (that may vary in the range of 1–10 km/s for the lithosphere and upper mantle), the Debye temperature is high enough; for depth H = 100 km, it is $\theta_d \approx$ 660 K ≈ 1000 °C and closely corresponds to the widely accepted model of the Earth Physics [*Magnitskiy, 1967; Stacey, 1969*].

The situation is radically changed with transition to rotational mode c_0 (2) defined by collective motion of the complete set of geophysical blocks, tectonic plates and geological structures [*Vikulin, 2011, p. 391–392; Vikulin, Ivanchin, 2013*]. Value c_0, that is characteristic of this mode according to (1), is smaller by five orders of magnitude than the transverse and longitudinal seismic velocities, and its Debye temperature (6) is negligible, $\theta_d \approx 10^{-2}$ K, which determines the possibility of quantum no-friction superfluid motion of geomedium, i.e. its rheidity [*Carey, 1953*], and / or super-plastic flow in the solid state [*Leonov, 2008*].

Debye temperature is proportional to the potential maximum oscillation frequency of constituent particles and / or mesovolume of the solid body and / or geophysical blocks, tectonic plates and other geological structures of the Earth. According to [*Vikulin, Krolevets, 2002*], this frequency for Earth is Chandler frequency that is characteristic of all the blocks comprising a seismotectonic belt.

It is obvious that, on the one hand, under the rotational model it is possible to combine the ideas of the classical theory of elasticity with symmetrical stress tensor and the concepts of non-linear properties of geological medium, i.e. its energy saturation. On the other hand, energy saturation of geomedium and / or its rheid properties – the ability to flow 'super-plastically' in the solid state [*Leonov, 2008*] – is the factor predetermining a possibility of describing geo-gravity movements within the framework of theoretical hydrostatic models (see below).

3. GEO-GRAVITATIONAL EFFECTS

Surface tension of Earth. By minimizing the gravitational energy of Earth, it is possible to determine its "surface tension" [*Kuznetsov, 2008, p. 101*], which is actually a balance between the attractive force (i.e. gravity) and the geodynamic field determining the structure of the substance of the geoid's surface, which should be basically of the planetary scale. In this balance, gravity can be represented by geoid waves [*Magnitskiy, 1967, p. 215–221*]. Geodynamic planetary field, that controls movements of the rotating block medium, is manifested by slow motion of the Earth surface. The surface tension of the geoid is quite high and amounts to 10^{19} erg/cm^2 [*Kuznetsov, 2008, p. 101*]; it is significantly higher than the surface tension of liquids and solids in laboratory experiments, which values are recorded in the range of 1–10^4 erg/cm^2. The above data suggest that the relationship between gravity (i.e. geoid waves with momentum nature [*Vikulin, 2009, p. 160–161*]) and geodynamic movements can be 'quite strong'.

According to [*Krylov, Sobolev, 1998*], gravitational waves were recorded in their Eötvös torsion balance observations; sources of such waves were earthquake foci in moving blocks of the lithosphere. A possibility of the influence of super-long gravitational waves of cosmic origin on geodynamic processes is described in principle in [*Khain, Khalilov, 2009*]; this publication presents a positive experience of short-term prediction of strong distant earthquakes on the basis of long-period gravitational precursors.

Float oscillations are fluctuations of the entire Earth which means planet orbiting movement in the direction of its axis of rotation. The existence of such oscillations is suggested by analyses of drifting zero levels of seismographs and gravimeters and the transverse mode of ocean tides of the northern and southern hemispheres [*Lin'kov, 1987, p. 144–163*]. Actually, float oscillations of Earth can be explained as geodynamic movements only with regard to gravitational movements of other cosmic bodies around Earth, primarily other planets of the Solar system. In this case, all the geodynamic movements, including float fluctuations, correlate with the amount of solar activity, which in its turn depends on orbital and rotational movements of the planets, mostly the giant planets Jupiter and Saturn, around their axes [*Vikulin, 2009, p. 380–381; Dolgachev et al., 1991; Timashev, 2003*].

Variations of gravitational constant and geophysical fields. The gravitational constant G is a fundamental empirical physical constant. According to the current measurements, $G = (6.67\pm0.01)\cdot10^{-8}$ dyn·cm^2·g^{-2}, and the accuracy of its determination, $\Delta G/G=10^{-3}$ is low, considering G as an empirical physical constant [*Yavorsky, Detlaf, 1979*].

For more than two centuries, measurements of G were taken by researchers in independent laboratories located in different places of the Earth, and a quite dense set of quantitative values of G has been collected. The accuracy of single determinations of G is gradually increasing, and it was estimated as 10^{-4} in the period from the end of the 20th century to the beginning of the 21st century. However, more accurate determinations of G have demonstrated more differences between the quantitative values. To the present, the two most accurate measurements of G have been obtained independently by groups of scientists from the University of Washington, USA and the International Bureau of Weights and Measures (BIPM), France. In both experiments, errors amounted to 10^{-4}, and deviations between the obtained values were in excess of the marginal error by 10 times [*Khain, Khalilov, 2009, p. 252–259*].

Large enough differences are revealed not only between individual definitions of G, but also between large series of observations comprising dozens of thousands (!) measurements. In the targeted studies conducted from 1985 to 1997, almost 40 thousand measurements of G were obtained, and an average value of G was estimated as $G=(6.6729\pm0.0002)\cdot10^{-8}$ dyn·cm^2·g^{-2}. In shorter time intervals, statistically significant deviations (+/–) from the average were noted, e.g.:

19 October 1995 – 25 January 1996 –
$G=(6.6726\pm0.0001)\cdot10^{-8}$ dyn·cm^2·g^{-2};
21 March 1993 – 13 July 1993 –
$G=(6.6737\pm0.0002)\cdot10^{-8}$ dyn·cm^2·g^{-2}
[*Khain, Khalilov, 2009, p. 276–277*].

The long-term observations give evidence that the recorded fluctuations of G values [*Khain, Khalilov, 2009, p. 284*] cannot be caused by any of the impact factors, such as changes in the geomagnetic field, instability of temperature and atmospheric pressure, the flow of residual gas in the vacuum chamber of the instrument, changing its tilt and the influence of the gravitational field associated with the change in the relative positions of Earth, Moon and Sun.

It is still unclear what is the cause of the above-mentioned contrasting determinations of the fundamental physical constant, and researchers have different hypothesis in this respect. According to P. Dirac [*Dirac, 1937*] and other physicists, G is not constant over time and its value is decreasing inversely in proportion with time in the same way as values of a number of other fundamental physical constants in the Big Bang model.

Time series of G values were analyzed by many researchers. A basic conclusion is that regular periods of 85, 53, 39, 23, 21, 17 days are typical of G variations in the third decimal place. It is revealed that solar activity varies in the same periods. Based on results of analyses of the time series, many researchers assume that variations of the gravitational constant are 'associated with a variety of space and geophysical phenomena …, which directly or indirectly affect the results of measurements' [*Khain, Khalilov, 2009, p. 279*].

Cosmic phenomena are discussed below. As for the 'geophysical processes', it may be noted that, according to [*Khmelevsky, 2007, p. 320; Stacey, 1969*], there is a close relationship between magnetic and gravity anomalies, which locations, strike and shapes are often coincident. A correlation between seismic activity of the Earth and variations in values of the gravitational constant G is discussed in [*Khain, Khalilov, 2009*]. Seismologists, volcanologists and surveyors [*Vikulin, 2011, p. 388–389*] have collected data which suggest that there is a correlation between patterns of seismic and volcanic activity at the Earth surface and anomalies of its shape in the form of geoid waves, which, in fact, are planetary gravitational anomalies [*Magnitskiy, 1967*].

The reviewed geophysical data support the above conclusion that the analyses of variations in measurements of the gravity constant do not actually reveal any changes in the value of the gravitational constant, but identify variations of the gravity field due to geophysical processes taking place when *G* is instrumentally measured on site.

4. GRAVITATIONAL WAVES AND COSMIC FACTORS

Earth in the Solar system and the Galaxy. The available data suggest that local geophysical and global gravity processes can interact with each other, and this conclusion is supported by relevant long-term observations. In [*Bagby, 1973*], it is stated that seismic activity is influenced by positions of Neptune and Uranus and lunar-solar tides. In [*Fedorov, 2001, 2007*], it is concluded that in the 20th century the amount of the Earth's volcanic activity depended on both the Earth's position at its orbit and distances from Earth to Sun and Mars.

Based on historical records, it is believed that the approach of Mars to Earth causes a variety of disasters, including hurricanes, typhoons, earthquakes and droughts or, on the contrary, floods. Anomalous natural phenomena and events associated with the 'great' approach of Mars to Earth on August 28, 2003 (when the distance between the planets was only 55.7 mln km versus a 'normal' distance of about 400 mln km) are analyzed in [*Khain, Khalilov, 2009, p. 337–341*] as follows: (1) 'From July to late September 2003, hurricanes and typhoons occurred on Earth twice more frequently than in similar periods in the past'; (2) 'Both atmospheric and geological disasters were anomalously highly active. The degree of activity of the atmospheric and geological manifestations of the planet's energy (typhoons and hurricanes, and earthquakes and volcanoes, respectively) exceeded the background values by a factor of 2.5 to 3'.

In the solar system, Earth revolves around the center of the galaxy at a highly eccentric orbit. It completes one revolution in 200–250 million years. Some researchers have already noted the fact that the duration of this period is generally coincident with the duration of Bertrand tectonic cycle, during which Earth periodically approaches to the center of the galaxy (perigalaction) and then moves away from it (apogalaction) and, naturally, Earth is subject to either stronger of weaker influence of gravity of the masses located in the center of the galaxy.

Quadrupole deformation of Earth. Based on data from ground-based instrumental observations in the period from 1976 to 1981, irregular global changes of gravity at the Earth's surface, Δg [*Bulange, 1981*] and angular velocities of the Earth rotation, $\Delta\omega$ were studied [*Pariysky, 1984*], and it was found that these parameters are well correlated as functions of time. Moreover, positive values of Δg correspond to negative values of $\Delta\omega$, instead of positive values, which would correlate with general compression of Earth. The above shows that compression of Earth at an in-situ measurement location is correspondent to an overall increase of the Earth momentum of inertia, which is possible only if expansion takes place elsewhere on the globe [*Bulange, 1981*]. Obviously, in this case, the Earth deformation is also quadrupole.

Analyses of satellite laser ranging (SLR) data reveal variations of values of second moment J_2 in decomposition of the Earth gravitational potential by spherical harmonics [*Cox, Chao, 1998*], which reflects the dynamics of the ratio of equatorial *A* (*a*) and pole *C* (*c*) moments of inertia (radii) of Earth as follows: $J_2 = (C–A)/MR_E^2 \approx \varepsilon$, $J_{2n-1} = 0$, $J_{2n} \approx \varepsilon^2$, $n = 2, 3, \ldots$, and it is quadrupole too [*Vikulin, 2009, p. 52–55, 149; Grushinsky, 1976, p. 225; Zharkov, 1983, p. 66; Magnitskiy, 1967, p. 209–215*]. Here $J_0 = 1$, $J_1 = 0$, *M* is the Earth mass; $R_E = (a+c)/2$ and $\varepsilon = (a - c)/a \approx$ ≈ 0.003 are the Earth average radius and compression, respectively.

The analysis shows that J_2 and variations of the measured gravitational constant *G* correlate with each other [*Khain, Khalilov, 2009, p. 309–313*].

It was noted in [*Ivanenko, Frolov, 1984*] that only one mechanism can explain quadrupole deformation of Earth as a result of the gravitational effect, in which the globe is in the gravitational field of the incident gravitational wave, and Earth behaves as its detector. Indeed, according to the general theory of relativity, a gravitational wave has two degrees of freedom, and in case of its interaction with the body in the plane perpendicular to the wave propagation direction, deformation typical of quadrupole oscillations will be noted [*Chiu, Hoffmann, 1964*].

Identification of quadrupole deformations of Earth and establishment of their correlation with variations of the gravitational constant allow us to further develop the above conclusion and to suggest that gravitational waves emitted from sources external to Earth may be a space factor that influences the values of the gravitational constant. It is known that any gravitational field is no more than a change in the space-time metrics. This important fact means that the geometric properties of space-time (its metrics) are defined by physical phenomena, but are not unchangeable properties of space and time" [*Landau, Lifshitz, 1980, p. 307*].

Thus, the above data and obtained results suggest that variations of the gravitational constant *G*, which are revealed by many researchers, seem to be dependent on processes taking place on sites where field measurements of *G* are taken by detectors. Two types of such processes are distinguished: (1) local geophysical processes manifested by rotational waves that occur on sites where the detectors are installed; properties of such waves are described above; (2) global processes associated with deformation of the entire Earth, which take place when gravitational waves from sources external to Earth are passing through Earth.

5. Discussion of results

The accumulated instrumental database is large and gives grounds to conclude that variations of geophysical fields can be described as a non-linear response of the discrete fractal medium with time-varying fractional dimension. According to the general theory of relativity, changes of the metrics (curvature) of space-time must be accompanied by gravitational waves [*Chiu, Hoffmann, 1964*; *Einstein, 1918*] and determined by geophysical phenomena [*Landau, Lifshitz, 1980*], as described above. Now the existence of the close relationship between gravity and geodynamic processes seems fairly obvious.

With regard to the block structure of geomedium and its characteristic stresses with momentum of force, a fundamentally new approach can be proposed for a better understanding of both geological and geophysical processes and their relationship with gravitational phenomena. The results obtained in our study provide for consideration of the problem of detection of gravitational waves at a new level of quality on the basis of the idea of interactions between the crustal blocks and the gravitational waves [*Braginsky et al., 1985*].

The effective cross section of the detector [*Chiu, Hoffmann, 1964*] recording gravitational waves is as follows: $\sigma \approx m|r|^2$, where $m|r|^2$ is the quadrupole momentum of the antenna. The effective cross section reaches its maximum when the distance between the two masses $|r|$ is close to the acoustic wavelength. Here acoustic waves mean elastic waves; in the case of Earth, acoustic waves mean longitudinal and / or transverse seismic waves. The sensitivity of this method proves insufficient when records are taken of short gravitational waves in their interaction with the crustal blocks and / or the entire Earth. According to estimates in [*Braginsky et al., 1985*], in order to ensure confident detection of gravitational waves by this method, the antenna's sensitivity should be increased by at least one or two orders of magnitude.

The situation can be radically changed, should rotational geodynamic perturbations c_0 (2) be referred to as a 'working tool', instead of elastic seismic waves. If rotational geodynamic perturbations are used to detect gravitational waves, other things being equal, the antenna's sensitivity of the antenna can be increased, and thus the task of detection of gravitational waves by the method described in [*Braginsky et al., 1985*] can be completely solved. Apparently, using the Eötvös torsion balance in the function of a seismograph to record slow movements of the Earth's surface can make it possible to detect gravitational waves [*Krylov, Sobolev, 1998*] and to successfully predict strong remote earthquakes on the basis of long-term gravitational precursors [*Khain, Khalilov, 2009*].

Under the conservation law of angular momentum, it is impossible or poorly probable that rotational stresses may be released by plastic deformation, and, consequently, the rotational stresses are accumulated in geomedium, i.e. elastic mantle, and convert it into the energy-saturated substance. Due to this property of stress preservation or the geomedium's lasting ' memory' of its previous state, the 'elementary' angle of the block's rotation, which reflects the dynamics of movement of the block's geomedium, cannot be considered small for long-term periods (equation 4, Figure 1). The sum of turns at the final angles does not have the additive property – it depends on the sequence of execution of such turns. Some of the fundamental provisions of global tectonics, which are based on Euler's theorem (D'Alembert-Euler) [*Zonenshain, Kovaleva, 1974; Le Pichon, 1968; Isaks et al., 1968; Morgan, 1968*] should to be revised.

The rheid property of geomedium or its potential superplastic flow in the solid state [*Leonov, 2008; Carey, 1953*] can be considered as a physical justification of the new paradigm of geology – the momentum vortex geodynamics [*Vikulin, Tveritinova, 2008; Vikulin et al., 2011*], under which the equilibrium shape of Earth is achieved by vortex motions of Dirichlet-Dedekind-Riemann and / or vortex geological structures [*Vikulin et al., 2013*], which were introduced in geology by J.S. Lee [*Lee, 1928*] (see also [*Vikulin, 2003, 2008b; Melekestsev, 1979; Milanovsky, 2007; Sleznak, 1972; Xie, 2004*]).

Studies of vortex flows with regard to gravitational energy of the bodies [*Kondratiev, 2003*] and data on vortex geological structures [*Vikulin, 2003; Milanovsky, 2007*] prove the existence of internal motions with vortex nature in rotating system, such as planets, stars and galaxies. A fundamentally important outcome of the above consideration is another possibility of obtaining new data on physical properties of planetary materials, such as viscosity, compressibility, magnetic field intensity, etc.

Under the rotary approach [*Vikulin, 2006, 2008a, 2010, 2011; Vikulin, Ivanchin, 1998, 2013; Vikulin et al., 2011, 2012a, 2012b, 2012c, 2013; Vikulin, Krolevets, 2002; Vikulin, Tveritinova, 2008*], the concepts of mechanics, gravity and geology are conforming and thus allow using the theory of potential, that takes into account the gravitational energy [*Kondratiev, 2003*], as a basis to describe geogravitational movements of Earth and its state of equilibrium. It is also likely that under this approach, the equilibrium state of Earth can also be described via a 'transfer' of gravitational energy in the energy of the state of stresses [*Ferronsky V.I., Ferronsky V.S., 2007*].

An alternative description of geodynamic (rheid) motions can be also provided in terms of non-linear (physical) acoustics as it considers that, aside from variables such as pressure, oscillation velocity and displacement, constant forces, such as the radiation pressure, occur in the acoustic field. The origin of the radiation pressure is related with changes of a time-average wave-carried impulse (momentum of force and / or angular momentum) in a certain volume. Such a pressure always occurs in continuous media because nonlinear effects take place even at relatively low intensities of sound (seismic wave amplitude). In its turn, the radiation pressure causes movements of the substance of the medium itself and the occurrence of acoustic flows

[*Krasil'nikov, Krylov, 1983*] or, in terms of geodynamics, rheid superplastic movements, including vortex geological structures. In the nonlinear physical acoustics, hydrodynamic and acoustic parameters are closely 'intertwined' with each other when the phenomenon of rotational flow or 'sound wind' is considered [*Gurbatov et al., 2008; Rudenko, Soluyan, 1975*].

Thus, the rotary approach, that is being further developed by the authors, provides justifications both in theory and practice for the existence of the Dirichlet-Dedekind-Riemann vortex flows in rotating gravitating non-viscous liquids. Such movements for the block rotating Earth, which substance is shown above to have rheid (superplastic) properties, can be also described in terms of physical acoustics.

6. Summary

The data and results presented in this article do not only confirm the relationship between geodynamics and gravity. Such data suggest the existence of a close relationship between the geodynamic and gravitational wave movements. It occurs that geodynamic waves and quadrupole gravitational changes of the Earth's shape are strongly interrelated. Therefore, the geodynamic waves can be referred to as a detector of gravitational perturbations, i.e. waves. Under such an approach, it becomes clear why, despite strenuous efforts recently made by many research teams, gravity and geodynamic (tectonic) waves have not been detected yet – they seems to be 'strongly' related phenomena requiring their joint recording [*Vikulin, 2011, p. 384–394*]. Results published in [*Krylov, Sobolev, 1998; Khain, Khalilov, 2009; Sherman, 2013*] are encouraging and supportive of the above statement.

In natural science, searching for an explanation of the physical mechanism that provides for the relationship between geological and gravitational phenomena is a fundamental challenge. An attempt to resolve the problem is described in [*Dmitrievsky et al., 1993*] under the concept of the system motion of substance on the basis of the new theory of vacuum and inertial fields, which combines the fundamental theoretical concepts of physics and geodynamics.

In our study, based on the available geodynamic data, it is concluded that the block motion in the rotating medium is equivalent to its own movement, but with its intrinsic momentum in the non-rotating coordinate system, and this conclusion can serve as a 'key' to understand the nature of spin [*Vilulin, 2009, p. 275*]. Indeed, it is known [*Levich et al., 1971, p. 38*] that "Schrodinger wave equation plays the same role in quantum mechanics as Newton's equation plays in classical mechanics". In quantum mechanics, the relationship between angular momentum and symmetry properties with regard to rotational motion "is particularly close, becoming essentially the main content of the concept of momentum. … A momentum acquires the sense of a quantum number, … and an issue of its origin becomes insignificant, and we naturally come to the concept of its 'intrinsic' momentum, which should be attributed to a particle regardless of whether it is 'complex' or 'elementary'" [*Landau, Lifshitz, 1981, p. 234–235*]. The stream of thought of geologist A.V. Peive becomes clear – based on analyses of geological data, he viewed 'the intrinsic potential of movements of the block' [*Pieve, 1961*] – in fact, its spin!

Therefore, a unified description of geodynamic and gravitational wave movements allow us to interpret the intrinsic momentum of a geological block (plate) and spin of an elementary particle as a manifestation of rotational (turning, momentum, vortex) properties of space-time.

Our results fully support the conclusion by V.I. Vernadsky [*Vernadsky, 1991*]: 'In the geologic history of our planet, there are time periods of higher or lower intensity of geological processes... We do not know any explanation of these facts, and it seems erroneous that most of the geologists believe that the cause is to be found inside the planet'. In other words, developing the theory of geological movements is also a 'key' to understanding the nature of time and space [*Aksenov, 2012*].

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