VIRIAL OSCILLATIONS OF CELESTIAL BODIES: V. THE STRUCTURE OF THE POTENTIAL AND KINETIC ENERGIES OF A CELESTIAL BODY AS A RECORD OF ITS CREATION HISTORY

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Abstract. The physical meaning of the terms of the potential and kinetic energy expressions, expanded by means of the density variation function for a nonuniform selfgravitating sphere, is discussed. The terms of the expansions represent the energy and the moment of inertia of the uniform sphere, the energy and the moment of inertia of the nonuniformities interacting with the uniform sphere, and the energy of the nonuniformities interacting with each other. It follows from the physical meaning of the above components of the energy structure, and also from the observational fact of the expansion of the Universe that the phase transition, notably, fusion of particles and nuclei and condensation of liquid and solid phases of the expanded matter accompanied by release of energy, must be the physical cause of initial thermal and gravitational instability of the matter. The released kinetic energy being constrained by the general motion of the expansion, develops regional and local turbulent (cyclonic) motion of the matter, which should be the second physical effect responsible for the creation of celestial bodies and their rotation.

Key words: N-body problem, Jacobi dynamics, virial oscillations

1. Introduction

In our previous works (Ferronsky et al., 1978, 1979, 1981, 1982, 1984, 1985, 1987) in order to solve Jacobi's virial equation $\ddot{\phi} = 2E - U$ for a nonuniform gravitating sphere, we introduced the structure coefficient $a = \alpha\beta$, which establishes a relationship between the potential and kinetic energies. Here E is the total energy of a system, $U = \alpha(GM^2/R)$ is the potential energy, $\phi = \frac{1}{2}J = \frac{1}{2}(\beta R)^2$ is the Jacobi function, J is the moment of inertia, M and R are mass and radius, α and β are dimensionless form-factors of radial mass distribution.

It was found by the authors that the structure coefficient lies between narrow limits for a wide range of density distributions with the minimum value for the uniform sphere.

While developing their global model for violent relaxation, Garcia Lambas et al. (1985) continued the study of the relationship between α and β for a nonuniform gravitating sphere. By the introduction of the auxiliary function of radial density variation, the form-factors were separated into components related to the structure of a uniform sphere and to its nonuniformities. It was shown by the authors that the

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product of the form-factors α and β achieves its absolute minimum for a uniform body.

After an analysis of these results we found that the separate components of the form-factors have definite physical meaning. The interpretation of dynamical effects of the potential and kinetic energy components throws light upon the history of the celestial body creation process.

2. Structure of Potential and Kinetic Energies

The auxiliary dimensionless function, introduced by Garcia Lambas et al. for the study of the relationship of the form-factors α and β, is

$$\psi(s) = \int_0^s \frac{(\rho_r - \rho_0)}{\rho_0} x^2 \, dx, \tag{1}$$

where $s = r/R$ is the ratio of the running radius to the radius of the sphere, ρ_0 is its mean density, ρ_r is the radial density and x is the running co-ordinate.

One can see that the function $\psi(s)$ expresses the variation of the mass density of spherical layers relative to the mean density of the sphere. From the integrals of the potential energy and the polar moment of inertia the following extensions for the form-factors α and β are obtained

$$\alpha = \tfrac{3}{5} + 3 \int_0^1 \psi x \, dx + \frac{9}{2} \int_0^1 \left(\frac{\psi}{x}\right)^2 dx, \tag{2}$$

$$\beta^2 = \tfrac{3}{5} - 6 \int_0^1 \psi x \, dx. \tag{3}$$

After some transformation, the relationship between the form-factors acquires the form

$$\alpha + \tfrac{1}{2}\beta^2 = \tfrac{9}{10} + \tfrac{9}{2}\lambda, \tag{4}$$

where

$$\lambda = \int_0^1 \left(\frac{\psi}{x}\right)^2 dx \geqslant 0. \tag{5}$$

Denoting the product of α and β by $Q = \alpha\beta$, one has

$$\beta^3 - (1.8 + 9\lambda)\beta + 2Q = 0. \tag{6}$$

In this way Garcia Lambas et al. (1985) obtained expressions for the expanded form-factors and their relationships. By variation of the product $\alpha\beta$ in the vicinity of $\lambda = 0$ and applying the Schwarz's inequality to the functions ψ/x and x^2, they have shown that the product $\alpha\beta$ has an absolute minimum for uniform mass density distribution.

It is worth noting that this important result has been obtained earlier by Wintner (1941) for a more general case of a gravitating mass point system without the condition of any symmetry of the density distribution. But for us the separation of the form-factors by function (1) is of main interest.

Thus, expression (2) represents an expansion of the potential energy of a nonuniform gravitating sphere in dimensionless form. Multiplying both sides by GM^2/R, expression (2) acquires its dimensional status

$$\alpha\frac{GM^2}{R} = \frac{GM^2}{R}\left[\frac{3}{5} + 3\int_0^1 \psi x \, \mathrm{d}x + \frac{9}{2}\int_0^1 \left(\frac{\psi}{x}\right)^2 \mathrm{d}x\right]. \tag{7}$$

Let us consider the physical meaning of the components in the right-hand side of the expression (7).

The value $\frac{3}{5}$ of the first term represents the potential energy of a uniform sphere with mass and radius of the nonuniform body.

The second term can be rewritten in the form

$$3\int_0^1 \psi x \, \mathrm{d}x \equiv 3\int_0^1 \left(\frac{\psi}{x}\right) x^2 \, \mathrm{d}x.$$

One can see that this is the additive part of the potential energy of the interaction of the nonuniformities with the uniform body.

The third term can be rewritten as

$$\frac{9}{2}\int_0^1 \left(\frac{\psi}{x}\right)^2 \mathrm{d}x \equiv \frac{9}{2}\int_0^1 \left(\frac{\psi}{x^2}\right)^2 x^2 \, \mathrm{d}x.$$

This is also the additive part of the potential energy of the interaction of the nonuniformities between themselves.

Here and further the nonuniformities of the mass density are determined as the difference between the given density of a spherical layer and the mean density of the body within the radius of the considered layer.

Note that in the Newtonian interpretation the potential energy has a non-additive category. It cannot be localized even in the simplest case of the interaction between two mass points. In our case of a gravitating sphere as a continuous body, for the interpretation of the additive component of the potential energy we can apply Hooke's concept. His relationship between the force and the caused displacement is linear. Therefore the displacement is in square dependence from the potential energy. Hooke's energy belongs to the additive parameters. In the considered case of a gravitating sphere, the Newtonian force acting on each spherical layer is proportional to its distance from the center. Thus, from a physical point of view, the interpretation of Newton and Hooke are identical.

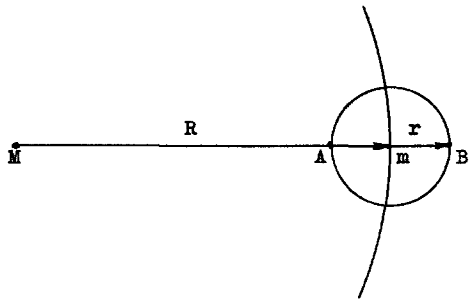

Figure 1. Roche's tidal forces for two bodies.

Let us now consider expression (3). It represents the polar moment of inertia of the same sphere in dimensionless form. It describes the kinetic energy in the case of a rotating body. Multiplying both sides of expression (3) by MR^2, we obtain a dimensional form

$$\beta^2(MR^2) = MR^2 \left[\tfrac{3}{5} - 6 \int_0^1 \psi x \, \mathrm{d}x \right] . \tag{8}$$

One can see again that the first term $\frac{3}{5}$ in the right-hand side represents the polar moment of inertia of a uniform sphere with mass and radius of the nonuniform body.

The second term describes the moment of inertia of the nonuniformities. It is also seen that the integrals of the second term of expressions (7) and (8) are identical.

3. Dynamical Effects of a Nonuniform Gravitating Sphere

3.1. ROCHE'S TIDAL APPROACH

In order to understand the dynamics of a uniform sphere and the nonuniformities of a gravitating nonuniform body, the tidal effects should be considered using Roche's approach and the principle of superposition. The main point of this task is as follows.

There are two interacting bodies of masses M and m (Figure 1). Let $M \gg m$ and $R \gg r$, where r is the radius of the body m and R is the distance between the bodies M and m. Assuming that the mass of the body M is uniformly distributed within the sphere of radius R, we can write the accelerations of the points A and B of body m as

$$q_A = \frac{GM}{(R-r)^2} - \frac{Gm}{r^2},$$

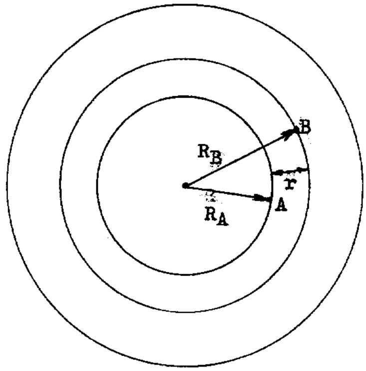

Figure 2. Roche's tidal forces for a gravitating nonuniform sphere.

$$q_B = \frac{GM}{(R+r)^2} + \frac{Gm}{r^2}.$$

The relative tidal acceleration of the points A and B is

$$\begin{aligned} q_{AB} &= G\left[\frac{M}{(r-r)^2} - \frac{M}{(R+r)^2} - \frac{2m}{r^2}\right] = \\ &= \frac{4\pi G}{3}\left[\rho_M R^3 \frac{4Rr}{(R^2-r^2)^2} - 2\rho_m r\right] \simeq \\ &\simeq \frac{8\pi G}{3} r(2\rho_M - \rho_m), \end{aligned}$$

where $\rho_M = M/\frac{4}{3}\pi R^3$ and $\rho_m = m/\frac{4}{3}\pi r^3$ are, respectively, the mean density distribution of the spheres of radius R and r. Roche's criterion states that the body of mass m is stable against the tidal force disruption of the body M if the mean density of the body m is at least double that of the body M in the sphere of radius R.

Roche considered the problem of the interaction between two seperate bodies without any interest to their creation history. From the point of view of the origin of celestial bodies and of the interpretation of dynamical effects, we are interested in the tidal stability of separate envelopes of the same body. For this purpose we can apply Roche's considered approach.

Let us assess the tidal stability of a spherical layer of radius R and thickness $r = R_B - R_A$ (Figure 2). The layer of mass m and mean density $\rho_m = m/4\pi R_A^2 r$ is affected in point A by tidal force of the sphere of radius R_A. The mass of the sphere is M and its mean density $\rho_m = M/\frac{4}{3}\pi R_A^3$. The tidal force in point B is due to the sphere of radius $R + r$ and mass $M + m$. Then the accelerations of the points A and B are

$$q_A = \frac{GM}{R_A^2} \quad \text{and} \quad q_B = \frac{G(M+m)}{(R_A+r)^2}.$$

The relative tidal acceleration of the points A and B is

$$\begin{aligned} q_{AB} &= GM\left[\frac{1}{R_A^2} - \frac{1}{(R_A+r)^2}\right] - \frac{Gm}{(R_A+r)^2} = \\ &= \left(\frac{8}{3}\pi G\rho_M - 4\pi G\rho_m\right) r = 4\pi G r\left(\frac{2}{3}\rho_M - \rho_m\right), (R \gg r). \end{aligned} \tag{9}$$

One can see that the numerical criterion of Roche's tidal stability is different from that for two separate bodies. But for the asessment of the dynamical effects it is important to note some other aspects of the result.

3.2. SELFSIMILARITY PRINCIPLE FOR A CONTRACTING UNIFORM BODY

In the case of a uniform density distribution ($\rho_M = \rho_m$), all spherical layers of the gravitating sphere move to the center with accelerations and velocities which are proportional to the distance from the center. It means that such a sphere contracts without loss of its uniformity. This property of selfsimilarity of a dynamical system without any discrete scale is uniqe for a uniform body.

A continuous system with uniform density distribution is also ideal from the point of view of Roche's criterion of stability with respect to the tidal effect. That is why there is deep physical meaning in the separation of the first term of the potential energy in expression (2). A uniform sphere is always similar in its structure in spite of the fact that it is continuously contracting. Here, we certainly do not consider the Coulomb forces effect. For this last case we have considered specific proton and electron branches of the evolution of the body (Ferronsky et al., 1987).

The selfsimilarity principle is also valid for a rotating uniform sphere, for which the velocities of the spherical layers are proportional to their radii. In expression (3) the first term of the moment of inertia determines also the constant component of the dynamical effect. Thus, the first terms of the potential and kinetic energy expressions from the basic state of a nonuniform gravitating sphere which is steady, relative to the tidal forces, in all parts and during all the time of the contraction of the system. At the same time it follows from the law of conservation of the energy that the two energies are equal, and the total energy is equal to zero.

Thus, in the ideal case of uniform density, the dissipation of the energy is inadmissible. Because there is no random motion and radiation, the temperature of such a sphere should be equal to zero.

3.3. CHARGES-LIKE MOTION OF NONUNIFORMITIES

Let us now discuss the tidal motion of nonuniformities due to their interaction with the uniform body. The potential and kinetic energies of these interactions are given by the second terms of expressions (2) and (3). In accordance with (9), nonuniformity motions look like the motion of electrical charges interacting on the background of a uniform sphere contraction. Spherical layers with densities exceeding that of the uniform body (positive anomalies) come together and move to the center in elliptic trajectories. The layers with deficit of the density (negative anomalies) come together but move from the center on hyperbolic path. Similar anomalies come together, but those with opposite signs are dispersed with forces proportional to the layer radius. In general, the system tends to reach a uniform and equilibrium state by means of redistribution of its density up to the uniform limit.

The given picture is complicated by the rotation of the body which always exists. Nonuniformities acquire extra-centrifugal acceleration. It develops the opposite effect. More dense layers move from the center and less dense move to the center. The resulting direction of the nonuniformity motion depends on the ratio of both factors. The physical relationship of the structural coefficients α and β in expressions (4) and (6) is developed here. The basis of this relationship is formed by the uniform sphere, and the relation itself is realized through the second terms of the right-hand side parts of expressions (2) and (3). In addition to that, the relationship predetermines the virial proportion between the potential and kinetic energies ($-U = 2T$). This statement is proved by the numerical values at the second integrals. From a physical point of view, the fact of the occurrence of the same integrals in expressions (2) and (3) is an evidence of the conversion of the potential energy into the rotational kinetic energy, during the appearance of the nonuniformities due to the phase-transition effects in the expanded homogeneous media.

The relationship (6), obtained by the introduction of $Q = \alpha\beta$ varying in narrow limits for a wide range of physical and nonphysical models of celestial bodies, has the structure of the van der Waals equation. This is a direct evidence of the involvement of the phase-transition effect into the process of creation of celestial bodies. The phase transitions are the only known natrual mechanisms for the appearance of the density nonuniformities in a uniform steady-state media to which any natural system approaches. So that, positive density anomalies are formed during condensation (fusion) of the matter and negative ones during its evaporation (fission).

3.4. ELECTROMAGNETIC COMPONENT AND EQUILIBRIUM RADIATION

We may now consider the third term of the potential energy extention (2). As mentioned above, the term represents in dimensionless form the energy of the interaction of the nonuniformities among themselves. We apply the analogy of

Table I
Numerical values of the parameter λ for a sphere with different laws of density distribution

Law of radial density distribution	α	β	$Q = \alpha\beta$	9λ
$\rho = \rho_0$	0.6	0.77	0.46	0
$\rho = \rho_0(1 - \frac{r}{R})$	0.74	0.63	0.47	0.086
$\rho = \rho_0[1 - (\frac{r}{R})^2]$	0.71	0.65	0.47	0.060
$\rho = \rho_0 \exp(-k\frac{r}{R})$	$0.16k$	$3.45\frac{1}{k}$	0.53	0.19
$\rho = \rho_0 \exp[-k(\frac{r}{R})^2]$	$\sqrt{\frac{k}{2\pi}}$	$1.8\sqrt{\frac{1}{k}}$	0.49	0.19
$\rho = \rho_0\delta(1 - \frac{r}{R})$	0.5	1.0	0.5	0.20

Table II
Numerical values of the parameter λ for politropic models of a sphere

Index of polytrope	α	β	$Q = \alpha\beta$	9λ
0	0.6	0.77	0.46	0
1	0.75	0.62	0.465	0.08
1.5	0.87	0.55	0.475	0.24
2	1.0	0.48	0.482	0.43
3	1.5	0.34	0.5	1.31
3.5	2.0	0.26	0.52	2.26

electrodynamics for its interpretation. Each particle there generates an external field. The energies of some other particles are determined by this field and their own charges. The resultant energy of all particle interactions gives the total potential energy. As far as the potential of the field is expressed by means of the Poisson equation through the density of charge in the same space point, then the total energy can be presented in additive form through the application of the squared field. If a nonequilibrium system is considered, then the Maxwell radiation field appears.

In our task the potential of the gravitational field is expressed in dimensionless form by the function $E = \psi/x^2$ (where ψ plays the role of a charge), and the term

$$\tfrac{9}{2}\lambda = \frac{9}{2}\int_0^1 \left(\frac{\psi}{x}\right)^2 \mathrm{d}x \equiv \frac{9}{2}\int_0^1 \left(\frac{\psi}{x^2}\right)^2 x^2\,\mathrm{d}x \equiv \frac{9}{2}\int_0^1 E^2\,\mathrm{d}V,$$

represents the field energy. This is seen from the expression, where $\mathrm{d}V = x^2\,\mathrm{d}x$ is the volume element in dimensionless form.

In order to determine the numerical value of λ, the calculations for a sphere with different laws of radial density distribution including the polytropic models were

Table III
Observational parameters of nebulae

Parameters	Visible dark nebulae			
	Small globula	Large globula	Intermediate cloud	Large cloud
M/M	> 0.1	3	$8 \cdot 10^2$	$1.8 \cdot 10^4$
R (pc)	0.03	0.25	100	20
$n(n/\text{cm}^3)$	$> 4 \cdot 10^4$	$1.6 \cdot 10^3$	100	20
$\frac{M}{\pi R^2}$ (g/cm^2)	$> 10^{-2}$	$3 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$3 \cdot 10^{-3}$

done. These models were used in our previous numerical calculations of the form-factors α and β (Ferronsky et al., 1978, 1987). The results, presented in Tables I and II, show that for the density distributions which have physical meaning (Dirac's envelopes, Gaussian and exponential distributions) and also for the polytrops with index 1.5, the parameter λ has the same constant value. We interpret this fact for a steady-state dynamical system as evidence of the existence of equilibrium radiation between a celestial body and the external flow. The numerical value of the parameter λ is equal to 0.022 for celestial bodies. There is also an observational confirmation of this conclusion. Spitzer (1968) demonstrates observational results of nebulae of different mass and size in Table 3.2 of his book which we reproduce here in Table III.

One can see that for masses of solar order and up to a huge size the value of M/R^2 remains constant. This fact proves the statement on the physical meaning of the third term of expression (2) which is the equilibrium radiation of a celestial body.

3.5. TWO FORMS OF EQUILIBRIUM STATE OF A GRAVITATING SPHERE

Taking into account the constancy of the value of λ and also that $2Q = 1$ for physical models, expression (6) becomes

$$\beta^3 - 2\beta + 1 = 0. \tag{10}$$

It is not difficult to find that

$$\beta_1 = 1 \quad \text{and} \quad \beta_2 = \frac{\sqrt{5}-1}{2} \simeq 0.63$$

which is the golden section. The third root has a negative value. Thus, the same value for the structural parameter Q corresponds to two sets of values of α and β.

In this connection we recall Maclaurin's solutions, generalizing the first Newtonian studies related to the gravitational equilibrium of rotating masses.

Maclaurin obtained an equation for the eccentricities of a rotating spheroid. This equation, even for zero angular velocity, gives two and only two possible figures: a uniform sphere and an infinitely falttened spheroid.

Thus, the existence of the two forms of equilibrium state has been known since Newton's and Maclaurin's time. We also note that in the evolutionary series of Maclaurin's spheriods a bifurcation point appears. At this point of Maclaurin's succession curve a new succession of equilibrated triaxial ellipsoids appears. This is the starting point of Jacobi's succession. A small deformation in the bifurcation point is natural and here the transformation of a figure from one into another is possible. The eccentricity of a figure at the bifurcation point is equal to 0.81, and the angular momentum in the units of $\sqrt{\pi G \rho}$ is $\sqrt{0.374}$. These two parameters, which define the bifurcation point, are close to the value of the golden section. Jacobi proceeds just from the idea that Maclaurin's consideration gives two solutions. The appropriate fractions which give the golden section are ratios of Fibonacci numbers. It is interesting to note that the first appropriate fractions of these numbers (1, $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$) give values of form-factors α and β for the final figures.

4. Applications

4.1. TEMPERATURE OF THE RELICT RADIATION

The conclusion about the constancy of the equilibrium radiation parameter λ enables to obtain the numerical value of its temperature. For this we equate the expressions of the black radiation energy and the volumetric density of that part of the gravitational energy which corresponds to the radiation energy in the Maxwell theory, that is

$$\sigma T^4 = \lambda \frac{GM^2}{R} \cdot \frac{1}{\frac{4}{3}\pi R^3}, \tag{11}$$

where σ is the Stefan–Boltzmann's constant and T is the absolute temperature.

From here

$$T = \sqrt[4]{\frac{3}{4\pi}\frac{\lambda G}{\sigma}} \cdot \sqrt{\frac{M}{R^2}}. \tag{12}$$

In accordance with Spitzer (1968), the value of $M/\pi R^2$ for globulae of solar to galactic mass is equal to $3 \cdot 10^{-3}$ g/cm^2 ($M/R^2 = 10^{-2}$). Our data shows that $\lambda = 0.022$. Then from Eq. (12) the value of $T \simeq 4$ K. This is the observed relict radiation.

Let us now consider expression (11) from the point of view of the solar system. The expression can be written in the form

$$(RT)^4 = \frac{\lambda GM^2}{\frac{4}{3}\pi\sigma}.$$

From here with the solar mass

$$RT = \sqrt{M} \cdot \sqrt[4]{\frac{\lambda G}{\frac{4}{3}\pi\sigma}} = 5 \cdot 10^{17}\ \text{cm} \cdot {}^\circ\text{K}.$$

This numerical value of RT was obtained in our works (Ferronsky et al., 1979, 1987) as the value of the proton branch of the star evolution. This theoretical solution has been proved by observational data of Spitzer. The electron branch of the evolution was also found there. Its RT value is 2000 times less than that of the proton branch in accordance with the ratio of their messes. Hence, the radius of the protosolar cloud is $\sim 10^{17}$ cm for the proton branch of the evolution and $\sim 5 \cdot 10^{13}$ cm for the electron branch. This is a possible explanation for the division of the solar system planets in two groups.

The planetary masses are by 10^3 to 10^7 times less than the solar mass and their radii are 10^{-2} to 10^{-4} solar radius. This estimation follows from the recalculation of the proton and electron branches of evolution. Therefore, the ratio M/R^2 for the planets is only 10–100 times more than that of a protostar obtained by Spitzer. The radiation of the planets and satellites should be in equilibrium with the outer flux which is the internal solar flux. In this connection the equilibrium temperature of the planets and satellites should be 3–10 times more than the star's temperature of 10–100° K. The existing direct measurements give evidence of two peaks in the relict radiation spectrum (4 K and 20 K). It means that our physics and numerical estimates are reasonable.

4.2. RELATIONSHIP BETWEEN THE MASS OF A CELESTIAL BODY AND ITS CONSTITUENT PARTICLES

In our work (Ferronsky et al., 1981) the relationship between the total mass of a celestial body and the average mass of its constituent particles was found in the form of $M\mu^2 =$ constant. The relationship was derived from the Chandrasekhar–Fermi (1951) equation describing the equilibrium between the gravitational and Coulomb interactions for some part of the body mass

$$\int_{(v)} \left[\rho \mathbf{v}^2 + 3p + \frac{\mathbf{H}^2 + \mathbf{E}^2}{8\pi} - \frac{(\nabla U)^2}{8\pi G} \right] \mathrm{d}V = 0, \tag{13}$$

where ρ is the density of the secondary body mass, $\mathbf{v}$ is the mean velocity, p is the internal pressure, $\mathbf{H}$ and $\mathbf{E}$ are the components of the electromagnetic field, G is the gravitational constant, V is the volume of the body, and U is the gradient of the gravitational field.

For the stage of secondary body bifurcation the kinetic terms in expression (13) are small and were omitted. But we did not take into account the condition of equilibrium radiation of the secondary body for its gravitational energy which has a factor $\frac{9}{2}\lambda = 0.1$ as it is seen from expression (2).

Thus, instead of the previous relation we must now write

$$\int_{(v)} 3p\,\mathrm{d}V = 0.1\frac{GM^2}{R},$$

from where

$$\frac{M}{\mu}\cdot\frac{e^2}{R^3\sqrt{\frac{\mu}{M}}} = 0.1\frac{GM^2}{R},$$

here $e = 4.8\cdot 10^{-10}$ is the electron charge.

Then we obtain

$$M\mu^2 = \text{const.} = 2\cdot 10^{-16} g^3. \tag{14}$$

In the cited work this numerical value was equal to $6.35\cdot 10^{-18} g^3$.

So that, for example, the particle responsible for the equilibrium radiation of the protosolar cloud at the stage of its bifurcation from the protogalaxy is

$$\mu = \sqrt{\frac{2\cdot 10^{-16}}{2\cdot 10^{33}}} = 10^{-24} g.$$

4.3. MASS OF THE UNIVERSE

The relationship $M\mu^2 = \text{const.}$, and the requirement that the particle with mass μ according to Wien's law provides the equilibrium radiation and the temperature of the equilibrium gravitating cloud, enable to determine the mass of the cloud which continually maintains the flux of the equilibrium radiation. In fact, the temperature of the equilibrium cloud is determined from relation (12). The frequency of the equilibrium black radiation according to Wien's law is $\gamma = AT (A = 10^{11}\ \text{Hz}/^\circ\text{K})$. The energy of this frequency and the particle mass μ are related as $\hbar\gamma = \mu c^2$ ($\hbar$ is Planck's constant and c is the light velocity). After the substitution of μ from here into the expression $M\mu^2 = B = 2\cdot 10^{-16} g^3$ and equating the relations with respect to the temperature, one can write

$$\sqrt[4]{\frac{3}{4\pi}\cdot\frac{\lambda G}{\sigma}\cdot\sqrt{\frac{M}{R^2}}} = \frac{C^2}{A\hbar}\sqrt{\frac{B}{M}}.$$

From this relation the mass M is equal to $\sim 10^{56}$ g and the mass of the particle which provides the equilibrium radiation is $\mu = 10^{-36}$ g. This particle should be the fundamental particle of the Universe.

4.4. MECHANISM OF CELESTIAL BODY CREATION

It was noted above that expressions (6) and (10) which establish the relationship between the potential and kinetic energies of a gravitating nonuniform sphere are similar to van der Waals equation. This case and also the fact that celestial bodies are condensed creatures with equilibrium radiation on the borders, make it possible to assume that the fundamental effect in their origin was the phase transition of the matter. The cosmological fact of the adiabatic expansion of the Universe provides the physical basis for the matter condensation at the early stage of the process. The appearance of the first condensate of the matter in the form of particles and nuclei should lead to the origination of nonuniformities which should immediately start to come together by tidal forces and to form the first protoclouds. The mass and the size of these first clouds were controlled by the mass of the first particles which provided equilibrium radiation with isotropic flux of radiation of the outer field, i.e. $M\mu^2 = \text{const.}$, $\lambda = \text{const.}$ The continuation of the process of condensation should lead to the creation of new particles and nuclei with respect to their masses, and to the appearance of new nonuniformities and new bodies. But the contraction of the body matter provokes the rise of the temperature and as a consequence, the vaporation of the volatile components. This new phase-translation stage should be responsible for the creation of the second generation bodies by means of the vapour expansion (negative anomaly), its condensation and creation of the secondary bodies.

From the point of view of the observed picture of space, the galaxies and the stars are bodies of the first generation. They have been formed after the appearance of the particles with masses of 10^{-30} and 10^{-24} g. Such particles provide the equilibrium radiation of galaxy and star masses. Their equilibrium radiation with the outer space at the moment corresponds to ~ 4 K. The planets and the satellites are bodies of the second generation. Their equilibrium radiation with the internal star space corresponds to 10–100K. In short, from the point of view of the considered analysis of the potential and kinetic energy record, the physical effects of creation of celestial bodies are the phase-transition processes of the matter during its expansion and condensation accompanied by tidal perturbations due to release of the condensational energy which is responsible for the rotational processes.

The most probable natural mechanism of the creation of celestial bodies can be observed in the Earth atmosphere. It relates to the global water cycle with all the physical elements of creation of secondary bodies, namely evaporation, expansion, condensation and formation of bodies.

In fact, the water vapour over the oceans (negative anomaly) is adiabatically expanded during its rise and is condensed into a liquid phase (positive anomaly). The released potential energy of vapour condensation continuously perturbs the translational motion of the inert oxygen and nitrogen atmosphere. The condensed atmospheric moisture comes together into clouds through tidal forces. At the border of a warm and moist front from one side and a dry but cool front of air masses

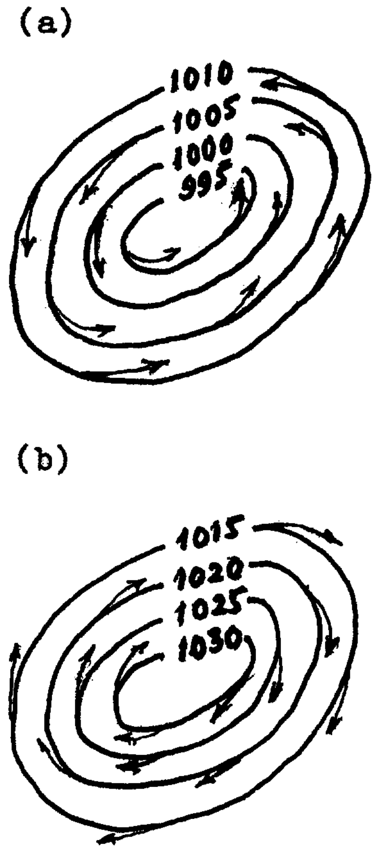

Figure 3. Mode of rotation, distribution of pressures and direction of filling in the cyclone (a) and anti-cyclone (b) for the Northern Hemisphere.

from the other side the process of condensation is accompanied by the creation of cyclones.

The physics of cyclone formation (Khromov, 1948) is based on the transformation of the potential energy of the vapour condensation into kinetic energy during adiabatic expansion. It is considered that $\frac{3}{4}$ of the cyclonic energy comes from the realization of the potential energy of vapour and $\frac{1}{4}$ is due to the difference in gravitational potential.

Cyclone creation starts by an invasion of warm and moist air mass with excess of kinetic energy into a cool and dry mass. As a result of quasi-wave perturbation from the warm mass side, the isobars are locked. This is the starting point of cyclone origination. All the cyclones in the Northern Hemisphere have counterclock-wise rotation and clock-wise in the Southern Hemisphere. The lower pressure in the center and the higher in the outer side are their characteristic features (Figure 3a). The growing of the cyclone proceeds on selfdeveloping basis. The moist air is

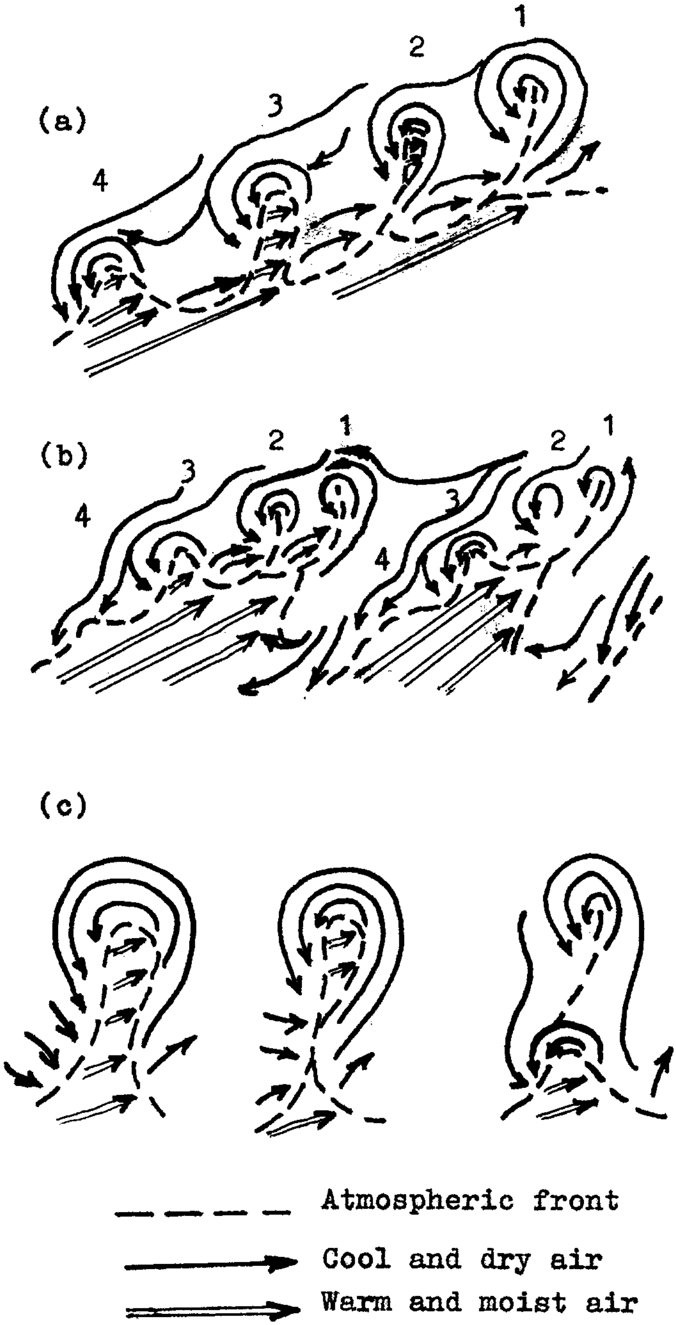

Figure 4. Formation of families of cyclones along an atmospheric front (a) along two fronts (b) and the creation of a small secondary cyclone (c)

continuously recharged into the low pressure bottom space of the cyclone from the surrounding domain. Due to adiabatic expansion the vapour is condensed here and the cyclone is growing and rotating by the released energy of condensation.

Cyclones are formed continuously by families of 3–5 creatures (Figure 4a) among the atmospheric front. Individual vorticities may come together into a deep cyclone of 2–3 thousand kilometer size in diameter. Such a cyclone is moved within an air mass flow but with $\frac{2}{3}$ to $\frac{3}{4}$ of its velocity. The Coriolis force drifts the cyclone to the equatorial plane direction. After 5–6 days the cyclone is filled in by the surrounding higher pressure air mass and disappears over the continents.

Anti-cyclonic vorticities are developed togther with cyclones. They are formed as a result of adiabatic compression of air masses being liberated from the condensation and falling down to the earth surface. The anti-cyclones have high pressure in the center and lower in the peripheric direction (Figure 3b) and their rotation has a clock-wise direction in the Northern Hemisphere.

In the case of the formation of two atmospheric fronts of warm and cool air masses two families of cyclones are developed (Figure 4b). Four families of cyclones are formed in the Northern Hemisphere simultaneously and continuously.

Sometimes secondary small cyclones are formed on the periphery of the main cyclone. They moves around the main cyclone in the same direction and with the same mode of rotation (Figure 4c).

The cyclone has an axis of rotation which passes through the points of minimum pressure of the moist air masses. In fact, the rotational axis always has an inclination with respect to the direction of the pressure and temperature gradient.

Thus, we observe the full scale process of body creation and the mechanism of birth of its rotation in the earth atmosphere. This is an excellent physical model for celestial body creation of both first and second generation.

5. Conclusion

In terms of the recognized structure of the potential and kinetic energies and of the dynamical effects of a gravitating nonuniform sphere, celestial bodies represent a hierarchy of energy anomalies. Similar anomalies (positive and negative) of energy in the scale of microcosmos are nuclei and their particles. From the point of view of this conception the physical meaning of such fundamental categories like gravitation and charge becomes understood.

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