FOUNDATIONS OF RELATIVISTIC GRAVITHERMODYNAMICS[1]

Danylchenko, Pavlo[2]

E-mail: pavlodanylchenko@gmail.com

Evolutionary self-contraction of microobjects of lower layers of gravithermodynamically bonded matter outpaces the similar self-contraction of its upper layers. This is the exact reason of the curvature of intrinsic space of matter. That is why gravitational field itself should be primarily considered as the field of spatial inhomogeneity of evolutionary decreasing of the size of matter microobjects in the background Euclidean space of expanding Universe. In correspondence to this the gravitational field itself is the field of spatial inhomogeneity of gravithermodynamic state of dense matter of compact astronomical objects, as well as of strongly rarefied gas-dust matter of space vacuum. And, therefore, the gravitational field fundamentally cannot exist without matter. That is why it is not an independent form of matter. It is shown that equations of the gravitational field of General Relativity (GR) should be considered as equations of spatially inhomogeneous gravithermodynamic state of only utterly cooled down matter. This matter can only be the hypothetical substances such as ideal gas, ideal liquid and the matter of absolutely solid body. The real matter will be inevitably cooling down for infinite time and never will reach the state that is described by the equations of gravitational field of the GR. The equivalence of only inert free energy of matter (and not of the total internal energy) to gravitational and inert masses is justified. It was proved that total energy of matter is equal in all frames of references of spatial coordinates and time that are moving relatively to matter. And that is precisely why there is a conform Lorentz-invariance of thermodynamic potentials and parameters. It is also shown that the tensor of energy-momentum of matter (right side of the gravitational field equation) should be formed not being based on external thermodynamic parameters, but being based exactly on the intranuclear gravithermodynamic parameters. Therefore, bodies free fall in gravitational field is an original realization of their tendency to increase the evolutionary self-contraction of microobjects of their matter, and the realization of the tendency of the whole gravitationally bonded inhomogeneous matter to the minimum of the integral values of its inert free energy and thermodynamic Gibbs free energy. Bodies that fall accelerate independently in spatially inhomogeneous medium of the outer space or atmosphere. Such bodies transform their continuously released intra-atomic energy into kinetic energy.

Keywords: gravithermodynamics, thermodynamics, gravity, gravitation, GR, SR, vacuum, inert free energy, Gibbs free energy, field, gauge deformation, collective space-time microstate, Gibbs microstate, limit velocity of matter, coordinate velocity of light, internal scale factor, spiral waves, micro-object, outer space, photosphere, redshift, quasar.

PACS: 05.70.-a, 04.40.-b, 04.20.-q

---

[1] Reports in The all-Ukrainian seminar from theoretical and mathematical physics to 80 anniversary by professor A.V. Swidzynskiy in Lutsk (27.02-1.03.2009) and in The 4-th Gamow international conference in Odessa (17-23.08.2009). Abbreviated versions of the article were published in Proceedings of all-Ukrainian seminar from theoretical and mathematical physics to 80 anniversary by professor A.V. Swidzynskiy TMP'2009, Lutsk, February 2009, in Nauk. visn. Volyn'University, 6, 2010, in "Philosophy & Cosmology 2010", 9, Poltava: Poltavskiy literator (2010) and publishing house "Nova knyga", Vinnytsia, 2020; 2nd online edition, revised and enlarged.

> But, it is similar to a building, one wing of which is made of fine marble (left part of the equation), but the other wing of which is built of low grade wood (right side of equation). The phenomenological representation of matter is, in fact, only a crude substitute for a representation which would correspond to all known properties of matter.
>
> Albert Einstein (Physics and reality)

Introduction

Clausius's Hypothesis about opportunity of the heat death of the Universe (1865) and also the misconceptions about non-invariance of thermodynamics equations to relativistic transformations led to false conclusion that methods of thermodynamics cannot be applied to the analysis of evolutional processes in megaworld. It is known now that the Universe cannot cool down at any as long as possible finite time period. Self-organization of spatially inhomogeneous thermodynamic states and gravitational fields that correspond to those states prevent matter from complete cooling down. The thing that prevents unlimited growth of entropy in the Universe is the self-organization of different structural formations, the complexity of which grows with every new hierarchy level of self-organization of natural objects that form them. Relativistic generalization of thermodynamics with the invariant absolute temperature is currently considered as the most acceptable generalization [Van Kampen, 1968; Bazarov, 1964; 1991].

Thermodynamics was already used in this or that manner for analysis of the processes of formation of megascopic Universe objects [Antonov, 1962; Lynden-Bell & Kalnajs, 1972; Polyachenko & Fridman, 1976; 1984; Saslaw, 1968; 1969; 1970; 1985; Binney & Tremaine, 1987]. The main researches that should be highlighted: researches on gravitational plasma [Finney & Tremaine, 1987; Binney, 1993], researches based on the kinetic theory of rarefied gas [Zhdanov & Roldugin, 1998], and also the theory of spatio-temporal evolution of nonequilibrium thermodynamic systems [Olemskoy & Koplyk, 1995]. Recently, being based on the analysis of self-organization processes in nonequilibrium systems [Prigogine & Nicolis, 1977; Prigogine, 1985] and on the more wide usage of the methods of statistical physics, thermodynamics of self-gravitating systems achieved the quite significant success [Chavanis, 2002; 2005; Katz, 2003]. However thermodynamic and gravitational descriptions of the self-organization processes of Universe astronomical objects are still not naturally merged. Therefore, phenomenological justification of the united nature of thermodynamic and gravitational properties of the matter [Danylchenko, 2008: 19; 2008a; 2009: 75; 2009a; 2010: 64; 2010a: 38; 2020: 5] is very important for the studying of megascopic astronomical objects and global processes in the Universe.

Thermodynamic states of matter, examined in General Relativity (GR), are self-inducted by matter spatially inhomogeneous states of this matter. This fact is caused by the presence of gravitational field in matter: Gravitational field is the cause of spatial inhomogeneity of rates of intra-atomic physical processes in matter and, therefore, it inducts not only the curvature, but also physical inhomogeneity of intrinsic space of matter [Danylchenko, 1994a; 2004: 33; 2008b: 45]. In rigid frames of reference of time and spatial coordinates (FR) this physical inhomogeneity of the space is in the mutual inequality of values of such hidden thermodynamic property of the matter as coordinate-like velocity v_{cv} of light in different points of this space [Möller, 1972].

The equations of GR gravitational field should be considered as just the equations of spatially inhomogeneous thermodynamic state of utterly cooled down matter. Such matter can be represented only by hypothetical substances such as ideal gas, ideal liquid and matter of absolutely rigid body. Real matter is doomed to cool down infinitely long without reaching the state that is described by the equations of GR gravitational field. This state of gradual quasi-homogeneous cooling down is described by considered here modified tensor equations of GR – equations of relativistic gravithermodynamics (RGTD).

Increasing of coordinate-like velocity of light during the distancing from compact matter of astronomical body can be the consequence of gradual change of thermodynamic parameters of the atmosphere and the outer space that surround this body. In this case spatial distributions of coordinate-like velocity of light, which are set by gravitational field, strictly correspond to concrete spatially inhomogeneous thermodynamic states of matter. Adding of the third independent parameter – coordinate-like velocity of light to any of two mutually independent thermodynamic parameters in GR guarantees only conventional consistency of this theory with objective reality. Indeed, the solutions of equations of gravitational field for any cluster of gravitationally-bounded matter are always examined in conventionally empty Universe. However, the Universe is not empty and, as united solution of equations of gravitational field and equations of thermodynamics for ideal liquid shows [Danylchenko, 2005b; 2008: 4], values of coordinate-like velocity of light are not vacuum values, but gravi-baric values. They are determined by the values of thermodynamic parameters of ideal liquid accurate to gauge coefficient. Only this coefficient can be considered as pseudovacuum value of coordinate-like velocity of light. In the case of presence of both mechanical and thermal equilibriums in ideal liquid this pseudovacuum value of coordinate-like velocity of light is the same within the whole liquid, which self-organized its spatially inhomogeneous equilibrium state and gravitational field that corresponds to this state [Danylchenko, 2005b; 2008: 4]. This fact allows us to consider this vacuum value as gauge parameter, that interconnects spatial and temporal metrics and cannot be observed in hypothetical gravity-quantum intrinsic FRs (GQ-FRs) of matter and in people's world FR in principle.

1. Gravitational nature of the pressure in ideal gas and in conventional emptiness.

The space of the Universe is infinite in a comoving FR in expanding Universe (CFREU). In GQ-FR the whole space of the Universe is inside the sphere of pseudo horizon of events (events on this pseudo horizon belong to infinitely far cosmological past) [Danylchenko, 2004: 33; 2005; 2005a: 95; 2008b: 45]. Therefore in GQ-FR the volume of the whole Universe V_U fundamentally can be finite. Although even infinitely far objects of CFREU are observed in this Universe, the infinitely large number of its astronomical objects is beyond the limits of space-time continuum (STC) of gravithermodynamically bonded matter. And therefore, according to the equation of the state of ideal gas, the pressure in GQ-FR cannot take not only infinitely large values, but also zero values: $p_U \geq RT/V_U$. Taking into account the fact, that not the absolute, but relative measurements of pressure are performed by all devices: $p = p_U - p_{U\min}$, the equation of mechanical equilibrium of matter in gravitational field should be as follows:

$$\frac{dp}{dr} = -(\mu c^2 + p + p_e)\frac{d\ln v_{cv}}{dr} = -\frac{(\mu c^2 + p + p_e)}{2b}\frac{db}{dr},$$

where: $b = v_{cv}^2/c^2$, $p_e \geq p_{U\min}$ is arbitrary small but still finite value of pressure on the surface of compact physical body that is located in conventionally empty space.

Then even in the case of zero density of the mass ($\mu = 0$) the radial distribution of pressure in conventionally empty space that surrounds the body formally strictly corresponds to the radial distribution of coordinate velocity of light of GR in this space:

$$\frac{dp}{dr} = -p_e\frac{d\ln v_{cv}}{dr} = -\frac{p_e}{2b}\frac{db}{dr}, \qquad p = p_e\left[1 - \ln\left(\frac{v_{cv}}{v_{cve}}\right)\right] = p_e\left[1 - \frac{1}{2}\ln\left(\frac{b}{b_e}\right)\right]. \quad (1)$$

The tendency of coordinate velocity of light to zero while approaching the fictive singular surface of pseudo horizon of events corresponds to the tendency of pressure to infinity in the same way as it takes place while approaching the real singular surface that separates external matter from internal antimatter in ultra massive neutron stars [Danylchenko, 2004: 33; 2005; 2005b; 2008: 4; 2008: 19; 2008a; 2008b: 45].

And this, of course, confirms the possibility to use the gradient of pressure in matter and in outer space as the gradient of gravitational field. The pressure in matter and in outer space, which is not caused by electromagnetic interaction of molecules, has namely the gravitational nature.

Conventionally empty space that surrounds such compact matter of The Universe has really never been empty and never will be completely empty. Even the highest cosmic vacuum should be considered as very rarefied gas-dust "incoherent matter", which obey the thermodynamic laws the same as ideal gas of non-interacting molecules[3].

That is why radial distribution of pressure that is set by (1) dependency indeed should correspond not to hypothetical absolute emptiness, but to rarefied gas-dust matter of the outer space that surrounds the compact astronomical body.

2. Maximal possible velocity of matter

The limitation of the velocity of physical bodies is indeed exists in such rarefied gas-dust matter. However, this limitation is not related to the velocity of light in the matter or in hypothetic absolute vacuum. In airspace, as well as in dense matter, the charged micro objects (protons) can propagate faster than the velocity of light. That is confirmed by the origination of the radiation, found by Cherenkov, in this case. On the other hand, hypothetical frequency of intranuclear interaction (alternative to the pseudovacuum velocity of light of GR) decreases while approaching the gravity center unlike the real frequency of electromagnetic interaction in matter, which increases. This is in a good correspondence with the fact that thermodynamic and gravity-evolutionary processes have opposite directions and is related to the fact that frequency of electromagnetic interaction in matter is greater when the temperature of the matter is greater. Due to the same reason the physical processes flow faster not on the surface but in hotter bowels of the astronomical objects despite the gravitational slowing down is predicted by GR for those processes.

The reason for limitation of velocity of physical bodies is indeed the nature of matter movement in the space. Physical vacuum is not carried away by physical body. Matter is only the non-mechanic excitement of physical vacuum (space-time modulations of its physical characteristics). Therefore, the perception of high-frequency discrete movement of the body in the space as the continuous motion is similar to cinematographic perception of discrete change of image frame. The limitation of body velocity can be related to the fact that it is impossible to reach infinitely high frequency of discrete change of Gibbs collective thermodynamic microstate (quantum «hologram») of the whole its RGTD-bonded matter and to the fact that it is impossible to reach the zero value of the length of spatial step shift (quantum micromovement) of the body. This frequency and this micromovement are de facto the de Brogile frequency $\mathbf{v}_B$ and wave length λ_B of the moving body. That is why instead of denying the possibility of moving body to overcome the velocity of light we should state the principal impossibility to reach the extremely big velocity $v_l = \sqrt{v v_B} = v_{B\min}$, that corresponds to the tending of $\mathbf{v}_B$ to infinity, and tending of

[3] Such "incoherent matter" (in a form of e.g. lonely atom), of course, can interact with the cloud of coherent virtual microobjects in the gravitational field of coherent matter that form collective Gibbs thermodynamic microstates.

$\lambda_B = v_l / \mathbf{v}_B$ to zero, when phase velocity of de Brogile wave propagation v_B reaches its minimal value, equal to maximal possible group velocity $v_{\max}$ of the whole matter of the body ($v_{B\min} = v_{\max} \equiv v_l$).

3. Physical essence of gravitational field

Purely gravitational nature of the pressure in ideal gas and also the tendency of coordinate velocity of light (and of equivalent to it maximal possible velocity of objects) to zero value only when pressure tends to infinity is in a good correspondence with the spiral-wave nature of matter [Danylchenko, 2004: 33; 2004b: 44; 2008b: 45; 2014: 21]. Pressure in matter in the outer space as well as the gradient of the strength of gravitational field increase with the increasing of density of turns of spiral-wave modulation of dielectric and magnetic permeability of physical vacuum. Spiral wave turns approach the physical body with the de Broglie frequency. With each turn that runs over the correspondent to body spiral-wave formation the center of mass of the body can discretely change its position in space. The body itself (correspondent to it spiral-wave formation) is gradually self-shrinkage in CFREU on the level of microobjects of its matter (terminal outlets of the turns of the common spiral-wave formation of the Universe). Exactly this fundamentally non-observable self-contraction of matter is responsible for the expansion of the Universe in the FR of people's world.

There is a thermodynamic quasi-equilibrium between gravitationally self-contracted compact matter and surrounding it arbitrary rarefied matter of the outer space. Therefore, pseudovacuum value of the hypothetical coordinate velocity of light in this rarefied liquid matter cannot differ from pseudovacuum value of the coordinate velocity of light in the space filled in by compact matter. And, consequently, this value should be the same in the whole Universe space, filled by gaseous and liquid matter. Thus, coordinate velocity of light of GR should indeed be considered not as vacuum velocity but as gravibaric velocity of light [Danylchenko, 2005b; 2008: 4; 2009: 75; 2009a; 2010: 64; 2020: 5]. Thus, vacuum value of the hypothetical coordinate velocity of light, which is a gauge parameter, should be considered as strictly equal to the constant of the velocity of light c in the whole space, filled in by any gaseous and simplest liquid matter that is in quasi-equilibrium thermodynamic (thermal and mechanical) state. And then, due to isotropy of radial distribution of the pressure in such matter we can reach the following conclusion. The fact that the rates of hypothetical coordinate (gravity-quantum) intrinsic time of the homogeneous matter differ in the points of matter, where values of gravitational potential are different, is caused only by inequality of the pressure and other thermodynamic parameters of this gaseous or liquid matter, which fills the whole space, in those points. And, therefore, all such homogeneous matter is not only in the state of mechanical and thermal equilibrium, but also on the same stage of evolutional decreasing of the level of improper value of its intranuclear energy. Of course, the closer is the matter to gravity center the smaller is its value of limit velocity of its motion (alternative to gravibaric coordinate velocity of light in partially modernized GR [Danylchenko, 2005b; 2008: 4; 2020: 5]) and, therefore, the smaller is its intranuclear inert energy and the smaller is the size of its microobjects in background Euclidean space of CFREU. However, this spatial inhomogeneity of evolutionary-gravitational self-shrinkage of matter in CFREU strictly corresponds to the spatial inhomogeneity of its thermodynamic state. And that is why all effects that take place in such gaseous or liquid matter and that are considered as gravitational are indeed purely thermodynamic.

Anisotropy of radial distribution of the pressure in matter is the characteristic for solid matter. That is why solid matter and liquid matter, located above the world Ocean level, are on the certain stage of lagging of evolutionary-gravitational decreasing of the level of improper value of its intranuclear energy. The water of world Ocean is also on the certain stage of lagging of this process since it covers the rigid body. However, gravitational reduction of the level of improper value of its intranuclear energy is in advance of the similar reduction for the objects that are above the world Ocean level. It means that gravitational field is the field of non-equal (spatially inhomogeneous) advance of evolutional decreasing of improper value of intranuclear energy of solid and any liquid matter. And such advance for solid and liquid matter cannot be smaller that the advance of evolutionary reduction of improper value of intranuclear energy of gaseous matter that is in contact with it. Thus, the stepped layer-by-layer realization of gravitational advance of evolutionary reduction of improper value of intranuclear energy of multilayer inhomogeneous matter takes place. The overall gravitational advance of evolutionary self-shrinkage of the whole upper layer of grvithermodynamically bonded gaseous matter is de facto increasing due to advancing evolutionary-gravitational self-shrinkage of solid body covered by this matter. Moreover, radial gradient of the real velocity of light in such gaseous matter can be significantly smaller than the gradient of conventional gravithermobaric velocity of light. And this, of course, can significantly reduce the blurring of spectral lines of radiation of such photospheric gaseous matter of stars.

In correspondence with all this, significant gravithermodynamic redshift of emission radiation spectrum can take place only for astronomical objects with a solid photosphere, as well as for liquid and gaseous astronomical objects, which have solid nucleus or are in non-equilibrium thermodynamic states. And, of course, gravithermodynamic redshift of radiation spectrum is the consequence of advance of evolutionary reduction of the intranuclear energy of lower layers of matter (the consequence of lagging of evolutional decreasing of intranuclear energy of radiating matter). Frequencies of emission radiations are determined only by the differences between energy atomic levels, values of which are not changed in atoms at quasi-equilibrium thermodynamic processes. Radial changes of matter RGTD-parameters, when liquid or gaseous matter is in hypothetical equilibrium thermodynamic state, lead to the change of only the frequency of quantum interactions in atomic nuclei. And it is not accompanied by redshift of its spatially homogeneous emission radiation and by widening of spectral lines of that emission radiation.

Due to all mentioned above the introduction of the count of unified thermodynamic time in atmospheric layer of the Earth instead of the counts of hypothetical gravity-quantum times (time rates of which are decreasing while approaching the gravity center) does not break the general covariance of equations and laws of physics.

4. Thermodynamic nature of the majority of gravitational effects

Analysis of solutions of the equations of GR gravitational field [Danylchenko, 2005b; 2008: 4; 2008: 19; 2008a] specifies the thermodynamic nature of majority of gravitational effects. All gravitational phenomena, except the phenomenon of curvature of intrinsic space of matter, are strictly thermodynamic in fact. For example, the fact that bodies, more dense than surrounding medium, tend to the gravity center, as well as the fact that bodies, less dense than surrounding medium, tend from the gravity center, is caused by the fact that the whole system (which consists from all bodies and the medium surrounding them) tends to the state of the minimum of the integral value of their thermodynamic enthalpy [Danylchenko, 2005b; 2008: 4]. In the case of presence of heat exchange integral value of purely thermodynamic Gibbs free energy also tends to minimum [Danylchenko, 2009: 75; 2009a; 2010: 64; 2010a: 38; 2020: 5], while integral value of entropy of all matter in the Universe tends to maximum. From the other hand, the pressure in ideal gas and in any other “incoherent matter” is not caused by intermolecular electromagnetic interaction and, consequently, this pressure itself has purely gravitational nature. And, therefore, physical phenomena and properties of matter, which are examined by thermodynamics and theories of gravity in a different phenomenological way, are based on the same fundamental nature of matter micro-objects (elementary pseudoparticles) [Danylchenko, 2004: 33; 2004b: 44; 2008b: 45].

In classical physics potential energy of gravitational field was considered as something external for the matter, while in GR potential energy is contained in matter itself. Indeed, free fall of the body is an inertial motion. Released potential energy of intranuclear bonds and intranuclear interactions in the atoms cores of matter of falling body together with the energies of nucleons that form these atoms transform into kinetic energy of body motion. And the excessive level of evolutionary lost intranuclear energy of matter, in fact, decreases. As it follows from united solutions of equations of gravitational field and thermodynamics equations [Danylchenko, 2004b: 44, 2005b; 2008: 4; 2009a; 2020: 5], all characteristics that determine gravitational properties of matter and phenomenon of Universe expansion are also contained in matter itself and cannot be considered as something external for the matter.

The change of collective spatial-temporal state of the whole gravithermodynamically bonded matter takes place simultaneously in its intrinsic time and in all points of its intrinsic space. That is why the rates of all physical processes in intrinsic STC of gravithermodynamically bond matter should be determined only by its thermodynamic parameters and should not directly depend on spatially inhomogeneous rate of hypothetical coordinate (gravity-quantum) time. Their rates will be non-equal only in cosmological time, rate of which in intrinsic time of matter is decreasing while approaching the gravity center.

5. Gravithermodynamic FR of people's world

In classical thermodynamics all intensive thermodynamic parameters of matter are determined via measuring of extensive parameters (which depend on those intensive parameters) of matter itself or matter of measuring instruments that are in thermal equilibrium with this matter. For example, the main method of temperature measuring is in the measuring of volume occupied by thermometer liquid. Pressure is determined via measuring of elastic deformation (caused by this pressure) of any element of recording instrument. Deformation and volume are both extensive parameters. This makes closed system of the pairs of mutually complementary intensive and extensive matter parameters self-consistent and guarantees invariance of intensive thermodynamic parameters to time transformations. And, thus, there is not only temporal invariance, but also Lorentz-invariance of used in thermodynamics proper values of intensive and extensive characteristics of matter. And it is similar to the principal invariance of the value of velocity of light by the intrinsic clock in the point of its dislocation and to the principal invariance of Hubble constant[4]. The majority of measurings of physical characteristics in FR of people's world is purely relative. They are strictly bonded not only to intrinsic clock, but also to other intrinsic instruments of operator who performs measurement. And, therefore, the influence of the instrument on the measurement result takes place not only in quantum, but also in classic physics. In contrast to microworld, in the macroworld the measurement results are only strictly determined.

And, therefore, invariant values of thermodynamic parameters and characteristics of motionless matter, which are used in classical thermodynamics, are self-sufficient and don't need to be a member of any FR. They can be members only of certain tracking system: system that tracks changes of thermodynamic parameters and characteristics of matter. And, from the other hand, global FR can be formed based on this tracking system. The presence of phenomena, for which frequency of their elementary acts depends only on absolute temperature, is necessary for this global thermodynamic FR

[4] In an comoving FR in expanding Universe the change of velocity of light is proportional to the change of the size of length standard and , therefore, proportional to the velocity of evolutional motion of matter to the center of its self-contraction. The

(GT-FR) to be non-artificial in nature. Then, the scale of absolute temperature can be linearly calibrated based on this frequency. The clock, using which the rates of hypothetical coordinate (gravity-quantum) proper times can be compared and dependences of these rates on parameters of thermodynamic states of these matters can be analyzed, can be realized based on this phenomenon.

And such phenomenon exists: dependence (obtained by Wien) of electromagnetic wave frequency, which corresponds to the maximum of spectral density of equilibrium thermal radiation, only on absolute temperature and proportionality of this frequency to absolute temperature: $\nu_{\max}=(\alpha k/h)T$, where k is Boltzmann constant, h is the Planck constant, α is the root of the equation: $\alpha/5=1-\exp(-\alpha)$. Therefore, united thermodynamic time is used in people world in fact, instead of gravity-quantum time, rate of which is not similar for different matters and depends on their gravithermodynamic states. Quantum processes in etalon matters can only be used for the counting of this time due to the stability of their rate in this matter when temperature T and pressure p remain unchanged. Thermodynamically invariant atomic characteristics – differences between energy levels ΔE_{ij} in atoms and frequencies of emission radiation $\nu_{ij} = \Delta E_{ij} / h$ corresponding to them also can be used for this time counting. Energy levels are defined by radiuses of allowed orbits of electron shells in the atom and, similar to intensive thermodynamic parameter, are the characteristic defined by extensive parameter (radius of allowed orbit) and, therefore, dependent on transformations of spatial coordinates not time. Therefore, electrons energy and, thus, energy levels in atoms are, similarly to thermodynamic internal energy of matter U, Lorentz-invariant and does not depend on the level of inert intranuclear energy of nucleons as well as on the gravitational potential (and on hypothetical coordinate pseudo-vacuum velocity of light that defines this potential). And, thus, it does not depend also on the rate of hypothetic coordinate (gravity-quantum) intrinsic time of matter. CFREU GR

Thus, the wavelength, as well as the frequency of not only thermal, but also emissive radiation, is determined only by individual properties and thermodynamic parameters of matter. Ant their values do not depend on the magnitude of gravitational potential in it as well as on the rate of hypothetical coordinate (gravity-quantum) intrinsic time of matter. And this means that real velocity of light in matter is also strictly determined only by its individual properties and thermodynamic parameters. And it cannot be greater than the limit velocity of motion of baryonic matter, that is also the function only of the individual properties and thermodynamic parameters of the same matter. And, therefore, hypothetical coordinate vacuum velocity of light of GR, is, of course, the nonsense since absolute vacuum fundamentally cannot exist not only in matter but also in the outer space.

---

velocity of evolutional motion of the matter obeys the Hubble law in this FR. All this guarantees the principal invariance of not only intrinsic value of velocity of light, but also Hubble constant in people's world FR.

Gravity (similarly to the evolutionary process of Universe expansion) reduces the magnitudes of radiuses of allowed orbits of electron shells in atom in background Euclidean space of CFREU. And, therefore, for astronomical objects (which matter is in the state of gravithermodynamic equilibrium) the non-Dopplerian (gravitational) blueshift of the wavelength of emissive radiation in the process of its generation takes place in CFREU instead of the redshift. However, the gravitational shift of the frequency of emissive radiation is absent in GT-FR since neither the radiuses of allowed electron orbits in atom nor the real velocity of propagation of interaction in matter depend on the value of strength of gravitational field on matter and on the spatial distribution of hypothethical coordinate velocity of light that defines this strength. Moreover, it corresponds to the accepted in GR concept of fundamental unobservability of gravitational deformation of matter on the level of its microobjects. And we, of course, should agree with this concept as well as with the fundamental unobsevability of relativistic deformation of moving matter. Otherwise the general covariance of equations and laws of physics would not be fulfilled.

Despite this the observability of deformation of the orbits of electron shells in atoms under the influence of gravitational pressure can take place in GR. However, if we suggest that while approaching the gravitational attraction center the radiuses of allowed orbits of electron shells are reduced very insignificantly (at least in photosphere of stars) then the very insignificant decrease of real velocity of propagation of electromagnetic interaction will compensate the influence of this on the frequency of emissive radiation. And, then, despite the decreasing of limit velocity of motion of baryonic matter (alternative to coordinate velocity of light of GR) the frequency of the same emissive radiation will, obviously, remain the same within the whole photospheric matter that is located in the spatially inhomogeneous state of equilibrium (in GT-FR, as well as in any GQ-FR). It means that widening of spectral lines of emission radiation can be only Dopplerian – can be caused only by the thermal fluctuations of molecules of the matter. This is confirmed by the absence of gravitational and thermodynamic blurring of spectral lines of excited atoms of cold rarefied galaxy medium even when values of their main quantum numbers are $n \approx 1000$ ($\lambda > 20\text{m}$) [Sorochenko & Salomonovich, 1987; Gordon & Sorochenko, 2009][5].

And, consequently, the significant non-Doplerian redshift of the spectrum of emissive radiation can take place only for those astronomical objects (that do not have a solid nucleus) the liquid and gaseous

[5] Their size, in correspondence to Bohr's model, reaches 0,1 mm, while the wave length of the line C766α of carbon is 20 meters. The reason that prevents the existence of more highly excited atoms is the background galactic radio emission that is propagated throughout the whole Galaxy. The brightness temperature of the background increases with the wave length increasing. That is why the density of quanta, capable to cause the induced transitions in the atom, increases with the increasing of the excitement level of the atom *n*. The sections of such transitions increases together with the increasing of *n*. As a result, when *n* value is close to 1000 the life time of the atom on current levels becomes so short that one cannot distinguish any spectral lines [Sorochenko & Salomonovich, 1987; Gordon & Sorochenko, 2009].

homogenous matter of which is in non-equilibrium thermodynamic state. And it will be determined exactly by the thermodynamic parameters of matter and not by the values of limit velocity of motion of baryonic matter and of correspondent to it gravitational potential. However in GR such astronomical objects are not considered at all since density of the hybrid enthalpy is used instead of density of the ordinary internal energy at rest $W_0/V=\mu_0 c^3/v_{cv}$ (together with density of the inert free energy at rest $E_0/V=m_0 c v_{cv}/V=\mu_0 c v_{cv}$) in the tensor of energy-momentum (where m_0 is the eigenvalue of the mass of one mole of matter; $\mu_0=m_0/V$ is the eigenvalue of density of matter mass).

So, all physical properties of such matter do not depend on gravitational field that is formed by its intranuclear characteristics. Gravitational field reveals itself in the presence of spatial gradients of thermodynamic parameters and potentials as well as other known parameters and characteristics of solid homogenous matter. That is why in RGTD, as well as in classic thermodynamics, it is enough to use only two independent parameters for the description of spatially inhomogeneous quasi-equilibrium thermodynamic state of continuous homogeneous matter. Three independent parameters are used in GR. It is considered that physical properties of the same such matter depend also on the magnitude of coordinate velocity of light in it when the values of its two thermodynamic parameters are equal. That is why purely thermodynamic redshift of radiation spectrum in photospheric layer of solid homogeneous liquid of gaseous matter (that is in the state of thermodynamic quasi-equilibrium) is considered in GR as gravitational. Though, of course, in general case it is indeed gravitationally-thermodynamic.

Despite the quite large velocity of motion of Solar system in the Universe (near 370 *km/s*) the anisotropy of namely the real velocity of light (and not the conventional coordinate velocity of light in hypothetical absolute vacuum) is absent in isotropic media. And, therefore, the matter (being adapted to its velocity of motion) not only reduces its size along the direction of its motion but also (being gaugely deformed [Danylchenko, 1994, 1994a]) sets the anisotropy of its physical properties (and of its refractive index of radiation [Danylchenko, 2009: 79]) in FR in which it moves. And this means that relativistic shrinkage of length of moving matter is determined neither by hypothetical coordinate velocity of light nor by alternative to it limit velocity of matter motion. And since not only the limit velocity of matter motion defines the magnitude of its relativistic length shrinkage it can be non-equal in the same point of space for different matters. That is why RGTD suggests the possibility of inequality of values of gravitational potentials (that are formed based on the limit velocity of matter motion) on the boundary of media and even phases of the same matter. However using the correspondent gauge coefficients the non-equal for different matters (and for their phase states) inranuclear as well as thermodynamic potentials (that are used in logarithmic gravitational potential) still can be lead to some unified logarithmic parameter of gravitational potential (similarly to using of conventional coordinate velocity of light in GR in hypothetical absolute vacuum, based on which the spatial distribution of logarithmic gravitational potentials is formed). Such universal parameter can be e.g. the limit velocity of mutual motion of all RGTD-bonded matters, at which all those matters are still able to form common collective Gibbs gravithermodynamic microstates.

And this means that logarithmic gravitational potentials can be formed based on some thermodynamic as well as other physical properties of matter. RGTD admits the usage (as gravitational potential) of not only the logarithm of limit velocity of matter motion or logarithm of its Gibbs free energy (that is inversely proportional to this velocity). Gravitational potential can also be formed in it based on the logarithm of function of internal scale factor of matter [Danylchenko, 2008: 19; 2008a; 2009a; 2020: 5] and of refractive index of its radiation (or of the real velocity of propagation of radiation in it v_{cm}) on the standard or chosen frequency of correspondent to it electromagnetic wave. Due to it the purely gravitational redshift of radiation $z_G=(\lambda_G-\lambda_0)/\lambda_0$ can be determined, being based on the fact that:

$$\lambda_G=\lambda_0(n_{hN}/n_{lA})\prod_{i=1}^{k}(n_h/n_l)_i \ ,$$

where: n_{hN} is the refractive index of the matter of continuous core of astronomical body on the boundary with the layer (that covers it) of another matter or another phase of the same matter; n_{lA} is the refractive index of the lower layer of atmosphere (photosphere); n_h and n_l are the refractive indexes of intermediate layer of matter on its upper and lower boundaries correspondingly; k – is the number of intermediate layers of matter.

6. Inert intranuclear energy of matter

Absolute temperature is an intensive parameter that characterizes only the level of thermal internal energy $U(T,p)$ of matter, which includes also potential energy of interatomic and intermolecular bonds. Invariance of all thermodynamic parameters and matter characteristics to time transformation denotes that all of them should be relativistic invariants. Therefore, temperatures of phase transitions should remain internal properties of moving matter. This means that the change of thermodynamic parameters and characteristics of matter should have indirect influence on the change inert free energy of matter. And, therefore, nonchemical internal potential energy of interatomic and intermolecular bonds can transform into kinetic energy only of chaotic, but not directed, motion of matter molecules.

Not the total $U=U_0+U_{ad}$ and not the ordinary internal energy at rest of matter $W_0 \equiv U_{00}=mc^4 v_{cv}^{-2}=m_0 c^3/v_{cv}$, but only the inert free energy at rest of matter $E_0=mc^2=m_0 c v_{cv}$ can be equivalent to the inert mass *m*. Additive compensation $U_{ad}=U-U_0>0$ of multiplicative representation of internal energy *U* of matter is spatially homogeneous and, consequently, does not depend on the strength of gravitational field.

In classical thermodynamics the intranuclear energy considered as one that is not changed in thermodynamic processes. In fact, it is not true. Part of potential intranuclear energy of gas, which pressure is adiabatically increasing, transforms into energy of chaotic[6] state of its nucleons and potential energy of stressed state of matter of the vessel that contains this gas [Danylchenko, 2008: 19; 2008a]. The release of intranuclear potential energy, which is reserved in deformed shell of the vessel that is in stressed state, takes place during the heating of compressed gas. Solid body freely expands during the process of its heating and the frequency of interaction of its nucleons decreases [Danylchenko, 2004: 33; 2008: 19; 2008a; 2008b: 45]. Thus, dilation of its gravity-quantum time takes place in a similar way as it happens during body unfree movement. However, increasing of thermal energy of the body, which is accompanied by the increasing of his thermal temperature *T*, is only non-significantly compensated by the decreasing of its intranuclear energy due to decreasing of intranuclear entropy S_N[7], which corresponds to one mole of matter, and due to decreasing of intranuclear temperature T_N. That is why no essential dependence of molar mass of matter on thermal component of its internal energy[8] can be observed. And it takes place despite the presence of mutual correlation between inert free energy *E* and thermodynamic Gibbs free energy *G* of matter. During the cooling down of the body non-significant part of its thermodynamic internal energy is spent on replenishment of intranuclear inert free energy. The similar decreasing of frequency of interaction of nucleons and

---

[6] It is obvious that chaos is inherent to microworld on all hierarchy levels of self-organization of matter microobjects.

[7] These gravitational parameters, which define the level of intranuclear energy of matter, are conventionally named so here only due to similarity with thermodynamic parameters, which define the level of molecular internal energy of matter. However they, the same as used in GR the pseudovacuum coordinate-like velocity of light and intrinsic time of the matter, can have another physical interpretation that will possibly better correspond to objective reality than considered here their primitive "thermodynamic" interpretation.

[8] The fact that mass of the mater does not depend on its thermal internal energy *U* has been noticed by many physicists [Tolman, 1969], including Einstein and Infeld: "Mass can be measured on the weights, but can we measure the heat? Does a piece of iron have bigger weight when it is heated to red-hot that when it is cold as ice? Experiment shows that no." [Einstein & Infeld, 1938]. In spite of the extra small (for the bodies of laboratory size) predicted by GR temperature-like relative change of gravity force, experiments that have an objective to measure temperature-like dependence of gravity force took place many times. However most of those experiments were not correctly conducted. The most precise measurements gave paradox results. The decreasing of the mass of heated bodies was observed instead of the predicted by GR increasing of their mass [Chen & Cook, 1993; Dmitriev, 2005].

releasing of intranuclear energy that corresponds to it takes place during the experiments with rotating gyroscope[9].

7. Generalization of RTGD equation

Inert free energy of matter should be taken into account in generalized differential equations of thermodynamics by means of multiplicative parameter of direct action $q_N = \eta_m N_{RE} v_{lb}/c = \eta_m (1 + T_{Ncr}^{-2} T_N^2)^{-1/2} \le \eta_m$, which is proportional to the limit value of local group velocity of matter v_{lb} in CFREU and, therefore, proportional to almost identical to it pseudovacuum coordinate-like velocity of light of GR in CFREU ($v_{cbv} \equiv v_{lb}$) [Danylchenko, 2004: 33; 2008: 19; 2008a; 2008b: 45; 2020: 5]. These equations should also contain a multiplicative parameter of reverse action that realizes the negative feedback. Such parameter is obviously the relativistic (longitudinal) external scale factor[10]:

$$N_{RE} = N_E/\Gamma_E = v_l/v_{lb} = \sqrt{1 + m_0^{-2} c^{-4} p_{Ncr}^2 V_N^2} \ge 1,$$

that increases while approaching the gravity center (and, therefore, while deepening into cosmological future) and is responsible for the curvature of intrinsic space of matter and together with q_N for the presence of spatial inhomogeneity of intranuclear values of temperature T_N, entropy S_N, pressure p_N [11] and pseudo-volume V_N [12]. Here: $\eta_m = c/v_{lcr} = m_0/m_{cr}$ is parameter that corresponds to certain matter and that defines the dependence between q_N and v_{lb}, as well as between other parameters of certain matter;

---

[9] As experiments show [Hayasaka & Takeuchi, 1989; Faller et al., 1990; Quinn & Picard, 1990], the weight of gyroscope is not increasing with the increasing of kinetic energy of its rotating rotor (as it could be expected when total energy is equivalent to gravitational mass), but, quite the contrary, is decreasing or is not changed at all. It is obvious that rotating movement of the matter when the center of mass is motionless is equivalent to its chaotic movement and, therefore, similar to the thermal motion of the molecules of matter. Therefore observed decreasing of gyroscope weight is possibly caused by the same reason that causes the decreasing of the weight of heated bodies.

[10] Due to continuous calibration of longitudinal (radial) standard of length in CFREU by its size in GT-FR on the surface of the body ($dR_e = d\bar{r}_e$) the $N_{RE} = 1$ is always on this surface. Due to relativistic non-fulfillment of simultaneity of events in cosmological time measured in the CFREU and events in GT-FR all intrinsic objects of the body belong to cosmological future. Due to this and due to the curvature of intrinsic space of the body $N_{RE} > 1$ for all its intrinsic objects.

[11] Intranuclear pressure is absent on the surface o the body ($N_{RE} = 1$) and can reach its critical (limit) value $N_{RE} = (1 - f_N^2)^{-1/2}$ in infinitely far cosmological future, when intanuclear Helmholtz free energy will be already absent ($F_N = 0$) for the matter.

[12] Here, the “intranuclear pseudo-volume” is just the distance of intranuclear interaction. When N_{RE} tends to 1, the intranuclear pressure in non-rigid spherical layers of the atoms and the intranuclear pseudo-volumes (distances of interaction) of those layers both tend to zero. If anisotropic mater indeed has non-uniform angular distribution of its weight [Einstein & Infeld, 1938], then external surfaces of non-rigid layers of its atoms can be ellipsoidal and the molar value of its effective gravitational volume can be proportional to the volume of the sphere with radius that is equal to the modulus of radius-vector of ellipsoidal surface.

$N_E{=}r/R{\ge}\Gamma_E$ is the transverse external scale factor[13], r and R are radial coordinates of matter in GT-FR and CFREU correspondingly; $\Gamma_E{>}1$ is relativistic shrinkage of the length of radial segments of the body that happens due to its evolutionary self-contraction in CFREU; m_{cr}, v_{lcr}, T_{Ncr} and p_{Ncr} are not similar for different phase states of the same matter, as well as for different matters, critical values[14] of molar mass of matter, limit velocity of its motion and also of intranuclear temperature and pressure correspondingly. In correspondence with this, the rate of quantum processes of intranuclear interaction between nucleons in global GT-FR can be characterized by relative average statistic value of frequency of this interaction $f_G{=}q_N N_{RE}{=}\eta_m v_l/c{=}v_l/v_{lcr}{\le}\eta_m$, that is proportional to the limit value of local group velocity of matter v_l in GT-FR (and, therefore, proportional to almost identical to it pseudovacuum coordinate-like velocity of light of GR[15] in GT-FR $v_{cv} = v_{cbv} N_{RE} \equiv v_l$ [Danylchenko, 2004: 33; 2008: 19; 2008a; 2008b: 45; 2020: 5]). Precisely f_G, similarly to v_{cv} in GR, is responsible for the presence of gravitational pseudo-force[16] $\mathbf{F}_G$, that forces matter for free fall. And this pseudo-force is proportional not to the mass, but to the Hamiltonian of the body $\mathrm{H}{=}\mathbf{const}(\hat{r})$:

$$\mathbf{F}_G{=}f_G\frac{d(\mathrm{H}/f_G)}{d\hat{r}}{=}{-}\mathrm{H}\frac{d\ln f_G}{d\hat{r}}{=}{-}\mathrm{H}\frac{d\ln m}{d\hat{r}}{=}{-}\mathrm{H}\frac{d\ln E_0}{d\hat{r}}{=}\mathrm{H}\frac{d\ln W_0}{d\hat{r}}.$$

According to it, frequency of nucleons intranuclear interaction in GT-FR:

$$f_G{=}N_{RE}f_N{=}m/m_{cr}{=}E_0/E_{0cr}{=}(W_0{-}S_N T_N{+}V_N p_N)/(W_{0cr}{-}S_{Ncr}T_{Ncr}{+}V_{Ncr}p_{Ncr})$$

is equal to the division of the mass m of one mole of matter by the critical value of this mass $m_{cr}{=}E_{cr}c^{-2}$, which corresponds to critical equilibrium value $W_{0cr}{=}m_{cr}c^2{+}S_{Ncr}T_{Ncr}{-}V_{Ncr}p_{Ncr}$ of the ordinary internal energy. Here:

[13] External scale factor, similarly to coordinate-like velocity of light, defines only the space-time configuration of self-organized spatially inhomogeneous state of matter and, similarly to it, does not characterize its properties observed in people's world and so is not a RGTD-parameter or characteristic of matter. They are external factors for closed system of pairs of mutually complementary intensive and extensive RGTD-parameters of matter and, therefore, it is not possible to measure them in people's world. Their values can be determined only indirectly and only with the accuracy limited by gauge coefficient. So not absolute, but their relative values can be determined.

[14] Here, under conventional term "critical values" we consider firstly the values of parameters of the same matter on the boundary of its phases or aggregate states.

[15] Coordinate-like velocity of light is not the characteristics of matter, but the characteristics of the form of its being – intrinsic space of GTD-bonded matter. Therefore, it cannot be directly used in equations of thermodynamics. Thermodynamic parameters and characteristics of matter are its self-sufficient properties and do not depend on the values of coordinate-like velocity of light. This pseudovacuum velocity of light sets only the spatial gradients of their values. The values themselves are determined by the boundary conditions.

[16] In GR only the mechanical component of gravitational pseudo-force, which is counterbalanced by the pressure p, is taken into account while the thermal component of gravitational pseudo-force, which is counterbalanced by the pressure of thermal radiation, is ignored [Möller, 1972; Danylchenko, 2005b; 2008: 4; 2008: 19; 2008a; 2004: 44].

$$W_0=E_0+S_NT_N-V_Np_N=\frac{\eta_m^2 m_{cr}c^2}{q_N N_{RE}}=\frac{\eta_m m_0 c^2}{q_N^* N_{RE}^*}=m_0c^2\sqrt{1-p_{Ncr}^{-2}p_N^2+T_{Ncr}^{-2}T_N^2}=\frac{m_0^2c^4}{\sqrt{m_0^2c^4+p_{Ncr}^2V_N^2-T_{Ncr}^2S_N^2}}=$$

$$=\frac{m_0^2c^4}{E_0}=\frac{m_0^2c^4p_N}{p_{Ncr}^2V_N}=\frac{m_0^2c^4T_N}{T_{Ncr}^2S_N}=m_0^2c^4\sqrt{\frac{1-p_{Ncr}^{-2}p_N^2}{m_0^2c^4-T_{Ncr}^2S_N^2}}=m_0^2c^4\sqrt{\frac{1+T_{Ncr}^{-2}T_N^2}{m_0^2c^4+p_{Ncr}^2V_N^2}},$$

$$W_0(q_N,N_{RE})=E_0(q_N,N_{RE})+S_N(q_N,N_{RE})T_N(q_N)-V_N(N_{RE})p_N(q_N,N_{RE}),$$

$$W_0(q_N^*,N_{RE}^*)=E_0(q_N^*,N_{RE}^*)+S_N(q_N^*)T_N(q_N^*,N_{RE}^*)-V_N(q_N^*,N_{RE}^*)p_N(N_{RE}^*),$$

$$E_0=m_0c^2q_NN_{RE}/\eta_m=m_{cr}c^2q_NN_{RE}=m_{cr}c^2q_N^*N_{RE}^*=\sqrt{m_0^2c^4+p_{Ncr}^2V_N^2-T_{Ncr}^2S_N^2}=\frac{m_0c^2}{\sqrt{1-p_{Ncr}^{-2}p_N^2+T_{Ncr}^{-2}T_N^2}}=$$

$$=\frac{p_{Ncr}^2V_N}{p_N}=\frac{T_{Ncr}^2S_N}{T_N}=\sqrt{\frac{m_0^2c^4-T_{Ncr}^2S_N^2}{1-p_{Ncr}^{-2}p_N^2}}=\sqrt{\frac{m_0^2c^4+p_{Ncr}^2V_N^2}{1+T_{Ncr}^{-2}T_N^2}},$$

$$F_{N0}=E_0-p_NV_N=\frac{m_0c^2[\eta_m^2-(\eta_m^2-q_N^2)N_{RE}^2]}{q_NN_{RE}}=\frac{m_0c^2q_N^*}{\eta_mN_{RE}^*}=\frac{V_N(p_{Ncr}^2-p_N^2)}{p_N}=\sqrt{(m_0^2c^4-T_{Ncr}^2S_N^2)(1-p_{Ncr}^{-2}p_N^2)}=$$

$$=\frac{(m_0^2c^4-T_{Ncr}^2S_N^2)T_N}{T_{Ncr}^2S_N}=\frac{m_0^2c^4-T_{Ncr}^2S_N^2}{\sqrt{m_0^2c^4+p_{Ncr}^2V_N^2-T_{Ncr}^2S_N^2}}=\frac{m_0c^2(1-p_{Ncr}^{-2}p_N^2)}{\sqrt{1-p_{Ncr}^{-2}p_N^2+T_{Ncr}^{-2}T_N^2}}=\frac{m_0^2c^4-p_{Ncr}^2V_N^2T_{Ncr}^{-2}T_N^2}{\sqrt{(m_0^2c^4+p_{Ncr}^2V_N^2)(1+T_{Ncr}^{-2}T_N^2)}},$$

$$H_{N0}=E_0+T_NS_N=\frac{m_0c^2\eta_mN_{RE}}{q_N}=\frac{m_0c^2[\eta_m^2-q_N^{*2}(1-N_I^{*2})]}{q_N^*N_I^*}=\frac{S_N(T_{Ncr}^2+T_N^2)}{T_N}=\sqrt{(m_0^2c^4+p_{Ncr}^2V_N^2)(1+T_{Ncr}^{-2}T_N^2)}=$$

$$=\frac{(m_0^2c^4+p_{Ncr}^2V_N^2)}{p_{Ncr}^2(V_N/p_N)}=\frac{m_0^2c^4+p_{Ncr}^2V_N^2}{\sqrt{m_0^2c^4+p_{Ncr}^2V_N^2-T_{Ncr}^2S_N^2}}=\frac{m_0c^2(1+T_{Ncr}^{-2}T_N^2)}{\sqrt{1-p_{Ncr}^{-2}p_N^2+T_{Ncr}^{-2}T_N^2}}=\frac{m_0^2c^4-T_{Ncr}^2S_N^2p_{Ncr}^{-2}p_N^2}{\sqrt{(m_0^2c^4-T_{Ncr}^2S_N^2)(1-p_{Ncr}^{-2}p_N^2)}},$$

$$S_N=\frac{m_0c^2N_{RE}}{\eta_mT_{Ncr}}\sqrt{\eta_m^2-q_N^2}=\frac{m_0c^2}{\eta_mT_{Ncr}}\sqrt{\eta_m^2-(q_N^*)^2}=\frac{m_0c^2}{T_{Ncr}}\sqrt{1-\frac{v_l^2}{c^2(N_{RE}^*)^2}}=\frac{ET_N}{T_{Ncr}^2}=\frac{m_0c^2T_N}{T_{Ncr}^2\sqrt{1-p_{Ncr}^{-2}p_N^2+T_{Ncr}^{-2}T_N^2}}=$$

$$=\frac{T_N}{T_{Ncr}}\sqrt{\frac{m_0^2c^4+p_{Ncr}^2V_N^2}{T_{Ncr}^2+T_N^2}}=\frac{p_{Ncr}^2V_N}{T_{Ncr}p_N}\sqrt{\frac{p_N^2}{p_{Ncr}^2}\left(1+\frac{m_0^2c^4}{p_{Ncr}^2V_N^2}\right)-1},$$

$$T_N=T_{Ncr}\frac{\sqrt{\eta_m^2-q_N^2}}{q_N}=T_{Ncr}\frac{\sqrt{\eta_m^2-(q_N^*)^2}}{q_N^*N_{RE}^*}=\frac{cT_{Ncr}}{v_l}\sqrt{1-\frac{v_l^2}{c^2(N_{RE}^*)^2}}=\frac{T_{Ncr}^2S_N}{E}=\frac{T_{cr}^2S_N}{\sqrt{m_0^2c^4+p_{Ncr}^2V_N^2-T_{Ncr}^2S_N^2}}=$$

$$=T_{Ncr}^2S_N\sqrt{\frac{1-p_{Ncr}^{-2}p_N^2}{m_0^2c^4-T_{Ncr}^2S_N^2}}=T_{Ncr}\sqrt{\frac{p_N^2}{p_{Ncr}^2}\left(1+\frac{m_0^2c^4}{p_{Ncr}^2V_N^2}\right)-1},$$

$$V_N=\frac{m_0c^2}{p_{Ncr}}\sqrt{N_{RE}^2-1}=\frac{m_0c^2q_N^*}{\eta_mp_{Ncr}}\sqrt{(N_{RE}^*)^2-1}=\frac{m_0cv_l^*}{p_{Ncr}}\sqrt{1-(N_{RE}^*)^{-2}}=\frac{m_0c^2p_N}{p_{Ncr}^2\sqrt{1-p_{Ncr}^{-2}p_N^2+T_{Ncr}^{-2}T_N^2}}=$$

$$=\frac{Ep_N}{p_{Ncr}^2}=\frac{p_N}{p_{Ncr}}\sqrt{\frac{m_0^2c^4-T_{Ncr}^2S_N^2}{p_{Ncr}^2-p_N^2}}=\frac{T_{Ncr}^2S_N}{p_{Ncr}T_N}\sqrt{1+\frac{T_N^2}{T_{Ncr}^2}\left(1-\frac{m_0^2c^4}{T_{Ncr}^2S_N^2}\right)},$$

$$p_N=p_{Ncr}\frac{\eta_m\sqrt{N_{RE}^2-1}}{q_NN_{RE}}=p_{Ncr}\sqrt{1-(N_{RE}^*)^{-2}}=\frac{cp_{Ncr}}{v_l}\sqrt{N_{RE}^2-1}=\frac{p_{Ncr}^2V_N}{E}=\frac{p_{Ncr}^2V_N}{\sqrt{m_0^2c^4+p_{Ncr}^2V_N^2-T_{Ncr}^2S_N^2}}=$$

$$=p_{Ncr}^2 V_N \sqrt{\frac{1+T_{Ncr}^{-2}T_N^2}{m_0^2c^4+p_{Ncr}^2V_N^2}}=p_{Ncr}\sqrt{1+\frac{T_N^2}{T_{Ncr}^2}\left(1-\frac{m_0^2c^4}{T_{Ncr}^2S_N^2}\right)};$$

$$q_N^*=\sqrt{\eta_m^2-N_{RE}^2(\eta_m^2-q_N^2)}=\eta_m\sqrt{1-m_0^{-2}c^{-4}T_{Ncr}^2S_N^2},$$

$$N_{RE}^*=r/(R^*\Gamma_E^*)=q_N N_{RE}/q_N^*=q_N N_{RE}[\eta_m^2-N_{RE}^2(\eta_m^2-q_N^2)]^{-1/2}=(1-p_{Ncr}^{-2}p_N^2)^{-1/2}$$

and Γ_E^* are conjugate values of the parameters q_N, N_{RE} and Γ_E that correspond to the points of intrinsic space of hollow astronomical body (separated by singular surface from its external space) where values of Schwarzschild radial coordinates *r* are the same as in external space.

It is obvious that not only m_{cr}, v_{lcr}, T_{Ncr} and p_{Ncr}, but also W_{0cr} are individual parameters that characterize certain matter and are, possibly, related only to its certain aggregate or phase state[17].

Lagrangian ordinary internal energy, the same as Hamiltonian inert free energy, is conserved in the process of matter free fall, since thermodynamic state of matter and, consequently, its thermodynamic internal energy are invariable during that process. The greater value of internal energy of matter (that corresponds to gravitational potential) is taken by the matter only in the state of the rest, when matter comes to thermodynamic equilibrium with environment.

Evolutionary increase of total internal energy of matter in CFREU also corresponds to the increase of this energy while approaching its the gravitational attraction center. But, since in CFREU: $N_{Eb}=N_E\exp[H_E(\tau-\tau_0)]=N_E/(1+z)$, $\Gamma_E=\mathbf{const}(\tau)$, $q_{Nb}=q_N\exp[-H_E(\tau-\tau_0)]=q_N(1+z)$, then: $f_G=q_{Nb}N_{Eb}=q_N N_E=\mathbf{const}(\tau)$ and, consequently, in people's world FR the evolutional increasing of internal energy cannot be observed in principle. Here: H_E is Hubble constant, that sets the speed of evolutional expansion of the Universe, τ is cosmological time, counted in CFREU by metrically homogeneous scale ($d\tau=dt$), *z* is Dopplerian redshift of the wave length of radiation of astronomical object, characteristics of which are being determined. However in CFREU according to Hubble law both molar internal energy and inert intranuclear molar inert free energy are changed and, therefore, the also equivalent to it molar mass is changed[18]:

$$W_{0b}=W_0N_b=W_0N_E\exp[H_E(\tau-\tau_0)]=W_0N_E/(1+z),$$

---

[17] It is also possible that in case of anisotropic matter those constants have non-equal values for different directions. Then the value of intranuclear energy of those matters will be dependent on their orientation related to the direction of gradient of gravitational field or to the motion direction. Such possibility can be taken into account due to results of experiment where the anisotropy of weight of monocrystal has been revealed [Einstein & Infeld, 1938]. The values of these constants for each certain matter can be determined by experimental dependencies of the change of intranuclear energy on the changes of temperature and pressure and, therefore, on the change of the Gibbs free energy.

[18] Total energy and momentum are saved only when time and space are homogeneous. The stationarity of the Universe is required for evolutionary saving of molar mass of the matter. Gradual decreasing of mass of rotating astronomical bodies in a binary star system was found by Taylor [Taylor et al., 1979] and Hulse, and, possibly, it is not only evolutionary but also

$$E_{0b}=m_b c^2=E_0/N_{Eb}=(E_0/N_E)\exp[-H_E(\tau-\tau_0)]=(E_0/N_E)(1+z)\,.$$

Not only the molar mass itself ([1+z] times), but also its concentration in intrinsic space of the matter ($[1+z]^3$ times) was bigger in that distant time [Danylchenko, 2008: 106]. And it means that the need in "dark non-barionic matter" [19] can be fictive.

Physical space that is rigidly connected with cooling down body self-contracts not only in CFREU, but also in intrinsic metric space of the body that has non-rigid intrinsic FR [Danylchenko, 1994: 52]:

$$R=\rho\exp[-(H_E+H_T)(\tau-\tau_0)], \qquad r=\rho\exp[-H_T(t-t_0)],$$

where: ρ is radial coordinate, which is counted by rigidly connected with body coordinate grid not in metric space but in physical space of gradually cooling down body, H_T is parameter that characterizes the speed of observed shrinkage of the dimensions of cooling down body.

And due to $EW=m_0^2c^4=\mathbf{const}$ the following situation will take place. The inert free energy and corresponding to it gravitational mass of the matter will decrease the same number of times as ordinary internal energy is increased. This is in a good correspondence with the results of experiments since for the many heated metallic bodies the decreasing of their mass is observed [Einstein & Infeld, 1938; Chen & Cook, 1993; Dmitriev, 2005][20].

Spatially inhomogeneous equilibrium RGTD-state of liquid and gaseous matter takes place in the case of fulfillment of the following: $W_j=(f_{Gi}/f_{Gj})W_i$. In the case of isotropy of radial distribution of physical parameters and characteristics of homogeneous matter of astronomical object it can be shown in the following way: $f_G(r)W(r)=\mathbf{const}(r)$. In the case of radial altitudinal multi-layer distribution of inhomogeneous matter this condition is fulfilled layer by layer, with the break on the boundaries of two media: $f_{G(k+1)}W_{(k+1)}<f_{Gk}W_k$, where $(k+1)$ is serial number of the less dense and, therefore, more distanced from the Galaxy center matter.

---

kinematic effect. However, it is mistakenly "connected" with the loss of energy of those objects that is carried away by principally non-existent gravitational radiation (gravitational waves).

[19] As we can see, the fictive need in "dark energy" and "dark non-baryonic matter" in the Universe is directly related to the phenomenon of Universe expansion in people's world FR and is caused by not understanding of real causes and physical essence of this phenomenon.

[20] Dependencies of molar mass of the liquid on the pressure and temperature can be determined by putting the liquid into the vessel under the randomly loaded vertical piston. The change of inert free energy (weight) of the liquid can be controlled with the help of several pairs of mutually selected by their sensibility load cells that are located above and under (under the piston) the liquid column and are connected according to the differential "bridge" scheme. Firstly, we should reach the zero value of many times ("cascadingly") amplified differential signal from upper and lower load cells with the help of balancing of the "bridge" in initial thermodynamic state of liquid. Secondly, we should increase the pressure in the liquid via loading the piston or increase the temperature via isobaric heating of the liquid. In order to determine the measurement errors, caused by the mutual difference of sensibilities of load cells, we can repeat measurements with swapping the load cells in each of their pairs (swap upper with lower).

In equations of GR gravitational field the hybrid thermodynamic enthalpy $H_{Th}=E_0-pV$ ($dH_{Th}=(E_0+pV)d\ln v_{cv}$)[21] is de facto used. This hybrid enthalpy is based on the fact that the density of internal energy U/V is changed to completely inert free energy $\mu c^2=E_0/V$. Equilibrium state of ideal liquid in GR is reached only in case of mutual absence of radial gradients of the following characteristics: $H_g^*=H_{Th}v_{cv}/c=\mathbf{const}(r)$, $T_g^*=Tv_{cv}/c=\mathbf{const}(r)$, $S=\mathbf{const}(r)$ [Tolman, 1969; Danylchenko, 2008: 4; 2008a; 2020: 5]. This conditions fulfill the more general condition of equilibrium state of liquids and gases:

$$G_g^*=(v_{cv}/c)G=H_g^*-ST_g^*=\mathbf{const}(r),$$

where: $dG_g^*=(U/c)dv_{cv}+Vdp_g^*-SdT_g^*=0$, $p_g^*=pv_{cv}/c$. This implies:

$$(U/Vc)dv_{cv}=-dp_g^*+(S/V)dT_g^*=-[(p-TS/V)dv_{cv}+v_{cv}dp-(v_{cv}S/V)dT]/c,$$

$$dp=-(U/V+p)d\ln v_{cv}+(S/V)dT_g^*,$$

and when $T_g^*=\mathbf{const}(r)$ and in the case of replacement of density of internal energy by the density of inert free energy there is a following, used in GR, dependency:

$$\frac{dp}{dr}=-(\mu c^2+p)\frac{d\ln v_{cv}}{dr}=-\frac{(\mu c^2+p)}{2b}\frac{db}{dr}, \qquad (2)$$

where: $b=v_{cv}^2/c^2$.

Equilibrium RGTD-states of matter, in which external gravitational pressure of upper layers of matter is counterbalanced not only by intrinsic pressure inside matter, but also by radiation (thermal) pressure ($T_g^*\neq\mathbf{const}(r)$), are not considered at all in GR, in contrast to RGTD. And, therefore, GR not only reflect physical reality in more simple way, but also is applied to equilibrium states of only cooled down to the limit homogeneous matter ($T_g^*=\mathbf{const}(r)$). That is why the reflection of physical reality in GR should be considered only as the special case of its reflection in RGTD.

Internal energy U of real gases and liquids depends on many pairs of their intensive (A_i) and extensive (a_i) thermodynamic parameters. However, it can also be shown as a sum of internal energy of hypothetic ideal gas (liquid) U_{id} and output of multiplication of resulting intensive ($A_\rho=TS/R_T=T^2S/pV$) and extensive ($a_\rho\equiv R_T=pV/T$) thermodynamic parameters:

$$U=U_{id}+\sum_{i=2}^{n}A_ia_i=U_{id}+A_\rho a_\rho,$$

[21] While the increment of inert free energy (when we differentiate by coordinate velocity of light) is positive the increment

$$dU = T_{id} dS_{id} + A_\rho da_\rho - pdV = TdS - pdV\ ,$$

where: $T_{id}=TR_T/R_{UT}$, $S_{id}=SR_{UT}/R_T$, $A_\rho a_\rho = T_{id} S_{id} = TS$. For gases: $a_i=R_{UT}B_iV^{1-i}$, B_i is virial coefficients that depend on both temperature and individual gas properties [Bazarov, 1964], while R_{UT} is universal gas constant and $R_T(r)=pV/T=\mathbf{const}(t)$ is spatial thermodynamic parameter of matter, that does not vary in space at conditions of quasi-equilibrium cooling down of matter (is the same on any radial distance *r* from the gravity center in the comoving to it frame of reference of spatial coordinates and time *t*). And exactly this invariability in space of $R_T(t)$ is responsible for the fact that properties of quasi-equilibrium cooling down real gases are close to properties of hypothetic ideal gas.

"Ideal" component U_{id} of internal energy is de facto identical to Helmholtz free energy F_T, while "ideal" component H_{Tid} of enthalpy is identical to the Gibbs free energy *G*:

$$U_{id} = U - a_\rho A_\rho = U - ST = F_T\ , \qquad H_{Tid}=H_T-a_\rho A_\rho=H_T-ST=G\ ,$$

$$dU_{id} = T_{id} dS_{id} - a_\rho dA_\rho - pdV = (TdS - \frac{TS}{R_T} dR_T) - (SdT + TdS - \frac{TS}{R_T} dR_T) - pdV = -SdT - pdV = dF_T\ ,$$

$$dH_{Tid}=T_{id}dS_{id}-a_\rho dA_\rho+Vdp=-SdT+Vdp=dG\ .$$

This, of course, is caused by the absence of binding energy ($\sum_{i=2}^{n} A_i a_i = A_\rho a_\rho = 0$) in ideal gas and ideal liquid due to the absence of electromagnetic interaction of their molecules and atoms. Self-organization of hierarchically more complicated interactions and interconnections in matter is in the tendency of Helmholtz and Gibbs free energies to their minimum.

Lower layers of matter, loaded by its upper layers form the extended system. The energy of such extended system [Bazarov, 1964] that consists of the whole RGTD-bonded matter is indeed equivalent to enthalpy. Moreover, as it is shown further, parameter a_ρ (in contrast to A_ρ parameter) takes the same value in the whole space filled by quasi-equilibrium cooling down homogeneous matter ($(\partial a_\rho/\partial r)_t=0$). And, therefore, Gibbs energy "behaves" as it is expected and only changes in space along the radial coordinate *r*. And when Gibbs energy changes in time it "behaves" like multiplicative component of enthalpy (like the energy of extended system).

This is quite logical and reflected in static equations of GR gravitational field. However in dynamics the four-momentum should be formed not by enthalpy, but by ordinary internal energy.

So, if equations of GR gravitational field are designed to get the solutions that correspond only to ideal (cooled down to the limit) matter, then the usage (together with inert free energy) of enthalpy

---

of the product of pressure and molar volume is negative.

instead of ordinary internal energy in those equations is justified. But, of course, not the Lorentz-invariant thermodynamic enthalpy (intrinsic value of enthalpy), but Lorentz-noninvariant intranuclear enthalpy (improper value of enthalpy) should be used in those equations. However, in order to get the solutions that correspond to quasi-equilibrium cooling down astronomical objects we should include not enthalpy, which includes free and binding energy of extended system, but ordinary internal energy with transition to functionally related to it thermodynamic total internal energy.

Total internal energy of matter has an influence on all physical processes. However, due to the fact that in various physical processes the part of its energy is bonded differently the different free energies are formed – inert free energy, Helmholtz free energy, Gibbs free energy and other more exotic free energies. And namely the free energies define the specifics of the flow of correspondent to them physical processes.

Spontaneous change of RGTD-state of coherent matter and, consequently, its free fall are possible only when they are accompanied by continuous decreasing f_G and thereby decreasing of matter thermodynamic mass at rest.

Since during the free fall of matter in gravitational field the inert free energy is consumed exactly the increments of this energy should be determined by the increments of extensive intranuclear parameters S_N and V_N. According to this, in the process of during matter free fall ($dS = 0$, $dV = 0$, $d\mathsf{L}{\equiv}dW{=}0$, $dW_0{>}0$, $d\mathsf{H}{\equiv}dE{=}0$, $dE_0{<}0$) evolutionary-gravitational increasing of intranuclear entropy ($dS_N{>}0$) that is accompanied (as a partial compensation for the effect of its increasing) by increasing of molar value of intranuclear volume ($dV_N{>}0$) and, thus, by the release of inert free energy E_0 (instead of thermal energy) with its further transformation into kinetic energy of it ordered motion takes:

$$d\mathsf{H}{\equiv}dE{=}{-}T_{RN}dS_N{+}p_{RN}dV_N{+}(\tilde{\mathbf{v}},d\mathbf{P}_{GT}){=}0\,,\quad dE_0{=}{-}T_{RN}dS_N{+}p_{RN}dV_N{=}{-}(\tilde{\mathbf{v}},d\mathbf{P}_{GT}){<}0\,,$$

$$d\mathsf{L}{\equiv}dW{=}S_NdT_{RN}{-}V_Ndp_{RN}{-}(\mathbf{P}_{GT},d\tilde{\mathbf{v}}){=}0\,,\qquad dW_0{=}S_NdT_{RN}{-}V_Ndp_{RN}{=}(\mathbf{P}_{GT},d\tilde{\mathbf{v}}){>}0\,.$$

Obviously, in the tensor of the energy-momentum of GR gravitational fields equations we should use Lorentz-noninvariant intranuclear RGTD-characteristics of matter instead of Lorentz-invariant and temporally invariant thermodynamic characteristics. For gradually quasi-equilibrium cooling-down matter we should use the density of ordinary internal energy $W_0/V{=}m_0c^3/Vv_l{=}m_0c^2\eta_m/Vf_G$ instead of the density of enthalpy.

In CFREU non-zero components of metric tensor are the following:

$$g_{11}{=}N_E^2(R,\tau){=}r^2(R,\tau)/R^2\,,\quad g_{22}{=}r^2(R,\tau),\quad g_{33}{=}r^2(R,\tau)\sin^2\theta,$$

$$g_{44}=-f_G^2(R,\tau)\Gamma_E^2(R,\tau)\eta_m^{-2}c^2=-f_{Gb}^2(R,\tau)\eta_m^{-2}c^2=-N_E^2(R,\tau)q_N^2(R,\tau)\eta_m^{-2}=-N_E^2(R,\tau)v_{cb}^2(R,\tau)\,.$$

According to this, the equations of gravitational field for homogeneous matter [Danylchenko, 2004: 33; 2008b: 45; 2009; 2020: 5]:

$$M_i^k=G_i^k-Gg_i^k/2-\lambda g_i^k=-\kappa\mathrm{T}_i^k=-(\kappa/V)[(c^{-2}W_0)U_iU^k+(W_0-E_0)\delta_i^k]=$$

$$=-\frac{\kappa}{V}\left[\left(\frac{m_0 f_G}{\eta_m}-\frac{p_N V_N}{c^2}+\frac{T_N S_N}{c^2}\right)U_iU^k+(T_N S_N-p_N V_N)\delta_i^k\right]=$$

$$=-\frac{\kappa m_0}{V}\left[\frac{\eta_m}{f_G}U_iU^k+c^2\left(\frac{\eta_m}{f_G}-\frac{f_G}{\eta_m}\right)\delta_i^k\right]=-\kappa\mu_0\left[\frac{1}{\sqrt{b}}U_iU^k+c^2\left(\frac{1}{\sqrt{b}}-\sqrt{b}\right)\delta_i^k\right]$$

in pseudo-Euclidean Minkowski space of CFREU are the following (in general case):

$$M_1^1=-\frac{2R^2}{r^3 f_{Gb}}\frac{\partial f_{Gb}}{\partial R}\frac{\partial r}{\partial R}-\frac{2\eta_m^2}{rc^2 f_{Gb}^3}\frac{\partial f_{Gb}}{\partial\tau}\frac{\partial r}{\partial\tau}+\frac{2\eta_m^2}{rc^2 f_{Gb}^2}\frac{\partial^2 r}{\partial\tau^2}+\frac{\eta_m^2}{r^2c^2 f_{Gb}^2}\left(\frac{\partial r}{\partial\tau}\right)^2-\frac{R^2}{r^4}\left(\frac{\partial r}{\partial R}\right)^2+$$

$$+\frac{1}{r^2}-\Lambda=-\frac{\kappa}{V}\left[\frac{W_0 v_b^2}{v_{lb}^2-v_b^2}+(T_N S_N-p_N V_N)\right]=-\frac{\kappa m_0 c^2}{V}\left[\frac{\eta_m v_{lb}^2}{f_G(v_{lb}^2-v_b^2)}-\frac{f_G}{\eta_m}\right]=-\kappa\mu b^{-2}(v_{lb}^2 r^2 R^{-2}-b^2c^2)\,,$$

$$M_1^4=-\frac{r^2\eta_m^2}{R^2c^2 f_{Gb}^2}M_4^1=\frac{2\eta_m^2}{rc^2 f_{Gb}^2}\left[\frac{1}{f_{Gb}}\frac{\partial f_{Gb}}{\partial R}\frac{\partial r}{\partial\tau}+\frac{1}{r}\frac{\partial r}{\partial R}\frac{\partial r}{\partial\tau}-\frac{\partial^2 r}{\partial R\partial\tau}\right]=-\frac{\kappa\eta_m^2 m_0 c v_{lb} v_b r}{f_G^2 R V(v_{lb}^2-v_b^2)}=-\frac{\kappa\mu_0 v_{lb} v_b r^3}{cb^3R^3}\,,$$

$$M_3^3=M_2^2=-\frac{R^2}{r^2 f_{Gb}}\frac{\partial^2 f_{Gb}}{\partial R^2}-\frac{R}{r^2 f_{Gb}}\frac{\partial f_{Gb}}{\partial R}-\frac{2\eta_m^2}{rc^2 f_{Gb}^3}\frac{\partial f_{Gb}}{\partial\tau}\frac{\partial r}{\partial\tau}+\frac{2\eta_m^2}{rc^2 f_{Gb}^2}\frac{\partial^2 r}{\partial\tau^2}+\frac{\eta_m^2}{r^2c^2 f_{Gb}^2}\left(\frac{\partial r}{\partial\tau}\right)^2-\frac{R^2}{r^3}\frac{\partial^2 r}{\partial R^2}+$$

$$+\frac{R^2}{r^4}\left(\frac{\partial r}{\partial R}\right)^2-\frac{R}{r^3}\frac{\partial r}{\partial R}-\Lambda=-\frac{\kappa m_0 c^2}{V}\left(\frac{\eta_m}{f_{Gb}}-\frac{f_{Gb}}{\eta_m}\right)=-\frac{\kappa}{V}(T_N S_N-p_N V_N)=-\kappa\mu_0 c^2\left(\frac{1}{\sqrt{b}}-\sqrt{b}\right)=-\kappa\mu c^2\left(\frac{1}{b}-1\right),$$

$$M_4^4=\frac{3\eta_m^2}{r^2c^2 f_{Gb}^2}\left(\frac{\partial r}{\partial\tau}\right)^2-\frac{2R^2}{r^3}\frac{\partial^2 r}{\partial R^2}+\frac{R^2}{r^4}\left(\frac{\partial r}{\partial R}\right)^2-\frac{2R}{r^3}\frac{\partial r}{\partial R}+\frac{1}{r^2}-\Lambda=\frac{\kappa}{V}\left[\frac{W_0 v_{lb}^2}{v_{lb}^2-v_b^2}-(T_N S_N-p_N V_N)\right]=$$

$$=\frac{\kappa m_0 c^2}{V}\left[\frac{f_{Gb}}{\eta_m}+\frac{\eta_m v_b^2}{f_{Gb}(v_{lb}^2-v_b^2)}\right]=\kappa\mu b^{-2}(b^2c^2+v_b^2 r^2 R^{-2})\,,$$

$$M_4^4-M_1^1=\frac{\kappa W_0}{V}\frac{(v_{lb}^2+v_b^2)}{(v_{lb}^2-v_b^2)}=\frac{\kappa\mu c^2}{b}(1+2r^2R^{-2}v_b^2/b)\,,$$

where: $W_0=\frac{\eta_m m_0 c^2}{f_G}=\frac{m_0c^2}{\sqrt{b}}=\frac{mc^2}{b}=E_0-p_N V_N+T_N S_N$ and $E_0=m_0c^2 f_G/\eta_m=m_0c^2\sqrt{b}=mc^2$ are the multiplicative component of total energy and the inert free energy of matter correspondingly;

$T_N S_N - p_N V_N = m_0 c^2\left(\frac{1}{\sqrt{b}} - \sqrt{b}\right)$, $v_b = \frac{dR}{d\tau} = -H_E R$, $\frac{v_b}{v_{cb}} = -r\sqrt{\frac{\Lambda}{3}\frac{\eta_m}{f_G}} = \mathbf{const}(\tau)$, $f_{Gb} = \sqrt{f_G^2 + \Lambda\eta_m^2 r^r/3} = \eta_m\sqrt{b + H_E^2 c^{-2} r^2}$,

$v_{lb} = (R/r)\sqrt{v_l^2 + \Lambda r^2 c^2/3} = \sqrt{bc^2 + H_E^2 r^2}/N_E$.

According to these equations for rigid intrinsic FR of matter ($r = \mathbf{const}(\text{t})$; $f_G(r) = \mathbf{const}(\text{t})$, $T_N(r) = \mathbf{const}(t)$; $S_N(r) = \mathbf{const}(t)$; $p_N(r) = \mathbf{const}(\text{t})$; $V_N(r) = \mathbf{const}(t)$) we can receive by metrically homogeneous scale of cosmological time τ ($d\tau \equiv dt$ when $dr = 0$) the following dependencies:

$$b'/abr - r^{-2}(1 - 1/a) + \Lambda = \kappa m_0 c^2 (b^{-1/2} - b^{1/2})/V = \kappa(T_N S_N - p_N V_N)/V,$$

$$a'/a^2 r + r^{-2}(1 - 1/a) - \Lambda = \kappa\mu c^2 = \kappa m_0 c^2 \sqrt{b}/V.$$

From where:

$$\frac{1}{a} = \frac{1}{N_{RE}^2} = \left(\frac{\partial r}{\partial \hat{r}}\right)^2 = 1 - \left(1 - \frac{1}{a_i} - \frac{\Lambda r_i^2}{3}\right)\frac{r_i}{r} - \frac{\kappa m_0 c^2}{\eta_m r}\int_{r_i}^{r}\frac{f_G r^2}{V}dr - \frac{1}{3}\Lambda r^2 =$$

$$= 1 - r_g(r)/r - \Lambda r^2/3 = 1 - r_g(r)/r - (1 - r_{ge}/r_c) r^2/r_c^2,$$

$$\sqrt{b} = \frac{v_c}{c} = \frac{f_G}{\eta_m} = \frac{1}{N_{RE}}\left(1 + \frac{\kappa m_0 c^2}{2}\int_{r_e}^{r}\frac{N_{RE}^3 r}{V}dr\right),$$

$$\left(\frac{\partial r}{\partial \tau}\right)_R = H_E R\left(\frac{\partial r}{\partial R}\right)_\tau = \widetilde{H}_E r/\sqrt{a(1 - v_b^2/v_{lb}^2)} =$$

$$= \widetilde{H}_E r/\sqrt{a(1 - H_E^2 r^2 \eta_m^2/c^2 f_{Gb}^2)} = \widetilde{H}_E r f_{Gb}(ab)^{-1/2}/\eta_m,$$

$$\tau(r,t) = \tau_k + (t - t_k) - \frac{\widetilde{H}_E}{c^2}\int_{r_k}^{r}\sqrt{\frac{a}{b}}\frac{\eta_m r}{f_{Gb}}dr,$$

$$R(r,t) = R(r,\tau_k)\exp[H_E(\tau_k - \tau)] = r_k \exp\left[H_E\left((\tau_k - \tau) + \frac{\eta_m}{\widetilde{H}_E}\int_{r_k}^{r}\frac{\sqrt{ab}}{f_{Gb} r}dr\right)\right],$$

$$R(r,t) = r_k \exp\left[H_E\left((t_k - t) + \frac{1}{\widetilde{H}_E \eta_m}\int_{r_k}^{r}\sqrt{\frac{a}{b}}\frac{f_{Gb}}{r}dr\right)\right],$$

where: $\widetilde{H}_E = H_E$ for the area of fundamental space of CFREU $R \in (R_0; \infty)$, in which $\partial r/\partial \hat{r} > 0$, and $\widetilde{H}_E = -H_E$ for the area $R \in (0; R_0)$, in which $\partial r/\partial \hat{r} < 0$.

When single objects and their aggregates form big collection (cluster) their total mass can essentially exceed the mass of central astronomical body (supermassive neutron star or quasar). The attraction of astronomical objects of the internal spherical layers of the galaxy can be much stronger than the attraction to the central body of the galaxy. Then, their collective gravitational influence can essentially distort the correspondence of the motion of peripheral astronomical objects to Kepler's laws. And, therefore, according to astronomical observations the velocities of rotation v_z of galaxy's peripheral astronomical objects required for prevention of joint collapse of all matter of the galaxy are much higher than the velocities of rotation of the separate peripheral astronomical objects required for prevention of the independent fall of those objects onto the central astronomical body.

If we do not take into account local peculiarities of distribution of average density of the mass in galaxies and examine only the general tendency of typical dependence of the orbital velocity of their objects on radial distance to the galaxy center, then the following dependence of this velocity on parameter *b* and, thus on radial distance *r*, can be matched to them:

$$v_z = \sqrt{\frac{2(b/b_e)^n}{1+(b/b_e)^{2n}}}\,v_{z\max} = c\left[4n^2\ln^2\left(\frac{r}{r_e}\right)+\left(\frac{c}{v_{z\max}}\right)^4\right]^{-\frac{1}{4}}.$$

Where:

$$b=b_e\left[(v_{z\max}/v_z)^2 \pm\sqrt{(v_{z\max}/v_z)^4-1}\right]^{1/n} = b_e\left[\pm 2nv_{z\max}^2 c^{-2}\ln(r/r_e)+\sqrt{1+[2nv_{z\max}^2 c^{-2}\ln(r/r_e)]^2}\right]^{1/n},$$

$$r=r_e\exp\left[\pm\frac{c^2}{2n}\sqrt{v_z^{-4}-v_{z\max}^{-4}}\right]=r_e\exp\left\{\pm\frac{c^2}{4nv_{z\max}^2}\left[\left(\frac{b}{b_e}\right)^n-\left(\frac{b_e}{b}\right)^n\right]\right\},$$

and: r_e is radius of the conventional friable galactic nucleus, on the surface of which the orbital velocity of objects can take its maximum possible value $v_{ze}(b_e)=v_{z\max}$.

The smaller value *b* corresponds to the larger value *n* of the index of density of friable galactic nucleus on the same big radial distances. However, only when values are extremely large $n>2^{25}$ the significantly lesser average density of matter beyond the friable galactic nucleus takes place and that is why the dependence of orbital velocities of galactic objects on radial distances can be close to Keplerian. When the parameter values are $n<2^{15}$ the orbital velocities of extra-nuclear objects are quite close to their maximum values $v_{z\max}<225\ km/s$ on quite big radial distances $r/r_e<20$:

$$\Delta v_z = v_{z\max} - c\left\{[2n\ln(r/r_e)]^2+(c/v_{z\max})^4\right\}^{-1/4} < 0{,}683\ [km/s].$$

This, of course, is related to the fact that big gradients of gravitational field on the periphery of such galaxies are formed not by their nuclei but by all large set of their objects.

Then, taking into account the negligible smallness of cosmological constant and of the pressure in the outer space of the galaxy, the following typical radial distribution of average density of mass of matter in the galaxy will take place in GR:

$$[\mu]_{GR}\approx\frac{1}{\kappa c^2}\left[\frac{a'}{a^2 r}+\frac{1}{r^2}\left(1-\frac{1}{a}\right)\right]\left(1-\frac{v_g^2}{bc^2}\right)=\frac{2v_z^2(1-v_z^2c^{-2})[1+2v_z^2c^{-2}-4n^2v_z^4c^{-4}\ln(r/r_e)]}{\kappa c^4 r^2(1+2v_z^2c^{-2})^2}\approx\frac{v_z^2}{4\pi\gamma\, r^2},$$

where $\gamma=\kappa c^4/8\pi$ is Newton's gravitational constant, and:

$$a\approx 1+2v_z^2c^{-2}=1+2\{[2n\ln(r/r_e)]^2+(c/v_{z\max})^4\}^{-1/2}.$$

Thus, according to GR, the bigger the index n and the lesser the value of parameter b_e, the lesser is maximum possible value of average density of mass of the matter on the edge of the galaxy. However, when $v_{z\max}=225\ km/s$, $r_e=5$ kpc, $r_{\lim}/r_e=20$, $n=2^{15}$ ($v_{z\lim}=224{,}317294$ km/s) and $b_e=0{,}99999551225433188$ ($b_{\lim}=0{,}999999888026921702$): $[\mu_{\lim}]_{GR}=6{,}276\ 10^{-24}\ kg/m^3$ is only 0,4% smaller than its approximate value. And, therefore, due to $v<<c$ it quite weakly depends on the index n of the density of friable galactic nucleus.

In RGTD (taking into account the negligible smallness of only cosmological constant) the completely different typical radial distribution of the average density of mass of the matter in the galaxy takes place:

$$[\mu]_{RGTD}\approx\frac{b\delta}{\kappa c^2r^2a(1-b)}=\frac{b[2v_z^2c^{-2}-(a-1)]}{\kappa c^2r^2a(1-b)}=\frac{b[4v_{z\max}^2c^{-2}b_e^nb^n-(a-1)(b^{2n}+b_e^{2n})]}{\kappa c^2r^2a(1-b)(b^{2n}+b_e^{2n})},$$

according to which it becomes infinitely small. The tendency to 1 of not only parameter a, but also parameter b, prevents the limitless decrease to zero of average density of mass of matter on the edge of the galaxy. That is why in RGTD, in contrast to GR, there cannot be in principle any shortage of baryonic mass not only in the center, but also on the edge of the galaxy.

Taking into account that in the outer space on the periphery of the galaxy $a_{\lim}-1\approx 1-b_{\lim}$ and, thus, $a_{\lim}=1{,}00000111973203677$ (when $2v_{z\lim}^2c^{-2}=1{,}11973203777\ 10^{-6}$), having the same initial data we can find the acceptable value of the average density of mass of matter on the edge of the galaxy: $[\mu_{\lim}]_{RGTD}=5\cdot 10^{-26}\ kg/m^3$. However, of course, when we have value b_e, that guarantees $\delta_{\lim}<10^{-15}$, the significantly smaller average density of mass of the matter on the edge of the galaxy can take place in RGTD. When $n=1$ ($v_{z\lim}=224{,}99999999936$ km/s) and the same value $\delta_{\lim}=10^{-15}$ ($b_e=0{,}99999606363264543$, $b_{\lim}=0{,}999999436721227408$) $[\mu_{\lim}]_{RGTD}=1{,}4\cdot 10^{-27}\ kg/m^3$.

As we can see in RGTD, in contrast to GR, index $n=2^{15}$ quite significantly (almost 36 times) increases the acceptable average value of density of mass of matter on the edge of the galaxy. However, due to mutual dependence of variable parameters n, b_e and a_e, that is defined by the principles of expedience and by corresponding to them negative feedbacks, the increasing of $[\mu_{\lim}]_{RGTD}$ will be indeed significantly smaller. The increasing of $[\mu_{\lim}]_{RGTD}$ on the galaxy periphery due to $n=2^{15}$ can be partially compensated by its decreasing due to decreasing of the value $\delta_{\lim}$.

As a result of evolutional decreasing of average density of matter in the Universe and gradual cooling down of the galaxy nuclei their parameters n, b_e ($b_{\lim}$) и a_e ($a_{\lim}$) are gradually changing. It is manifested in a gradual distancing of astronomical objects from the galaxy center. The speeds of gradual change of these parameters are not equal for different galaxies that may result in the non-equality of galactic values of Hubble constant. However, the difference of galactic values from the global value of Hubble constant, which corresponds only to evolutional expansion of the Universe, is negligibly small in modern time. But in far cosmological past it could be more significant due to the big values of average density of matter in the Universe and, thus, due to the smaller values of parameter b (and, consequently, of defined by them values of coordinate velocity of light) in the outer space of the Universe. Nowadays it is more significant only in non-rigid FRs [Danylchenko, 1994: 52] of cooling-down astronomical bodies.

Radial distribution of parameter a can be found via the solution of differential equation:

$$\frac{ra'}{a}+(a-1)-\kappa\mu c^2\left[1+\frac{v_z^2}{b(c^2-v_z^2)}\right]=$$

$$=\frac{ra'}{a}+(a-1)-\frac{[(1-a)(b^{2n}+b_e^{2n})+4v_{z\max}^2c^{-2}b_e^nb^n][b(b^{2n}+b_e^{2n})+2v_{z\max}^2c^{-2}b_e^nb^n(1-b)]}{(1-b)(b^{2n}+b_e^{2n})[(b^{2n}+b_e^{2n})-2v_{z\max}^2c^{-2}b_e^nb^n]}=$$

$$=\frac{ra'}{a}+\frac{(b^{2n}+b_e^{2n})(a-1)}{(1-b)[(b^{2n}+b_e^{2n})-2v_{z\max}^2c^{-2}b_e^nb^n]}-\frac{4v_{z\max}^2c^{-2}b_e^nb^{n+1}[(b^{2n}+b_e^{2n})+2v_{z\max}^2c^{-2}b_e^nb^{n-1}(1-b)]}{(1-b)(b^{2n}+b_e^{2n})[(b^{2n}+b_e^{2n})-2v_{z\max}^2c^{-2}b_e^nb^n]}=0$$

and, taking into account that $dr=(rc^2/2v_z^2b)db$, and $v_{z\max}<<c$, – of another equation:

$$\frac{1}{a}\frac{da}{db}+\frac{c^2(b^{2n}+b_e^{2n})^2(a-1)}{4v_{z\max}^2b_e^nb^{n+1}(1-b)[(b^{2n}+b_e^{2n})-2v_{z\max}^2c^{-2}b_e^nb^n]}-\frac{(b^{2n}+b_e^{2n})+2v_{z\max}^2c^{-2}b_e^nb^{n-1}(1-b)}{(1-b)[(b^{2n}+b_e^{2n})-2v_{z\max}^2c^{-2}b_e^nb^n]}\approx$$

$$\approx\frac{1}{a}\frac{da}{db}+\frac{c^2(b^{2n}+b_e^{2n})(a-1)}{4v_{z\max}^2b_e^nb^{n+1}(1-b)}-\frac{1}{(1-b)}=\frac{1}{a}\frac{da}{db}+\frac{c^2(a-1)}{2v_z^2b(1-b)}-\frac{1}{(1-b)}=\frac{1}{a}\frac{da}{db}+\frac{(a-1)}{(1-b)r}\frac{dr}{db}-\frac{1}{(1-b)}=0\,.$$

In the obtained solutions of equations the density of equivalent to energy mass is integrated not by its intrinsic values $\mu_{0GR}=m_0/V$, which are determined via different intrinsic clocks as it is in used GR. It is integrated by its values $\mu_{RGTD}=\sqrt{b}m_0/V=f_Gm_0/\eta_mV$ observed using the same clock. In all other means these solutions are formally correspond to the solutions of GR for cooled down to the limit matter ($S=\mathbf{const}(r)$), which is in the state of mechanical equilibrium [Danylchenko, 2005b; 2008: 4]:

$$dp/dr+(\mu_0c^2+p)b'/2b=0\,.$$

In this case, not only the conditions $T_g^* = T\sqrt{b} = \mathbf{const}(r)$ and $H_{Tg}^* = H_T\sqrt{b} = \mathbf{const}(r)$ are fulfilled, but also the used in obtained solutions condition $G_g^* = G\sqrt{b} = (H_T - TS)\sqrt{b} = \mathbf{const}(r)$ is also fulfilled:

$$dH_{Tg}^*(S) = \sqrt{b}TdS + \sqrt{b}Vdp + (H_T/2\sqrt{b})db = 0 .$$

Due to mutual proportionality of $f_G(r) = \eta_m\sqrt{b(r)}$ and $\sqrt{b}$ ($\mathbf{grad}\ln f_G = \mathbf{grad}\ln\sqrt{b}$), the matter STC, which is obtained based on the analysis of spatial distribution of Lorentz-noninvariant intranuclear RGTD-characteristics of matter, is identical to STC obtained in GR when ignoring both Lorentz-invariance and temporal invariance of thermodynamic parameters and characteristics of matter.

It should also be mentioned here that, according to GR and RGTD, the ideal gas ($pV = R_{UT}T$) cannot have gravitational field in principle. Molar energy of ideal gas and, consequently, coordinate-like velocity of light in it are the same at all points of the space filled by this gas:

$$E_0 = m_0c^2\sqrt{b} = (H_T - pV)\sqrt{b} = (H_T - R_{UT}T)\sqrt{b} = H_{Tg}^* - R_{UT}T_g^* = \mathbf{const}(r) , \quad v_{cv} = \sqrt{b}c = \mathbf{const}(r) .$$

And it means that the phenomenon of gravitation is related to electromagnetic interaction of molecules of matter and, therefore, has purely electromagnetic nature.

8. Generalized equations of thermodynamics

Thermodynamic processes in matter confront the intranuclear evolutionary and gravitational processes in it. While in mechanics and in gravitation theories the main role is played by the inert free energy $E = mc^2 = m_0cv_l\Gamma_m$ (equivalent to gravitational and inert mass), in thermodynamics the main role is given to the total internal energy $U = W + U_{ad} = m_0c^3/v_l\Gamma_m + U_{ad}$ of matter. Therefore, frequency of intranuclear interaction $f_G = f_N N_{RE} = \eta_m v_l / c \le \eta_m$ corresponds to inversely proportional to it frequency of electromagnetic interaction of its molecules in the comoving FR:

$$f_I = q_M N_I = (v_{cm}/c)N_I = \psi_m c/v_l = \psi_{m0}c/v_{lc} \ge \psi_m \qquad (f_{Icr} = f_{Gcr} = 1).$$

This frequency is changing together with the change of velocity of light $v_{cm} = cq_M \le v_l$ in matter (that corresponds to radiation refractive index n_m at the wavelength of maximum of energy of thermal radiation) and with the change of internal scale factor $N_I = \delta l_{cr} / \delta l \ge 1$ of matter [Danylchenko, 2008: 19; 2008a; 2009a; 2020: 5]. Here: $\chi_m = \chi_{m0}/\Gamma_m = \Gamma_{mcr}/\Gamma_m$; $\psi_m = \psi_{m0}/\Gamma_m = \chi_m/\eta_m = v_{lcr}\Gamma_{mcr}/c\Gamma_m$; $\psi_{m0} = \chi_{m0}/\eta_m = v_{lc/cr}/c = \Gamma_{mcr}v_{lcr}/c$ and $\eta_m = c/v_{lcr}$ are the constants[22] of a matter, which is not identical for

[22] These constants unambiguously correspond only to the homogeneous matter of not layered astronomical body that does not possesses any matter outside its borders. In any other case it is only gaugely changed since due to logarithmicity of gravitational potential (that is formed based on correspondent thermodynamic potential) it does not directly influence the

different matters and for their various phase or aggregate states and not dependent both on strength of gravitational field and on matter thermodynamic parameters; v_l and v_{lcr} are maximum possible (limit) velocities of matter in any point on the phase boundary of the same matter and on the boundary of different matters correspondingly; $v_{lc}=\Gamma_m v_l > v_l$ and $v_{lc/cr}=\Gamma_m v_{lcr}$ are the limit velocity of quasi-equilibrium cooling down matter in the comoving with it the non-rigid FR (so not in the metric STC, but in the inseparable from matter its own physical STC, in which the radial motion of molecules of matter, which cooling down is absent and the time is counted by the clocks coming with them); Γ_m and $\Gamma_{mcr}\equiv\chi_{m0}$ are the expected purely Lorentz time dilatations of matter (that moves in the process of quasi-equilibrium cooling down) in arbitrary point and on the phase boundary of the same matter or with another matter respectively; δl_{cr} is maximal possible distance of electromagnetic interaction between molecules of certain matter or its critical value; *c* is constant of the velocity of light.

In contrast to used in cosmology spatially inhomogeneous external scaling factor N_E, which is the cause of the curvature of matter intrinsic space, internal scaling factor N_I takes nonsimilar values for different matters and depends on thermodynamic state of matter. This factor characterizes the distinction between average statistic value of interaction distance δl in the atoms of concrete matter and the value of this distance δl_{cr} that corresponds to critical equilibrium values of internal energy multiplicative component U_{cr}[23], Gibbs free energy G_{cr}, temperature T_{cr}, pressure p_{cr}. And if parameter $q_M = v_{cm}/c = 1/n_m < 1$ characterizes the difference of real velocity of electromagnetic interaction propagation in matter from the constant of velocity of light *c*, then N_I is responsible for compensation of the influence of decreasing of propagation velocity of electromagnetic wave on the frequency of electromagnetic interaction f_I of matter microobjects. If for gases and simplest liquids the dependencies of instantaneous values of their thermodynamic parameters and potentials on q_M and N_I allow to separate these variables, then instantaneous value of their Gibbs free energy (that corresponds to their instantaneous thermodynamic microstates) can be expressed via these two parameters and via their function R_T in the following way:

$$\breve{G}(q_M,N_I,\breve{R}_T)=\breve{U}(q_M,N_I,\breve{R}_T)-\breve{S}(q_M,N_I,\breve{R}_T)\breve{T}(q_M,N_I,\breve{R}_T)+\breve{V}(q_M,N_I)\breve{p}(q_M,N_I)\,.$$

---

strength of gravitational field. Changes of the strength of gravitational field in it take place under the influence of other matters on the formation of its spatially inhomogeneous thermodynamic state [Danylchenko, 2008:19; 2008a; 2009a; 2020: 5].

[23] Critical values of internal energy and other thermodynamic potentials and parameters of gas take place on the boundary of stable retention of its molecules by RGTD-bond. They are determined by correspondent to them values on the boundary between gas and liquid or solid matter.

Methods of thermodynamics allow us to analyze equilibrium states of matter even when there is no analytic dependence of thermal energy of matter on its thermodynamic parameters. With the purpose of revealing of some features let us examine analytic representation of such dependency for gases and simple liquids. According to it the instantaneous values of main thermodynamic parameters and potentials can be represented in the following way:

$$\breve{S}=-\left(\frac{\partial\breve{G}_T}{\partial\breve{T}}\right)_{\breve{p}}=-\left(\frac{\partial\breve{F}_T}{\partial\breve{T}}\right)_{\breve{V}}=\frac{\beta_{ST}\breve{R}_T}{\beta_{pV}}(\hat{S}),\qquad \breve{T}=\left(\frac{\partial\breve{H}_T}{\partial\breve{S}}\right)_{\breve{p}}=\left(\frac{\partial\breve{U}}{\partial\breve{S}}\right)_{\breve{V}}=\frac{\beta_{pV}U_{cr}}{\breve{R}_T}(\hat{T})=\frac{c\psi_m\beta_{pV}U_{cr}}{v_l\breve{R}_T},$$

$$\breve{V}=\left(\frac{\partial\breve{H}_T}{\partial\breve{p}}\right)_{\breve{S}}=\left(\frac{\partial\breve{G}_T}{\partial\breve{p}}\right)_{\breve{T}}=\frac{U_{cr}}{p_l}(\hat{V}),\qquad \breve{p}=-\left(\frac{\partial\breve{U}}{\partial\breve{V}}\right)_{\breve{S}}=-\left(\frac{\partial\breve{F}_T}{\partial\breve{V}}\right)_{\breve{T}}=\beta_{pV}\,p_l(\hat{p}),$$

$$\breve{U}=\breve{U}_0+\breve{U}_{ad}=\frac{\breve{R}_T\breve{T}}{\beta_{pV}}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\frac{\breve{T}\breve{S}}{\breve{R}_T}d\breve{R}_T=\frac{\breve{p}\breve{V}}{\beta_{pV}}+\beta_{ST}\int_{\breve{R}_{T0}}^{\breve{R}_T}(\hat{T})(\hat{S})\frac{d\breve{R}_T}{\breve{R}_T}=$$

$$=U_{cr}\left[q_MN_I+\beta_{ST}\int_{\breve{R}_{T0}}^{\breve{R}_T}(q_MN_I/\breve{R}_T)\ln(q_M^lN_I)d\breve{R}_T\right]=\breve{a}_\rho\breve{T}/\beta_{pV}+\int_{\breve{a}_\rho}^{\breve{a}_\rho}\breve{A}_\rho d\breve{a}_\rho=$$

$$=U_{cr}\left[\left(\frac{p_l\breve{V}}{U_{cr}}\right)^{-\beta_{pV}}\exp\left(\frac{\beta_{pV}\breve{S}}{\breve{R}_T}\right)+\beta_{pV}\int_{\breve{R}_{T0}}^{\breve{R}_T}\left(\frac{p_l\breve{V}}{U_{cr}}\right)^{-\beta_{pV}}\exp\left(\frac{\beta_{pV}\breve{S}}{\breve{R}_T}\right)\frac{\breve{S}}{\breve{R}_T^2}d\breve{R}_T\right]=$$

$$=U_{cr}\left[\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)^{\frac{\beta_{pV}}{\beta_H}}\exp\left(\frac{\beta_{pV}\breve{S}}{\beta_H\breve{R}_T}\right)+\beta_{pV}\int_{\breve{R}_{T0}}^{\breve{R}_T}\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)^{\frac{\beta_{pV}}{\beta_H}}\exp\left(\frac{\beta_{pV}\breve{S}}{\beta_H\breve{R}_T}\right)\frac{\breve{S}}{\breve{R}_T^2}d\breve{R}_T\right]=$$

$$=\left\{\breve{R}_T\breve{T}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\beta_H\ln\left(\frac{\breve{R}_T\breve{T}}{U_{cr}\beta_{pV}}\right)-\beta_{pV}\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)\right]\breve{T}d\breve{R}_T\right\}\frac{1}{\beta_{pV}}=$$

$$=U_{cr}\left[(\hat{T})+\beta_{ST}\int_{\breve{R}_{T0}}^{\breve{R}_T}(\hat{T})(\hat{S})\frac{d\breve{R}_T}{\breve{R}_T}\right]=\frac{1}{\beta_{pV}}\left\{\breve{R}_T\breve{T}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pV}U_{cr}}\right)+\beta_{pV}\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]\breve{T}d\breve{R}_T\right\},$$

$$\breve{F}_T=\breve{U}-\breve{S}\breve{T}=U_{cr}\left[(\hat{T})-\beta_{ST}\int_{[(\hat{S})(\hat{T})/\breve{R}_T]_0}^{(\hat{T})(\hat{S})/\breve{R}_T}\breve{R}_Td\left(\frac{(\hat{T})(\hat{S})}{\breve{R}_T}\right)\right]=\breve{F}_{T0}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\frac{\breve{S}\breve{T}}{\breve{R}_T}d\breve{R}_T=$$

$$=U_{cr}\left\{[1-\ln(\hat{T})-\beta_{pV}\ln(\hat{V})](\hat{T})+\int_{\breve{R}_{T0}}^{\breve{R}_T}[\ln(\hat{T})+\beta_{pV}\ln(\hat{V})](\hat{T})/\breve{R}_T]d\breve{R}_T\right\}=$$

$$=\frac{1}{\beta_{pV}}\left\{\breve{R}_T\breve{T}\left[1-\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pV}U_{cr}}\right)-\beta_{pV}\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pV}}\right)+\beta_{pV}\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]\breve{T}d\breve{R}_T\right\},$$

$$\breve{H}_T=\breve{U}+\breve{p}\breve{V}=\breve{U}+\breve{R}_T\breve{T}=\breve{H}_{T0}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\frac{\breve{T}\breve{S}}{\breve{R}_T}d\breve{R}_T=\frac{\beta_H\breve{R}_T\breve{T}}{\beta_{pV}}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\frac{\breve{T}\breve{S}}{\breve{R}_T}d\breve{R}_T=$$

$$=U_{cr}\{\beta_H(\hat{T})+\beta_{ST}\int_{\breve{R}_{T0}}^{\breve{R}_T}[(\hat{T})(\hat{S})/\breve{R}_T]d\breve{R}_T\}=$$

$$=U_{cr}\left[\beta_H\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)^{\frac{\beta_{pV}}{\beta_H}}\exp\left(\frac{\beta_{pV}\breve{S}}{\beta_H\breve{R}_T}\right)+\beta_{pV}\int_{\breve{R}_{T0}}^{\breve{R}_T}\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)^{\frac{\beta_{pV}}{\beta_H}}\exp\left(\frac{\beta_{pV}\breve{S}}{\beta_H\breve{R}_T}\right)\frac{\breve{S}}{\breve{R}_T^2}d\breve{R}_T\right]=$$

$$=\frac{\beta_H}{\beta_{pV}}\left\{\breve{R}_T\breve{T}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pV}U_{cr}}\right)-\frac{\beta_{pV}}{\beta_H}\ln\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)\right]\breve{T}d\breve{R}_T\right\}=$$

$$=\frac{1}{\beta_{pV}}\left\{\beta_H\breve{R}_T\breve{T}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pV}U_{cr}}\right)+\beta_{pV}\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]\breve{T}d\breve{R}_T\right\}=$$

$$=c\psi_mU_{cr}\left\{\frac{\beta_H}{v_l}+\beta_{ST}\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln\left(\frac{c\psi_m}{v_l}\right)-(l-1)\ln n_m\right]\frac{d\breve{R}_T}{\breve{R}_Tv_l}\right\},$$

$$\breve{G}=\breve{H}_T-\breve{S}\breve{T}=U_{cr}\left[\beta_H(\hat{T})-\beta_{ST}\int_{[(\hat{S})(\hat{T})/\breve{R}_T]_0}^{(\hat{S})(\hat{T})/\breve{R}_T}\breve{R}_Td\left(\frac{(\hat{S})(\hat{T})}{\breve{R}_T}\right)\right]=\breve{G}_0+\int_{\breve{R}_{T0}}^{\breve{R}_T}\frac{\breve{S}\breve{T}}{\breve{R}_T}d\breve{R}_T=$$

$$=\beta_HU_{cr}\left\{\left[1-\ln(\hat{T})+\frac{\beta_{pV}}{\beta_H}\ln(\hat{p})\right](\hat{T})+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln(\hat{T})-\frac{\beta_{pV}}{\beta_H}\ln(\hat{p})\right]\frac{(\hat{T})}{\breve{R}_T}d\breve{R}_T\right\}=$$

$$=\frac{\beta_H\breve{a}_\rho\breve{T}}{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{a}_\rho d\breve{A}_\rho=\frac{\beta_H\breve{R}_T\breve{T}}{\beta_{pV}}\left[1-\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pv}U_{cr}}\right)+\frac{\beta_{pV}}{\beta_H}\ln\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)\right]+$$

$$+\int_{\breve{R}_{T0}}^{\breve{R}_T}\left[\frac{\beta_H}{\beta_{pV}}\ln\left(\frac{\breve{R}_T\breve{T}}{\beta_{pV}U_{cr}}\right)-\ln\left(\frac{\breve{p}}{\beta_{pV}p_l}\right)\right]\breve{T}d\breve{R}_T=\breve{H}_{T0}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_Td\breve{A}_\rho=$$

$$=c\psi_mU_{cr}\left\{\frac{\beta_H}{v_l}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_Td\left(\frac{\beta_{ST}}{\breve{R}_Tv_l}\left[\ln\left(\frac{c\psi_m}{v_l}\right)-(l-1)\ln n_m\right]\right)\right\}=$$

$$=\frac{c\psi_m U_{cr}\beta_{ST}}{v_l}\left\{\left[\frac{\beta_H}{\beta_{ST}}-\ln\left(\frac{c\psi_m}{v_l}\right)-(1-l)\ln n_m\right]+v_l\int\limits_{\breve{R}_{T0}}^{\breve{R}_T}\left[\ln\left(\frac{c\psi_m}{v_l}\right)-(l-1)\ln n_m\right]\frac{d\breve{R}_T}{\breve{R}_T v_l}\right\},$$

where: $\breve{U}_0=(\hat{T})U_{cr}$, $\breve{H}_{T0}=\beta_H\breve{U}_0$, $\breve{G}_0=\beta_G\breve{U}_0$, $\breve{F}_{T0}$ are multiplicatively dependent on q_M and N_I components of instantaneous values of internal energy, enthalpy, Gibbs free energy and Helmholtz free energy of instantaneous Gibbs microstate of matter correspondingly;

$\breve{U}_{ad}=\sum\limits_{i=2}^{n}\int\limits_{\breve{a}_{i0}}^{\breve{a}_i}\breve{A}_i d\breve{a}_i=\int\limits_{\breve{a}_{\rho 0}}^{\breve{a}_\rho}\breve{A}_\rho d\breve{a}_\rho=\int\limits_{\breve{R}_{T0}}^{\breve{R}_T}(\breve{T}\breve{S}/\breve{R}_T)d\breve{R}_T>0$ is instantaneous value of realized via negative feedback partial additive compensation of multiplicative representation of thermodynamic potentials of microstate of matter (a multiplicative decrease in its free energies over time); $\breve{A}_\rho=\breve{T}\breve{S}/\breve{R}_T$, $\breve{a}_\rho\equiv\breve{R}_T=\breve{p}\breve{V}/\breve{T}$; $(\hat{S})=\ln(q_M^l N_I)$, $(\hat{T})=(\hat{p})(\hat{V})=q_M N_I=f_I=\chi_m/f_G=\psi_m c/v_{cv}\equiv\psi_m c/v_l$, $(\hat{V})=q_M^{-1/k}N_I^{-m}$, $(\hat{p})=q_M^{1+1/k}N_I^{1+m}$ are normalized values of thermodynamic parameters (entropy, temperature, molar volume and pressure) of Gibbs microstates of matter;

$$\beta_{ST}=\frac{km-1}{klm-1}>0,\qquad \beta_{pV}=\frac{k(l-1)}{klm-1}>0,\qquad \beta_H=\frac{H_{T0}}{U_0}=1+\beta_{pV}=\frac{k(lm+l-1)-1}{klm-1},$$

$$\beta_G=\frac{\breve{G}_0}{\breve{U}_0}=1+\beta_{pV}-\beta_{ST}\ln(q_M^l N_I)=\frac{k(lm+l-1)-1}{klm-1}-\frac{l(km-1)}{klm-1}\ln q_M-\frac{km-1}{klm-1}\ln N_I,$$

$$\beta_{GR}=\frac{\breve{G}}{\breve{U}_0}=1+\beta_{pV}-\frac{\beta_{ST}}{(\hat{T})}\int\limits_{\breve{A}_{\rho 0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=\frac{k(lm+l-1)-1}{klm-1}-\frac{km-1}{(klm-1)q_M N_I}\int\limits_{[(\hat{S})(\hat{T})/\breve{R}_T]_0}^{(\hat{S})(\hat{T})/\breve{R}_T}\breve{R}_T d\left[\frac{q_M N_I\ln(q_M^l N_I)}{\breve{R}_T}\right];$$

$p_l=np_{cr}$, while: *n* is the hidden variable that is the indicator of the magnitudes of instantaneous microfluctuations of values of pressure and molar volume when $\breve{p}\breve{V}=\mathbf{const}$ and during not absolutely rigid retention of occupied by gas constant volume;

k, l, m are the hidden variables that are indicators of the influence of parameters q_M and N_I on the parameters of thermodynamic microstates of latently coherent matter[24].

Variables *k, l, m* and *n* characterize instantaneous collective microstates of the whole gravithermodynamically bonded matter and similarly to the wave functions of quantum mechanics can take with certain probability any arbitrary instantaneous values. The probability that Gibbs microstate of matter have instantaneous energy, the corresponding certain composition of values of these variables,

[24] It is possible that latent coherence of matter is brought on (together with the new moment of its proper time) by the next turn of spiral wave of space-time modulation of dielectric and magnetic permeabilities of physical vacuum [Danylchenko, 2008: 19; 2014: 21].

obviously, is represented by canonic Gibbs distribution. The concrete mathematic expectations $\tilde{k}$, $\tilde{l}$, $\tilde{m}$, $\tilde{n}$ of those variables correspond to parameters of a thermodynamic macrostate of matter.

Normalized values of thermodynamic parameters of instantaneous microstates of matter are mutually related via the following dependencies:

$$(\hat{S})=l\ln q_M+\ln N_l=\ln\left(\frac{c\psi_m}{v_l}\right)+(1-l)\ln n_m=\frac{\beta_H}{\beta_{ST}}\ln(\hat{T})-\frac{\beta_{pV}}{\beta_{ST}}\ln(\hat{p})=\frac{\ln(\hat{T})}{\beta_{ST}}+\frac{\beta_{pV}}{\beta_{ST}}\ln(\hat{V})=\frac{\beta_H}{\beta_{ST}}\ln(\hat{V})+\frac{\ln(\hat{p})}{\beta_{ST}},$$

$$\ln(\hat{T})=\ln q_M+\ln N_l=\ln\left(\frac{c\psi_m}{v_l}\right)=\frac{\beta_{ST}}{\beta_H}(\hat{S})+\frac{\beta_{pV}}{\beta_H}\ln(\hat{p})=\beta_{ST}(\hat{S})-\beta_{pV}\ln(\hat{V})=\ln(\hat{p})+\ln(\hat{V}),$$

$$\ln(\hat{V})=-\frac{\ln q_M}{k}-m\ln N_l=-m\ln\left(\frac{c\psi_m}{v_l}\right)+\frac{1-km}{k}\ln n_m=\frac{\beta_{ST}}{\beta_H}(\hat{S})-\frac{\ln(\hat{p})}{\beta_H}=\frac{\beta_{ST}}{\beta_{pV}}(\hat{S})-\frac{\ln(\hat{T})}{\beta_{pV}}=\ln(\hat{T})-\ln(\hat{p}),$$

$$\ln(\hat{p})=\frac{k+1}{k}\ln q_M+(m+1)\ln N_l=(m+1)\ln\left(\frac{c\psi_m}{v_l}\right)+\frac{km-1}{k}\ln n_m=$$
$$=\beta_{ST}(\hat{S})-\beta_H\ln(\hat{V})=-\frac{\beta_{ST}}{\beta_{pV}}(\hat{S})+\frac{\beta_H}{\beta_{pV}}\ln(\hat{T})=\ln(\hat{T})=\ln(\hat{T})-\ln(\hat{V}).$$

As it was expected, all instantaneous thermodynamic potentials reach their minimum independently both on the values of variables *l, k*, *m*, *n*, and on the value of spatial gas-related (liquid-related) parameter $\breve{R}_T$:

$$\left(\frac{\partial\breve{U}}{\partial\breve{R}_T}\right)_{\breve{S},\breve{V}}=0,\qquad \left(\frac{\partial\breve{H}_T}{\partial\breve{R}_T}\right)_{\breve{S},\breve{p}}=0,\qquad \left(\frac{\partial\breve{F}_T}{\partial\breve{R}_T}\right)_{\breve{T},\breve{V}}=0,\qquad \left(\frac{\partial\breve{G}}{\partial\breve{R}_T}\right)_{\breve{T},\breve{p}}=0.$$

And, moreover, the change in space of available thermodynamic parameters of cooling down matter is inevitably accompanied by the change of its hidden thermodynamic parameters Γ_m and v_l:

$$\left(\frac{\partial U}{\partial\bar{r}}\right)_t=T\left(\frac{\partial S}{\partial\bar{r}}\right)_t-p\left(\frac{\partial V}{\partial\bar{r}}\right)_t=-U_0\left[\left(\frac{\partial\ln\Gamma_m}{\partial\bar{r}}\right)_t+\left(\frac{\partial\ln v_l}{\partial\bar{r}}\right)_t\right],$$

$$\left(\frac{\partial H_T}{\partial\bar{r}}\right)_t=T\left(\frac{\partial S}{\partial\bar{r}}\right)_t+V\left(\frac{\partial p}{\partial\bar{r}}\right)_t=-H_{T0}\left[\left(\frac{\partial\ln\Gamma_m}{\partial\bar{r}}\right)_t+\left(\frac{\partial\ln v_l}{\partial\bar{r}}\right)_t\right],$$

where: $\partial\bar{r}$ is the increment of metric radial distance.

And the bigger the distance from matter to the gravitational attraction center the smaller is its internal energy. That is why in contrast to inert intranuclear energy (which is the greater the greater the distance from the substance to the gravitational attraction center) the thermal energy behaves like a negative mass. And this is confirmed by numerous investigations of the influence of heating of matter on its weight [Einstein & Infeld, 1938; Chen & Cook, 1993; Dmitriev, 2005].

Precisely the condition of spatial homogeneity of hierarchic complexity of RGTD-bonded matter R_T=**const**(r)[25] determines the spatial distribution of the set of main thermodynamic parameters of this quasi-equilibrium cooling down matter.

According to received expressions for thermodynamic potentials limit velocity of matter motion v_l (the equivalent to pseudo-vacuum velocity of light v_{cv} in GR) is the thermodynamic hidden parameter. At that the founded in GR by Tolman [Tolman, 1969] condition for the mechanic equilibrium of cooled down to the limit matter[26]:

$$T_g^*=Tv_{cv}/c\equiv Tv_l/c=\psi_{m0}U_{cr}\widetilde{\beta}_{pV}/R_T=\mathbf{const}(r)\,, \qquad (3)$$

could be fulfilled for real gases and liquids only due to the possibility of self-realization by them of optimal values of mathematic expectations of their hidden variable β_{pV}:

$$\widetilde{\beta}_{pV}(T,p)=\widetilde{\beta}_{pV0}(T_0,p_0)\frac{R_T(T,p)}{R_T(T_0,p_0)}\,.$$

The same way, additional condition $S=S_g^*=\mathbf{const}(r)$ and derived from it condition:

$$TSv_l/c=T_g^*S_g^*=\psi_{m0}\widetilde{\beta}_{ST}U_{cr}[\ln\psi_{m0}-\ln(v_l/c)-(\widetilde{l}-1)\ln n_m]=\mathbf{const}(r)$$

for cooled down to the limit matter could be fulfilled for correspondent to them values of mathematical expectation of hidden variable β_{ST}:

$$\widetilde{\beta}_{ST}(T,p)=\widetilde{\beta}_{ST0}(T_0,p_0)\frac{\ln\psi_{m0}-\ln(v_{l0}/c)-(\widetilde{l}_0-1)\ln n_{m0}}{\ln\psi_{m0}-\ln(v_l/c)-(\widetilde{l}-1)\ln n_m}\,.$$

However, considering all of this normalized value of enthalpy H_T:

$$H_{Tg}^*=H_Tv_{cv}/c=U_{cr}\psi_{m0}(1+\widetilde{\beta}_{pV})\neq\mathbf{const}(r)\,,$$

---

[25] This is nothing more than the expression of the tendency to align the magnitudes of any intensive parameters of matters in the whole filled with them space. Only such main (field) intensive thermodynamic parameters as temperature and pressure in principle cannot be (or become) absolutely spatially homogenous in quasi-equilibriumly cooling down matter. Some other the fielded intensive thermodynamic parameters, which are related to the possibility of appearance of not only gravitational but also magnetic and electric fields in the RGTD-bonded matter, also cannot become absolutely spatially homogenous.

[26] At the first sight the increasing of thermal, and thus also total, energy of the gas while approaching the gravitational attraction center is paradoxical since its inert free energy, and thus its inert mass, are, on the contrary, decreasing. However this is the undeniable fact. Even the temperature of the air is increasing with the decreasing of the height above the surface of the Earth. So the matter that fell inertially in gravitational field should (in the process of decelerating of its motion) at first cool down and only then heat up, using the thermal energy of objects of the environment. That will happen since the part of its kinetic energy will be spent for the deformation and destruction of the objects on which it has fallen. It is impossible to achieve the required increasing of total internal energy of fallen matter using only the transition of kinetic energy into thermal energy. It is identical to the compressed freon, which after its expansion cools down the environment. Unfortunately this effect cannot be checked with gases due to the absence of absolutely rigid balloon, which would not compress the gas that is inside of it after hitting the ground. However it will probably be possible to check it on rigid enough solid matter if we would place in its center the shockproof fast-acting temperature sensor with the device that would remotely transmit the results of the temperature measurement.

since $\widetilde{\beta}_{pV} \neq \mathbf{const}(r)$. And this already does not correspond to the equations of GR gravitational field [Danylchenko, 2008: 19; 2008a]. Moreover, spatial inhomogeneity of hidden parameters $\widetilde{\beta}_{pV}$ and $\widetilde{\beta}_{ST}$ does not correspond to the concept of self-creation (by matter) of a single collective Gibbs thermodynamic microstate with similar in the whole space hidden variables *k*, *l*, *m* and *n*.

And, therefore, the only substances that can be in mechanic equilibrium state in GR are cooled down to the limit hypothetic substances – matter of rigid body, ideal gas and ideal liquid that are only substances for which $R_T = R_{UT} = \mathbf{const}$ and, thus, $\widetilde{\beta}_{pV} = \mathbf{const}(r)$ and $H_g^* = \mathbf{const}(r)$. The absence in GR of the force (that acts on trial body) of radiational (electromagnetic) resistance to the fall of this body in gravitational field also denotes this. $F_r = \mathrm{H}\,\mathbf{grad}(\ln S) = 0$ due to $S = \mathbf{const}(r)$, where H is Hamiltonian of trial body that falls free in gravitational field.

However, such cooled down to the limit hypothetical substances in principle cannot form their spatially inhomogeneous thermodynamic state and, thus, cannot create gravitational field that corresponds to it. The reason for this is the absence of electromagnetic interactions of their molecules. And this, of course, is one of the main internal contradictions of used in equations of GR gravitational field simplified reflection of thermodynamic properties of matter.

Only matter which continuously (quasi-equilibrium) cooling down and have $W_{Rg}^* \equiv U_{0g}^* = U_0 \Gamma_m v_{cv}/c = U_{cr}\psi_{m0} = \mathbf{const}(r)$ (when $A_\rho = TS/R_T = T^2 S/pV = \mathbf{const}(t)$, $R_T = \mathbf{const}(r)$, $\widetilde{\beta}_{pV} = \mathbf{const}(r)$ and $\widetilde{\beta}_{ST} = \mathbf{const}(r)$) can be the real matter in GR. And it is quite possible in the case of the following dependence of parameter R_T on purely Lorentz dilatation of intrinsic time of the matter Γ_m, the values of coordinate-like velocity of light $v_{cv} \equiv v_l$ and on the light refractive index n_m and on mathematical expectation of the value of hidden thermodynamic variable $\widetilde{l} > 1$ of matter:

$$R_T = R_{Te} \frac{\Gamma_{me} v_{le} [\ln\psi_{m0} - \ln(\Gamma_m v_l / c) - (\widetilde{l} - 1)\ln n_m]}{\Gamma_m v_l [\ln\psi_{m0} - \ln(\Gamma_{me} v_{le} / c) - (\widetilde{l} - 1)\ln n_m]},$$

where: R_{Te}, Γ_{me}, v_{le}, n_{me} are values of parameters on the phase boundary inside of matter of with any other matter. However, it is possible only if use unstable entropy in equations of gravitational field of GR (as it is in RGTD). In this case not the entropy but the parameter R_T (which characterizes the same hierarchical complexity of matter in all space) is spatially homogeneous.

The conditions of mechanic and thermal quasi-equilibrium are in the dependencies of thermodynamic potentials on thermodynamic parameters of quasi-equilibrium cooling down matter. For the energy of extended system, (which enthalpy is) [Bazarov, 1964], we will have:

$$\left(\frac{\partial H_T}{\partial \tilde{r}}\right)_t = -(W+pV)\left(\frac{\partial \ln v_{lc}}{\partial \tilde{r}}\right)_t = -V\left(\frac{\mu c^4}{v_l^2\Gamma_m}+p\right)\left[\left(\frac{\partial \ln v_l}{\partial \tilde{r}}\right)_t + \left(\frac{\partial \ln \Gamma_m}{\partial \tilde{r}}\right)_t\right] = V\left(\frac{\partial p}{\partial \tilde{r}}\right)_t + T\left(\frac{\partial S}{\partial \tilde{r}}\right)_t,$$

where: $W \equiv U - U_{ad} = U_0 = Ec^2 v_{lc}^{-2} = mc^4 v_l^{-2}/\Gamma_m = m_0 c^3/v_{lc}$ is the ordinary internal energy of matter, identical to multiplicative component of total internal energy U; $U_{ad} = \mathbf{const}(r)$ is the mathematical expectation of partial additive compensation of multiplicative representation of thermodynamic potentials of matter; $\mu = m/V = m_0 v_l/cV$ is mass density of matter;

$$\left(\frac{\partial U}{\partial \tilde{r}}\right)_t = \left(\frac{\partial W}{\partial \tilde{r}}\right)_t = -W\left(\frac{\partial \ln v_{lc}}{\partial \tilde{r}}\right)_t = -p\left(\frac{\partial V}{\partial \tilde{r}}\right)_t + T\left(\frac{\partial S}{\partial \tilde{r}}\right)_t, \quad \left[\frac{\partial (pV)}{\partial \tilde{r}}\right]_t = -pV\left(\frac{\partial \ln v_{lc}}{\partial \tilde{r}}\right)_t = p\left(\frac{\partial V}{\partial \tilde{r}}\right)_t + V\left(\frac{\partial p}{\partial \tilde{r}}\right)_t.$$

According to this the conditions of thermal and mechanical quasi-equilibrium for cooling down matter will be as follows correspondingly:

$$\left(\frac{\partial p}{\partial \tilde{r}}\right)_t = -(W/V+p)\left(\frac{\partial \ln v_l}{\partial \tilde{r}}\right)_t = -\left(\frac{\mu c^4}{v_l^2\Gamma_m}+p\right)\left(\frac{\partial \ln v_l}{\partial \tilde{r}}\right)_t = \frac{(\tilde{m}+1)\tilde{\beta}_{pV}}{V\tilde{\beta}_H}\left(\frac{\partial H_T}{\partial \tilde{r}}\right)_t = \frac{\tilde{k}(\tilde{l}-1)(\tilde{m}+1)}{V[\tilde{k}(\tilde{l}\,\tilde{m}+l-1)-1]}\left(\frac{\partial H_T}{\partial \tilde{r}}\right)_t,$$

$$\frac{T}{V}\left(\frac{\partial S}{\partial \tilde{r}}\right)_t = -\left(\frac{\Gamma_m \mu c^4}{v_{lc}^2}+p\right)\left(\frac{\partial \ln \Gamma_m}{\partial \tilde{r}}\right)_t = \frac{\tilde{\beta}_{ST}}{V\tilde{\beta}_H}\left(\frac{\partial H_T}{\partial \tilde{r}}\right)_t = \frac{\tilde{k}\tilde{m}-1}{V[\tilde{k}(\tilde{l}\,\tilde{m}+\tilde{l}-1)-1]}\left(\frac{\partial H_T}{\partial \tilde{r}}\right)_t. \quad (4)$$

At $\tilde{\beta}_{ST}=0$ ($\tilde{k}\tilde{m}=1$, $S=0$) we will receive the condition of mechanic equilibrium for the extremely cooled down matter in GR. The absence (in used in GR condition) of mechanical equilibrium (2), purely Lorentz dilatation of time Γ_m and square of the coordinate velocity of light $v_{cv}^2 \equiv v_l^2$ is related not only to its usage only for static states of matter, but also to the usage of the inert free energy $E = m_0 c v_{lc}$ (that is equivalent to gravitational and inert mass) instead of the total internal energy $U = U_0 + U_{ad} = Ec^2 v_{lc}^{-2} + U_{ad} = m_0 c^3/v_{lc} + U_{ad}$ in the expression for the enthalpy of matter and to the ignoring in GR of Lorentz-invariance of thermodynamic parameters and potentials.

Obviously, the spatial homogeneity of the product of inert free energy and multiplicative component of total internal energy of matter $EU_0 = \mathbf{const}(r)$ (that takes place not only for cooled down to the limit matter in GR, but also for quasi-equilibrium cooling down matter) also corresponds to the homogeneity of hierarchic complexity of matter ($R_T = \mathbf{const}(r)$). In this case the inert free energy of one mole of matter that moves in the process of its cooling down is identical to the Hamiltonian $E = E_0\Gamma_m = m_0 c v_l \Gamma_m \equiv \mathrm{H}$ inert free energy at rest E_0 of matter. While the multiplicative component of its total internal energy $U_0 \equiv W = W_0/\Gamma_m = m_0 c^3/v_l \Gamma_m \equiv \mathrm{L}$ that is defined by the proper value of its molar mass is de facto identical to the Lagrangian of ordinary internal energy of matter W_0. The matter potentially can accumulate the correspondent to W_0 total internal energy $U=W_0+U_{ad}>W_0/\Gamma_m+U_{ad}$ after the equilibrium state of rest is reached but only due to the heat exchange with the environment.

And exactly due to the invariance of limit velocity of matter motion in commoving with it FR $v_{lc}=v_l\Gamma_m=\mathbf{inv}$ relatively to the transformation of spatial coordinates and time, not only the Hamiltonian E_0 and Lagrangian W_0, but also the internal energy of matter U (and, thus, all other thermodynamic potentials and thermodynamic parameters of any matter) are Lorentz-invariant.

That is why even in case of the conventional absence of gravitational field conform-Lorentz transformations [Danylchenko, 1994: 22] of increments of coordinates and time and of the velocities of matter motion should be used instead of the ordinary Lorentz transformations. If body moves at velocity v_0 and taking this into account its limit velocity in the direction of motion in FR$_{out}$ of external observer is v_{lx}, then in commoving with it FR$_0$ the increments of coordinates (and, thus, of metrical segments) of its moving objects and time will be as follows:

$$\frac{1}{r'}dx'_m=\frac{1}{r}\frac{dx_m-v_0dt}{\sqrt{1-v_0^2v_{lx}^{-2}}}, \qquad \frac{dy'_m}{r'}=\frac{dy_m}{r}, \qquad \frac{dz'_m}{r'}=\frac{dz_m}{r}, \qquad \frac{v'_l}{r'}dt'=\frac{v_{lx}}{r}\frac{dt-v_0v_{lx}^{-2}dx_m}{\sqrt{1-v_0^2v_{lx}^{-2}}},$$

where: v_m and v_l are the real and limit velocities of motion of observed in FR$_{out}$ object (matter) correspondingly; $v'_l=v_{lx}\Gamma_0$ and $\Gamma_0=(1-v_0^2v_{lx}^{2})^{-1/2}$ are the limit velocity of motion and purely Lorentz dilatation of rate of intrinsic time of the same object in FR$_0$ correspondingly; dx'_m, dy'_m, dz'_m are the increments of metrical segments, and: dx_m, dy_m, dz_m are the increments of coordinates of mobile objects in FR$_{out}$ of observer of the motion of the whole body and its objects; $r'=N_0r=\sqrt{y'^2+z'^2}$ and $r=\sqrt{y^2+z^2}$ are correspondingly the metrical (in both FRs) and in FR$_{out}$ the coordinate segments in transverse section of moving body; $N_0=r'/r=(v'_l/v_{lx})^p=(1-v_0^2v_{lx}^{-2})^{-p/2}$ is the scale factor of the FR$_0$ in FR$_{out}$.

According to this, the transformations of velocities of motion will have the following form:

$$\frac{v'_{mx}}{v'_l}=\frac{1}{v_{lx}}\frac{v_{mx}-v_0}{1-v_0v_{mx}v_{lx}^{-2}}=\frac{1}{c}\frac{\breve{v}_{mx}-\breve{v}_0}{1-\breve{v}_0\breve{v}_{mx}c^{-2}}, \qquad \frac{v'_{my}}{v'_l}=\frac{v_{my}}{v_{lx}}\frac{\sqrt{1-v_0^2v_{lx}^{-2}}}{1-v_0v_{mx}v_{lx}^{-2}}=\breve{v}_{my}\frac{\sqrt{1-\breve{v}_0^2c^{-2}}}{1-\breve{v}_0\breve{v}_{mx}c^{-2}}\frac{v_{ly}}{v_{lx}}, \qquad \frac{v'_{mz}}{v'_l}=\frac{v_{mz}}{v_{lx}}\frac{\sqrt{1-v_0^2v_{lx}^{-2}}}{1-v_0v_{mx}v_{lx}^{-2}},$$

where by the proportionally synchronized clock of observer (by which the limit velocity of motion in the point of instant dislocation of moving body is strictly equal to the constant of velocity of c) the velocities of motion of moving object and of FR$_0$ are equal to $\breve{v}_{mx}=v_{mx}c/v_{lx}$, $\breve{v}_{my}=v_{my}c/v_{ly}$, $\breve{v}_{mz}=v_{mz}c/v_{lz}$ and

$\breve{v}_0 = v_0 c / v_{lx}$ correspondingly. Usage of them instead of the universal astronomic (common planetary) time does not have an effect on the results of observation in FR_0.

From here, when $v_{mx} = v_{lx}$ we will have $v'_{mx} = v'_l$, and when $v_{my} = v_{ly} = v_{lx}(1 - v_0^2 v_{lx}^{-2})^{-1/2} = v'_l$ we will have $v'_{my} = v'_l$. And this means that not only real velocities of propagation of radiation in moving matter but also the alternative to hypothetical vacuum velocity of light limit velocity of matter is anisotropic in moving body in $FR_{out.}$ And it takes its minimal value in the direction of matter motion:

$$v_{lx} = v'_l / N_0^{1/p} = v'_l \sqrt{1 - \breve{v}_0^2 c^{-2}} = v'_l \sqrt{\left(1 + \sqrt{1 - 4 v_0^2 v_l'^{-2}}\right) / 2} ,$$

This its minimal value when gravitational field is hypothetically absent[27] ($v'_l = c$) will be determined by the dependence that guarantees the Lorentz-invariance of thermodynamic potentials and parameters in this case as well:

$$v_{lx} = c \sqrt{\left(1 + \sqrt{1 - 4 v_0^2 c^{-2}}\right) / 2} .$$

It is obvious that not only the fundamentally unobservable in FR of people's world gravitational self-contraction of matter (on the level of its microobjects) in the background Euclidean space [Zel'dovich & Grishchuk, 1988], but also its motion can cause the advance of evolutionary self-contraction of matter of moving bodies in CFREU comparing to the conventionally motionless bodies in it. However, it should be taken into account that the ordinary Lorentz transformations as well as the conform-Lorentz transformations are the transformations of increments of only spatial coordinates and not of metrical segments. Relativistic shrinkages of length and volume of moving bodies should be fundamentally unobservable in the people's world similarly to the gravitational shrinkage of molar volume of matter in background Euclidean space. General covariance of formulation of physical laws will be fulfilled if the kinematic "curvature" (densening) of intrinsic space of observer of moving matter is used instead of them. That is why the molar volume of matter as well as all other its thermodynamic parameters are invariant relatively to spatial-temporal transformations.

Thus, the motion of the matter causes in CO_{out} not only the increasing of its refractive index of radiation $n_x = n_y \left(1 + \sqrt{(1 - 4 v_0 v_l'^{-2})/2}\right)^{-1/2}$ in the direction of the motion, but also the anisotropic relativistic (kinematic) self-contraction of it in both longitudinal and transversal directions [Danylchenko, 2009: 79]. According to this we will have the following expressions for the transformation of increments of metrical segments ($d\breve{x}_m$, $d\breve{y}_m$, $d\breve{z}_m$) and coordinates, and also for the velocities of motion:

[27] Namely the applicability of the concept of limit velocity of motion for the description of not only the gravitational field, but also the motion, urged the author to reject the usage of such a term as coordinate velocity of light.

$$dx'_m \equiv d\widehat{x}'_m = d\widehat{x}_m - \widehat{v}_0 dt = \left(\frac{v'_l}{v_{lx}}\right)^{p+1}(dx_m - v_0 dt) = \frac{dx_m - v_0 dt}{(1-v_0^2 v_{lx}^{-2})^{(p+1)/2}}, \qquad dy'_m \equiv d\widehat{y}'_m = d\widehat{y}_m = \left(\frac{v'_l}{v_{lx}}\right)^{p} dy_m = \frac{dy_m}{(1-v_0^2 v_{lx}^{-2})^{p/2}},$$

$$dz'_m \equiv d\widehat{z}'_m = d\widehat{z}_m = \left(\frac{v'_l}{v_{lx}}\right)^{p} dz_m = \frac{dz_m}{(1-v_0^2 v_{lx}^{-2})^{p/2}}, \qquad dt' = \left(\frac{v'_l}{v_{lx}}\right)^{p}(dt - v_0 v_{lx}^{-2} dx_m) = \frac{dt - v_0 v_{lx}^{-2} dx_m}{(1-v_0^2 v_{lx}^{-2})^{p/2}},$$

$$v'_{mx} = \frac{v'_l}{v_{lx}} \frac{v_{mx} - v_0}{1 - v_0 v_{mx} v_{lx}^{-2}} = \frac{v_{mx} - v_0}{(1 - v_0 v_{mx} v_{lx}^{-2})\sqrt{1 - v_0^2 v_{lx}^{-2}}}, \qquad v'_{my} = \frac{v_{my}}{1 - v_0 v_{mx} v_{lx}^{-2}}, \qquad v'_{mz} = \frac{v_{mz}}{1 - v_0 v_{mx} v_{lx}^{-2}}.$$

According to the increment of interval:

$$(ds)^2 = (dx'_m)^2 + (dy'_m)^2 + (dz'_m)^2 - v_l'^2 (dt')^2 = N_0^2[(dx_m)^2 + (dy_m)^2 + (dz_m)^2 - v_{lx}^2 (dt)^2] = (d\widehat{x}_m)^2 + (d\widehat{y}_m)^2 + (d\widehat{z}_m)^2 - v_l'^{2p} v_{lx}^{2(1-p)} (dt)^2$$

when: $dx'_m = 0$, $dy'_m = 0$ and $dz'_m = 0$ we will have $dx_m = v_0 dt$, and $v_l'^2 (dt')^2 = N_0^2 (1 - v_0^2 v_{lx}^{-2}) v_{lx}^2 (dt)^2 = v_l'^{2(p-1)} v_{lx}^{2(2-p)} (dt)^2$. According to this the Lorentz dilatation of the rate of intrinsic time of moving body will take place when scale factor is $N_0 = v'_l / v_{lx} = (1 - v_0^2 v_{lx}^{-2})^{-1/2}$ $(p=1)$[28], and will be absent when scale factor is $N_0 = (v'_l / v_{lx})^2 = (1 - v_0^2 v_{lx}^{-2})^{-1}$ $(p=2,\ dt' = dt)$. And, consequently, it is quite possible that there indeed should not be any time dilatation of the rate of count of moving clock. However, of course, this can be related only to inertial motion ob body in the Universal gravitational field that surrounds it, while purely Lorentz dilatation of the rate of time in commoving to moving body FR_0 is completely compensated by all-round self-contraction of this body in FR_{out} ($N_0 = \Gamma_0^2$). At least, the deceleration of orbital motion of astronomical objects of far galaxies that are distancing from us at high velocities is not confirmed by astronomical observations[29]. When we artificially accelerate any body it is as if we sent it to the cosmological future relatively to conventionally resting in the Universe bodies. And after it starts inertially moving under the influence of Universal gravitational field it will only gradually lose its accumulated energy due to its deceleration by the matter of the outer space. And only when its kinetic energy will start to correspond to the certain trajectory of motion in Universal gravitational field there will be no time dilatation of the rate of count of its clock by the motion. Because of conform Lorentz-invariance not only of ordinary $W = m_0 c^3 / v'_l$ $(v'_l \equiv v_{lc} = \Gamma_0 v_{lx})$ and total $U = W + U_{ad}$ internal energies of matter, but also of its inert free energy $E = m_0 c v'_l$, its momentum will be determined in the following way:

---

[28] According to condition of GR for the conventionally empty space $ab=1$ coordinate value of conform-Lorentz shrinkage of the length of matter of moving body is in inverse ratio to v_{lx}.

[29] Astronomers, quite the contrary, are looking for non-baryonic dark matter, which would allow to explain the quite big velocities of orbital motion of astronomical objects on the edge of far galaxies that are distancing from us at high velocities. Moreover, in order to explain the imaginary accelerated expansion of the Universe (that follows from the false notion about the dilatation of intrinsic time of distant galaxies) astronomers are forced to “fill” the Universe also with dark energy.

$$\mathbf{P}_0=\sqrt{E^2v_{lx}^{-2}-E_0^2c^{-2}}=vv_{lx}^{-2}E=m_0v_0cv_l'v_{lx}^{-2}=\frac{2cm_0v_0}{v_l'+\sqrt{v_l'^2-4v_0^2}}=m_0c\sqrt{v_l'^2v_{lx}^{-2}-1}\,.$$

And since integration by parameter R_T takes place in the space, because of $R_T=R_{T0}=\mathbf{const}(r)$ the spatial additive compensation U_{ad} for quasi-equilibrium cooling down matter is not only invariable but is also can be very insignificant. And this, obviously, takes place not only far from the sources of radiation in molecular clouds of cold non-ionized gas, but also in highly rarefied cold plasma of the outer space even despite its mainly non-equilibrium thermodynamic state. In contrast to the condition of quasi-equilibrium of cooling down $A_\rho=\mathbf{const}(t)$, the condition of spatial homogeneity of hierarchical complexity $R_T=\mathbf{const}(r)$ for this plasma can also be fulfilled. And, consequently, not only in quasi-equilibrium cooling down matter, but also in the outer space the U_{ad} can be negligibly small ($\varsigma_a\approx 1$). However, even if spatial additive compensation U_{ad} would take any arbitrary small value the total internal energy of matter fundamentally cannot be smaller than its component – the inert free energy E, since: $U=U_0+U_{ad}>U_0=Ec^2v_l^{-2}\Gamma_m^{-2}=\Gamma_m mc^4v_{lc}^{-2}$.

Due to the smallness of U_{ad} not only the logarithm[30] of ordinary internal energy, but also logarithms total internal energy and enthalpy can be used as gravitational potential:

$$\mathbf{grad}\varphi=c^2\mathbf{grad}\ln W\approx c^2\mathbf{grad}\ln U\,,$$

$$\mathbf{grad}\varphi=c^2\mathbf{grad}\ln H_{T0}\approx c^2\mathbf{grad}\ln H_T=-\varsigma c^2\mathbf{grad}\ln(v_{lc}/c)=-\varsigma c^2\mathbf{grad}[\ln(v_l/c)+\ln\Gamma_m]\,,$$

where: $\varsigma=1/[1+U_{ad}/U_{cr}\psi_{m0}c(1+\widetilde{\beta}_{pV})]$ is the coefficient of resistance of matter of the environment to the fall of bodies in gravitational field. And, so, self-creation by matter of the own spatially inhomogeneous thermodynamic state is responsible for the appearance of gravitational field in it.

Since parameter:

$$R_T=\frac{TS}{A_\rho}=\frac{U_{cr}\widetilde{\beta}_{ST}q_MN_l\ln(q_M^{\tilde{l}}N_l)}{A_\rho}=\frac{U_{cr}\widetilde{\beta}_{ST}c\psi_m[\ln\psi_m-\ln(v_l/c)+(\tilde{l}-1)\ln(v_{cm}/c)]}{A_\rho v_l}\neq R_{T0}$$

[30] Only such logarithmic gravitational potentials can correspond to the Einstein concept of inertia of free fall of bodies in gravitational field. Exactly when gravitational potential is equal to the logarithm of coordinate velocity of light in hypothetical absolute vacuum the Hamiltonian of body that falls free in this vacuum is conserved in GR ($\varsigma_v=1$) [Danylchenko, 2020: 85]. Moreover, due to mutual dependence of gravitational potential (that is the logarithmic function of the limit velocity of matter) and thermodynamic parameters of matter there can be a misconception about the possibility to locally change the strength of gravitational field via the change of matter thermodynamic state. However it is not true, since the spatial distribution of the strength of gravitational field is the product of collective spatially inhomogeneous state of the whole gravithermodynamically bonded matter. Therefore, any matter that is located in this gravitational field should obey the collective influence. Namely the logarithmicity of gravitational potential allows to gaugely change it without changing the strength of gravitational field.

expressed not only via constants (including also A_ρ=**const**(t) which characterizes the quasi-equilibrium of the process of cooling down of matter throughout the whole time), but also via velocity of the light in matter v_{cm}, limit velocity of motion v_l and purely Lorentz dilatation of the rate of flowing of intrinsic time of the matter that moves in the process of quasi-equlibriumly cooling down $\Gamma_m \neq \mathbf{const}(r)$ ($\psi_m = \psi_{m0}/\Gamma_m \neq \mathbf{const}(r)$), then only via them we can in temporal form (via A_ρ) or in spatial form (via $a_\rho \equiv R_T$) express instantaneous values of all main thermodynamic parameters and potentials of RGTD-bonded matter:

$$\breve{T}=\frac{\breve{A}_\rho\beta_{pV}}{\beta_{ST}(l\ln q_M+\ln N_I)}=\frac{\breve{A}_\rho\beta_{pV}}{\beta_{ST}[\ln\psi_{m0}-\ln(v_{lc}/c)+(l-1)\ln(v_{cm}/c)]}=$$

$$=\frac{U_{cr}\beta_{pV}q_M N_I}{\breve{R}_T}=\frac{U_{cr}\beta_{pV}c\psi_{m0}}{\breve{R}_T v_{lc}}=\frac{\breve{p}\breve{V}}{\breve{R}_T}=\frac{U_{cr}\beta_{pV}}{\breve{R}_T}\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{S}}{\breve{R}_T}\right)\right]^{\beta_{pV}}=$$

$$=\beta_{pV}\breve{A}_\rho\left[\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)+(1+\beta_{pV})\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]^{-1}=\frac{U_{cr}\beta_{pV}}{\breve{R}_T}\left[\frac{\breve{p}}{p_l\beta_{pV}}\exp\left(\frac{\breve{S}}{\breve{R}_T}\right)\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}},$$

$$\breve{S}=\frac{U_{cr}\beta_{ST}^2 q_M N_I(l\ln q_M+\ln N_I)^2}{\beta_{pV}\breve{A}_\rho}=\frac{\beta_{ST}\breve{R}_T(l\ln q_M+\ln N_I)}{\beta_{pV}}=$$

$$=\frac{U_{cr}c\psi_{m0}\beta_{ST}^2[\ln\psi_{m0}-\ln(v_{lc}/c)+(l-1)\ln(v_{cm}/c)]^2}{\beta_{pV}\breve{A}_\rho v_{lc}}=$$

$$=(\beta_{ST}\breve{R}_T/\beta_{pV})[\ln\psi_{m0}-\ln\Gamma_m-\ln(v_l/c)+(l-1)\ln(v_{cm}/c)]=$$

$$=\frac{U_{cr}\beta_{pV}\breve{A}_\rho}{\breve{T}^2}\left[\frac{\breve{p}}{p_l\beta_{pV}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{\beta_{pV}}{\beta_H}}=\frac{U_{cr}\beta_{pV}\breve{A}_\rho}{\breve{T}^2}\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}=$$

$$=(\beta_{pV}^{-2}\breve{p}\breve{V}/\breve{A}_\rho)[\ln(\breve{p}/p_l\beta_{pV})+\beta_H\ln(\breve{V}p_l/U_{cr})]^2,$$

$$\breve{p}=p_l\beta_{pV}q_M^{1+1/k}N_I^{1+m}=p_l\beta_{pV}\left(\frac{c\psi_{m0}}{\Gamma_m v_l}\right)^{1+m}\left(\frac{c}{v_{cm}}\right)^{m-1/k}=\frac{\breve{R}_T\breve{T}}{\breve{V}}=$$

$$=p_l\beta_{pV}\left(\frac{U_{cr}}{p_l\breve{V}}\right)^{1+\beta_{pV}}\exp\left(\frac{\beta_{pV}\breve{A}_\rho}{\breve{T}}\right)=p_l\beta_{pV}\left(\frac{\breve{R}_T\breve{T}}{U_{cr}\beta_{pV}}\right)^{1+1/\beta_{pV}}\exp\left(-\frac{\breve{S}}{\breve{R}_T}\right)=$$

$$=p_l\beta_{pV}\left(\frac{\breve{S}\breve{T}^2}{U_{cr}\beta_{pV}\breve{A}_\rho}\right)^{1+\frac{1}{\beta_{pV}}}\exp\left(-\frac{\breve{A}_\rho}{\breve{T}}\right)=p_l\beta_{pV}\left(\frac{U_{cr}}{p_l\breve{V}}\right)^{1+\beta_{pV}}\exp\left(\frac{\beta_{pV}\breve{S}}{\breve{R}_T}\right),$$

$$\breve{V}=\frac{U_{cr}}{p_l q_M^{1/k} N_I^m}=\frac{U_{cr}}{p_l}\left(\frac{v_{lc}}{c\psi_{m0}}\right)^m\left(\frac{v_{cm}}{c}\right)^{m-\frac{1}{k}}=\frac{\breve{R}_T\breve{T}}{\breve{p}}=$$

$$=\frac{U_{cr}}{p_l}\left[\left(\frac{p_l\beta_{pV}}{\breve{p}}\right)\exp\left(\frac{\beta_{pV}\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{1}{1+\beta_{pV}}}=\frac{U_{cr}}{p_l}\left(\frac{U_{cr}\beta_{pV}}{\breve{R}_T\breve{T}}\right)^{\frac{1}{\beta_{pV}}}\exp\left(\frac{\breve{S}}{\breve{R}_T}\right)=$$

$$=\frac{U_{cr}}{p_l}\left(\frac{U_{cr}\beta_{pV}\breve{A}_\rho}{\breve{S}\breve{T}^2}\right)^{\frac{1}{\beta_{pV}}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)=\frac{U_{cr}}{p_l}\left[\left(\frac{p_l\beta_{pV}}{\breve{p}}\right)\exp\left(\frac{\beta_{pV}\breve{S}}{\breve{R}_T}\right)\right]^{\frac{1}{1+\beta_{pV}}},$$

$$\breve{U}=\breve{U}_0+\breve{U}_{ad}=U_{cr}q_M N_I+\int_{\breve{R}_{T0}}^{\breve{R}_T}\breve{S}\breve{T}\frac{d\breve{R}_T}{\breve{R}_T}=\breve{U}_0+\breve{S}\breve{T}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{S}\breve{T}\frac{d\breve{A}_\rho}{\breve{A}_\rho}=$$

$$=U_{cr}[1+\beta_{ST}\ln(q_M^l N_I)]q_M N_I-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=\frac{U_{cr}\psi_{m0}c}{v_{lc}}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\breve{S}\breve{T}\frac{d\breve{R}_T}{\breve{R}_T}=\breve{S}\breve{T}\left(1+\frac{\breve{T}}{\beta_{pV}\breve{A}_\rho}\right)-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{S}\breve{T}\frac{d\breve{A}_\rho}{\breve{A}_\rho}=$$

$$=U_{cr}\left(1+\frac{\beta_{pV}\breve{A}_\rho}{\breve{T}}\right)\left[\frac{\breve{p}}{p_l\beta_{pv}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=$$

$$=U_{cr}\left(1+\frac{\beta_{pV}\breve{A}_\rho}{\breve{T}}\right)\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T a\breve{A}_\rho=\frac{\breve{p}\breve{V}}{\beta_{pV}}\left[1+\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)+(1+\beta_{pV})\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho,$$

$$\breve{F}_T=\breve{U}_0-\breve{U}_{ad}^*=U_{cr}q_M N_I-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=\frac{U_{cr}c\psi_{m0}}{v_{lc}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=$$

$$=\frac{\breve{p}\breve{V}}{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\breve{p}\breve{V}}{\beta_{pV}}\left[\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)+(1+\beta_{pV})\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]\frac{d\breve{A}_\rho}{\breve{A}_\rho}=\frac{\breve{S}\breve{T}^2}{\beta_{pV}\breve{A}_\rho}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{S}\breve{T}\frac{d\breve{A}_\rho}{\breve{A}_\rho}=$$

$$=U_{cr}\left\{\left[\frac{\breve{p}}{p_l\beta_{pv}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\beta_{pV}}{\breve{T}}\left[\frac{\breve{p}}{p_l\beta_{pV}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}d\breve{A}_\rho\right\}=$$

$$=U_{cr}\left\{\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\beta_{pV}}{\breve{T}}\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}d\breve{A}_\rho\right\},$$

$$\breve{H}_T=\breve{H}_{T0}+\breve{a}_\rho\breve{A}_\rho-\breve{U}_{ad}^*=\breve{H}_{T0}+\breve{S}\breve{T}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{S}\breve{T}\frac{d\breve{A}_\rho}{\breve{A}_\rho}=U_{cr}(1+\beta_{pV})q_M N_I+\int_{\breve{R}_{T0}}^{\breve{R}_T}\breve{A}_\rho d\breve{R}_T=$$

$$=\breve{H}_{T0}+\breve{U}_{ad}=U_{cr}[(1+\beta_{pV})+\beta_{ST}\ln(q_M^l N_l)]q_M N_l-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=$$

$$=\frac{U_{cr}(1+\beta_{pV})\psi_{m0}c}{v_{lc}}+\int_{\breve{R}_{T0}}^{\breve{R}_T}\breve{S}\breve{T}\frac{d\breve{R}_T}{\breve{R}_T}=\breve{S}\breve{T}\left(1+\frac{(1+\beta_{pV})\breve{T}}{\beta_{pV}\breve{A}_\rho}\right)-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{S}\breve{T}\frac{d\breve{A}_\rho}{\breve{A}_\rho}=$$

$$=U_{cr}\left\{\left(1+\beta_{pV}+\frac{\beta_{pV}\breve{A}_\rho}{\breve{T}}\right)\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\beta_{pV}}{\breve{T}}\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}d\breve{A}_\rho\right\}=$$

$$=U_{cr}\left(1+\beta_{pV}+\frac{\beta_{pV}\breve{A}_\rho}{\breve{T}}\right)\left[\frac{\breve{p}}{p_l\beta_{pV}}\exp\frac{\breve{A}_\rho}{\breve{T}}\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}-U_{cr}\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\beta_{pV}}{\breve{T}}\left[\frac{\breve{p}}{p_l\beta_{pV}}\exp\frac{\breve{A}_\rho}{\breve{T}}\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}d\breve{A}_\rho=$$

$$=\frac{\breve{p}\breve{V}(1+\beta_{pV})}{\beta_{pV}}\left[1+\frac{1}{1+\beta_{pV}}\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)+\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]-\frac{1}{\beta_{pV}}\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{p}\breve{V}\left[\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)+(1+\beta_{pV})\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]\frac{d\breve{A}_\rho}{\breve{A}_\rho},$$

$$\breve{G}=\breve{H}_{T0}-\breve{U}_{ad}^*=\frac{U_{cr}(1+\beta_{pV})\psi_{m0}c}{v_{lc}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=\frac{(1+\beta_{pV})\breve{S}\breve{T}^2}{\beta_{pV}\breve{A}_\rho}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{S}\breve{T}\frac{d\breve{A}_\rho}{\breve{A}_\rho}=$$

$$=\frac{(1+\beta_{pV})\breve{p}\breve{V}}{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\breve{p}\breve{V}}{\beta_{pV}}\left[\ln\left(\frac{\breve{p}}{p_l\beta_{pV}}\right)+(1+\beta_{pV})\ln\left(\frac{p_l\breve{V}}{U_{cr}}\right)\right]\frac{d\breve{A}_\rho}{\breve{A}_\rho}=$$

$$=U_{cr}\left\{(1+\beta_{pV})\left[\frac{\breve{p}}{p_l\beta_{pv}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\beta_{pV}}{\breve{T}}\left[\frac{\breve{p}}{p_l\beta_{pV}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\frac{\beta_{pV}}{1+\beta_{pV}}}d\breve{A}_\rho\right\}=$$

$$=U_{cr}\left\{(1+\beta_{pV})\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}-\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\frac{\beta_{pV}}{\breve{T}}\left[\frac{U_{cr}}{p_l\breve{V}}\exp\left(\frac{\breve{A}_\rho}{\breve{T}}\right)\right]^{\beta_{pV}}d\breve{A}_\rho\right\},$$

where: $\left(\frac{\partial\breve{U}}{\partial\breve{A}_\rho}\right)_{\breve{S},\breve{V}}=0$, $\left(\frac{\partial\breve{H}_T}{\partial\breve{A}_\rho}\right)_{\breve{S},\breve{p}}=0$, $\left(\frac{\partial\breve{F}_T}{\partial\breve{A}_\rho}\right)_{\breve{T},\breve{V}}=0$, $\left(\frac{\partial\breve{G}}{\partial\breve{A}_\rho}\right)_{\breve{T},\breve{p}}=0$;

$v_{lc}=\Gamma_m v_l$ is the limit velocity of quasi-equilibrium cooling down matter in comoving with it FR (in its own space-time continuum (STC), in which the radial motion of molecules of cooling down matter is absent); $\breve{U}_{ad}^*=\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}\breve{R}_T d\breve{A}_\rho=\int_{\breve{A}_{\rho0}}^{\breve{A}_\rho}(\breve{S}\breve{T}/\breve{A}_\rho)d\breve{A}_\rho\geq0$ is instantaneous value of partial additive compensation of multiplicative representation of thermodynamic potentials of matter microstate (multiplicative increase of bound energy as we approach the gravity center); $\breve{G}$ is the instantaneous value of Gibbs energy G (that is similar to the Lagrangian, since it constantly tends to its minimum too).

As we can see, due to $A_\rho(r)=\mathbf{const}(t)$ when homogeneous matter is quasi-equilibrium cooling down the changes in time of its Gibbs free energy and Helmholtz free energy take place similarly to the changes in space of multiplicative component of internal energy U_0 and enthalpy H_{T0} correspondingly[31]. Precisely, if:

$$\left(\frac{\partial U}{\partial \hat{t}}\right)_r = -(U+U_{ad}^*)\left\{1+\frac{\tilde{\beta}_{ST}}{1+\tilde{\beta}_{ST}\left[\ln(c\psi_{m0}/v_{lc})+(\tilde{l}-1)\ln n_m\right]}\right\}\left[\left(\frac{\partial \ln v_l}{\partial \hat{t}}\right)_r+\left(\frac{\partial \Gamma_m}{\partial \hat{t}}\right)_r\right]+$$

$$+\frac{(U+U_{ad}^*)\tilde{\beta}_{ST}(\overleftrightarrow{l}-1)}{1+\tilde{\beta}_{ST}[\ln(c\psi_{m0}/v_{lc})+(\tilde{l}-1)\ln n_m]}\left(\frac{\partial \ln n_m}{\partial \hat{t}}\right)_r, \text{ then:}$$

$$\left(\frac{\partial F_T}{\partial \hat{t}}\right)_r = -S\left(\frac{\partial T}{\partial \hat{t}}\right)_r - p\left(\frac{\partial V}{\partial \hat{t}}\right)_r = -U_0\left(\frac{\partial \ln v_{lc}}{\partial \hat{t}}\right)_r = -U_0\left[\left(\frac{\partial \ln \Gamma_m}{\partial \hat{t}}\right)_r+\left(\frac{\partial \ln v_l}{\partial \hat{t}}\right)_r\right],$$

$$\left(\frac{\partial G}{\partial \hat{t}}\right)_r = -S\left(\frac{\partial T}{\partial \hat{t}}\right)_r + V\left(\frac{\partial p}{\partial \hat{t}}\right)_r = -H_{T0}\left(\frac{\partial \ln v_{lc}}{\partial \hat{t}}\right)_r = -H_{T0}\left[\left(\frac{\partial \ln \Gamma_m}{\partial \hat{t}}\right)_r+\left(\frac{\partial \ln v_l}{\partial \hat{t}}\right)_r\right],$$

where: $\partial \hat{t}$ is the increment of metric time of cooling down matter in a comoving with it FR.

In the process of free fall of matter in gravitational field the Helmholtz and Gibbs thermodynamic free energies, as well as the Hamiltonian of inert free energy of matter, are conserved not only due to the presence of weightlessness in its FR ($v_{lc}=\Gamma_m v_l=\mathbf{const}(t)$), but also due to the total compensation of the influence of gravitation on its thermodynamic state by the motion. However it is possible only in hypothetical absolutely empty space. But when there is a resistance to motion these energies will be gradually increasing due to the matter cannot reach the required for their conservation value Γ_m and thus also due to accommodation of the matter of falling body to the new thermodynamic state of matter of the environment.

Before the appearance of spatial inhomogeneity of limit velocity of matter v_l the only thing that could interfere its distancing from the future gravity center (due to tending of its Gibbs thermodynamic energy to its minimum) was the electromagnetic interaction of its molecules. That is why the hypothetic ideal gas and ideal liquid in principle cannot create their gravitational field.

As we see, here we have a dependency of spatial distribution of intrinsic values of these thermodynamic parameters and potentials (not the dependency of spatial distribution of other their values observed by other clocks and by other length standards) on v_{lc} (and, so, also on Γ_m and v_l). It

[31] The authors of GR, obviously, intuitively understood this fact. That is why GR is the genial creation, despite the fact that it ignores the principal invariance of thermodynamic parameters and potentials relatively to space-time transformations.

would be non-logical if Γ_m and v_l would not influence on spatial distribution of the set of intrinsic values of main thermodynamic parameters of matter. So this does not contradict to invariance of thermodynamic parameters and potentials of matter relatively to the space-time transformations. On the contrary, it only confirms the fact that limit velocity of matter motion v_l, as well as Γ_m, is the internal hidden RGTD-parameter of matter and not the non-dependent on certain RGTD-state of matter external gravitational parameter.

At Tolman condition (3) and when $\beta_{pV}=\mathbf{const}(r)$ the parameter R_T should be invariable not only in space, but also in time. And this can correspond to the substance that abnormally cooling down ($S\neq\mathbf{const}(r)$) and due to $TS=R_T A_\rho=\mathbf{const}(r)$ has exactly the following thermodynamic parameters:

$$T=T_g^* c/v_{lc}, \qquad S=S_g^* v_{lc}/c\,^{32}, \qquad p=p_{cr}\left(\frac{v_{lc}}{v_{lc/cr}}\right)^{-\frac{\tilde{\beta}_H}{\tilde{\beta}_{pV}}}\exp\left[\frac{\tilde{\beta}_H(R_T A_\rho-U_{ad}^*)(v_{lc/cr}-v_{lc})}{\tilde{\beta}_{pV}H_{T0g}^*}\right],$$

$$V=\frac{c\tilde{\beta}_{pV}H_{T0g}^*}{v_{lc/cr}\tilde{\beta}_H p_{cr}}\left(\frac{v_{lc}}{v_{lc/cr}}\right)^{\frac{1}{\tilde{\beta}_{pV}}}\exp\left[\frac{\tilde{\beta}_H(R_T A_\rho-U_{ad}^*)(v_{lc}-v_{lc/cr})}{\tilde{\beta}_{pV}H_{T0g}^*}\right],$$

where: $T_g^*=\mathbf{const}(r)$, $S_g^*=\mathbf{const}(r)$, $H_{T0g}^*=H_{T0}v_{lc}/c=\mathbf{const}(r)$, $pV=c\tilde{\beta}_{pV}H_{T0g}^*/v_{lc}\tilde{\beta}_H$; p_{cr} and $v_{lc/cr}$ are the critical values of parameters on the phase boundary of the substance or between substances.

The refractive index of such matter:

$$n_m=\left[\frac{c\psi_{m0}}{v_{lc}}\exp\left(-\frac{v_{lc}R_T A_\rho}{c\psi_{m0}U_{cr}\tilde{\beta}_{ST}}\right)\right]^{1/(\tilde{l}-1)}$$

depends not only on values of its characteristic parameters ψ_{m0} and U_{cr} and on the limit velocity of its motion v_{lc}, but also on the parameters $\tilde{l}$, $\tilde{\beta}_{ST}$ and R_T, that change in time together with the cooling down of matter.

Obviously, the stability of magnitude of extensive parameter $A_\rho=T^2S/pV$ takes place in the process of quasi-equilibrium cooling down of matter. If we experimentally find its averaged value for researched matter at the beginning of the research or if we measure the increments of thermodynamic parameters:

$$\left(\frac{\partial\ln S}{\partial\hat{t}}\right)_r=\left(\frac{\partial\ln p}{\partial\hat{t}}\right)_r+\left(\frac{\partial\ln V}{\partial\hat{t}}\right)_r-2\left(\frac{\partial\ln T}{\partial\hat{t}}\right)_r,$$

we can determine its entropy:

---

[32] Such spatial distribution of entropy does not correspond to the condition (4) and, therefore, is abnormal. Possibly it can be peculiar for astronomical formations that have extraordinary topology.

$$S=\frac{U_{cr}\widetilde{\beta}_{pV}A_\rho}{T^2}\left[\frac{p}{p_l\widetilde{\beta}_{pv}}\exp\left(\frac{A_\rho}{T}\right)\right]^{\frac{\widetilde{\beta}_{pV}}{\widetilde{\beta}_H}}=\frac{U_{cr}\widetilde{\beta}_{pV}A_\rho}{T^2}\left[\frac{U_{cr}}{p_lV}\exp\left(\frac{A_\rho}{T}\right)\right]^{\widetilde{\beta}_{pV}}=\frac{pV}{\widetilde{\beta}_{pV}^2A_\rho}\left[\ln\left(\frac{p}{\widetilde{\beta}_{pV}p_l}\right)+\widetilde{\beta}_H\ln\left(\frac{p_lV}{U_{cr}}\right)\right]^2=$$

$$=\frac{A_\rho R_T}{T}=R_T\left[\frac{1}{\widetilde{\beta}_{pV}}\ln\left(\frac{R_TT}{\widetilde{\beta}_{pV}U_{cr}}\right)+\ln\left(\frac{p_{cr}V}{U_{cr}}\right)\right]=R_T\left[\widetilde{\varepsilon}+\frac{1}{\widetilde{\beta}_{pV}}(\ln R_T+\ln T)+\ln V\right]=$$

$$=R_T\left[\left(1+\frac{1}{\widetilde{\beta}_{pV}}\right)\ln\left(\frac{R_TT}{\widetilde{\beta}_{pV}U_{cr}}\right)-\ln\left(\frac{p}{\widetilde{\beta}_{pV}p_{cr}}\right)\right]=R_T\left[\widetilde{\varepsilon}+\left(1+\frac{1}{\widetilde{\beta}_{pV}}\right)(\ln R_T+\ln T)-\ln p\right]=$$

$$=R_T\left[\left(1+\frac{1}{\widetilde{\beta}_{pV}}\right)\ln\left(\frac{p_{cr}V}{U_{cr}}\right)+\frac{1}{\widetilde{\beta}_{pV}}\ln\left(\frac{p}{\widetilde{\beta}_{pV}p_{cr}}\right)\right]=R_T\left[\widetilde{\varepsilon}+\left(1+\frac{1}{\widetilde{\beta}_{pV}}\right)\ln V+\frac{\ln p}{\widetilde{\beta}_{pV}}\right],$$

where: $\widetilde{\varepsilon}=\ln p_{cr}-(1+1/\widetilde{\beta}_{pV})\ln(m_0c^3/v_{lcr})-(\ln\widetilde{\beta}_{pV})/\widetilde{\beta}_{pV}=\mathbf{const}(\Delta t)$ and $\widetilde{\beta}_{pV}=\mathbf{const}(\Delta t)$ are mathematical expectations of the values of functions of arbitrary changing hidden variables *l, k*, *m*, *n,* which are the strictly constant magnitudes during the whole not very long time of the existence of any Gibbs thermodynamic microstate.

However, if we know $\widetilde{\varepsilon}$ and $\widetilde{\beta}_{pV}$ and if we determine only the molar volume of quasi-equilibrium cooling down gas and the pressure in it, then we can determine only its bond energy:

$$W_{bnd}=ST=Vp\left[\widetilde{\varepsilon}+\left(1+\frac{1}{\widetilde{\beta}_{pV}}\right)\ln V+\frac{\ln p}{\widetilde{\beta}_{pV}}\right]. \tag{5}$$

In order to determine the entropy and, thus, the value of parameter A_ρ we should additionally measure the temperature of the gas. It is obvious that parameters $\widetilde{\varepsilon}$ and $\widetilde{\beta}_{pV}$ of the equation of the state of gas (5) can be determined also experimentally in the process of controlled change of its bond energy as well as of all its thermodynamic parameters.

The research of thermodynamic properties of matter should be performed only in its equilibrium states or using the dependencies of its thermodynamic potentials on thermodynamic parameters that take into account the variability of parameter R_T in the process of this research ($R_T\neq\mathbf{const}(t)$). In order to determine both the thermal expansion coefficient α and pressure γ and the elastic modulus K_T of gas or liquid it is enough to know only the thermal equation of the state (parameter R_T):

$$\alpha=\frac{1}{V_0}\left(\frac{\partial V}{\partial T}\right)_p=\frac{1}{V_0p}\left[R_T+T\left(\frac{\partial R_T}{\partial T}\right)_p\right],\qquad \gamma=\frac{1}{p_0}\left(\frac{\partial p}{\partial T}\right)_V=\frac{1}{p_0V}\left[R_T-T\left(\frac{\partial R_T}{\partial T}\right)_V\right],$$

$$K_T=-V_0\left(\frac{\partial p}{\partial V}\right)_T=\frac{R_TT}{V_0}-T\left(\frac{\partial R_T}{\partial V}\right)_T.$$

In order to determine their thermal capacity when volume and pressure are invariant[33] and, thus, all their thermodynamic potentials we should know not only R_T and critical phasic values of pressure p_{cr} and of internal energy multiplicative component $U_{cr}=m_0c^3/v_{lcr}$, but also the mathematical expectation $\tilde{\beta}_{pV}$ of the value of hidden variable $\beta_{pV}=\breve{p}\breve{V}/\breve{U}_0$:

$$C_V=\left(\frac{\partial U}{\partial T}\right)_V=\frac{1}{\tilde{\beta}_{pV}}\left[R_T+T\left(1+\frac{\tilde{\beta}_{pV}S}{R_T}\right)\left(\frac{\partial R_T}{\partial T}\right)_V\right]=\frac{1}{\tilde{\beta}_{pv}}\left\{R_T+T\left[1+(1+\tilde{\beta}_{pV})\ln\left(\frac{R_TT}{\tilde{\beta}_{pV}U_{cr}}\right)-\tilde{\beta}_{pV}\ln\left(\frac{p}{\tilde{\beta}_{pV}p_l}\right)\right]\left(\frac{\partial R_T}{\partial T}\right)_V\right\}=$$

$$=T\left(\frac{\partial S}{\partial T}\right)_V=\frac{1}{\tilde{\beta}_{pv}}\left\{R_T+T\left[1+\ln\left(\frac{R_TT}{\tilde{\beta}_{pV}U_{cr}}\right)+\tilde{\beta}_{pV}\ln\left(\frac{p_lV}{U_{cr}}\right)\right]\left(\frac{\partial R_T}{\partial T}\right)_V\right\},$$

$$C_p=T\left(\frac{\partial S}{\partial T}\right)_p=\left(\frac{\partial U}{\partial T}\right)_p+R_T+T\left(\frac{\partial R_T}{\partial T}\right)_p=\frac{1+\tilde{\beta}_{pV}}{\tilde{\beta}_{pV}}\left[R_T+T\left(1+\frac{\tilde{\beta}_{pV}S}{(1+\tilde{\beta}_{pV})R_T}\right)\left(\frac{\partial R_T}{\partial T}\right)_p\right],$$

$$C_p-C_V=R_T+T\left[\left(\frac{1+\tilde{\beta}_{pV}}{\tilde{\beta}_{pV}}+\frac{S}{R_T}\right)\left(\frac{\partial R_T}{\partial T}\right)_p-\left(\frac{1}{\tilde{\beta}_{pV}}+\frac{S}{R_T}\right)\left(\frac{\partial R_T}{\partial T}\right)_V\right],\qquad U=\frac{R_TT}{\tilde{\beta}_{pV}}+\int_{R_{T0}}^{R_T}\frac{TS}{R_T}dR_T.$$

Based on thermodynamic dependencies of thermal capacities when volume and pressure are invariant we can determine the mathematical expectation of dependencies of these functions on individual parameters R_T and θ, and, consequently, on any pair of main thermodynamic parameters:

$$\tilde{\beta}_{pV}=\frac{R_TT}{U_0}=\frac{R_T\left[\left(\frac{\partial R_T}{\partial T}\right)_p-\left(\frac{\partial R_T}{\partial T}\right)_V\right]}{C_V\left(\frac{\partial R_T}{\partial T}\right)_p-(C_p-R_T)\left(\frac{\partial R_T}{\partial T}\right)_V+T\left(\frac{\partial R_T}{\partial T}\right)_p\left(\frac{\partial R_T}{\partial T}\right)_V}.$$

The following correspond to the thermal Van der Waals equation of the state of real gases:

$$R_T=\frac{pV}{T}=\frac{R_{UT}}{(1+a/pV^2)(1-b/V)}=\frac{R_{UT}V}{V-b}-\frac{a}{TV}=R_{UT}\left[\frac{V}{V-b}-\theta\right],\qquad \theta=\frac{a}{R_{UT}TV},$$

$$dV=\frac{V^2[R_{UT}dT-(V-b)dp]}{pV^2-a(1-2b/V)},\qquad \left(\frac{\partial R_T}{\partial T}\right)_V=\frac{a}{T^2V}=\frac{R_{UT}\theta}{T},$$

$$\left(\frac{dR_T}{\partial T}\right)_p=\frac{p}{T}\left[\left(\frac{\partial V}{\partial T}\right)_p-\frac{V}{T}\right]=\frac{(R_{UT}-R_T)+a(1-2b/V)/(TV)}{T[1-a(1-2b/V)/(pV^2)]}=\frac{R_T\{R_{UT}[1+\theta(1-2b/V]-R_T\}}{T[R_T-R_{UT}\theta(1-2b/V)]},$$

$$\tilde{\beta}_{pV}=\frac{R_T\{R_T[R_{UT}(1-2\theta\, b/V)-R_T]+R_{UT}^2\theta^2(1-2b/V)\}}{R_T(C_V+R_{UT}\theta)\{R_{UT}[1+\theta(1-2b/V)]-R_T\}-R_{UT}\theta(C_p-R_T)[R_T-R_{UT}\theta(1-2b/V)]},$$

where: *a* and *b* are individual constants of certain matter.

---

[33] Heat capacity when pressure is invariant is determined not by internal energy of the matter itself, but by equivalent to its enthalpy the energy of extended system that consists of this matter and the load that supports the needed pressure.

According to this we receive the simple expression for the entropy of hypothetical ideal gas:

$$S=C_{V0}\ln\left(\frac{C_{V0}T}{U_{cr}}\right)+R_{UT}\ln\left(\frac{C_{V0}p_{cr}V}{R_{UT}U_{cr}}\right)=S_{cr}+C_{V0}\ln\left(\frac{T}{T_{cr}}\right)+R_{UT}\ln\left(\frac{V}{V_{cr}}\right)=S_k+C_{V0}\ln\left(\frac{T}{T_k}\right)+R_{UT}\ln\left(\frac{V}{V_k}\right),$$

where: $S_{cr}=(C_{V0}+R_{UT})\ln(C_{V0}T_{cr}/U_{cr})$, $C_{V0}=R_{UT}/\widetilde{\beta}_{pV}$; $V_{cr}=R_{UT}T_{cr}/p_{cr}$ and T_{cr} are critical phasic values of molar volume and temperature of ideal gas; V_k and T_k are their another arbitrary values.

The following expressions correspond to more precise Dieterici first thermal equation that uses an exponent with the same parameter $\theta=a/(R_{UT}TV)$:

$$R_T=\frac{R_{UT}}{1-b/V}\exp(-\theta), \qquad dV=\frac{R_{UT}(1+\theta)\exp(-\theta)dT-(V-b)dp}{p-aV^{-2}\exp(-\theta)},$$

$$\left(\frac{dR_T}{\partial T}\right)_p=\frac{R_{UT}(1+2\theta)\exp(-\theta)-R_T}{T\left[1-a\exp(-\theta)/(pV^2)\right]}=\frac{R_T\left[R_{UT}(1+2\theta)\exp(-\theta)-R_T\right]}{T\left[R_T-R_{UT}\theta\exp(-\theta)\right]}=\frac{R_T\Psi}{T},$$

$$\left(\frac{\partial R_T}{\partial T}\right)_V=\frac{R_T\theta}{T}, \qquad C_V=(1+\theta)\frac{R_T}{\widetilde{\beta}_{pV}}+\theta S, \qquad C_p=(1+\Psi)\frac{(1+\widetilde{\beta}_{pV})R_T}{\widetilde{\beta}_{pV}}+\Psi S,$$

$$C_p-C_V=[(1+\Psi)(1+1/\widetilde{\beta}_{pV})-(1+\theta)/\widetilde{\beta}_{pV}]+(\Psi-\theta)S,$$

$$\widetilde{\beta}_{pV}=\frac{(\Psi-\theta)R_T}{\Psi C_V-\theta C_p+\theta(1+\Psi)R_T}=\frac{R_T(1+\theta)\left[R_{UT}(1+\theta)\exp(-\theta)-R_T\right]}{R_{UT}\left[(1+2\theta)C_V+\theta^2C_p+\theta(1+\theta)R_T\right]\exp(-\theta)-R_T(C_V+\theta C_p)}.$$

Obviously, experimentally found heat capacities of gases can be represented as functions of only R_T and θ parameters.

Hidden variables β_{ST} and β_{pV} are invariant magnitudes in any moment of time that corresponds to the certain Gibbs collective microstate of the whole RGTD-bonded matter. And, thus, their derivatives by any thermodynamic parameter are equal to zero. The same can be told regarding mathematical expectations of those hidden variables $\widetilde{\beta}_{ST}$ and $\widetilde{\beta}_{pV}$, despite the dependence of their values on other thermodynamic parameters of matter.

9. The comparison of reflection of physical reality in RGTD and in GR

For astronomical bodies, which homogenous simplest liquid or gaseous matter is in the state of mechanic and thermal equilibrium, the frequencies of interaction f_G and f_I are strictly determined by the values of pressure and temperature in matter. For solid or liquid astronomical bodies and also for gaseous matter, which covers them or which is not in the state of thermodynamic equilibrium, those frequencies can also depend on the magnitude of gravitational advance of evolutionary decreasing of their intranuclear energy. And, consequently, if for continuous homogenous gaseous matter non-

Dopplerian redshift of radiation spectrum is sort of strictly thermodynamic, then for layered homogenous gaseous matter (that covers solid or liquid core) it is gravitationally-thermodynamic. And this is, obviously, related to the fact that in contrast to evolutionary shrinkage the gravitational shrinkage of matter is accompanied by the increasing of the density (in background Euclidean space of CFREU) of turns of spiral waves of spatial-temporal modulation of dielectric and magnetic permeabilities of physical vacuum.

However, in equilibrium RGTD-states of the whole set of different matters the gradients of logarithms of f_I and f_G of all matters are strictly determined by gradients of pressure and temperature in them and, therefore, are strictly equal to the gradient of limit velocity of motion v_l of the whole RGTD-bonded inhomogeneous matter. Moreover, due to $U_0 \equiv W$ and $U_0 E = \mathbf{const}(r)$ not only the conditions $W_0 f_G = W_0 v_l \eta_m / c = \mathbf{const}(r)$, $E_0 / f_G = E_0 c / v_l \eta_m = \mathbf{const}(r)$, but also the conditions $U_0 v_l = \mathbf{const}(r)$, $U_0 / f_I = U_0 f_G / \chi_m = U_0 v_l \eta_m / \chi_m c = \mathbf{const}(r)$ are also fulfilled within the borders of the whole RGTD-bonded continuous homogeneous matter that is in the state of mechanical and thermal equilibrium. All this allows using in the partially modernized GR only intranuclear properties of matter for the formation of metric tensor, but both intranuclear and thermodynamic properties of matter for the formation of energy-momentum tensor. However, Lorentz-invariance of pressure in the matter is ignored in the such modernized GR.

All the more so, separate contributions to gravitational potential of velocity of light in matter v_{cm} and internal scaling factor N_I are not important for the determination of gravitational pseudo-forces. However, the form of radial distribution of gravitational potential in STC of astronomical body that consists of this matter and the form of generalized relativistic linear element depend on their contributions [Danylchenko, 2009: 79]. Therefore, the conversion of these characteristics are not gauge when the named contributions are redistributed. The presence of internal scaling factor is not taken into account in GR: function only of coordinate-like velocity of light is used as gravitational potential. In intrinsic spaces of matter changes of electromagnetic interaction distances are unobservable in GR in principle, while spatial inhomogeneity of this distance for uniform matter that takes place in background Euclidean space (and, consequently, spatial inhomogeneity of the values of its scaling factor) causes the curvature of matter intrinsic space. The one thing that points on it is the usage of the function of not the interaction frequency, but of common for all substances coordinate pseudo-vacuum (gravibaric[34]) velocity of light in GR as the gravitational potential.

[34] In contrast to GR, where equilibrium thermodynamic state is considered only for the matter that is cooled down to the limit, in RGTD not the hypothetical gravithermobaric velocity of light (analogous to gravibaric velocity of light) but the limit velocity of matter motion in conventionally empty space is used in the relativistic transformations of increments of

Size of quantum length standard of the gas is decreasing in people world at the adiabatic increasing of this gas. This fact and the fact that change of distances of interaction of matter microobjects (which determine size of its quantum length standard) is unobservable in GR in principle leads to increasing of corresponding to this gas gravity-quantum value of metrical volume of the vessel that contains this gas[35]. Therefore, gravity-quantum metrical value of gas molar volume is decreasing not so fast as thermodynamic metrical value of its molar volume due to the presence of negative feedback [Danylchenko, 1994a; 2005c; 2008: 19; 2008a]. Such gravitational shrinkage of the size of quantum standard of length that takes place on the matter micro-objects level is analogous to relativistic shrinkage of the size of quantum standard of length along the direction of matter motion. However we cannot introduce the common space for GQ-FR of all matters because of the presence of the different intrinsic metrics of the space for each matter [Danylchenko, 2008: 19; 2008a]. Therefore, not gravity-quantum but thermodynamic metrical value of matter molar volume is used in the GR and in people's world. In analogy to quantum clock[36], quantum and any other length standards can be used in GT-FR of people world only due to stability of their length when values of temperature and pressure remain constant. The least influenced by temperature and pressure are only the atomic standards of length that are based on the stability of frequencies of emission radiations. According to all of this, in RGTD, the same as in GR, it is rational to use only the common for all matters intrinsic space[37] of GT-FR. And, that is why f_G, f_I and v_l should be considered as the parameters that are not identical, but equivalent to pseudo-vacuum coordinate-like velocity of light v_{cv} of GR. The usage of the common for the whole gravitationally-bonded matter RGTD-time that is counted by standard atomic clock (instead of conventional gravity-quantum times, which flow rate is different for different matters and in different points of the space, and which are counted by their hypothetical quantum clock) is quite rational. It allows avoiding the necessity of transformation of time within the whole matter that is in the sate of RGTD-equilibrium. The possibility and necessity of this is due to the existence of closed

---

coordinates of moving matter. This is related to the fact that the values of conventional gravithermobaric velocity of light can vary for different matters in the same point of the space. Only the gradients of logarithms of these gravithermobaric velocities of light will be equal for them.

[35] This is analogous to its decreasing in the background Euclidean space while approaching the center of the star. However in the latter case he decreasing of the quantum length standard corresponds to the increasing of not only internal but also external scaling factor. That is why the curvature of intrinsic space of the star takes place.

[36] In contrast to the rate of conventional quantum clock the rate of atomic clocks does not change in quasi-equilibrium processes of the change of thermodynamic state of their matter.

[37] The examination of every certain matter in intrinsic quantum space can be useful during the analysis of its thermal equations of the state. The multiplicative change of the magnitude of molar volume that takes place during the conform transformation of spatial coordinates should be accompanied by the partial additive compensation of this change in the thermodynamics. It is possible that non-equal for different gases additive corrections for molar volume of ideal gas, which are used in thermal equations of the state, are directly related to inequality of their internal scaling factors.

system[38] of all self-consistent pairs of additive one to another intensive and extensive parameters of matter when it is in the state of RGTD-equilibrium. Existence of such closed system is revealed in the fulfillment of the Le Chatelier-Braun principle in all RGTD-processes[39].

In contrast to gravitational potentials and external scaling factors used in GR, RGTD-values of gravitational potentials and internal scaling factors are not equal for different contacting matters. Only spatial gradients of the logarithms of frequency f_G of intranuclear and f_I of electromagnetic interaction in all matters (they are identical to gravitational field strength), as well as spatial gradients of the logarithms of internal scaling factor N_I, are mutually equal in the same world point. These spatial gradients of logarithms f_G ($\mathbf{grad}\ln f_G = \mathbf{grad}\ln(v_l / c) \equiv \mathbf{grad}\ln(v_{cv} / c)$) for all matters[40] are identical to the gravitational field strength in this point. The presence of identical spatial gradients in the same point of space justifies the usage in GR of the conventional coordinate (pseudo-vacuum) velocity of light v_{cv} instead of intranuclear frequency of interaction f_G. Related to it problems appear in GR only in the process of "stitching" of the solutions of equations of gravitational field for different matters. And this is related also to their stitching with fictive solutions for physically unreal absolutely empty space (spatially inhomogeneous pseudo-vacuum) [Danylchenko, 2008: 19; 2008a]. So, differential equations of GR gravitational field are definitely determine only the gradients of potentials and not the gauge transformed potentials of gravitational field themselves. However, in non-empty space they principally allow to switch from v_{cv} to f_G, f_I and v_{cm}. And, therefore, these problems are solvable in GR. It is necessary and enough to determine (from equations of thermodynamics) the values of f_{I0} and v_{cm0} only in any single point of matter that is in the equilibrium RGTD-state. Then the spatial distributions of f_I and v_{cm} in any matter can be determined with the help of the solutions of GR equations. It is necessary to use correspondent v_{cm0} and f_{I0} values of coordinate-like velocity of light v_{cv0} and the known dependency of v_{cm} on f_I or on correspondent to f_I thermodynamic parameters of matter.

Decreasing of the lengths of electron orbits in atoms and, therefore, also the decreasing of the wave length of emissive radiation in the photosphere of quasi-equilibrium compressed gas is

---

[38] Due to the self-consistency of all pairs of intensive and extensive parameters this system should be considered not only as closed, but also as self-enclosed.

[39] Not only the gravitational pseudo-force, but also the buoyancy force that partially or completely compensates this pseudo-force influence the moving matter in water, atmosphere or outer space. All RGTD-parameters (including intranuclear temperature and intranuclear entropy) are changing, according to principle of Le Chatelier-Braun, in submerged to water matter, which is lighter than it is in the process of reaching the new state of its equilibrium.

[40] Of course, the denser matter (body), which is placed into less dense matter medium, induce the additional local gravitational field in it. And, thus, it changes the spatial distribution of strengths of total gravitational field. However, in the process of body free fall, commoving with it its intrinsic gravitational field does not affect the acceleration of its free fall.

practically completely compensated by decreasing of velocity of radiation propagation in it. This is also confirmed by the fact that emission radiation frequencies practically do not depend on thermodynamic parameters of matter. This is also reflected in the negligibly small broadening of spectral lines.

However, such total compensation is absent at non-equilibrium state of ionized gas (proton-electron plasma) of quasars, situated in strong electromagnetic field (very saturated by radiation). Due to this and due to the proximity of the photosphere of shell-like quasars to the singular sphere they have the big gravitational redshift of the wavelength of radiation.

In contrast to "cooling down" stars, supernovae are heating up and, therefore, not contracting but catastrophically expanding due to annihilation of matter and antimatter [Danylchenko, 2005b; 2008: 4; 2004: 33; 2008b: 45]. Instead of undercompensation of gravitational shift of radiation spectrum its thermodynamic overcompensation takes place – as a result, not red but blue gravithermodynamic shift of this spectrum takes place. Decreasing of quantum length standard (increasing of N_I) that is not completely compensated by the decreasing of velocity $\breve{v}_c$ of interaction propagation causes not only the increasing of the frequency of electromagnetic interactions $f_I = N_I v_{cm}/c \neq \mathbf{const}$ for the supernovae, but also increasing of the frequencies of emissive radiation $\mathbf{v} = \mathbf{v}_0 N_I v_{cm}/N_{I0} c \neq \mathbf{const}$.

Therefore, energy of ionized rarefied gas of the dropped supernovae shells, as well as non-Doppler values of its emissive radiation, can be increasing along with increasing of pressure in the outer space at the advancing to cosmological past. Actual value of red shift of supernovae radiation spectrum can be substantially lower than its theoretical value, determined by Hubble relation, due to the presence of such negative feedback. So the presence of dark energy in the Universe is not necessary.

Obviously in GR gravitational field equations not strictly thermodynamic value of matter molar volume is mainly used. Therefore, additional coordinates transformation is required for the transition from used in GR local intrinsic FRs of matter and from similar to them GQ-FRs to GT-FRs of people's world. Only in this case the curvature of intrinsic spaces of matter is determined only by spatially inhomogeneous relativistic shrinkage of radial intervals and by radial delay in gauge evolutionary-gravitational of matter self-contracting in CFREU (by evolutionary-gravitational "deformation" of its micro-objects).

10. Internal contradictions in the theory of relativity and the main differences between the theory of relativity and relativistic gravithermodynamics.

Below is the list of facts that are internal contradictions in GR and SR:

1. The necessity in use of proper time (instead of classical absolute time) of moving matter, rate of which is determined by the rates of quantum processes in matter, is declared in SR. However, standard atomic or quartz clock is used instead of quantum clock of this matter. The rate of standard atomic or quartz clock, in contrast to the rate of quantum clock, is set not by the standard of time or hypothetical pseudovacuum velocity of light but by (used in them) the standard of length and pseudoreal velocity of propagation of electromagnetic interaction, which corresponds not to the real but to the standard external conditions. And, therefore, their time count, in contrast to quantum clock, does not depend or dismissively weakly depend on thermodynamic parameters of matter and on correspondent to them velocity of propagation of electromagnetic interaction. Thus, the influence of pressure and temperature on relativistic dilation of intrinsic (gravity-quantum) time of matter is not taken into account in the process of non-comfort (non-inertial) motion of this matter that is accompanied by the appearance of internal stresses and elastic deformations in it. Not only the relativistic but also the gravitational dilatation of the rate of gravity-quantum time has an influence on the rate of only intranuclear processes and, for sure, not of thermodynamic or biological processes. The changes of collective spatial-temporal state of the whole gravithermodynamically bonded matter take place synchronously and, therefore, with the same frequency in the whole space occupied by it. That is why the leading role in the people's world indeed belongs to the uniform gravithermodynamic time and not to hypothetical gravity-quantum times.

The influence of pressure and temperature in matter on conformal-relativistic (non-elastic) shrinkage of coordinate intervals in matter is also not taken into account in the SR. Exactly this shrinkage is responsible for the origin in observer's FR of the gravitationally-kinematic curvature of the part of its intrinsic space filled by non-comfort (non-inertially) moving matter. This leads not only to the unsuitability of SR trivial (non-conform) transformations of increments of coordinates and time for the transition from intrinsic FR of rotating matter to observer FR (Ehrenfest paradox), but also to the separate problems in GR.

On the other hand all this shows that both SR and GR are based purely on intranuclear physical processes. And, consequently, the usage of thermodynamic extranuclear parameters of matter instead of its gravithermodynamic intranuclear parameters in tensor of energy-momentum of GR is nonsense.

2. The fact that intrinsic STC of matter is formed directly by matter itself is declared in GR. In spite of this, values of components of STC metric tensor are considered to be independent from all properties of matter, located in concrete point of space. Thus, metric tensor in this point determines equal (not gauge mutually transformable, as it is expected) values of gravitational potentials for all possible thermodynamic states of matter Therefore, coordinate velocity of light, used in GR, is not a characteristic of matter, but, in fact, is a characteristic of the form of matter being – space, and can take

any values that do not correspond to thermodynamic matter parameters[41] and to real velocities of propagation of electromagnetic waves in it. This leads to the necessity of using in GR the special differential operators for dependencies of matter energy and momentum on its physical parameters. It also leads to the need to replace very massive neutron stars[42], which have the topology of a hollow body in the background Euclidean space and mirror-symmetric inner space, fictional "black holes".

3. Influence of gravitation on matter, as well as influence of nonuniform motion on matter, causes not only spatial inhomogeneity of the gravity-quantum rates of proper time of matter. This influence also leads to inhomogeneous deformation of matter on the level of correspondent to its nucleons terminal outlets of the turns of the common spiral-wave formation of the Universe in both background intrinsic space of the observer and in background Euclidean space of CFREU [Zel'dovich & Grishchuk, 1988]. The principle of unobservability of such deformation in all matter intrinsic FRs remains valid in GR. However, there is some exception in GR for relativistic length shrinkage: it is considered as observable in all FRs, not comoving with moving matter. This leads to the finiteness of the intrinsic space of matter in the Schwarzschild solution of the equations of gravitational field when the value of cosmological constant is non-zero and also to the formation of four-momentum by the enthalpy of matter and not by the ordinary internal energy and also to other disadvantages of relativistic generalization of thermodynamics with Lorentz-noninvariant volume [Danylchenko, 2006: 27; 2008: 60].

4. Changeability of values of interaction distances of matter micro-objects in thermodynamic processes (these values together with the velocity of propagation of interaction determine the frequency of interaction) is not taken into account in GR. This causes the fact that GR gravitational field equations correspond to FRs of STC, but not to GT-FR of all matters, to which RGTD equations correspond. This makes GR equations useable only for homogeneous matter.

The fact that vacuum (coordinate-like pseudo-vacuum) velocity of light is more privileged than true velocity of light in matter in SR and GR makes these theories more corresponding to unrealizable in principle – degenerate states of matter than to real states [Danylchenko, 2005b; 2008: 4; 2008: 19; 2008a]. The fact that relativistic time dilation, as well as gravitational potential (and integral equations of gravitational field in matter), are strictly independent from concrete values of

[41] When coordinate-like velocity of light tends to zero the pressure and the temperature of matter tend to infinity. And, therefore, singularities on the external surfaces of astronomical bodies cannot appear in principle. However, this is ignored in the solutions of GR gravitational field equations.

[42] The mass of such neutron star is not limited by anything since the minimum possible value of Schwarzschild radial coordinate (which corresponds to its mid singular surface that separates matter and antimatter) can be arbitrary large [Danylchenko, 2005; 2005b; 2008: 4].

any characteristics[43], of this matter denotes the excessive simplicity of SR and GR that causes the primitiveness of representation of objective reality by these theories. The “beauty” of these theories, related to their simplicity, does not correspond to, in fact, not very “beautiful” objective reality.

In spite of this, the most of the original positions and principles of SR and GR are saved in RGTD. The main distinguishing characteristics of RGTD are the following original positions and principles:

1. Physical vacuum is a continuous (structureless) substance that is not involved in motion and rests in CFREU. Matter micro-objects (elementary pseudo-particles) and electromagnetic waves are only the non-mechanically excited states of this substance [Danylchenko, 2004: 33; 2004b: 44; 2008b: 45].

2. RGTD-state of matter is the spatially inhomogeneous average statistical macrostate of this matter. This state is determined by statistical distribution of possibilities of various collective space-time microstates (Gibbs microscopic states) of the whole gravitationally bonded matter. Discrete changes of collective space-time microstate of matter take place at de Broglie frequency, which corresponds to the collection of all jointly moving objects of this matter, and propagate as the quanta of action with a superluminal phase velocity. This takes place instantly in FR, comoving with matter, because of the fact that propagation front of quantum of action (that is responsible for the change of collective space-time micro-state of matter) is identical to the propagation front of succeeding time instant of moving matter both in CFREU and in FR of each of the observers of its motion.

3. Transfer of phase changes of collective space-time microstate of matter, as well as of graviinertial field (gravitational field, removable by coordinates transformation) strength, at a superluminal velocity do not accompanied by the propagation of changes of electrical and magnetic field strengths in the matter and, so, not accompanied by energy transfer [Danylchenko, 2004: 3; 2008b: 3]. Released intranuclear energy of matter transforms into kinetic energy of directed motion before matter is filled in with external energy transferred at velocity of sound. Therefore, despite of the change of its motion velocity, matter moves only inertially during this period of time. In fact, free fall of matter in graviinertial field takes place.

4. Any arbitrarily rarefied matter of cosmic vacuum should be considered as “incoherent matter”, which abides to the thermodynamic laws, in analogy to ideal gas of non-interacting molecules [Danylchenko, 2008: 19; 2008a]. Because of this, and also because of principal unattainability of the zero value of pressure in gas-dust matter of outer space, it is inadmissible not to take into account gradual decreasing of pressure in cosmic vacuum at the distancing from compact matter. And,

[43] In fact only the spatial gradients of this parameters of matter (not the determined by them gravitational potentials) can be independent.

therefore, vacuum solutions of gravitational field equations are senseless. Moreover, the absence of absolute vacuum makes the postulation in SR of isotropy of hypothetical vacuum velocity of light in moving body in FR (in which the matter motion is observed) outdated. SR transformations admit the anisotropy of real velocity of light in moving isotropic matter in this FR. And, of course, relativistic transformations should also allow the anisotropy of the real speed of light in the very rarefied gas-dust matter of outer space carried away by a moving astronomical body. In turbulent layer between dragged and not dragged by motion matter the gradual transition from anisotropy to isotropy of velocity of light will take place.

5. In contrast to the velocity of propagation of real electromagnetic waves in matter, conventional gravitermobaric (gravibaric) velocity of light in homogeneous matter, which is not equal but only proportional to the pseudo-vacuum coordinate-like velocity of light in GR and limit velocity of motion of baryonic matter in RGTD, does not depend on the frequency of these waves. Values of this velocity are equal in straight and opposite directions at propagation of radiation along the direction of matter motion. This is caused by the fact that motion inducts relativistic changes of refractive index of moving matter. These changes cause the fact that values of gravi-baric components of longitudinal and transversal values of refractive index are not similar. The values of longitudinal and transversal components of refractive index guarantee the invariance to the transformations of coordinates and time of thermodynamic potentials and parameters of matter and the correspondence of relativistic values of longitudinal and transversal components of gravi-baric velocity of light to generalized relativistic nonvacuum transformations of spatial coordinates, time and velocities [Danylchenko, 2009: 79].

6. Relativistic transformations of spatial coordinates and time of SR are the vacuum degeneration of generalized relativistic transformations [Danylchenko, 2009: 79]. Relativistic shrinkage of coordinate size ("coordinate intervals") is conform-Lorentz in general case and, therefore, is able to guarantee the invariance to the transformations of coordinates and time of thermodynamic potentials and parameters of matter as well as guarantee the absence of relativistic dilatation of intrinsic time for inertially moving bodies. And it depends not only on velocity of matter motion, but also on the pressure inside the matter[44]. The fact that graviinertial field is originated in nonuniformly rectilinearly moving matter, as well as in rotating matter, causes the fact that unobservable in principle all-round deformation of matter is gravitationally-kinematic, in fact. Relativistic time dilation for any noninertially moving matter is also gravitationally-kinematic. And it is purely gravitational for inertially moving massive astronomical object that has its own gravitational field as well as for any body that is even non-inertially moving but has the conform deformed Möller FR.

[44] It will also be dependent on the temperature in the case of the absence of thermal equilibrium in matter.

Gravi-inertial field in GR can be considered as removable only conventionally. Spatial inhomogeneities of thermodynamic state and of observable (non-relativistic) deformation of moving matter that correspond to coordinates transformation are not removed at this transformation. Differentiated tracking of the influence of removable and unremovable gravitational fields on spatial inhomogeneity of thermodynamic state of matter is impossible in GR in general case. Therefore, in GR, in contrast to RGTD, in general case gravitationally-relativistic dilation of physical processes in matter cannot be decomposed on multiplicative components that separately correspond to unremovable (external) and eliminable gravitational fields and to purely kinematic impact.

7. Intrinsic spaces of matter are metrically homogeneous (isometric) in principle. Gravitational, as well as relativistic, shrinkages of dimensions (length standards) and molar volumes are unobservable in these spaces. Gravitational curvature and comoving with moving object kinematic “curvature” of intrinsic space of motion observer are observable in these spaces, instead of these shrinkages. Similarly, the relativistic dilatation of the rate of only coordinate (and not metric) time is observed in GT-FRs on the distant galaxies (which move away from the observer and at the same time freely fall on the pseudo-horizon of events). Therefore, purely Lorentz relativistic transformations of SR are the transformations of the increments only of coordinates, but not of metrical intervals [Danylchenko, 2006: 27; 2008: 60]. And, moreover, in contrast to conform-Lorentz transformations they do not guarantee the invariance of thermodynamic potentials and parameters as well as the absence of dilatation of intrinsic time for inertially moving bodies.

8. General covariance of equations of matter motion and state (and, in fact, general covariance of the majority of physical laws) to the coordinates transformations takes place only for spaces of the GT-FRs of matter, namely, only for the spaces, in which matter deformations caused by relativistic and evolutionary-gravitational “deformations” of its micro-objects (correspondent to them spiral-wave formations) are unobservable in principle. Such deformations are “observable” in background Euclidean space [Zel’dovich & Grishchuk, 1988] of CFREU (only in this space Universe can be homogeneous). A completely different formulation of the majority of nature laws, as well as other transformation of intensive and extensive parameters and characteristics of matter that correspond to this formulation and possibly different form of equations that determine interrelations between them are needed for intrinsic GQ-FRs of matter, in which not only evolutionary but also RGTD-“deformations” of its micro-objects (changes of their interaction distances) are unobservable in principle.

9. All thermodynamic parameters and characteristics of matter are invariant under both transpositional gravitational (spatio-temporal) and relativistic (conform-Lorentz) transformations of coordinates and time in principle. And, consequently, temperatures of phase transitions are the internal

properties of matter of not only resting, but also moving bodies. The permanence (Lorentz-invariance) of observed thermodynamic state of moving matter when switch from its observation from any of IFR to the observation from any other IFR is provided by the calibration effect of classic inertial (hypothetic uniform) motion on the matter. It is guaranteed by the save of initial proportionality of observed rates of all physical processes to the rate of intrinsic time of moving matter. Ant the cause of all this is the self-consistency of all pairs of intensive and extensive thermodynamic parameters of matter that are complementary to each other. They form the self-enclosed RGTD-system.

10. Spatial inhomogeneity of RGTD-state of the whole gravitationally bonded matter (including extremely strongly rarefied "incoherent matter" of the outer space) is the cause of the presence of gravity. In ideal gas and in ideal liquid this spatial inhomogeneity fundamentally cannot be self-organized due to the absence of electromagnetic interaction between molecules of these hypothetic substances. This inhomogeneity is reflected in real homogeneous matter as certain spatial distribution of inert free energy and of corresponding to this energy the nominal intensive parameter – relative average statistical value of the frequency of intranuclear interactions (alternative to pseudo-vacuum coordinate-like velocity of light of GR). That is why gravitational field is de facto the field of spatial inhomogeneity of gravithermodynamic state of matter and cannot be any independent form of matter. This field was originated due to the gravithermodynamic advance in the evolutionary process of increase of total internal energy and correspondent to it decrease of the inert free energy in lower layers of matter. And it is the consequence of self-organization of collective macrostate of jointly moving matter that corresponds to the minimums of total (integral) values of all free energies of this matter. However, of course, gravitational field can be also considered as the spatial distribution in CFREU of the density of turns of spatial-temporal modulation of dielectric and magnetic permeabilities of physical vacuum.

11. In relativistic thermodynamics, the same as in classical thermodynamics, all characteristic functions (potentials, including the gravitational potential – logarithm of conventional gravithermobaric velocity of light or limit velocity of matter) of liquid and gaseous matter, which is under the influence of only all-round pressure and is in the state of both thermal and mechanical equilibriums, are determined only by two independent parameters [Danylchenko, 2008: 19; 2008a] (while in GR there are three such parameters). In GR it is suggested that in the state of thermodynamic equilibrium not only the strictly concrete, but also different values of coordinate-like velocity of light of astronomical objects of different mass can correspond to all identical thermodynamic parameters of one and the non-rigid (liquid or gaseous) matter within the whole volume of astronomical objects. In RGTD only the values of maximal possible velocity of motion of baryonic matter can be different and only for liquids and gases that are in the equilibrium thermodynamic state or for liquids that cover solid bodies and also

for the solid (rigid) astronomical bodies themselves (the process of evolutionary decreasing of intranuclear energy of matter of such bodies always advances this process in the matter of external space). Moreover, in RGTD gravitational field equations define only equal gradients of logarithms of relative frequency of intranuclear (quantum) interactions for all matters. However, the values of this frequency themselves are not the same are not the same and not only for different matters, but even for different atoms of matter molecules.

12. Bodies free fall in gravitational field – is an original realization of tendency of the whole gravitationally bonded matter to the minimum of the integral value not only of inert free energy, but also of thermodynamic Gibbs free energy. Bodies that fall independently accelerate in physically inhomogeneous space. In such way bodies transform their continuously released intranuclear energy into kinetic energy. And this happens due to the fact that momentum is not conserved (in physically inhomogeneous space [Noether, 1918]) by virtual quanta of energy, which are the objects of exchange in the process of interaction between atoms and nucleons (correspondent to nucleons terminal outlets of the turns of spiral waves [Danylchenko, 2004: 33; 2004b: 44; 2008b: 45]).

13. Removable gravitational (graviinertial) field, which is inducted by quasi-hyperbolic motion of matter during the process of its free fall, totally compensates external gravitational field. And, therefore, more dense particles cannot overtake less dense particles of "incoherent matter" in principle. Pressure in this matter, as well as relative frequency of intranuclear interactions, is spatially homogeneous (and this is reflected in the zero-gravity state). Matter free fall can be strictly inertial motion of matter only in hypothetic absolute vacuum. Therefore, matter free fall in atmosphere, as well as in the outer space, is only a quasi-inertial motion.

14. Not the total internal energy of matter, but only its inert free energy, which is equal to the sum of free energies of nucleons and energies of intranuclear bonds and interactions, is equivalent to inert mass. Therefore, gravitational force that does not execute work is equal to the product of the Hamiltonian of only inert free energy of the matter and the gradient of logarithm of relative frequency of intra-atomic interactions. By analogy, d'Alembert inertial pseudo-force is equal to the product of the Hamiltonian of matter inert free energy and the derivative of logarithm of purely Lorentz time dilation along traversed path. And, consequently, there is no need in the proving of mutual equality of gravitational and inert masses of matter.

15. When the thermodynamic state of liquid or gaseous matter is equilibrium the gradients of conventional average value of frequency of intranuclear interactions are determined only by the gradients of its gravithermodynamic parameters. The frequency of the wave of one and the same emissive radiation remains the same in the whole (and even extremely rarefied) gas that is located at the long distance from the gravity center. And, therefore, declared in GR gravitational redshift of the

spectrum of emissive radiation of purely gaseous matter (which is strictly in thermodynamic equilibrium) of the non-layered astronomical object that does not have liquid or solid nucleus is impossible in principle. It can be only purely thermodynamic. The non-Dopplerian shift of the maximum of the spectral density of heat radiation in this astronomical object is strictly determined only by the temperature of matter in its photosphere. Gravitational redshift of the spectrum of emission radiation can take place only for non-rigid (liquid or gaseous) matters that are in non-equilibrium thermodynamic state or for any multilayered astronomical objects (including those containing a liquid or solid nucleus). And, therefore, non-Dopplerian redshift of the spectrum of emission radiation is mainly thermodynamic for the majority of astronomical objects. Mainly the Doppler broadening of spectral lines takes place for them. The very significant gravitational-thermodynamic redshift can be found only for the radiation of electron-proton plasma of quasar photosphere, which is located nearby the singular surface and, thus, in the strong electromagnetic field.

11. Conclusion

Gravitational field is the field of spatial inhomogeneity of gravithermodynamic state of matter and is not an independent substance (form of matter). Gravitational field cannot exist without matter, in principle, and, consequently, cannot have its own energy and own linear momentum that differs from energy and linear momentum of matter, which formed that field. Therefore, conservation of the sums of values of energy-momentum and moment of momentum together for matter and for gravitational field [Logunov & Mestvirishvili, 1989] is not necessary both in GR and in the RGTD. All bonds and interactions between matter structural elements have the same electromagnetic nature [Danylchenko, 2004: 33; 2004b: 44; 2008b: 45], despite they all considerably differ one from another. And, therefore, gravitational field cannot be completely similar by its properties to electromagnetic field. Nature abhors uniformity. Nature “uses” new forms of bonds and interactions between matter structural elements on each new hierarchical level of self-organization of matter objects. However, for sure, all these forms are rather similar, because they are based on the same laws and principles of appropriateness. Statistical laws, which guarantee the correspondence of equations of RGTD-state of matter to the variational principles and, consequently, Le Chatelier-Braun principle, are the basis of gravitational and other RGTD-properties of matter. Gravity forces are evolutionary-gravitational pseudo-forces that force all matter objects to tend to spatially inhomogeneous collective equilibrium states with the minimums of the integral values inert free energy and thermodynamic Gibbs free energy of the whole gravitationally bonded matter. Because of this, GR gravitational field equations are, in fact, relativistic equations of spatially inhomogeneous RGTD-state of gauge-evolving matter (equations of RGTD) [Danylchenko, 2008: 19; 2008a; 2009: 75; 2009a; 2010: 64; 2010a: 38; 2020: 5]. And, therefore, gravity – is only the peculiar (sui generis) manifestation of electromagnetic nature of the matter on the appropriate hierarchical level of self-organization of matter objects. And, of course, there are no such objects as gravitons and gravitational waves that transfer energy (if, of course, moving matter itself is not considered as these waves).

Not the total internal energy of matter, but its inert free energy is equivalent to gravitational and inert masses. Thermodynamic internal energy, which consists of the Lagrangian of ordinary internal rest energy (multiplicative component) and additive compensation of its multiplicative representation, is de facto the total energy of matter since it includes even the released kinetic energy of its motion. Thermodynamic internal energy of matter is equal in all FRs of bodies that move relatively to it. And exactly this is the guarantee of Lorentz-invariance of all thermodynamic potentials and parameters of matter. The motion of the matter as well as its gravitational self-contraction in background Euclidean space of the Universe leads to its advance over unobservable in people's world evolutionary self-contraction of the conventionally motionless matter in the Universe. That is why the release of kinetic energy is always accompanied by the decreasing of limit velocity of matter motion (that is identical to coordinate velocity of light of matter in GR) and the decreasing of its inert free energy.

The internal energy of matter is bonded in a different ways in different physical processes. That is why we have various free energies in different processes. Both the change of the inert free energy[45] of matter (caused by its inertial motion) and its evolutionary decrease in CFREU do not directly influence the thermodynamic parameters of matter that are changed only in thermodynamic processes. That is why it is fundamentally unobservable in intrinsic FRs of matter in the similar way as evolutionary and caused by motion reduction of molar volume of matter is unobservable in commoving with expanding Universe FR. The gravitational reduction of molar volume of matter when approaching the gravitational attraction center is also unobservable directly in intrinsic FRs of matter. However, we still can say about its presence in Euclidean space of CFREU due to the presence of gravitational curvature of intrinsic space of matter. And we also can indirectly say about the presence of evolutionary self-contraction of matter due to the presence of the process of Universe expansion in FR of people's world.

Reference

Antonov, V.A.: 1962, Dynamics of galaxies and star clusters. *West. Leningrad State Univ.*, **7,** 135 (1962); Alma-Ata: Nauka, 1973.

Bazarov, I.P.: 1964, *Thermodynamics.* New York: Pergamon Press, [distributed in the Western Hemisphere by Macmillan, New York] (1964); *Thermodynamics: Textbook for Higher Educational Establishments*. Moscow: Vysshaya Shkola (1991).

[45] E.g. when planets move by the elliptic orbits around the Sun.

Binney, J., Tremaine, S.: 1987, *Galactic Dynamics*. Princeton: Princeton Univ. Press.

Binney, J.: 1993, Gravitational plasmas. *Plasma Physics; an introductionary course*. Cambridge: Cambridge Univ. Press, 291-318.

Chavanis, P.H.: 2002, Statistical mechanics of two-dimensional vortices and stellar systems, in Dynamics and thermodynamics of systems with long range interactions. *Lecture Notes in Physics*, **602**, Berlin et al.: Springer-Verlag.

Chavanis, P.H.: 2005, On the lifetime of metastable states in self-gravitating systems. *Astronomy and Astrophysics*, **432,** 117-138.

Chen, Y.T., Cook, Alan: 1993**,** Gravitational Experiments in the Laboratory. *Cambridge Univ. Press*, (1993); https://doi.org/10.1017/CBO9780511563966 (2009).

Danylchenko, Pavlo: 1994, Frames of reference of coordinates and time, pseudo-inertially contracting. *Gauge-evolutionary theory of the Universe* (in Russian), Vinnytsia, **1**, 22-51. http://pavlo-danylchenko.narod.ru/docs/Ketm.pdf (in Russian).

Danylchenko, Pavlo: 1994, Rigid reference frames of coordinates and time, contracting in Minkowski space. *Gauge-evolutionary theory of the Universe*, **1**, Vinnytsia, 1994: 52-75. http://pavlo-danylchenko.narod.ru/docs/Ketm.pdf (in Russian).

Danylchenko, Pavlo: 1994a, *Foundations of The Gauge-Evolutional Theory of The Creation*, Vinnitsa Ukraine. http://pavlo-danylchenko.narod.ru/docs/Osnovy_Rus.html; Kiev: N&T (2005c). http://n-t.org/tp/ns/ke.htm.

Danylchenko, Pavlo: 2004, The nature of relativistic length shrinkage. *Gauge-evolutional interpretation of special and general relativities,* Vinnytsia Ukraine: O.Vlasuk, 3-14. http://pavlo-danylchenko.narod.ru/docs/Nature_Eng.html.

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: O.Vlasuk, 33-61; Nova knyga, 2008b: 45-95. http://pavlo-danylchenko.narod.ru/docs/Possibilities_Eng.html.

Danylchenko, Pavlo: 2004, Phenomenological justification of linear element of Schwarzschild solution of GR gravitational field equations. *Gauge-evolutional interpretation of special and general relativities*. Vinnytsia: O.Vlasuk, 62-78; Nova knyga, 2008b: 96-112. http://pavlo-danylchenko.narod.ru/docs/Schwarzschild_Eng.html.

Danylchenko, Pavlo: 2004b, 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) www.sciteclibrary.ru/rus/catalog/pages/8276.html.

Danylchenko, Pavlo: 2005, Extraordinary topology of very massive neutron stars and quasars. *Theses of reports at the XXII conference "The modern problems of extragalactic astronomy"*, Pushchino, 16-18 July 2005. http://prao.ru/conf/22_conf/rus/thesis.html; Kyiv: NiT. http://n-t.ru/tp/ng/nt.htm (in Russian).

Danylchenko, Pavlo: 2005a, Physical essence of singularities in Schwarzschild solution of General Relativity gravitational field equations. *Sententiae: special edition **1** Philosophy & Cosmology*, Vinnytsia: UNIVERSUM-Vinnytsia, 95-104. http://www.bazaluk.com/journals/journal/3.html (in Russian).

Danylchenko, Pavlo: 2005b, United solution of GR gravitational field equations and thermodynamics equations for ideal liquid in the state of its thermal equilibrium. *Theses of reports at the XII Russian gravitational conference*, Kazan, June 20-26, 39-40.

Danylchenko, Pavlo: 2006, Relativistic thermodynamics with Lorentz-invariant extensive volume. *Sententiae: special edition **2** Philosophy & Cosmology.* Vinnytsia: UNIVERSUM-Vinnytsia, 27-41. http://www.bazaluk.com/journals/journal/6.html (in Russian).

Danylchenko, Pavlo: 2008, United solution of GR gravitational field equations and thermodynamics equations for ideal liquid in the state of its thermal equilibrium. *Introduction to Relativistic Gravithermodynamics.* Vinnytsia: Nova knyga, 4-18. http://pavlo-danylchenko.narod.ru/docs/UnitedSolution_Rus.html (in Russian).

Danylchenko, Pavlo: 2008, United nature of gravitational and thermodynamic properties of matter. *Introduction to Relativistic Gravithermodynamics*. Vinnytsia: Nova knyga, 19-59. http://pavlo-danylchenko.narod.ru/docs/UnitedNature.html (in Russian).

Danylchenko, Pavlo: 2008, Relativistic thermodynamics with Lorentz-invariant extensive volume. *Introduction to Relativistic Gravithermodynamics*. Vinnitsa Ukraine: Nova knyga, 60-94. http://pavlo-danylchenko.narod.ru/docs/RelativisticGeneralization_Rus.html.

Danylchenko, Pavlo: 2008, Relativistic Values of radial coordinates of distant astronomical objects of expanding Universe.*Introduction to Relativistic Gravithermodynamics* (in Russian), Vinnytsia: Nova knyga, 106-128. http://pavlo-danylchenko.narod.ru/docs/RelativisticValues.html (in Russian).

Danylchenko, Pavlo: 2008a, United nature of gravitational and thermodynamic properties of matter. *Abstracts of the RUSGRAV-13*, June 23 – 28. Moscow: PFUR, 109 (in Russian).

Danylchenko, Pavlo: 2008b, Relativistic length shrinkage and gravitational waves. Superluminal propagation velocity. *Gauge-evolutional interpretation of special and general relativities*. Vinnytsia: Nova knyga, 3-23. http://pavlo-danylchenko.narod.ru/docs/rsd.html (in Russian).

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", 75-79 (in Russian) http://pavlo-danylchenko.narod.ru/docs/SvidzinskySeminar.pdf.

Danylchenko, Pavlo: 2009, Generalized relativistic transformations. *Proceedings of all-Ukrainian seminar from theoretical and mathematical physics TMP'2009*. Feb. 27 – Mar. 1, Lutsk: Volyn'University Press "Vezha", 79-83 (in Russian). http://pavlo-danylchenko.narod.ru/docs/GeneralizedTransformations.htm.

Danylchenko, Pavlo: 2009a, Foundations of Relativistic Gravithermodynamics. Program and abstracts *of the IV Gamov international conference in Odessa*, 17-23.08.2009, P. 20. *Poster presentation based on previously unpublished (in full) work by the author:* http://pavlo-danylchenko.narod.ru/docs/Gravithermodynamics_Eng.htm.

Danylchenko, Pavlo: 2010, Foundations of Relativistic Gravithermodynamics. *Nauk. visn. Volyn'Univ*., **6**, 64-71 (in Russian). http://pavlo-danylchenko.narod.ru/docs/VisnykVolyn.pdf.

Danylchenko, Pavlo: 2010a, Foundations of Relativistic Gravithermodynamics. *Philosophy & Cosmology 2010*, **9**, 38-50 (in Russian) http://ispcjournal.org/journals/2010/2010-5.pdf, https://cyberleninka.ru/article/n/osnovy-relyativistskoy-gravitermodinamiki.

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, Lutsk: Volyn'University Press "Vezha", 21-26. http://pavlo-danylchenko.narod.ru/docs/spiralwaveuniverse.html (in Russian).

Danylchenko, Pavlo: 2020, Foundations of Relativistic Gravithermodynamics. *Foundations and consequences of Relativistic Gravithermodynamics* (in Ukrainian), Vinnytsia: Nova knyga, 5-84. http://pavlo-danylchenko.narod.ru/docs/FoundationRGTDUkr.pdf (in Ukrainian).

Dmitriev, Alexander: 2005, *Controllable gravitation.* Moscow: Novi centr, (in Russian), http://bourabai.kz/aldmitriev/gravity.htm.

Einstein, Albert, Infeld, Leopold: 1938, Is heat a substance? *The Evolution of Physics: The Growth of Ideas from Early Concepts to Relativity and Quanta*. London: The scientific book club III Charing Gross Road (1938)

Faller, J.E., Hollander, W.J., Nelson, P.G., Mc Hugh, M.P.: 1990, Gyroscope weighing experiment with a null result Phys. *Rev. Lett.*, **64**, 825-826.

Fridman, A.M., Polyachenko, V.L. 1984, *Physics of Gravitating Systems*. 2 vols. New York: Springer.

Gordon, M.A., Sorochenko, **R.L.:** 2003, Radio Recombination Lines. *Their Physics and Astronomical Applications.* Series: Astrophysics and Space Science Library, **282** Springer (2009).

Hayasaka, H., Takeuchi, S.: 1989, Anomalous Weight Reduction on a Gyroscope's Right Rotations around the Vertical Axis on the Earth. *Phys. Rev. Lett.* **63**, N25, 2701-2704.

Katz, J.: 2003, Thermodynamics and Self-Gravitating Systems. *Found. Phys*., **33,** 223-269.

Lynden-Bell, D.A., & Kalnajs, J.: 1972, *On the generating mechanism of spiral structure,* MNRAS, **157** 1-30.

Logunov, Anatoly and Mestvirishvili, Mirian: 1989, *The Relativistic Theory Of Gravitation.* Moscow: Mir.

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

Noether, Emmy: 1918, Invariante Variationsprobleme. *Math-phys.* Klasse – Göttingen: Nachr. D. König. Gesellsch. D. Wiss., 235-257.

Olemskoy, A.I., Koplyk, I.V.: 1995, Theory of space-time evolution of a nonequilibrium thermodynamic system. *Physics-Uspekhi* **165,** 1105-1144.

Polyachenko, V.L., Fridman, A.M. 1976, *Equilibrium and stability of gravitating systems.* Moscow: Nauka.

Prigogine, I., Nicolis, G.: 1977, *Self-Organization in Non-Equilibrium Systems: From Dissipative Structures to Order through Fluctuations***.** New York: J. Wiley and Sons.

Prigozhyn, I.: 1985, *From the existing to the emerging: time and complexity in physical sciences.* Moscow: Nauka (in Russian).

Quinn, T.J., Picard, A.: 1990, The mass of spinning rotors: no dependence on speed or sense of rotation**.** *Nature*, **343**, N6260, 732-735.

Saslaw, W.C.: 1968, Gravithermodynamics-I. Phenomenological equilibrium theory and zero time fluctuations. *Mon. Not. R. astr. Soc*., **141,** 1-25.

Saslaw, W.C.: 1969, Gravithermodynamics-II. Generalized statistical mechanics of violent agitation. *Mon. Not. R. astr. Soc.*, **143,** 437-459.

Saslaw, W.C.: 1970, *Gravithermodynamics-III. Phenomenological non-equilibrium theory and finite-time fluctuations* // Mon. Not. R. astr. Soc., **147** P.253 – 278 (1970);

Saslaw, W.C.: 1985, *Gravitational Physics of Stellar and Galactic Systems.* – Cambridge: Cambridge Univ. Press.

Sorochenko, R.L., Salomonovich, A.E.: 1987, Giant atoms in space. *Priroda,* **11**, 82-94.

Taylor, J.H., Fowler, L.A. and Weisberg, J.M.: 1979, Measurements of General Relativistic Effects in the Binary Pulsar PSR1913+16. *Nature*, **277**, 437-440.

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

Van Kampen, N.G.: 1968, Relativistic Thermodynamics of Moving Systems. *Phys. Rev.,* **173,** 295-301.

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

Zhdanov, V.M., Roldugin, V.I.: 1998, Non-equilibrium thermodynamics and kinetic theory of rarefied gases. *Physics-Uspekhi* **168,** 407-438.