SOLUTIONS OF THE STANDARD DIFFERENTIAL EQUATION OF THE DYNAMIC GRAVITATIONAL FIELD OF A FLAT GALAXY

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Abstract

The solution to the gravitational field equations of a flat galaxy has been found. It is shown that at the edge of the galaxy the excessively strong ordinary (unreduced) centrifugal pseudo-forces of inertia are compensated mainly by centripetal pseudo-forces of evolutionary self-contraction of matter in the background Euclidean space of expanding Universe, and not by the weak gravitational pseudo-forces at the edge of the galaxy. The strength of the dynamic gravitational field of spiral and other flat (or superthin) galaxies, according to their two-dimensional topology, is inversely proportional to the radial distance, not to its square. And this is the case, despite the inverse proportionality of the strength of individual gravitational fields of all spherically symmetric astronomical objects of the galaxy exactly to the square of radial distance. The general solution of the equations of the gravitational field of the galaxy with an additional certain parameter n is found. At possible values of $n < 1$, the velocity of the orbital motion of stars is slightly less than the highest possible velocity even at the edge of the galaxy. According to the General Relativity (GR) equations and the Relativistic Gravithermodynamics (RGTD) equations, the configuration of the dynamic gravitational field of a flat galaxy in a quasi-equilibrium state is standard (canonical in RGTD). That is because it is not determined at all by the spatial distribution of the average mass density of its non-continuous matter. After all, this spatial distribution of the average mass density of the galaxy's matter is itself determined by the standard configuration of its dynamic gravitational field. The standard value of the average density of mass of matter at the edge of a galaxy is determined by the cosmological constant Λ and by the difference between unity and the maximum value of the parameter b_c. And it is a non-zero standard value, despite the gravitational radius at the edge of a galaxy takes the zero value. Therefore, in the RGTD and in the appropriate interpretation of the GR, in contrast to the orthodox interpretation of the GR, there can be no shortage of baryonic mass. And therefore, the Universe does not need dark non-baryonic matter at all.

Keywords: galactic dynamics; spiral structure; General Relativity; flat (or superthin) galaxy; dark non-baryonic matter; Relativistic Gravithermodynamics.

1. Introduction

In 1934, Swiss astronomer Fritz Zwicky discovered that the total gravitational mass of a galaxy – calculated using the gravitational virial theorem – was significantly greater than the luminous mass observed through optical methods. This suggested that the majority of a galaxy's gravitational mass is invisible [1, 2]. According to Newton's law of universal gravitation, the rotational speed of stars within a galaxy should decrease as their distance from the center increases. However, in the 1970s, American astronomer Vera Rubin and her colleagues observed that the rotational velocity of gas in spiral galaxies remains nearly constant at varying radii. This phenomenon, known as the asymptotically flat rotation curve, remains one of the key mysteries in astrophysics [3 – 5].

The problem of the lack of enough amount of baryonic matter in galaxies has been the subject of many research works [6 – 18]. But it has not yet been solved. This research considers the possibility of a radical solution to the problem without the use of ghostly dark non-baryonic matter based on the fact that the decrease in gravitational field strength along the planes of flat galaxies is inversely proportional to the radial distance, and not to its square, and based on the spatiotemporal non-invariance of the gravitational constant [19, 20]. And the possibility of this is confirmed by the corresponding solution of the gravitational field equations of a flat galaxy [19 – 22].

Due to the fact that evolutionary decrease of the radius r of the star´s orbit is fundamentally unobservable in the intrinsic frames of references of coordinates and time (FR) of matter, this radius is the same (r=**invar)** in all FRs. The orbital velocities of galaxies and their stars that are observed on an exponential physically homogeneous scale of intrinsic time t [19, 23] of any observer should also be considered real in the observer´s FR. Taking this into account, a dynamic gravitational field [22] of galaxies is examined in this paper: the field in which the velocities v of the hypothetical equilibrium circular motion (r=**const**) of astronomical objects in equilibrium state do not depend directly on the radial coordinate r, but depend only on the value of the coordinate vacuum velocity of light $v_{cv} = c\sqrt{b_c}$ of general relativity (GR) **or** on the equivalent limit velocity of matter motion v_l (or v_{lc}) of the relativistic gravithermodynamics (RGTD) [19, 20, 23]. Thus, unlike the modified Newtonian dynamics proposed by Mordechai Milgrom [24, 25], both in the orthodox GR and in its modification by the RGTD, the speed of orbital motion of astronomical objects in a flat galaxy, albeit indirectly, still depends on their radial distance to the center of the galaxy.

Because of this, the Λ-reduced (evolutionarily weakened) centrifugal pseudo-force of inertia [19, 20]:

$$\mathbf{F}_{in} = m_{in}\hat{v}^2(1-\Lambda r^2)/r(1-\Lambda r^2/3) = \mathbf{F}_{in0} + \mathbf{F}_{inE} \approx m_{in}v^2/b_c r - 2m_{in}v^2 r/b_c v^2(r_c^2 - r^2),$$

which “balances” (compensates) the gravitational pseudo-force in a rigid FR of matter, depends in GR and RGTD on the cosmological fundamental constant $\Lambda = 3H_E^2 c^{-2} = \mathbf{const}(t)$ and, therefore, on the Hubble fundamental constant $H_E = \mathbf{const}(t)$. The fundamental invariability of these constants in the intrinsic time t of matter ensures the continuity of the intrinsic space of a rigid FR [19, 20].

Here: $\mathbf{F}_{in0} = m_{in}v^2/b_c r$ is ordinary (unreduced) centrifugal pseudo-force of inertia; $\mathbf{F}_{inE} = -2\Lambda m_{in}\hat{v}^2 r/(3-\Lambda r^2) = -2H_E^2 m_{in}v^2 r/b_c(c^2 - H_E^2 r^2) \approx -2m_{00}v^2 r/\sqrt{b_c}(r_c^2 - r^2)$ is centripetal evolutionary pseudo-force, which pushes matter towards the center of the galaxy, thereby compensating within the galaxy (when $r<\Lambda^{-1/2}$) the centrifugal gravitational pseudo-force, which is responsible for the evolutionary distancing of other galaxies from it according to Hubble's law; $r_c \approx c/H_E$ is the radius of the event pseudo-horizon, which covers the entire infinite fundamental space of the Universe [19] in the FR of any matter due to the fundamentally unobservable in FR of people´s world evolutionary self-contraction (in fundamental space) of matter spiral-wave microobjects, which are the so-called elementary particles [19, 26 – 28].

Therefore, astronomical objects in distant galaxies move in stationary, rather than divergent spiral orbits precisely due to the presence (in the observer's FR) of the action on them not only of gravitational, but also of evolutionary centripetal pseudo-force. And it is precisely this evolutionary centripetal pseudo-force that causes these same astronomical objects to move in convergent spiral orbits in the comoving with expanding Universe FR (CFREU) [19] (due to fundamental unobservability (in the observer's FR) of evolutionary self-contraction of matter in fundamental space of the CFREU).

The dependence of Λ-reduced centrifugal pseudo-force of inertia exactly on the intrinsic value of the object's orbital velocity $\hat{v} = vc/v_{lc} = v/\sqrt{b_c}$ actually compensates for the non-identity of its inertial mass $m_{in} = m_{gr}b_c$ to the much larger gravitational mass m_{gr} and thereby provides the possibility of using a single galactic value ${}^gG_{00}$ of the gravitational constant in the FR_g of the galaxy. But in the FR_{si} of each of the stars of this galaxy there may be their own values ${}^SG_{00i} = {}^gG_{00}\,{}^gb_{ci}^{-2}$ of the gravitational constant [19 – 22], according to which the planets and satellites rotate relative to them. Similarly, in the FR_E of the Earth, each of the distant galaxies may also have its own gravitational constant ${}^{g}G_{00e} = {}^{E}G_{00}\,{}^{E}b_{ce}^{-2}$. The failure to take this into account, together with the failure to take into account the two-dimensional topology of flat galaxies, are the main reasons for the imaginary need for dark non-baryonic matter in the Universe. After all, compensation for the mutual non-identity of the inertial and gravitational masses of only the most distant galaxies does not provide compensation for the mutual non-identity of the inertial and gravitational masses of their stars.

Thus, in the own time of astronomical objects of a distant galaxy, the inertial mass of their matter is actually identical to the gravitational mass of the matter, as it should be. The fact that gravitational mass of objects of a distant galaxy in the FR of the Earth observer is greater is due to a much higher temperature of their matter in the distant past. And this is similar to the much higher temperature of matter in the bowels of the Earth. And therefore, the observed thermodynamic parameters of matter in any distant galaxy strictly correspond to the thermodynamic parameters of the Earth's matter. Therefore, the values of the parameter b_c in a distant galaxy strictly correspond to the values of the absolute temperature of its matter in the observed distant past. And therefore, the Earth's gravitational field strictly corresponds to the thermodynamic state of the matter of the Universe in any distant past.

The second reason for the imaginary need for dark non-baryonic matter may be the erroneous conclusion about the presence of relativistic dilation of intrinsic time for objects of distant galaxies. Because of this, objects of distant galaxies should move in their intrinsic time at much higher speeds than according to the clock of an observer from the Earth. In fact, galaxies “fall” onto the event pseudo-horizon by inertia, and therefore their objects, which also rotate relative to centers of galaxies by inertia, do not have dilation of intrinsic time at all [19, 20]. The galaxies that cooled down, and therefore were previously much larger, always had (and still have) non-rigid FRs. The variable function $u(v)$ [22], which corresponds to a non-rigid FR and at which there will be no need in dark non-baryonic matter in a flat galaxy, can be determined using the parameter "ε" for any such galaxy.

It turned out that this dynamic gravitational field corresponds well to flat (or superthin) galaxies in which, for not very large values of the parameter n <1 [19 – 22], the velocity v of the orbital motion of stars is slightly less than the highest possible velocity even at the edge of the galaxy [29 – 31].

Based on the hypothesis of the spiral-wave nature of both microobjects of matter [26, 27] and the entire Universe as a whole [28], the author came to the conclusion that the coordinate vacuum velocity of light in GR and the equivalent limit velocity of motion of matter in RGTD are hidden intranuclear parameters of matter. It is precisely with this hypothesis that the another hypothesis is connected: the hypothesis of a quantum change in the location (discrete microscopic shift of the coordinates of the spiral waves nuclei) of matter in space, which occurs with the de Broglie frequency in the process of orbital motion of matter in a quasi-equilibrium state (its motion by inertia in a quantum-variable gravitational field). The quantum change in the parameters of the gravitational field of the galaxy occurs together with the quantum change in the quasi-equilibrium thermodynamic state of matter, which quantumly cools with the de Broglie frequency [19, 32]. Only the quasi-equilibrium of the thermodynamic state of the cooling matter is caused precisely by the occurrence of short-term equilibrium disturbances in the quantum process of discrete loss of thermal energy by the matter. After all, the energy levels corresponding to the equilibrium are quantized according to the polynomial solutions of the gravitational field equations [19, 32].

Richard Tolman [33] showed that in the quasi-equilibrium state of continuum matter, the values of its extranuclear thermodynamic parameters and, above all, the absolute temperature T are correlated (coordinated) with the intranuclear parameter v_{cv} (Tv_{cv}=$\mathbf{const}(r)$). Of course, such correlation is absent in the entire non-continuous matter of the galaxy. That is why

Albert Einstein [34] was right when he stated that, unlike the metric tensor, the energy-momentum tensor he proposed is similar to low-quality wood. This is what prompted the author to endow matter with other hidden intranuclear parameters and potentials [19]. Analysis of the relationships between these intranuclear parameters and potentials led to the conclusion that the gravitational and inertial masses of matter are equivalent to each other only according to the intrinsic clock of this matter [19, 35]. It turned out that in the general case, the gravitational mass is equivalent to the Lagrangian of the ordinary rest energy of matter, and the inertial mass is equivalent to the Hamiltonian of only the matter inert free energy, only which is similar to the internal energy of thermodynamics [19, 35]. This is what allowed author to confirm Dirac's hypothesis about the existence of an evolutionary change in the gravitational constant [36]. The justification of the spatiotemporal non-invariance of the gravitational constant also contributed to this [19, 20]. If its value ${}^{E}G_{00}$ is conditionally invariant according to the intrinsic clock of matter, its effective value ${}^{E}G_{eeff}={}^{g}G_{00e}={}^{E}G_{00}c^{4}v_{lce}^{-4}$ depends on the value of the limit velocity of motion v_{lc}, and therefore, in distant galaxies it increases with the approach to the event pseudo-horizon. But in the observer's FR this is revealed not only in a way of increase in the gravitational constant, but also in a way of increase in the value of the gravitational mass of matter relatively to the value of its inertial mass $m_{gr}=m_{in}c^{2}v_{lc}^{-2}$. It is precisely ignoring of this that leads to the imaginary need for dark non-baryonic matter in a flat galaxies.

The use of the difference between the values of the densities of gravitational and inertial masses (instead of the negligible value of pressure p in cosmic space) in the differential equations of the dynamic gravitational field (spatial distribution of potentials of this field is formed by moving matter) made it possible to obtain a standard (canonical in RGTD) differential equation, in which the spatial distributions of the gravitational and inertial masses of galactic matter are absent. Thus, the gravitational field equations themselves began to determine standard distributions of the mass of matter in a flat galaxy, depending on the variable function $u(v)$, on the certain value of the parameter n and on the value of mass of the loose nucleus of the galaxy.

In these equations, as in the equations of Lorentz-invariant thermodynamics [19, 37 – 39], the kinematic parameters v and $\Gamma(v,\ v_{cv})$ and the parameters a and b of the hypothetical static gravitational field are hidden internal parameters of matter. Not only all fundamentally measurable thermodynamic parameters, but also the parameters a_c and b_c (or analogous to them parameters a_s and b_s) of the dynamic gravitational field depend on those hidden internal parameters. Therefore, the direct use of v and $\Gamma(v,\ v_{cv})$ of galaxy objects and a and b of the hypothetical static gravitational field in these equations is unnecessary. And this is an important feature of both the GR gravitational field equations and the RGTD gravitational field equations derived from them. In the very solution of the canonical differential equation of the gravitational field, both the logarithmic potential of the gravitational field [19, 20], and the identity (for all observers) of the spatial distribution of the relative value of limit velocity of motion precisely according to the gravity-quantum clock of a separate point i in its pseudo-centric ^{ic}FR [19, 20] are used:

$$ {}^{ic}v_{lcj} = c\left(\frac{v_{lcj}}{v_{lci}}\right)^{(v_{lci}/c)^2} = c\left(\frac{v_{lc0j}}{v_{lc0i}}\right)^{(v_{lc0i}/c)^2} = \mathbf{invar} \quad \left[\ln({}^{ic}b_{cj}) = \frac{b_{ci}}{2}\ln\frac{b_{cj}}{b_{ci}} = {}^{ic}b_{c0j} = \frac{b_{c0i}}{2}\ln\frac{b_{c0j}}{b_{c0i}} = \mathbf{invar}\right], $$

$$ \frac{d\ln b_c}{dr} = \frac{b_{c0i}}{b_{ci}}\frac{\ln b_{c0}}{dr} = \frac{{}^{E}G_{0gi}}{{}^{E}G_{00}}\frac{\ln b_{c0}}{dr} = \sqrt{\frac{{}^{g}G_{00}}{{}^{E}G_{00}}}\frac{\ln b_{c0}}{dr}, $$

where: ${}^{g}G_{00}$ and ${}^{E}G_{0gi}$ are the intrinsic and observed external values of the gravitational "constant" of a galaxy, respectively; $b_{c0} = v_{lc0}^2 c^{-2}$ is a parameter of the dynamic gravitational field in the intrinsic FR_0 of a galaxy.

2. Solutions of the equation of a galaxy dynamic gravitational field

In the tensor of energy-momentum of the RGTD not only intranuclear pressure p_N but also intranuclear temperature T_N is taken into account [19 – 22]:

$$b_c' / a_c b_c r - r^{-2}(1 - 1/a_c) + \Lambda = \kappa(T_N S_N - p_N V_N)/V = \kappa(m_{gr} - m_{in})c^2/V = \kappa m_{00}c^2(1/\sqrt{b_c} - \sqrt{b_c})/V\text{, (1)}$$

$$a_c' / a_c^2 r + r^{-2}(1 - 1/a_c) - \Lambda = \kappa E/V = \kappa m_{in}c^2/V = \kappa m_{00}c^2\sqrt{b_c}/V\text{,}$$

$$[\ln(b_c a_c)]' / a_c r = (b_c'/b_c + a_c'/a_c)/a_c r = \kappa W/V = \kappa m_{gr}c^2/V = \kappa m_{00}c^2/\sqrt{b_c}V\text{,}$$

where: $r = ({}^E r^2 - {}^E r_g^2)^{1/2}$ is the radial distance to the object from the center of a galaxy, ${}^E r$ and ${}^E r_g$ are the radial distances from the observer to the objects and to the center of a galaxy, respectively; b_c and a_c are the parameters of the dynamic gravitational field equations of a non-continuous matter of a galaxy; $p_V V_N = \tilde{\beta}_{pVN} E = b_c \tilde{\beta}_{pVN} m_{gr} c^2 = \tilde{\beta}_{pVN} m_{in} c^2$, $\tilde{\beta}_{pVN} \neq \mathbf{const}(r)$, $T_{00N} = T_N \sqrt{b_c} = \mathbf{const}(r)$, $m_{00} = m_{gr}\sqrt{b_c} = m_{in}/\sqrt{b_c} = \mathbf{const}(r)$, $\mu_{00} = m_{00}/V \neq \mathbf{const}(r)$ is the density of a matter intrinsic mass, $\mu_{in} = m_{00}\sqrt{b_c}/V \neq \mathbf{const}(r)$ is the density of a matter inertial mass, $\mu_{gr} = m_{00}/\sqrt{b_c}V = \mu_{in}/b_c \neq \mathbf{const}(r)$ is the density of a matter gravitational mass, $S_N = m_{gr}c^2/T_N = m_{00}c^2/T_{00} = \mathbf{const}(r)$ is the intranuclear entropy, $V \neq \mathbf{const}(r)$ and $V_N \neq \mathbf{const}(r)$ are the molar and intranuclear volumes of matter, respectively, $W = m_{gr}c^2$ is the Lagrangian of the ordinary rest energy W_0 of matter (multiplicative component $G_0 = G - U_{ad} \equiv W_0$ of the thermodynamic Gibbs free energy G of matter), $E = m_{in}c^2$ is the Hamiltonian of the inert free energy E_0 of matter, $U_{ad} = \mathbf{const}(r)$ is the additive compensation of the multiplicative spatial transformation of component U_0 of the internal energy U of matter [19, 32, 33].

In addition, according to the RGTD equations, the configuration of the dynamic gravitational field of a galaxy in a quasi-equilibrium state is standard (canonical in RGTD). That is so because it is not determined at all by the spatial distribution of the average density of mass of its non-continuous matter. After all, this spatial distribution of the average density of mass of the galaxy's matter is itself determined by the standard configuration of its dynamic gravitational field:

$$S'=\frac{d[r/a_c(1-b_c)]}{dr}=\frac{1-r_g'-\Lambda r^2}{(1-b_c)}+\frac{(r-r_g-\Lambda r^3/3)}{(1-b_c)^2}b_c'=-\frac{b_c S}{r(1-b_c)}+\frac{(1-\Lambda r^2)}{(1-b_c)^2},\quad (2)$$

$$S=\frac{r}{a_c(1-b_c)}=\frac{r-r_g-\Lambda r^2/3}{1-b_c}=\exp\int\frac{-b_c dr}{(1-b_c)r}\times\int\left[\frac{(1-\Lambda r^2)}{(1-b_c)^2}\exp\int\frac{b_c dr}{(1-b_c)r}\right]dr,$$

where the parameter S can be conditionally considered as the distance from the event pseudo-horizon.

The trivial solution of equation (2), which takes place at:

$$b_c=b_{ce}\left(\frac{3-\Lambda r^2}{3-\Lambda r_e^2}\right),\quad S_0=\frac{r-\Lambda r^3/3}{1-b_c}=\frac{(r-\Lambda r^3/3)(3-\Lambda r_e^2)}{3-\Lambda r_e^2-b_{ce}(3-\Lambda r^2)},\quad r_g=\frac{(1-b_c)r_{ge}}{(1-b_{ce})}\exp\int_{r_{ge}}^{r_g}\frac{b_c dr}{r(1-b_c)}=$$

$$=\frac{(1-b_c)r_{ge}}{(1-b_{ce})}\exp\frac{2b_{ce}\ln(r/r_e)-(1-\Lambda r_e^2/3)\{\ln[r^2+(3/\Lambda-r_e^2)/b_{ce}-3/\Lambda]-\ln[(1/b_{ce}-1)(3/\Lambda-r_e^2)]\}}{2(1-\Lambda r_e^2/3-b_{ce})},$$

does not correspond to physical reality. After all, because of $b_c'=-2b_{ce}\Lambda r/(3-\Lambda r_e^2)\neq 0$ at $r\neq 0$, the solution does not imply the presence of event pseudo-horizon in the FR of matter. And the parameter b_c, unlike the parameter a_c, does not depend on the gravitational radius r_g. And therefore, gravity is absent in the FR corresponding to this trivial solution.

The gravitational potential of the dynamic gravitational field of the flat (or superthin) galaxies depend on the complete galactic value of the gravitational constant (the effective value of the gravitational constant ${}^E G_{eeff}={}^E G_{0ge}/b_{ce}={}^E G_{00}b_{ce}^{-2}$ in the observer's FR). Since the thing that depends on this effective value is the density of the inertial mass of matter (equivalent to its inert free energy), which previously (when $r>\Lambda^{-1/2}$, $db_c/dr<0$) gradually increased in cosmological time (time measured in the CFREU [19, 20]), but now (when $r<\Lambda^{-1/2}$, $db_c/dr>0$) gradually decreases with approaching the center of gravity. And therefore, flat galaxies, which previously were cooling in quasi-equilibrium state (due to $T\sqrt{b_c}\approx\mathbf{const}$), and which are now more "hot" when approaching their centers, can have predominantly non-rigid FRs.

According to the mutual non-identity of the gravitational and inertial masses of matter we find the square of the rotation velocity of astronomical object relatively to the galaxy center according to the equations (2, 3) of gravitational field of RGTD:

$$[\hat{v}^2]_{RGTD} = \frac{v^2}{b_c} = \frac{c^2 r(3-\Lambda r^2)b_c'}{6b_c^2(1-\Lambda r^2)} = \frac{c^2 a_c(3-\Lambda r^2)}{6b_c(1-\Lambda r^2)}\left\{\left(1-\frac{1}{a_c}\right)+\left[\frac{\kappa m_{00}c^2}{V}\left(\frac{1}{\sqrt{b_c}}-\sqrt{b_c}\right)-\Lambda\right]r^2\right\} >> [\hat{v}^2]_{GR} \quad (3)$$

As we can see, at the same radial distribution of the average density of the mass $\mu_{00} = m_{00}/V$ of baryonic matter the circular velocities of rotation of astronomical objects relatively to the galaxy center are much bigger in RGTD than in GR. And this is, of course, related to the fact that:

$$(T_N S_N - p_N V_N)/V \equiv (m_{gr} - m_{in})c^2/V = \mu_{00}c^2(1/\sqrt{b_c} - \sqrt{b_c}) >> p \,.$$

Moreover, a strength of the dynamic gravitational field of flat (superthin) galaxies, according to their two-dimensional topology, is inversely proportional to the radial distance, not to its square. And this is the case, despite the inverse proportionality of the strength of individual gravitational fields of all its spherically symmetric astronomical objects exactly to the square of radial distance.

Therefore, the fictitious need for dark non-baryonic matter in flat galaxies (which follows from the GR gravitational field equations) can be completely eliminated if the motion of astronomical objects is analyzed using the RGTD equations of dynamic gravitational field and diffeomorphically-conjugated forms [40] and if take into account the two-dimensional topology of the galaxies:

$$\hat{v} = \frac{v}{\sqrt{b_c}} = \sqrt{\frac{2\,\mathrm{LH}_e (b_c/b_{ce})^n}{\mathrm{HL}_e[1+(b_c/b_{ce})^{2n}]}}\hat{v}_e = \sqrt{\frac{2(b_c/b_{ce})^n}{b_c[1+(b_c/b_{ce})^{2n}]}}v_e = \frac{v_e}{\sqrt{b_c}}\left\{1+\frac{4n_g^2 v_e^4}{c^4}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\right]^2\right\}^{-1/4},$$

$$v = b_c^{1/2}\hat{v} = \left\{\frac{1}{2}\left[\left(\frac{b_c}{b_{ce}}\right)^n+\left(\frac{b_{ce}}{b_c}\right)^n\right]\right\}^{-1/2} \qquad v_{\max} = \left\{v_e^{-4}+\frac{4n_g^2}{c^4}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u(b_c)\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\right]^2\right\}^{-1/4},$$

$$r-\frac{\Lambda r^3}{3}=\frac{(r_e-\Lambda r_e^3/3)(1-b_c)^u}{(1-b_{ce})^u}\exp\left[\pm\frac{c^2}{2n_g}\sqrt{v^{-4}-v_e^{-4}}\right]=\frac{(r_e-\Lambda r_e^3/3)(1-b_c)^u}{(1-b_{ce})^u}\exp\left\{\frac{c^2 v_{\max}^{-2}}{4n_g}\left[\left(\frac{b_c}{b_{ce}}\right)^n-\left(\frac{b_{ce}}{b_c}\right)^n\right]\right\},$$

$$b_c=k_b b_{ce}=b_{ce}\left[\left(\frac{v_{\max}}{v}\right)^2\pm\sqrt{\left(\frac{v_{\max}}{v}\right)^4-1}\right]^{1/n}=$$

$$=b_{ce}\left\{\sqrt{1+\frac{4n_g^2v_e^4}{c^4}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u(b_c)\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\right]^2}\pm\frac{2n_gv_e^2}{c^2}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u(b_c)\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\right]\right\}^{1/n},$$

$$b_c'=\frac{db_c}{dr}=\frac{n_g(1-\Lambda r^2)}{n\left(r-\frac{\Lambda r^3}{3}\right)\left\{\frac{c^2}{2v_e^2b_c}\sqrt{1+\frac{4n_g^2v_e^4}{c^4}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e-r_e^3/3}\right)-u(b_c)\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\right]^2}-\frac{u(b_c)}{1-b_c}+\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\frac{du}{db_c}\right\}}=$$

$$=\frac{{}^EG_{00}M_{00g}\varsigma(1-\Lambda r^2)}{c^2r_eb_{ce}^2\left(r-\frac{\Lambda r^3}{3}\right)\left\{\frac{c^2}{4v_e^2b_c}\left[\left(\frac{b_c}{b_{ce}}\right)^n+\left(\frac{b_{ce}}{b_c}\right)^n\right]-\frac{u(b_c)}{1-b_c}+\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\frac{du}{db_c}\right\}},$$

$$\frac{b_c'}{b_ca_cr}-\frac{1}{r^2}\left(1-\frac{1}{a_c}\right)+\Lambda-\frac{\kappa m_{00}c^2}{V}\left(\frac{1}{\sqrt{b_c}}-\sqrt{b_c}\right)=$$

$$=\frac{{}^EG_{00}M_{00g}\varsigma(1-\Lambda r^2)(r^{-2}-r_gr^{-3}-\Lambda/3)}{c^2r_eb_{ce}^2\left(1-\frac{\Lambda r^2}{3}\right)\left\{\frac{c^2}{4v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n+\left(\frac{b_{ce}}{b_c}\right)^n\right]-b_c\left[\frac{u(b_c)}{1-b_c}-\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\frac{du}{db_c}\right]\right\}}-\frac{r_g}{r^3}+\frac{2\Lambda}{3}-\frac{\kappa m_{00}c^2}{V}\left(\frac{1}{\sqrt{b_c}}-\sqrt{b_c}\right)=0,$$

$$V=\frac{n\kappa m_{00}c^2(1-\Lambda r^2/3)\left\{(1/\sqrt{b_{ce}})\left[\sqrt{1+A^2}\mp A\right]^{\frac{1}{2n}}-\sqrt{b_{ce}}\left[\sqrt{1+A^2}\pm A\right]^{\frac{1}{2n}}\right\}\left(\sqrt{1+A^2}-B\right)}{2n_gv_e^2c^{-2}(1-\Lambda r^2)(r^{-2}-r_gr^{-3}-\Lambda/3)-n(1-\Lambda r^2/3)(r_gr^{-3}-2\Lambda/3)\left(\sqrt{1+A^2}-B\right)},$$

$$\mu_{grst}=\frac{m_{00}}{\sqrt{b_c}V}=\frac{2\varsigma M_{00g}\,{}^EG_{00}v_e^2(1-\Lambda r^2)(r^{-2}-r_gr^{-3}-\Lambda/3)}{\kappa c^6r_eb_{ce}^2(1-b_c)(1-\Lambda r^2/3)\left(\sqrt{1+A^2}-B\right)}+\frac{2\Lambda/3-r_gr^{-3}}{\kappa c^2(1-b_c)},\ \mu_{grpst}=\frac{2\Lambda/3}{\kappa c^2(1-b_{c\max})}=\frac{H_E^2}{4\pi\,{}^EG_{00}(1-b_{c\max})},$$

where: $A=\frac{2n_gv_e^2}{c^2}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u(b_c)\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\right]$, $B=\frac{2b_cv_e^2}{c^2}\left[\frac{u(b_c)}{1-b_c}-\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\frac{du}{db_c}\right]$, $r_g=r_{ge}+\int_{r_e}^{r}r_g'dr$,

$b_c=v_{lc}^2c^{-2}=b_{ce}(b_{c0}/b_{ce0})^{n_0/n}=b_{ce}(b_{c0}/b_{ce0})^{b_{ce0}/b_{ce}}$ and $b_{ce}=v_{lce}^2c^{-2}\approx(1+2z_e)(1+z_e)^{-2}$ are the parameters of the gravitational field of the galaxy in the observer's FR; b_{c0} and b_{ce0} are the parameters of the gravitational field in the galaxy's intrinsic centric FR_{0g}; $(dv/db_c)_e=(dv/dr)_e=0$; $n_g={}^EG_{eeff}M_{00g}b_{ce}c^{-2}/r_e=\varsigma M_{grg}m_{gre}\,{}^EG_{00}c^{-2}/m_{00e}r_e=\varsigma M_{00g}\,{}^EG_{00}c^{-2}/r_eb_{ce}>1$, $n={}^EG_{00}/{}^EG_{0ge}=b_{ce}<1$, $n_0={}^gG_{00}/{}^gG_{0e}=b_{ce0}<1$; ${}^EG_{eeff}=\varsigma{}^EG_{0ge}/b_{ce}=\varsigma{}^EG_{00}b_{ce}^{-2}$ and ${}^EG_{0ge}={}^EG_{00}/n={}^EG_{00}/b_{ce}$ are, respectively, the effective and real values of the gravitational constant of the galactic star

e in FR_E; $^gG_{00}$ and $^gG_{0e}$ are the gravitational constants in FR_{0g}, respectively, of the galaxy and its star e; $\varsigma \geq 1$ is an indicator of the level of zonal anomaly of the gravitational field caused by the location of the galaxy in a cosmosphere with an increased average density of matter or by the high speed of the galaxy's motion on a picture plane; $u(r)$ is the indicator of the presence of non-rigidity of the FR_{0g} of a galaxy that was cooling in quasi-equilibrium state ($\mathbf{F}_{in}$<-$\mathbf{F}_{gr}$); r_e is the radius of the conventional galactic loose nucleus, on the surface of which of the observed orbital velocity v of objects can take its maximum possible value $v_{\max} \equiv v_e = b_{ce}^{1/2} \hat{v}_e(b_e) = v_{lce} \hat{v}_e / c$; M_{00g} and $M_{grge} = M_{00g} / \sqrt{b_{ce}}$ are the ordinary and gravitational masses of the loose nucleus of the galaxy; m_{00e} and m_{gre} are the ordinary and gravitational masses of a galactic star e moving in a circular orbit at the maximum possible speed; r_g and r_{ge} are the gravitational radii of any layer of the galaxy and its loose nucleus, respectively; μ_{grst} is the standard value of the gravitational mass density of the galaxy matter, μ_{grpst}=4,8596 $10^{-27}/(1-b_{c\max})$ is the non-zero standard value at the edge of the galaxy ($r_p=\Lambda^{-1/2}$= =1,1664 10^{26} [m]=3,78 [Gpc] [19, 20]) of the gravitational mass density of the galaxy matter still held by the galaxy in quasi-equilibrium state, despite the zero value of the gravitational radius at its boundary (r_{gp}=0, $b'_{cp} \equiv (db_c / dr)_p = 0$).

Thus, the variation of the gravitational constant does indeed occur not only in time (a possibility suggested by Dirac [36]), but also in space. It varies similarly to the coordinate velocity of light, and therefore a function of it can be used as a gravitational potential.

Moreover, the spatial distribution of the potentials of gravitational field of a flat galaxy does not actually depend on the values of local gravitational radii of this galaxy. The values of these local gravitational radii themselves depend on the gravitational field parameter b_c and determine both the curvature of the galaxy's intrinsic space and the spatial distribution of the allowed average mass density of matter. Consequently, new massive astronomical objects captured by the gravitational field of the galaxy will only have to fall onto its loose nucleus. And if the loose nucleus of the galaxy contains antimatter [41], those objects will be annihilated by it.

The dependence of the local values of the gravitational radii of a galaxy on the radial coordinate is determined from the following differential equation:

$$r'_g = \kappa\mu_{in}c^2r^2 = \frac{\dfrac{2n_g v_e^2(1-\Lambda r^2)}{nc^2(1-\Lambda r^2/3)\left(\sqrt{1+A^2}-B\right)}\left(1-\dfrac{r_g}{r}-\dfrac{\Lambda r^2}{3}\right)+\left(\dfrac{2\Lambda r^2}{3}-\dfrac{r_g}{r}\right)}{\dfrac{1}{b_{ce}}\left\{\sqrt{1+\dfrac{4n_g^2v_e^2}{c^2}\left[\ln\left(\dfrac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u(b_c)\ln\left(\dfrac{1-b_c}{1-b_{ce}}\right)\right]^2}\mp\dfrac{2n_g v_e^2}{c^2}\left[\ln\left(\dfrac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right)-u(b_c)\ln\left(\dfrac{1-b_c}{1-b_{ce}}\right)\right]\right\}^{\frac{1}{n}}-1},$$

or using dependent on it parameter *S*:

$$dS = d\left(\frac{r-r_g-\Lambda r^3/3)}{1-b_c}\right) = -\frac{n}{n_g}\left\{\frac{c^2}{4v_e^2 b_c}\left[\left(\frac{b_c}{b_{ce}}\right)^n+\left(\frac{b_{ce}}{b_c}\right)^n\right]-\frac{u(b_c)}{1-b_c}+\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\frac{du}{db_c}\right\}\left(1-\frac{\Lambda r^2}{3}\right)\left[\frac{b_c S}{(1-\Lambda r^2)(1-b_c)}-\frac{r}{(1-b_c)^2}\right]db_c,$$

$$r_g = r-\frac{\Lambda r^3}{3}-(1-b_c)\exp\left[-\int\frac{b_c dr}{(1-b_c)r}\right]\times\int\left\{\frac{1-\Lambda r^2}{(1-b_c)^2}\exp\left[\int\frac{b_c dr}{(1-b_c)r}\right]\right\}dr = r-\frac{\Lambda r^3}{3}-$$

$$-\frac{nc^2(r_e-\Lambda r_e^3/3)(1-b_c)}{4n_g v_e^2}\exp\left[-\int\frac{b_c dr}{(1-b_c)r}\right]\times\int_{b_{ce}}^{b_c}\left\{\frac{[(b_c/b_{ce})^n+(b_{ce}/b_c)^n]}{b_c(1-b_c)^2}-\frac{4v_e^2c^{-2}u}{(1-b_c)^3}\right\}\exp\left\{\frac{c^2}{4n_g v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n-\left(\frac{b_{ce}}{b_c}\right)^n\right]+\int\frac{b_c dr}{(1-b_c)r}\right\}db_c =$$

$$= \frac{nc^2(r_e-\Lambda r_e^3/3)(1-b_c)}{4n_g v_e^2}\exp\left[-\int\frac{b_c dr}{(1-b_c)r}\right]\times\int_{b_{ce}}^{b_c}\left\{\left[1-\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\left(\frac{b_c(1-\Lambda r^2/3)}{1-\Lambda r^2}-1\right)\frac{du}{db_c}\right]\frac{1}{(1-b_c)^2}-\right.$$

$$\left.-\frac{u}{(1-b_c)^3}\left[\frac{b_c(1-\Lambda r^2/3)}{1-\Lambda r^2}-1\right]+\frac{\Lambda c^2[(b_c/b_{ce})^n+(b_{ce}/b_c)^n]}{6v_e^2(r^{-2}-\Lambda)(1-b_c)^2}\right\}\exp\left\{\frac{c^2}{4n_g v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n-\left(\frac{b_{ce}}{b_c}\right)^n\right]+\int\frac{b_c dr}{(1-b_c)r}\right\}db_c,$$

where: $\displaystyle\int\frac{b_c dr}{(1-b_c)r} = \frac{n}{n_g}\int\frac{1-\Lambda r^2/3}{(1-\Lambda r^2)(1-b_c)}\left\{\frac{c^2}{4v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n+\left(\frac{b_{ce}}{b_c}\right)^n\right]-\frac{b_c u}{1-b_c}+b_c\ln\left(\frac{1-b_c}{1-b_{ce}}\right)\frac{du}{db_c}\right\}db_c$.

At u=-1 ($v_e = c/\sqrt{2}$, $\mathbf{F}_{in} << -\mathbf{F}_{gr}$) this solution of the standard equation of the dynamic gravitational field of a flat galaxy allegedly degenerates. After all, in this case the value of the gravitational radius of the galaxy becomes proportional to the cosmological constant Λ, and therefore to the Hubble constant:

$$r_g = \frac{2n\Lambda(3r_e-\Lambda r_e^3)(1-b_c)}{9n_g}\exp\left[-\int\frac{b_c dr}{(1-b_c)r}\right]\times\int_{b_{ce}}^{b_c}\frac{r^2\{b_c+c^2v_e^{-2}(1-b_c)[(b_c/b_{ce})^n+(b_{ce}/b_c)^n]/4\}}{(1-\Lambda r^2)(1-b_c)^3}\exp\left\{\frac{c^2}{4n_g v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n-\left(\frac{b_{ce}}{b_c}\right)^n\right]+\int\frac{b_c dr}{(1-b_c)r}\right\}db_c.$$

But in fact the cosmological constant Λ, like the parameter b_c, is a hidden parameter of almost all physical characteristics of matter. And it is thanks to it that at $b_{ce} > (1-\Lambda r_e^2)/(1-\Lambda r_e^2/3)$ in the non-rigid FR of a cooling flat galaxy in a state of observant self-contraction ($u = -c^2v^{-2}/2$, $\mathbf{F}_{in} << -\mathbf{F}_{gr}$), the radial values of the gravitational radii $r_g(r)$ of a flat galaxy become larger than in the hypothetical rigid FR of the flat galaxy (u=0, $\mathbf{F}_{in} = -\mathbf{F}_{gr}$).

Thus the trivial solution of the equation takes place both at u=0 ($\mathbf{F}_{in} = -\mathbf{F}_{gr}$) and at a negative value of the parameter $u = -\varepsilon(z_e)c^2v^{-2}/2$ ($\mathbf{F}_{in} < -\mathbf{F}_{gr}$), where: $\varepsilon(z_e) \le 1$ is the galactic constant, which determines the rate of contraction of a galaxy and is apparently dependent on the redshift z of the wavelengths of its emission radiation.

And therefore, when $b_{ce} > (1-\Lambda r_e^2)/(1-\Lambda r_e^2/3)$, the smaller the maximum orbital velocity $v_e < c/\sqrt{2}$ of astronomical objects in the galaxy, the greater in the latter case the value of the gravitational radius on the surface of its loose nucleus will be.

Also what is important is that even in an incredibly weak gravitational field (when $\varepsilon(z_e) = 1$, $u = -c^2v^{-2}/2$, $\mathbf{F}_{in} << -\mathbf{F}_{gr}$) and even at large radial distances, astronomical objects will rotate around the center of the galaxy with orbital velocities very close to the maximum possible speed [30, 31]. After all, regardless of the value of the variable function u, the orbital velocities of astronomical objects in a flat galaxy at n=b_{ce}=0 can theoretically be equal to the maximum velocity $v_{\max} \equiv v_e$ at all radial distances.

Moreover, it is precisely thanks to $b_{ce} > (1-\Lambda r_e^2)/(1-\Lambda r_e^2/3)$ that this takes place at $u = -c^2v^{-2}/2$ ($\varepsilon(z_e) = 1$, $\mathbf{F}_{in} << -\mathbf{F}_{gr}$) at very large distances from the center of the galaxy. After all, when $u = -c^2v^{-2}/2$ ($\varepsilon(z_e) = 1$, $\mathbf{F}_{in} << -\mathbf{F}_{gr}$), the radial distances from the center to the objects of the cooling flat galaxy at the same value of the parameter b_c were much greater in the past than the hypothetical radial distances that could be much smaller at u=0 ($\mathbf{F}_{in} = -\mathbf{F}_{gr}$):

$$r - \frac{\Lambda r^3}{3} = \left(r_e - \frac{\Lambda r_e^3}{3}\right)\left(\frac{1-b_{ce}}{1-b_c}\right)^{\frac{c^2}{2v^2}} \exp\left[\pm \frac{c^2}{2n_g}\sqrt{v^{-4} - v_e^{-4}}\right] = \left(r_e - \frac{\Lambda r_e^3}{3}\right)\left(\frac{1-b_{ce}}{1-b_c}\right)^{\frac{c^2}{2v^2}} \exp\left\{\frac{c^2}{4n_g v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n - \left(\frac{b_{ce}}{b_c}\right)^n\right]\right\} >>$$

$$>> \left(r_e - \frac{\Lambda r_e^3}{3}\right)\exp\left[\pm \frac{c^2}{2n_g}\sqrt{v^{-4} - v_e^{-4}}\right] = \left(r_e - \frac{\Lambda r_e^3}{3}\right)\exp\left\{\frac{c^2}{4n_g v_e^2}\left[\left(\frac{b_c}{b_{ce}}\right)^n - \left(\frac{b_{ce}}{b_c}\right)^n\right]\right\},$$

$$\frac{dr}{db_c} = \frac{nc^2(r - \Lambda r^3/3)}{4n_g v_e^2 b_c(1-\Lambda r^2)}\left\{\frac{1}{1-b_c}\left[\left(\frac{b_c}{b_{ce}}\right)^n + \left(\frac{b_{ce}}{b_c}\right)^n\right] - n_g \ln(1-b_c)\left[\left(\frac{b_c}{b_{ce}}\right)^n - \left(\frac{b_{ce}}{b_c}\right)^n\right]\right\} >> \frac{c^2(r - \Lambda r^3/3)}{4v_e^2 b_c(1-\Lambda r^2)}\left[\left(\frac{b_c}{b_{ce}}\right)^n + \left(\frac{b_{ce}}{b_c}\right)^n\right].$$

3. Absence of relativistic time dilation during the orbital motion of galactic objects

The GR gravitational field equations de facto correspond to spatially inhomogeneous thermodynamic states of only utterly cooled down matter. The similar to them equations of RGTD correspond to spatially inhomogeneous thermodynamic states of gradually cooling down matter. In addition, in RGTD, unlike GR, bodies that move by inertia in a gravitational field, influence (by their movement) the configuration of the dynamic gravitational field surrounding them. At the same time, in equilibrial processes, along with the usage of ordinary Hamiltonians and Lagrangians, in RGTD it is also possible to use GT-Hamiltonians and GT-Lagrangians. Therefore, in RGTD for matter that cools quasi-equilibrially the Hamiltonian (GT-Hamiltonian) four-momentum is formed not by the Hamiltonian of enthalpy, but by the Hamiltonian (GT-Hamiltonian) of the inert free energy, and Lagrangian (GT-Lagrangian) four-momentum is formed by the Lagrangian (GT-Lagrangian) of ordinary rest energy (multiplicative component of thermodynamic Gibbs free energy G) of matter of astronomical object [19].

The GT-Lagrangian of the ordinary rest energy of the matter:

$$\mathrm{L}_c = m_{gr}c^2 = m_{gr0}c^2(1+v^2v_l^{-2})^{-1/2} = m_{00}c^3/v_{lc} = \mathrm{H}_c/b(1+\hat{v}^2c^{-2}) = \mathrm{H}_c/b(1+v^2v_l^{-2}) = \mathrm{H}_c/b_c$$

forms the four-momentum not with the GT-Hamiltonian momentum, but with the GT-Lagrangian momentum:

$$\mathrm{P}_{Lc} = m_{gr0}v/\hat{\Gamma}_c = m_{gr0}v(1+v^2v_l^{-2})^{-1/2} = m_{00}cv/v_{lc} = m_{00}vc(v_l^2+v^2)^{-1/2} = m_{00}vc/v_{lc} = m_{00}\hat{v}\,.$$

Then: $W_0^2 = \mathrm{L}_c^2 + c^4v_l^{-2}\,\mathrm{P}_{Lc}^2 = m_{00}^2c^6v_l^{-2}/(1+v^2v_l^{-2}) + m_{00}^2c^6v_l^{-4}v^2/(1+v^2v_l^{-2}) = m_{00}^2c^6v_l^{-2} = m_{gr0}^2c^4$,

$$(ds_c)^2 = v_{lc}^2(dt)^2 - (d\hat{x})^2 - (d\hat{y})^2 - (d\hat{z})^2 = b_cc^2(dt)^2 - (d\hat{l})^2 = (v_l^2+v^2)(dt)^2 - (d\hat{l})^2 = bc^2(dt)^2 = \mathbf{invar}\,,$$

$$\hat{v} = vb_c^{-1/2} = vc/v_{lc} = vc/v_l\hat{\Gamma}_c\,,\ \ \hat{\Gamma}_c = (1+v^2v_l^{-2})^{1/2}\,,\ \ b_c = b\hat{\Gamma}_c^2 = (v_l^2+v^2)c^{-2} = b+v^2c^{-2} = v_{lc}^2c^{-2}\,.$$

And therefore, the condition of quasi-equilibrium precisely in the dynamic gravitational field of the galaxy of all its objects moving by inertia leads to both the absence of relativistic dilation of their intrinsic time and the invariance of their intrinsic time with respect to relativistic transformations. The spatial homogeneity of the rate of intrinsic time in entire gravithermodynamically bound matter is consistent with the single frequency of change of its collective spatially inhomogeneous Gibbs microstates, which is not affected by either a decrease (during approaching gravity center) in the frequency of intranuclear interaction or an increase (during approaching gravity center) in the frequency of extranuclear intermolecular interactions. Moreover, this is ensured even without conformal transformations of the space-time interval s. Therefore, like the parameters v_l, v_{lc}, b and Γ_m in thermodynamics [19, 37, 38], the parameter b_c (or its analogous parameter b_s) in the RGTD is a hidden internal parameter of the moving matter. And the usage of this parameter in the equations of the dynamic gravitational field of the RGTD allows us not to additionally use the velocity of matter in those equations, as well as in the equations of thermodynamics.

A similar dependence of the parameter v_{lc} on the velocity also occurs for distant galaxies that are in the state of free fall onto the event pseudo-horizon of the expanding Universe: $v_{lcg}^2 \equiv c^2 = v_{lg}^2 + v_g^2$. After all, according to Hubble's law and the Schwarzschild solution of the gravitational field equations with a non-zero value of the cosmological constant $\Lambda = 3H_E^2 c^{-2}$ and a zero value of the gravitational radius:

$$v_{lg}^2 = c^2(1 - \Lambda r^2/3) = c^2 - H_E^2 r^2 = c^2 - v_g^2 .$$

The use of the parameter $b_s = b\Gamma_s^2 = b/(1 - v^2 c^{-2}/b) = v_{ls}^2 c^{-2} = \mathbf{const}(t)$, built on the basis of relativistic size shrinkage $\Gamma_s = (1 - v^2 v_l^{-2})^{-1/2}$, in the equations of the dynamic gravitational field of the RGTD is also possible. However, in order to ensure the absence of dilation of intrinsic time of matter moving in a gravitational field by inertia, it will be necessary to use conformal Lorentz transformations (instead of the usual Lorentz transformations) of the increments of spatial coordinates and time [19, 37 – 39]. The solutions of the equations of dynamic gravitational field of the RGTD do not depend on the usage of the parameter b_c or the parameter b_s in them. The only parameters that will differ are the parameters of hypothetical static gravitational fields (which are reproduced on the basis of those parameters b_c and b_s).

The transition from the dynamic to the hypothetical static gravitational field of the galaxy when u=0 ($\mathbf{F}_{in} = -\mathbf{F}_{gr}$) is carried out as follows:

$$^{s}b = \frac{b_s}{2}\left(1+\sqrt{1-\frac{4v^2}{b_s c^2}}\right) = \frac{b_s}{2}\left(1+\sqrt{1-\frac{8v_e^2}{b_s c^2[(b_{se}/b_s)^n + (b_s/b_{se})^n]}}\right), \quad ^{s}b_e = \frac{b_{se}}{2}\left(1+\sqrt{1-\frac{4v_e^2}{b_{se}c^2}}\right) \text{ (in GR and RGTD);}$$

$$b = b_c(1-\hat{v}^2c^{-2}) = b_c - v^2c^{-2} = b_c - \frac{2v_{\max}^2(b_c/b_{ce})^n}{c^2[1+(b_c/b_{ce})^{2n}]} = b_c - \frac{v_e^2}{c^2\sqrt{1+\{2n_g v_e^2 c^{-2}\ln[(r-\Lambda r^3/3)/(r_e-\Lambda r_e^3/3)]\}^2}},$$

$$b_e = b_{ce}(1-\hat{v}_e^2c^{-2}) = b_{ce} - v_e^2c^{-2}, \qquad b' = b_c' + \frac{4n_g^2 v^6(1-\Lambda r^2)}{c^6(r-\Lambda r^3/3)}\ln\left(\frac{r-\Lambda r^3/3}{r_e-\Lambda r_e^3/3}\right) > b_c' \quad \text{(in RGTD).}$$

The gravitational force acting in a static gravitational field on a conditionally motionless body is greater than the gravitational force acting in a dynamic gravitational field on the same body that is moving ($b' > b_c'$). And this is not only due to the decrease in the gravitational mass of the body due to its movement. After all, in a space full of rapidly moving bodies, the intensity of the dynamic gravitational field also decreases. That is why it is necessary to use precisely the dynamic gravitational field instead of a static one in calculations of the rotational motion of galactic objects.

Thus, in the equations of the dynamic gravitational field of RGTD, as in the equations of thermodynamics, not only gravitational, but also relativistic indicators are internal hidden parameters of the RGTD-state of matter in motion. And that is why in RGTD, unlike orthodox GR, the use of an external relativistic description of the state of matter in motion is not always required.

4. Analysis of the properties of a galaxy dynamic gravitational field

The FR practically equivalent the FR of an observed galaxy is galaxy's intrinsic FR_{g0}, the transition to which can be reached by transforming the parameters. The invariants of such a transformation are not only the radii of the circular orbits of astronomical objects in the galaxy, but also the following relations:

$v_0 / v_{e0} = v / v_e = \mathbf{invar}$, $\quad n_0 \ln k_{b0} = n \ln k_b = \mathbf{invar}$ $\quad [b_{ce0} \ln(b_{c0} / b_{ce0}) = b_{ce} \ln(b_c / b_{ce}) = \mathbf{invar}$].

The following dependence of the orbital velocity of objects of galaxies on parameter b_{c0} and, thus on radial distance r, can be applied to these objects in centric intrinsic $^{ec}\mathrm{FR}_{g0}$ of galaxy [19, 20]:

$$v_0 = v_{e0}\sqrt{\frac{2}{(b_{c0}/b_{ce0})^{b_{ce0}} + (b_{ce0}/b_{c0})^{b_{ce0}}}} = v_{e0}\left\{1 + \frac{4n_{g0}^2 v_{e0}^4}{c^4}\left[\ln\left(\frac{r - \Lambda r^3/3}{r_e - \Lambda r_e^3/3}\right) - u(b_{c0})\ln\left(\frac{1-b_{c0}}{1-b_{ce0}}\right)\right]^2\right\}^{-\frac{1}{4}},$$

where: $n_{g0} = n_g b_e / b_{e0}$, $v_{e0}^2 = v_e^2 b_{e0} / b_e$, $b_{c0} = b_{ce0}(b_c / b_{ce})^{\frac{b_{ce}}{b_{ce0}}} = b_{ce0}\left[(v_{e0}^2 v_0^{-2} \pm \sqrt{v_{e0}^4 v_0^{-4} - 1}\right]^{\frac{1}{b_{ce0}}} =$

$$= b_{ce0}\left\{\sqrt{1 + \frac{4n_{g0}^2 v_{e0}^4}{c^4}\left[\ln\left(\frac{r - \Lambda r^3/3}{r_e - \Lambda r_e^3/3}\right) - u(b_{c0})\ln\left(\frac{1-b_{c0}}{1-b_{ce0}}\right)\right]^2} \pm \frac{2n_{g0}v_{e0}^2}{c^2}\left[\ln\left(\frac{r - \Lambda r^3/3}{r_e - \Lambda r_e^3/3}\right) - u(b_{c0})\ln\left(\frac{1-b_{c0}}{1-b_{ce0}}\right)\right]\right\}^{\frac{1}{b_{ce0}}},$$

$$r - \frac{\Lambda r^3}{3} = \frac{(r_e - \Lambda r_e^3/3)(1-b_{c0})^u}{(1-b_{ce0})^u}\exp\left[\pm\frac{c^2}{2n_{g0}}\sqrt{v_0^{-4} - v_{e0}^{-4}}\right] = \frac{(r_e - \Lambda r_e^3/3)(1-b_{c0})^u}{(1-b_{ce0})^u}\exp\left\{\frac{c^2 v_{e0}^{-2}}{4n_{g0}}\left[\left(\frac{b_{c0}}{b_{ce0}}\right)^{b_{ce0}} - \left(\frac{b_{ce0}}{b_{c0}}\right)^{b_{ce0}}\right]\right\}.$$

In the Schwarzschild solution of the GR equations with a non-zero value of the cosmological constant Λ, in addition to the Schwarzschild singular sphere, on which only the infinitely distant cosmological future is always located, there is also a singular sphere of the event pseudo-horizon, on which only the infinitely distant cosmological past is always located [19, 20]. Moreover, if the radius of the fictitious sphere of the infinitely distant cosmological future of any astronomical object takes zero value in the background Euclidean space [19, 42], then the radius of the fictitious sphere of the infinitely distant cosmological past is, on the contrary, takes infinitely large value in it. And this corresponds to both the conformal infinity considered by Roger Penrose [43] and the conformal zero.

Relativistic non-simultaneity in cosmological time τ of events that take place in different locations but simultaneous in the intrinsic time t of matter turns out to be a mutual agreement of the Schwarzschild solutions of the gravitational field equations in CFREU and FR of matter [19, 20]. And this is due to the use of the physically homogeneous scale of proper time of matter instead of the metrically and spatially homogeneous scale of intrinsic time of the matter. Otherwise, the values of almost all physical parameters and characteristics of the matter would have to be continuously renormalized. It is because of this that on the singular surface (b_c=0) of the event pseudo-horizon, the gravitational "constant" according to the Dirac hypothesis [36] takes an infinitely large value.

And this corresponds to a very slow rate of physical processes ($b_c \approx 0$) in the distant cosmological past near the event pseudo-horizon. Moreover, it actually refutes the incredibly rapid initial rate of physical processes according to the false theory of the Big Bang of the Universe, which localizes the Universe in the distant past at a "point" instead of localizing its distant cosmological past in the observer's FR on a sphere with the maximum possible radius $r_c=(\Lambda/3)^{-1/2}$.

Thanks to: $m_{gre}(d\ln b_c/dr)_e = m_{gre0}(d\ln b_{c0}/dr)_e (n_0/n)^{3/2}$ [$\ln(v_{lc}/v_{lce}) = v_{lce}^{-2} v_{lce0}^{2} \ln(v_{lc0}/v_{lce0})$, $m_{gre} = m_{gre0} v_{lce0}/v_{lce}$, when: $G_{00} = \mathbf{const}(v_{lce})$, $M_{00} = \mathbf{const}(v_{lce})$, $m_{00} = \mathbf{const}(v_{lce})$, $r_e = \mathbf{const}(v_{lce})$], $a_c = a_{c0}$ and $v_e/v_{lce} = v_{e0}/v_{lce0}$, we have the following relations for the centrifugal pseudo-forces of inertia and for the gravitational pseudo-forces in the intrinsic ${}^{ec}FR_g$ of a distant galaxy and in the ${}^{E}FR$ of the observer of this galaxy:

$$ {}^{g}\mathbf{F}_{ine0} = \frac{m_{ine0} c^2 v_{e0}^2}{r_e v_{lce0}^2} = {}^{E}\mathbf{F}_{ine} \frac{m_{ine0}}{m_{ine}} = {}^{E}\mathbf{F}_{ine} \frac{v_{lce0}}{v_{lce}} = {}^{E}\mathbf{F}_{ine} \sqrt{\frac{n_0}{n}} , $$

$$ {}^{g}\mathbf{F}_{gre0} = \frac{m_{gre0}}{2\sqrt{a_{ce0}}} \left(\frac{d\ln b_{c0}}{dr}\right)_e = {}^{E}\mathbf{F}_{gre} \sqrt{\frac{n_0}{n}} = \frac{m_{gre}}{2\sqrt{a_{ce}}} \left(\frac{d\ln b_{c}}{dr}\right)_e \sqrt{\frac{n_0}{n}} = \frac{m_{gre0}}{2\sqrt{a_{ce0}}} \left(\frac{d\ln b_{c0}}{dr}\right)_e \frac{n_0^2}{n^2} = {}^{E}\mathbf{F}_{gre0} \frac{{}^{ge}G_{00}}{{}^{E}G_{00}} , $$

where: ${}^{g}\mathbf{F}_{gre0} = -{}^{g}\mathbf{F}_{ine0} = -{}^{E}\mathbf{F}_{ine} v_{lce0}/v_{lce} = {}^{E}\mathbf{F}_{gre}\sqrt{n_0/n}$ and ${}^{g}\mathbf{F}_{ine0}$ are the galactic internal values of the gravitational pseudo-force and the centrifugal pseudo-force of inertia acting on star *e*, respectively; ${}^{E}\mathbf{F}_{gre} = -{}^{E}\mathbf{F}_{ine} = -{}^{E}\mathbf{F}_{ine} v_{lce0}/v_{lce} = {}^{E}\mathbf{F}_{gre}\sqrt{n_0/n}$ and ${}^{E}\mathbf{F}_{ine}$ are the observed external values of gravitational pseudo-force and the centrifugal pseudo-force of inertia acting on the star *e* in the observer's ^{E}FR respectively; ${}^E\mathbf{F}_{gre0}$ is the gravitational pseudo-force acting on a similar star in a similar hypothetical galaxy at a small distance from the observer.

In the case of using the gravithermodynamic (astronomical) intrinsic time (b_{c0}=1) of a distant galaxy, we obtain the galactic value of the gravitational constant ${}^g G_{00} = {}^E G_{00} b_{ce}^{-2}$.

Thus, the lack of temporal invariance of the gravitational "constant" refutes not only the Big Bang of the Universe, but also the need for dark non-baryonic matter.

In centric intrinsic FR$_{g0}$ of the galaxy when $u = -c^2 v^{-2}/2$ ($\mathbf{F}_{in} << -\mathbf{F}_{gr}$) the following typical radial distribution of the average density of gravitational mass of the matter in the galaxy takes place:

$$\mu_{grst0} = \frac{m_{00}}{\sqrt{b_{c0}}V} = \frac{2n_{g0}v_{e0}^2(1-\Lambda r^2)(r^{-2} - r_{g0}r^{-3} - \Lambda/3)}{n_0 \kappa c^4 (1-b_{c0})(1-\Lambda r^2/3)\left(\sqrt{1+A^2} - B\right)} + \frac{2\Lambda/3 - r_{g0}r^{-3}}{\kappa c^2 (1-b_{c0})},$$

$$A = \frac{2n_{g0}v_{e0}^2}{c^2}\left[\ln\left(\frac{r-\Lambda r^3/3}{r_e - \Lambda r_e^3/3}\right) + \frac{c^2}{2v_0^2}\ln\left(\frac{1-b_{c0}}{1-b_{ce0}}\right)\right], \quad B = \frac{1}{2}\left\{n_{g0}\ln\left(\frac{1-b_{c0}}{1-b_{ce0}}\right)\left[\left(\frac{b_{c0}}{b_{ce0}}\right)^{n_0} - \left(\frac{b_{ce0}}{b_{c0}}\right)^{n_0}\right] - \frac{b_{c0}}{1-b_{c0}}\left[\left(\frac{b_{c0}}{b_{ce0}}\right)^{n_0} + \left(\frac{b_{ce0}}{b_{c0}}\right)^{n_0}\right]\right\}.$$

According to this distribution, when at the edge of the galaxy the gravitational mass density of matter still held by the galaxy in quasi-equilibrium, becomes non-zero standard:

$$\mu_{grst0} = 2\Lambda/3\kappa c^2 (1-b_{c0\max}) = H_E^2/4\pi\, {}^E G_{00}(1-b_{c0\max}).$$

It is obvious that the essential time dilation, which is being observed for far galaxies, can be considered as evolutionary-gravitational phenomenon that is consistent with the linear Hubble dependence of redshift of wavelength of radiation and that significantly differs from this dependence only for quasars that have very strong gravitational field.

Due to the low strength of gravitational field outside the loose nuclei of galaxies they can indeed be considered as "island Universes" [44 – 46] (non-isolated island systems [47]) that have individual intrinsic values of gravitational constant.

5. The loose nucleus of a galaxy as an antiquasar

In a galaxy that is not a continuous astronomical self-formation the coordinate velocity of light v_{ce} can be significantly greater than zero on the median surface with the minimum possible value of the Schwarzschild radius r_e. After all, the prevention of the annihilation of stars containing antimatter [41] with stars containing matter is ensured by their rotation around the median surface, which does not allow them to fall onto this surface, and even more so to cross it.

Therefore, we cannot exclude the possibility that most quasars are “loose nuclei” of galaxies that have the loose structure and the topology of a hollow “loose body” in the background Euclidean space [19, 42] of the CFREU and the mirror symmetry of their intrinsic space. Then, precisely, near the median spherical surface of the galaxy with the minimum possible value of the Schwarzschild radius r_e in the matter-antimatter intrinsic FR, the maximum velocity speed of both the outer stars consisting of matter and the inner stars consisting of antimatter takes place. Catastrophic annihilation of these stars does not occur only due to the fact that they do not cross the median spherical surface of the galaxy, which, due to the constant renormalization of the size of the length standard in CFREU, has a constant radius $R_{t/e}=r_e$ in it at any intrinsic time t. But the antistars in galaxy's loose nucleus can absorb and annihilate non-galactic matter. This is what allows the loose nucleus of a galaxy to be a powerful antiquasar, capable of emitting large amounts of electromagnetic energy for a long time.

If the value of radius $r_e=R_{t/e}$ of the surface of loose nucleus of the galaxy is the minimum possible in mirror symmetric configuration of intrinsic space of the galaxy then its “loose nucleus” will de facto be the antiquasar. And this will take place when in CFREU $(dr/dR)_e=0$ and $(db_c/dR)_e=0$:

$$r = r_e(1+\widetilde{R}/R_e)(1+R_e/\widetilde{R})/4 = [r_e+\widetilde{R}_t(\tau)][1+r_e/\widetilde{R}_t(\tau)]/4\,,$$

$$\widetilde{R}_{t/inside}(\tau)=\psi R(t)+r_c(1-\sqrt{1-r_e/r_c})^2=r\left(1-\sqrt{1-r_e/r}\right)^2,$$

$$r_e^2/\widetilde{R}_{t/outside}(\tau)=\psi r_e^2/R(t)+r_c(1-\sqrt{1-r_e/r_c})^2=r\left(1-\sqrt{1-r_e/r}\right)^2=\widetilde{R}_{t/inside}(\tau),$$

$$\psi=1-\left(1-\sqrt{1-r_e/r_c}\right)^2 r_c/r_e,\quad r_c=c/H_E,\quad R_{inside}(t,r)R_{outside}(t,r)=r_e^2,$$

$$R_{inside}(t)=r\left(1-\sqrt{1-r_e/r}\right)^2/\psi-r_c\left(1-\sqrt{1-r_e/r_c}\right)^2/\psi,$$

$$\frac{1}{R_{outside}(t)}=\left[\left(1+\sqrt{1-r_e/r}\right)^{-2}/r-\left(1+\sqrt{1-r_e/r_c}\right)^{-2}/r_c\right]\frac{1}{\psi}=r_e^{-2}\left[r\left(1-\sqrt{1-r_e/r}\right)^2-r_c\left(1-\sqrt{1-r_e/r_c}\right)^2\right]\frac{1}{\psi}=R_{inside}(t)r_e^{-2}\cdot$$

$\widetilde{R}=\widetilde{R}_t(\tau)R_e/r_e$ and $\widetilde{R}_t(\tau)$ are the values of the radial coordinate R in CFREU; τ is the cosmological time measured in CFREU.

And, consequently, all stars of loose nucleus of galaxy will consist of only antimatter.

6. Conclusion

1. At the edge of the galaxy ($r_p\approx\Lambda^{-1/2}$), the excessively strong ordinary (unreduced) centrifugal pseudo-forces of inertia are compensated mainly by centripetal pseudo-forces of evolutionary self-contraction of matter in the fundamental (background) Euclidean space [19, 42] of comoving with expanding Universe FR, and not by the weak gravitational pseudo-forces at the edge of the galaxy.

2. The strength of the dynamic gravitational field of spiral and other flat (or superthin) galaxies, according to their two-dimensional topology, is inversely proportional to the radial distance, not to its square. And this is the case, despite the inverse proportionality of the strength of individual gravitational fields of all its spherically symmetric astronomical objects exactly to the square of radial distance.

3. The gravitational constant decreases evolutionarily in cosmological time along with the decrease in the average density of matter in the Universe.

4. In the Universe there may be anomalous zones with an increased average density of matter, and therefore with an increased effective value ${}^{E}G_{eeff}$ of the gravitational constant (ς>1).

5. Galaxies moving in the picture plane with large meridional or sagittal velocities should also be considered "anomalous". After all, the proposed dynamic gravitational field assumes only the evolutionary radial distancing of galaxies from the observer and directly (without using the gravitational field anomaly index ς) takes into account only the presence of the orbital motion of the stars of the galaxy.

6. The gravitational potentials of the dynamic gravitational field of flat galaxies do depend on the effective value of the gravitational constant ${}^{E}G_{eeff}={}^{E}G_{0g}\varsigma/b_{ce}={}^{E}G_{00}\varsigma b_{ce}^{-2}\approx{}^{E}G_{00}\varsigma(1+z_e)^4(1+2z_e)^{-2}$.

7. All flat (or superthin) galaxies have only the dynamic gravitational fields in which the velocities v of the hypothetical equilibrium circular motion (r=**const**) of objects in equilibrium state are already taken into account in the parameter b_c and, moreover, do not depend directly on the radial coordinates r, but depend only on the limit values of the motion velocity of matter $v_{lc}=c\sqrt{b_c}$, and theses galaxies have mainly non-rigid FRs.

8. Along with the decrease in the limit value of the motion velocity of matter v_{lc}, the effective value of the gravitational constant increases. And this is manifested precisely in the non-identity of the gravitational mass, which is equivalent to the Lagrangian of ordinary total energy, and the much smaller inertial mass, which is on the contrary equivalent to the Hamiltonian of only the inert free energy of matter.

9. Dynamic gravitational field corresponds well to flat (or superthin) galaxies in which, at the possible values of parameter $n=b_{ce}<1$, the velocity of the orbital motion of stars is only slightly less than the highest possible velocity even at the edge of the galaxy.

10. There is no relativistic dilation of intrinsic time during the orbital motion of galactic objects.

11. The centrifugal pseudo-forces of inertia depend also on the cosmological fundamental constant $\Lambda = 3H_E^2 c^{-2} = \mathbf{const}(t)$ and therefore on Hubble fundamental constant $H_E = \mathbf{const}(t)$, exactly the invariance of which in the intrinsic time t of matter ensures in principle the continuity of the spatial continuum of a rigid FR [19, 20].

12. The variable function *u(v),* the value of the parameter $n=b_{ce}$, the value of the indicator ς of the level of the gravitational field zonal anomaly and the value of mass of the galaxy loose nucleus, at which there will be no need in dark non-baryonic matter in the galaxy, can be applied to any flat galaxy.

13. Therefore, dark non-baryonic matter may turn out to be the same theoretical misconception and imaginary entity [20] as dark energy, the Big Bang of the Universe and black holes (which are actually neutron stars that have a hollow-body topology and mirror symmetry of their own space [20, 41, 48]).

If all stars of the galaxy move in stationary or quasi-stationary orbits, then it can be considered that the galaxy is in a quasi-equilibrium state. According to the RGTD equations, the configuration of the dynamic gravitational field of a galaxy in a quasi-equilibrium state is standard (canonical in RGTD). That is because it is not determined at all by the spatial distribution of the average density of mass of its non-continuous matter. After all, this spatial distribution of the average mass density of the galaxy's matter is itself determined by the standard configuration of its dynamic gravitational field. In the equations of the dynamic gravitational field of RGTD, as in the equations of thermodynamics, not only gravitational, but also relativistic indicators are internal hidden parameters of the RGTD-state of matter in motion. And that is why in RGTD, unlike orthodox GR, the use of an external relativistic description of the state of matter in motion is not always required.

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Conflicts of Interest

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References

1. **Zwicky, F.**: 1933, Die rotverschiebung von extragalaktischen nebeln. *Helvetica Physica Acta*, 6, 110-127.

2. **Zwicky, F.**: 1937, On the Masses of Nebulae and of Clusters of Nebulae. *The Astrophysical Journal*, **86**, 217-246, https://doi.org/10.1086/143864.

3. **Rubin, V.C., and Ford Jr., W.K.**: 1970, Rotation of the Andromeda Nebula from a Spectroscopic Survey of Emission Regions. *The Astrophysical Journal*, **159**, 379-403, https://doi.org/10.1086/150317.

4. **Rubin, V.C., Thonnard N., and Ford Jr., W.K.:** 1980, "Rotational properties of 21 SC galaxies with a large range of luminosities and radii, from NGC 4605 /R = 4kpc/ to UGC 2885 /R = 122 kpc/", *Astrophys. J.*, **238,** 471.

5. **Corbelli, E., and Salucci, P.**: 2000, The Extended Rotation Curve and the Dark Matter Halo of M33. *Monthly Notices of the Royal Astronomical Society*, 311, 441-447, https://doi.org/10.1046/j.1365-8711.2000.03075.x.

6. **Schmidt, M.**: 1966, "The Gravitational Field of the Galaxy." *Symposium - International Astronomical Union, Cambridge University Press*, doi:10.1017/s0074180900105303.

7. Cook, M.W.: 1972, "Approximate Solutions of the Relativistic Gravitational Field Equations to Describe Clusters of Galaxies." *Australian Journal of Physics, CSIRO Publishing*, doi:10.1071/ph720299.

8. Cooperstock, F.I., and Steven Tieu: 2005, "Perspectives on Galactic Dynamics via General Relativity", *Cornell University*, https://arxiv.org/pdf/astro-ph/0512048.

9. Cooperstock, F.I., and Steven Tieu: 2007, "GALACTIC DYNAMICS VIA GENERAL RELATIVITY: A COMPILATION AND NEW DEVELOPMENTS." *International Journal of Modern Physics A, World Scientific*, doi:10.1142/s0217751x0703666x.

10. **Hernández, X., et al**.: 2009, "An Empirical Gravity Law up to Galactic Scales." *Cornell University*, https://arxiv.org/abs/0904.1434v1.

11. **Buist, Hans J.T., and Amina Helmi**: 2014, "A New Fitting-Function to Describe the Time Evolution of a Galaxy's Gravitational Potential." *Astronomy and Astrophysics, EDP Sciences*, doi:10.1051/0004-6361/201323059.

12. Buist, Hans J.T., and Amina Helmi: 2016, "A New Fitting-Function to Describe the Time Evolution of a Galaxy's Gravitational Potential (Corrigendum)" *Astronomy and Astrophysics, EDP Sciences*, doi:10.1051/0004-6361/201323059e.

13. McGaugh S.S., F. Lelli, and J. Schombert: 2016, Radial Acceleration Relation in Rotationally Supported Galaxies, *Phys. Rev. Lett.* **117, Iss.** 20, 201101, arXiv:1609.05917 [astro-ph.GA], https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.117.201101.

14. Hees, A., Famaey B., and Bertone G.: 2017, "Emergent gravity in galaxies and in the Solar System" *Phys. Rev.* **D95,** No. 6, 064019, arXiv:1702.04358 [astro-ph.GA].

15. Tuveri, Matteo, and Mariano Cadoni: 2019, "A New Perspective on Galactic Dynamics." *Cornell University*, https://arxiv.org/pdf/1904.08209.pdf.

16. Moffat, J.W.: 2020, "Gravitational Theory of Cosmology, Galaxies and Galaxy Clusters." *The European Physical Journal C*, Springer Science+Business Media, doi:10.1140/epjc/s10052-020-08482-x.

17. Gu, Gu, Ying-Qiu: 2022, Simplification of Galactic Dynamic Equations. Symmetry, **14**, Article 407, https://doi.org/10.3390/sym14020407.

18. Gu, Ying-Qiu, and Ying-Qiu Gu: 2024, Explanation of Two Important Empirical Relations for Galaxies. *Journal of Applied Mathematics and Physics*, **12**, No. 1, https://doi.org/10.4236/jamp.2024.121023.

19. Danylchenko, Pavlo: 2022, *Foundations of Relativistic Gravithermodynamics*. Vinnytsia: TVORY [ISBN: 978-617-552-072-7] (in Ukrainian), https://elibrary.com.ua/m/articles/view/FOUNDATIONS-OF-RELATIVISTIC-GRAVITHERMODYNAMICS-6th.

20. **Danylchenko, Pavlo**: 2020, Theoretical misconceptions and imaginary entities in astronomy, cosmology and physics. *Foundations and consequences of Relativistic Gravithermodynamics*. Vinnytsia: Nova knyga [ISBN: 978-966-382-843-5], 85-128 (in Ukrainian), https://elibrary.com.ua/m/articles/view/Theoretical-misconceptions-and-imaginary-entities-in-astronomy-cosmology-and-physics-6th.

21. Danylchenko, Pavlo: 2021, Solution of equations of the galaxy gravitational field. *Proceed. Fourth Int. Conference APFS'2021*. Lutsk: *Volyn University Press "Vezha"* [ISBN: 978-966-940-362-9], 33-36, https://elibrary.com.ua/m/articles/view/SOLUTION-OF-EQUATIONS-OF-THE-GALAXY-GRAVITATIONAL-FIELD-2021-05-27.

22. Danylchenko, Pavlo: 2025, Solution of the standard differential equation of the dynamic gravitational field of a galaxy. *Proceed. VI Int. Conference «Actual problems of fundamental science» (APFS'2025)*. Lutsk: *Volyn University Press "Vezha"* [ISBN: 978-966-940-655-2], 30-33, https://elibrary.com.ua/m/articles/view/SOLUTIONS-OF-THE-

STANDARD-DIFFERENTIAL-EQUATION-OF-THE-DYNAMIC-GRAVITATIONAL-FIELD-OF-A-GALAXY.

23. Danylchenko, Pavlo: 2009, Foundations of Relativistic Gravithermodynamics. *Proceedings of all Ukrainian seminar from theoretical and mathematical physics TMP'2009.* Feb. 27 – Mar. 1, Lutsk: *Volyn'University Press "Vezha"* [ISBN: 978-966-600-395-2], 75-79 (in Russian), https://elibrary.com.ua/m/articles/view/FOUNDATIONS-OF-RELATIVISTIC-GRAVITHERMODYNAMICS.

24. Milgrom, M.: 1983, A Modification of the Newtonian Dynamics – Implications for Galaxies. *The Astrophysical Journal.* **270**, 371-383, ISSN 0004-637X, https://ui.adsabs.harvard.edu/abs/1983ApJ...270..365M/abstract, https://doi.org/10.1086/161131.

25. Bekenstein, J. and Milgrom, M.: 1984, Does the Missing Mass Problem Signal the Breakdown of Newtonian Gravity? *Astrophysical Journal*, **286**, 7-14, https://doi.org/10.1086/162570.

26. Danylchenko, Pavlo: 2004, The spiral-wave nature of elementary particles. *Proceedings of International scientific conference "D.D. Ivanenko – outstanding physicist-theorist, pedagogue",* Poltava Ukraine: ed. Rudenko O.P., 44-55. (in Russian) https://elibrary.com.ua/m/articles//download/11184/3433.

27. Danylchenko, Pavlo: 2004, About possibilities of physical unrealizability of cosmological and gravitational singularities in General relativity. *Gauge-evolutional interpretation of special and general relativities*, Vinnytsia: Nova knyga, 2008b: 45-95. https://elibrary.com.ua/m/articles//download/11203/3411.

28. Danylchenko, Pavlo: 2014, Spiralwave model of the Universe. *Proceedings of all-Ukrainian seminar on theoretical and mathematical physics: in honour of 85th anniversary of Anatoli Swidzynski*, *Lutsk Feb. 27 – Mar. 1 2014*, Lutsk: *Volyn Univer. Press "Vezha"* [ISBN: 978-966-2750-02-5], 21-26 (in Russian), https://elibrary.com.ua/m/articles/view/СПИРАЛЬНОВОЛНОВАЯ-МОДЕЛЬ-ВСЕЛЕННОЙ.

29. Thompson, Todd: 2011, Mass Distribution in Galaxies, Lecture 39: Dark Matter & Dark Energy. *Astronomy 1144: Introduction to Stars, Galaxies, and Cosmology* January 2011. http://www.astronomy.ohio-state.edu/~thompson/1144/Lecture40.html.

30. Pogge, Richard: 2006, Lecture 41: Dark Matter & Dark Energy._*Astronomy 162: Introduction to Stars, Galaxies, & the Universe,* http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit6/dark.html.

31. Bennett, Jeffrey, Donahue Megan, et al.: 2012, The essential cosmic perspective. Boston: Addison-Wesley, The 8th Edition 2017.

32. Danylchenko, Pavlo: 2022, The solutions of equations of gravitational field for quantum quasi-equilibrium cooling down gases. *Proceed. XI Int. Conference RNAOPM-2022.* Lutsk: *Volyn Univer. Press "Vezha"* [ISBN: 978-966-940-404-6], 98-100, https://elibrary.com.ua/m/articles/view/THE-SOLUTIONS-OF-EQUATIONS-OF-GRAVITATIONAL-FIELD-FOR-QUANTUM-QUASI-EQUILIBRIUM-COOLING-DOWN-GASES.

33. Tolman, Richard: 1969, *Relativity thermodynamics and cosmology*. Oxford: *At the Clarendon press*.

34. Einstein, Albert: 1936, Physik und Realität, *Journal of The Franklin Institute: Devoted to Science and the Mechanic Arts*, **221** No. 3, 313–347.

35. Danylchenko, Pavlo: 2022, Non-identity of inertial and gravitational masses. *Proceed. XI Int. Conference RNAOPM-2022.* Lutsk: *Volyn Univer. Press "Vezha"* [ISBN: 978-966-940-404-6], 96-97, https://elibrary.com.ua/m/articles/view/NON-IDENTITY-OF-INERTIAL-AND-GRAVITATIONAL-MASSES.

36. Dirac, Paul Adrien Maurice: 1978, Cosmology and the gravitational constant, *Directions in Physics*, ed. by P.A.M. Dirac. New York: *John Wiley & Sons, Inc.,* **11**, 71–92.

37. Danylchenko, Pavlo: 2025, Relativistic transformations of coordinate increments and metric segments of bodies moving in a gravitational field by inertia. *Proceed. VI Int. Conference APFS'2025*. Lutsk: *Volyn University Press "Vezha"* [ISBN: 978-966-940-655-2], 26-29, https://elibrary.com.ua/m/articles/view/RELATIVISTIC-TRANSFORMATIONS-OF-COORDINATE-INCREMENTS-AND-METRIC-SEGMENTS-OF-BODIES-MOVING-IN-A-GRAVITATIONAL-FIELD-BY-INERTIA.

38. Danylchenko, Pavlo: 2021, The condition of invariance of thermodynamic potentials and parameters with regard to the relativistic transformations. *Proceed. Fourth Int. Conference APFS'2021*. Lutsk: *Volyn Univer. Press "Vezha"* [ISBN: 978-966-940-362-9], 37-40, https://elibrary.com.ua/m/articles/view/The-condition-of-invariance-of-thermodynamic-potentials-and-parameters-with-regard-to-the-relativistic-transformations.

39. Danylchenko, Pavlo: 2022a, The instantaneous values of main thermodynamic parameters and potentials that are characteristic to Gibbs thermodynamic microstates. *Proceed. XI Int. Conference RNAOPM-2022.* Lutsk: *Volyn Univer. Press "Vezha"* [ISBN: 978-966-940-404-6], 101-107, https://elibrary.com.ua/m/articles/view/THE-INSTANTANEOUS-VALUES-OF-MAIN-THERMODYNAMIC-PARAMETERS-AND-POTENTIALS-THAT-ARE-CHARACTERISTIC-TO-GIBBS-THERMODYNAMIC-MICROSTATES.

40. Trokhimchuck, Petro P.: 1985, Contradictions in modern physical theory. The method of diffeomorphically-conjugated forms and some its applications, Preprint *USC AS* the USSR, Sverdlovsk.

41. Danylchenko, Pavlo: 2025, On the possibility of the permanent existence of antimatter in the Universe. *Proceed. VI Int. Conference APFS'2025*. Lutsk: *Volyn*

University Press “Vezha” [ISBN: 978-966-940-655-2], 23-25, https://elibrary.com.ua/m/articles/view/ON-THE-POSSIBILITY-OF-THE-PERMANENT-EXISTENCE-OF-ANTIMATTER-IN-THE-UNIVERSE.

42. Zeldovich, Yakov & Grischuk Leonid: 1988, General relativity is correct! (Methodical notes). *Physics-Uspekhi* (in Russian), **155**, 517.

43. Penrose, Roger: 1968, Structure of space-time. New York, Amsterdam: W.A. Benjamin, Inc.

44. Gordon, Kurtiss J.: 1969, HISTORY OF OUR UNDERSTANDING OF A SPIRAL GALAXY: MESSIER 33 // THE ISLAND UNIVERSE THEORY. *Quarterly Journal of the Royal Astronomical Society* **10**, 293-307.

45. Weinberg, David H.: 2010, From the Big Bang to Island Universe: Anatomy of a Collaboration. Ohio State University Department of Astronomy. June 2010, *Narrative, edited by J. Phelan.* https://arxiv.org/pdf/1006.1013.pdf.

46. Koberlein, Brian: 2013, *Island Universe*. https://briankoberlein.com/post/island-universe/.

47. Möller, Christian: 1972, *The Theory of Relativity*, Oxford: *Clarendon Press*.

48. Fuller, R.W., Wheeler J.A.: 1962, *Phis. Rev.*, **128**, 919**.**