Preferred Spatial Directions in the Universe. Part II. Matter Distributed along Orbital Trajectories, and Energy Produced from It

Larissa Borissova

E-mail: lborissova@yahoo.com

Using General Relativity we study the rotating space of an orbiting body (of the Earth in the Galaxy, for example). In such a space Einstein's equations predict that: (1) the space cannot be empty; (2) it abhors a vacuum (i. e. a pure λ-field), and so it must also possess a substantive distribution (e. g. gas, dust, radiations, etc.). In order for Maxwell's equations to satisfy Einstein's equations, it is shown that: (1) a free electromagnetic field along the trajectory of an orbiting body must be present, by means of purely magnetic "standing" waves; (2) electromagnetic fields don't satisfy the Einstein equations in a region of orbiting space bodies if there is no distribution of another substance (e. g. dust, gas or something else). The braking energy of a medium pervading space equals the energy of the space non-holonomic field. The energy transforms into heat and radiations within stars by a stellar energy mechanism due to the background space non-holonomity, so a star takes energy for luminosity from the space during the orbit. Employing this mechanism in an Earth-bound laboratory, we can obtain a new source of energy due to the fact that the Earth orbits in the non-holonomic fields of the space.

1 If a body undergoes orbital motion in a space, the space cannot be empty

This paper extends a study begun in *Preferred Spatial Directions in the Universe: a General Relativity Approach* [1]. We considered a space-time described by the metric*

$$ds^2 = \left(1-\frac{2GM}{c^2 r}-\frac{\omega^2 r^2}{c^2}\right)c^2 dt^2 - \frac{2\omega r^2}{c}\,c dt\, d\varphi - \\ -\left(1+\frac{2GM}{c^2 r}\right)dr^2 - r^2 d\varphi^2 - \frac{2\omega \mathrm{v} r^2}{c^2}\, d\varphi\, dz - dz^2, \tag{1}$$

where $G = 6.67\times10^{-8}\,\frac{\text{cm}^3}{\text{g}\times\text{sec}^2}$ is Newton's gravitational constant, M is the value of an attracting mass around which a test-body orbits, ω is the cyclic frequency of the orbital motion, v is the linear velocity at which the body, in common with the gravitating mass, moves with respect to the observer and his references.

In fact, this metric describes (in quasi-Newtonian approximation) the space along the path of a body which orbits another body and moves in common with it with respect to the observer's reference frame (which determine his physical reference space), for instance, the motion of the Earth in the Galaxy. So this metric is applicable to bodies orbiting anywhere in the Universe.

Here we study, using Einstein's equations, a space described by the metric (1). This approach gives a possibility of answering this question: does some matter (substance and/or fields) exist along the trajectory of an orbiting body, and what is that matter (if present there)?

*The metric is given in the cylindrical spatial coordinates r, φ, z. See [1] for the reason.

The general covariant Einstein equations are†

$$R_{\alpha\beta} - \frac{1}{2}\, g_{\alpha\beta}\, R = -\kappa\, T_{\alpha\beta} - \lambda\, g_{\alpha\beta}\,, \tag{2}$$

where $R_{\alpha\beta}$ is Ricci's tensor, $g_{\alpha\beta}$ is the fundamental metric tensor, R is the scalar (Riemannian) curvature, $\kappa = \frac{8\pi G}{c^2} = 1.86\times10^{-27}\,\frac{\text{cm}}{\text{g}}$ is Einstein's gravitational constant, $T_{\alpha\beta}$ is the energy-momentum tensor of a distributed matter, λ is the so-called cosmological term that describes non-Newtonian forces of attraction or repulsion‡. A space-time is *empty* if $R_{\alpha\beta} = 0$. In this case, $R = 0$, $T_{\alpha\beta} = 0$, $\lambda = 0$, i. e. no substance and no λ-fields. A space-time is pervaded by *vacuum* if $T_{\alpha\beta} = 0$ but $\lambda \neq 0$ and hence $R_{\alpha\beta} \neq 0$.

The Einstein equations can be applied to a wide variety of distributions matter, even inside atomic nuclei. We can therefore, with the use of the Einstein equations, study the distribution of matter in any scaled part of the Universe — from atomic nuclei to clusters of galaxies.

We use the Einstein equations in chronometrically invariant form, i. e. expressed in the terms of physical observed values (chronometric invariants, by A. Zelmanov [3, 4]). In such a form, the general covariant equations (2) are represented by the three sorts of their observable (chronometrically invariant) projections: the projection onto an observer's

†The space-time (four-dimensional) indices are $\alpha, \beta = 0, 1, 2, 3$.

‡Depending upon the sign of λ: $\lambda > 0$ stands for repulsion, while $\lambda < 0$ stands for attraction. The *cosmological term* is also known as the λ-term. The forces described by λ (known as λ-forces) grow in proportional to distance and therefore reveal themselves in full at a "cosmological" distance comparable to the size of the Universe. Because the non-Newtonian gravitational fields (λ-fields) have never been observed, for our Universe in general the numerical value of λ is expected to be $\lambda < 10^{-56}\,\text{cm}^{-2}$. Read Chapter 5 in [2] for the details.

time line, the mixed (space-time) projection, and the projection onto the observer's spatial section [3, 4]

$$\begin{aligned}&\frac{{}^*\partial D}{\partial t}+D_{jl}D^{lj}+A_{jl}A^{lj}+{}^*\nabla_j F^j-\frac{1}{c^2}F_jF^j=\\&=-\frac{\kappa}{2}\left(\rho c^2+U\right)+\widetilde{\lambda}c^2;\end{aligned}\qquad(3)$$

$${}^*\nabla_j\left(h^{ij}D-D^{ij}-A^{ij}\right)+\frac{2}{c^2}F_jA^{ij}=\kappa J^i;\qquad(4)$$

$$\begin{aligned}&\frac{{}^*\partial D_{ik}}{\partial t}-\left(D_{ij}+A_{ij}\right)\left(D^j_k+A^{\cdot j}_{k\cdot}\right)+DD_{ik}-\\&-D_{ij}D^j_k+3A_{ij}A^{\cdot j}_{k\cdot}+\frac{1}{2}\left({}^*\nabla_iF_k+{}^*\nabla_kF_i\right)-\\&-\frac{1}{c^2}F_iF_k-c^2C_{ik}=\\&=\frac{\kappa}{2}\left(\rho c^2h_{ik}+2U_{ik}-Uh_{ik}\right)+\widetilde{\lambda}c^2h_{ik},\end{aligned}\qquad(5)$$

where $\rho=\frac{T_{00}}{g_{00}}$ is the observable density of matter, $J^i=\frac{cT^i_0}{\sqrt{g_{00}}}$ is the vector of the observable density of impulse, $U^{ik}=c^2T^{ik}$ is the tensor of the observable density of the impulse flow (the stress tensor), $U=h_{ik}U^{ik}$. We include $\widetilde{\lambda}$ in the equations because the metric (1) is applicable at any scale, not only the cosmological large scale*.

By the theory of physical observable quantities [3, 4], the quantities D_{ik}, F_i, A_{ik} and C_{ik} are the observable characteristics of the observer's reference space: the chr.inv.-tensor of the rates of the space deformation†

$$D_{ik}=\frac{1}{2}\frac{{}^*\partial h_{ik}}{\partial t},\qquad(6)$$

the chr.inv.-vector of the observable gravitational inertial force

$$F_i=\frac{c^2}{c^2-\mathrm{w}}\left(\frac{\partial \mathrm{w}}{\partial x^i}-\frac{\partial v_i}{\partial t}\right),\qquad(7)$$

the chr.inv.-tensor of the angular velocity of the observable rotation of the space (the space non-holonomity tensor)

$$A_{ik}=\frac{1}{2}\left(\frac{\partial v_k}{\partial x^i}-\frac{\partial v_i}{\partial x^k}\right)+\frac{1}{2c^2}\left(F_iv_k-F_kv_i\right),\qquad(8)$$

where $h_{ik}=-g_{ik}+\frac{g_{0i}\,g_{0k}}{g_{00}}=-g_{ik}+\frac{1}{c^2}v_iv_k$ is the observable spatial chr.inv.-metric tensor, $v_i=-\frac{c\,g_{0i}}{\sqrt{g_{00}}}$ is the linear velocity of the rotation of the observer's space reference, $\mathrm{w}=c^2(1-\sqrt{g_{00}})$ is the gravitational potential. The quantity $C_{ik}=h^{mn}C_{imkn}$ is built on the tensor of the observable three-dimensional chr.inv.-curvature of the space

$$\begin{aligned}C_{imkn}=H_{imkn}-\frac{1}{c^2}&\left(2A_{mi}D_{nk}+A_{in}D_{mk}+\right.\\&\left.+A_{nm}D_{ik}+A_{mk}D_{in}+A_{ki}D_{mn}\right),\end{aligned}\qquad(9)$$

which possesses all the properties of the Riemann-Christoffel curvature tensor $R_{\alpha\beta\gamma\delta}$ in the observer's spatial section, and constructed with the use $H_{lkij}=h_{jm}H^{\cdots m}_{lki\cdot}$, where $H^{\cdots m}_{lki\cdot}$ is the chr.inv-tensor similar to Schouten's tensor [5]

$$H^{\cdots m}_{lki\cdot}=\frac{{}^*\partial\Delta^j_{il}}{\partial x^k}-\frac{{}^*\partial\Delta^j_{kl}}{\partial x^i}+\Delta^m_{il}\Delta^j_{km}-\Delta^m_{kl}\Delta^j_{lm},\qquad(10)$$

while Δ^k_{ij} are the observable chr.inv.-Christoffel symbols

$$\Delta^k_{ij}=h^{km}\Delta_{ij,m}=\frac{1}{2}\left(\frac{{}^*\partial h_{im}}{\partial x^j}+\frac{{}^*\partial h_{jm}}{\partial x^i}-\frac{{}^*\partial h_{ij}}{\partial x^m}\right).\qquad(11)$$

In the formulae $\frac{{}^*\partial}{\partial x^i}=\frac{\partial}{\partial x^i}-\frac{1}{c^2}\frac{{}^*\partial}{\partial t}$ and $\frac{{}^*\partial}{\partial t}=\frac{1}{\sqrt{g_{00}}}\frac{{}^*\partial}{\partial t}$ are the chr.inv.-spatial derivative and the chr.inv.-time derivative respectively, while ${}^*\nabla_i$ is the spatial chr.inv.-covariant derivative, for instance, the chr.inv.-divergence of a chr.inv.-vector is ${}^*\nabla_i\,q^i=\frac{{}^*\partial q^i}{\partial x^i}+q^i\frac{{}^*\partial\ln\sqrt{h}}{\partial x^i}=\frac{{}^*\partial q^i}{\partial x^i}+q^i\Delta^j_{ji}$. See [3, 4] or [2] for the details.

We have obtained [1] for the metric (1) the non-zero components of the observable chr.inv.-metric tensor

$$\begin{aligned}&h_{11}=1+\frac{2GM}{c^2r}, &&h_{22}=r^2\left(1+\frac{\omega^2r^2}{c^2}\right),\\&h_{23}=\frac{\omega r^2\mathrm{v}}{c^2}, &&h_{33}=1,\\&h^{11}=1-\frac{2GM}{c^2r}, &&h^{22}=\frac{1-\frac{\omega^2r^2}{c^2}}{r^2},\\&h^{23}=-\frac{\omega\mathrm{v}}{c^2}, &&h^{33}=1,\end{aligned}\qquad(12)$$

nonzero components of F^i and A_{ik}

$$\begin{aligned}&F^1=\left(\omega^2r-\frac{GM}{r^2}\right)\left(1+\frac{\omega^2r^2}{c^2}\right),\\&A^{12}=\frac{\omega}{r}\left(1-\frac{2GM}{c^2r}+\frac{\omega^2r^2}{2c^2}\right),\quad A^{31}=\frac{\omega^2\mathrm{v}r}{c^2},\end{aligned}\qquad(13)$$

and non-zero components of C_{ik}

$$C_{11}=-\frac{GM}{c^2r^3}+\frac{3\omega^2}{c^2},\quad C_{22}=-\frac{GM}{c^2r}+\frac{3\omega^2r^2}{c^2}.\qquad(14)$$

Let's substitute the components of F_i, A_{ik}, C_{ik} and the chr.inv.-derivatives into the chr.inv.-Einstein equations (3), (4), and (5). We obtain

$$\omega^2+\frac{GM}{r^3}+\frac{2\omega^4r^2}{c^2}-\frac{3\omega^2GM}{c^2r}=-\frac{\kappa}{2}\left(\rho c^2+U\right)+\widetilde{\lambda}c^2;\qquad(15)$$

$$\kappa J^1=0;\quad \kappa J^2=\frac{5\omega GM}{c^2r^3};\quad \kappa J^3=-\frac{2\omega^2\mathrm{v}}{c^2};\qquad(16)$$

$$\begin{aligned}&\frac{3GM}{r^3}+\frac{6\omega^4r^2}{c^2}-\frac{\omega^2GM}{c^2r}+\frac{6G^2M^2}{c^2r^4}=\\&=\left[\frac{\kappa}{2}\left(\rho c^2-U\right)+\widetilde{\lambda}c^2\right]\left(1+\frac{2GM}{c^2r}\right)+\kappa U_{11};\end{aligned}\qquad(17)$$

*As probable $\widetilde{\lambda}\sim\frac{1}{R^2}$, where R is the spatial radius of a given region, so the larger the size of a considered region, the smaller is λ. See [2].

†The spatial (three-dimensional) indices are $i,k=1,2,3$.

$$\frac{9\omega^4 r^4}{c^2} - \frac{9\omega^2 GM}{c^2 r} + \frac{2G^2M^2}{c^2r^2} = \\ = \left[\frac{\kappa}{2}\left(\rho c^2 - U\right) + \widetilde{\lambda} c^2\right] r^2 \left(1 + \frac{\omega^2 r^2}{c^2}\right) + \kappa U_{22}\,; \tag{18}$$

$$\frac{\omega^3 \mathrm{v} r^2}{c^2} - \frac{\omega \mathrm{v} GM}{c^2 r} = \left[\frac{\kappa}{2}\left(\rho c^2 - U\right) + \widetilde{\lambda} c^2\right]\frac{\omega \mathrm{v} r^2}{c^2} + \kappa U_{23}\,; \tag{19}$$

$$\frac{\kappa}{2}\left(\rho c^2 - U\right) + \widetilde{\lambda} c^2 + \kappa U_{33} = 0\,. \tag{20}$$

Equations (15–20) are written for an arbitrary energy-momentum tensor $T_{\alpha\beta}$. As is well known, the left side of the Einstein equations must have a positive sign. We therefore conclude, from the first (scalar) chr.inv.-Einstein equation (15), that the cosmological term $\widetilde{\lambda}$ must be $\widetilde{\lambda} \geqslant 0$. (If $\widetilde{\lambda} > 0$, the non-Newtonian λ-force is the force of repulsion). So, in order to have the metric (1) satisfy the Einstein equations, we can have only the repulsive non-Newtonian forces in the given region described by the metric (1).

We express the right side of the general covariant Einstein equations (2) as the algebraic sum of two tensors

$$\kappa \widetilde{T}_{\alpha\beta} = \kappa T_{\alpha\beta} - \frac{\widetilde{\lambda}}{\kappa}\, g_{\alpha\beta}\,, \tag{21}$$

where the first tensor describes a substance, while the second describes vacuum (λ-fields). We assume that the given space is permeated by only λ-fields, i. e. $T_{\alpha\beta} = 0$. In such a case the observable components of the energy-momentum tensor of vacuum are

$$\widetilde{\rho} = -\frac{\widetilde{\lambda}}{\kappa}\,, \qquad \widetilde{J}^i = 0\,, \qquad \widetilde{U}^{ik} = \frac{\widetilde{\lambda} c^2}{\kappa}\,. \tag{22}$$

We see that the observable density of vacuum $\widetilde{\rho} = \mathrm{const}$ is $\widetilde{\rho} < 0$, if $\widetilde{\lambda} > 0$ and $\widetilde{J}^i = 0$. So the $\widetilde{\lambda}$-vacuum is a medium with a negative constant density, and also no flows of mass (energy) therein.

We obtain from the the second (vector) chr.inv.-Einstein equation (16): $J^1 = 0$, $J^2 \neq 0$, $J^3 \neq 0$ ($J^3 < 0$), so $J^i \neq 0$ in general. Because $J^i = 0$ in vacuum, we conclude that:

> Any region of space described by the metric specifically along the trajectory of any orbiting body in the Universe cannot be pervaded solely by vacuum, but must also be permeated by another distributed substance.
>
> Orbital motion is the main kind of motion in the Universe. We therefore conclude that the space of the Universe must be non-empty; necessarily filled by a substance (e. g. gas, dust, radiations, etc.). Being a direct deduction from the Einstein equations, this is one more fundamental fact predicted by Einstein's General Theory of Relativity.

Naturally, as astronomical observations in recent decades testify, such substances as gas, dust and radiations are found in any part of that region of the Universe that is accessible by modern astronomical techniques. We therefore aim to describe the medium pervading space, by means of the algebraical sum of two energy-momentum tensors

$$T_{\alpha\beta} = T^{(\mathrm{g})}_{\alpha\beta} + T^{(\mathrm{em})}_{\alpha\beta}\,, \tag{23}$$

where $T^{(\mathrm{em})}_{\alpha\beta}$ is set up for electromagnetic radiations as in [6], while $T^{(\mathrm{g})}_{\alpha\beta}$ describes an ideal liquid or gas

$$T^{(\mathrm{g})}_{\alpha\beta} = \left(\rho_{(\mathrm{g})} - \frac{p}{c^2}\right) b^\alpha b^\beta - \frac{p}{c^2}\, g^{\alpha\beta}, \tag{24}$$

where $\rho_{(\mathrm{g})}$ is the observable density of the medium, p is the pressure within it, while $b^\alpha = \frac{dx^\alpha}{ds}$ is the four-dimensional velocity of the flow of the medium with respect to the reference space (reference body). Gas is a medium in which particles move chaotically with respect to each other, and also with respect to an observer's reference space. So a reference space doesn't accompany to flow of mass (energy) in the gas.

The observable components of $T^{(\mathrm{g})}_{\alpha\beta}$ are

$$\frac{T_{00}}{g_{00}} = \frac{\rho_{(\mathrm{g})} - \frac{p}{c^2}}{1 - \frac{{}^*u^2}{c^2}} - \frac{p}{c^2}\,, \qquad J^i = \frac{\rho_{(\mathrm{g})} - \frac{p}{c^2}}{1 - \frac{{}^*u^2}{c^2}}\, {}^*u^i, \\ U^{ik} = \frac{\left(\rho_{(\mathrm{g})} - \frac{p}{c^2}\right) {}^*u^i\, {}^*u^k}{1 - \frac{{}^*u^2}{c^2}} + p\, h^{ik}, \tag{25}$$

while the trace of the stress-tensor U^{ik} is

$$U = \frac{\left(\rho_{(\mathrm{g})} - \frac{p}{c^2}\right) {}^*u^2}{1 - \frac{{}^*u^2}{c^2}} + 3p\,, \tag{26}$$

where ${}^*u^i = \frac{dx^i}{d\tau}$ is the three-dimensional observable velocity of the flow of the medium (${}^*u^2 = {}^*u_i {}^*u^i = h_{ik} {}^*u^i {}^*u^k$).

A reference frame (space) where the flow stream of a mass is $q^i = c^2 J^i \neq 0$, doesn't accompany the medium. As seen from (16) and (25), given the case we are considering, ${}^*u^1 = 0$, while ${}^*u^2 \neq 0$ and ${}^*u^3 \neq 0$. Hence:

> If a body orbits at a radius r in the z-direction, a substantive medium that necessarily pervades the space has motions in the φ and z-directions (in the cylindrical spatial coordinates r, φ, z).

2 Maxwell's equations in a rotating space: a body can orbit only if there is a non-zero interplanetary or interstellar magnetic field along the trajectory

What structure is attributed to an electromagnetic field if the field fills the local space of an orbiting body? As is well known, the energy-momentum tensor of an electromagnetic field has the form [6]

$$T^{(\mathrm{em})}_{\alpha\beta} = \frac{1}{4\pi c^2}\left(-F_{\alpha\sigma}F^{\sigma\cdot}_{\cdot\beta} + \frac{1}{4}\, F_{\sigma\tau}F^{\sigma\tau} g_{\alpha\beta}\right), \tag{27}$$

where $F_{\alpha\beta} = \frac{1}{2}\left(\frac{\partial A_\beta}{\partial x^\alpha} - \frac{\partial A_\alpha}{\partial x^\beta}\right)$ is Maxwell's electromagnetic field tensor, while A^α is the four-dimensional electromagnetic field potential given the observable chr.inv.-projections

$\varphi = \frac{A_0}{\sqrt{g_{00}}}$ and $q^i = A^i$ (the scalar and vector three-dimensional chr.inv.-potentials). The observable chr.inv.-components of $T^{(\mathrm{em})}_{\alpha\beta}$ obtained in [2] are

$$\begin{aligned} &\rho_{(\mathrm{em})} = \frac{E^2 + H^{*2}}{8\pi c^2}\,, \quad J^i_{(\mathrm{em})} = \frac{1}{4\pi c}\,\varepsilon^{ikm} E_k H_{*m}\,, \\ &U^{ik}_{(\mathrm{em})} = \rho_{(\mathrm{em})} h^{ik} - \frac{1}{4\pi}\left(E^i E^k + H^{*i} H^{*k}\right), \\ &U_{(\mathrm{em})} = \rho_{(\mathrm{em})}\,, \end{aligned} \tag{28}$$

where E_i and the H^{*i} are the observable chr.inv.-electric and magnetic field strengths, which are the chr.inv.-projections of the electromagnetic field tensor $F_{\alpha\beta}$ (read Chapter 3 in [2] for the details):

$$E_i = \frac{{}^*\partial\varphi}{\partial x^i} + \frac{1}{c}\frac{{}^*\partial q^i}{\partial t} - \frac{\varphi}{c^2}\,F^i, \tag{29}$$

$$H^{*i} = \frac{1}{2}\,\varepsilon^{imn} H_{mn} = \frac{1}{2}\,\varepsilon^{imn}\left(\frac{{}^*\partial q_m}{\partial x^n} - \frac{{}^*\partial q_n}{\partial x^m} - \frac{2\varphi}{c} A_{mn}\right). \tag{30}$$

We consider electromagnetic fields that fill the space as electromagnetic waves — free fields without the sources that induced them. By the theory of fields, in such an electromagnetic field the electric charge density and the current density vector are zero. In such a case Maxwell's equations have the chr.inv.-form [2]:

$$\left.\begin{aligned} &{}^*\nabla_i E^i - \frac{2}{c}\,\Omega_m H^{*m} = 0 \\ &\varepsilon^{ikm}\,{}^*\widetilde{\nabla}_k\left(H_{*m}\sqrt{h}\right) - \frac{1}{c}\frac{{}^*\partial}{\partial t}\left(E^i\sqrt{h}\right) = 0 \end{aligned}\right\}\ \mathrm{I} \tag{31}$$

$$\left.\begin{aligned} &{}^*\nabla_i H^{*i} + \frac{2}{c}\,\Omega_m E^{*m} = 0 \\ &\varepsilon^{ikm}\,{}^*\widetilde{\nabla}_k\left(E_m\sqrt{h}\right) + \frac{1}{c}\frac{{}^*\partial}{\partial t}\left(H^{*i}\sqrt{h}\right) = 0 \end{aligned}\right\}\ \mathrm{II} \tag{32}$$

where $H_i = \frac{1}{2}\,\varepsilon_{imn} H^{mn}$, and ${}^*\widetilde{\nabla}_k = {}^*\nabla_k - \frac{1}{c^2}\,F_k$ denotes the chr.inv.-physical divergence.

Because of the ambiguity of the four-dimensional potential A^α, we can choose for $\varphi = 0$ [6]. A space wherein the metric (1) is stationary, gives $\frac{{}^*\partial q^i}{\partial t} = 0$. Because the components of $g_{\alpha\beta}$ depend solely on $x^1 = r$ of the spatial coordinates r, φ, z, the components of the energy-momentum tensor depend only on r. In such a case we obtain, from formulae (29) and (30), $E_i = 0$, $H^{*1} = H_{*1} = 0$, $H^{*2} = \frac{1}{\sqrt{h}}\frac{\partial q_3}{\partial r}$ and $H^{*3} = -\frac{1}{\sqrt{h}}\frac{\partial q_2}{\partial r}$, so the aforementioned chr.inv.-Maxwell equations take the form

$$\begin{aligned} &\Omega_m H^{*m} = 0\,, \\ &\varepsilon^{ikm}\,{}^*\widetilde{\nabla}_k\left(H_{*m}\sqrt{h}\right) = 0\,, \\ &{}^*\nabla_i H^{*i} = 0\,. \end{aligned} \tag{33}$$

We substitute into the first of these equations the values $\Omega_1 = 0$, $\Omega_2 = \frac{\omega^2 r \mathrm{v}}{c^2}$ and $\Omega_3 = \frac{\omega}{r}\left(1 - \frac{2GM}{c^2 r} + \frac{\omega^2 r^2}{2c^2}\right)$ we have calculated for the metric (1). As a result we obtain a correlation between two components of the electromagnetic field vector chr.inv.-potential q^i, that is

$$q_2' = \frac{\omega \mathrm{v} r^2}{c^2}\,q_3'\,, \tag{34}$$

where the prime denotes the differentiation with respect to r.

With the use of (30) we obtain H_{*2} and H_{*3}

$$H_{*2} = r\left(1 - \frac{GM}{c^2 r} + \frac{\omega^2 r^2}{2c^2}\right) q_3'\,, \quad H_{*3} = 0\,, \tag{35}$$

so the second equation of (33) takes the form

$$r q_3''\left(1 - \frac{GM}{c^2 r} + \frac{\omega^2 r^2}{2c^2}\right) + q_3'\left(2 - \frac{GM}{c^2 r} + \frac{2\omega^2 r^2}{c^2}\right) = 0\,, \tag{36}$$

while the third equation of (33) is satisfied identically.

Equation (36) has separable variables, and so can be rewritten as follows

$$\frac{dy}{y} = -\frac{dr}{r}\left(1 + \frac{3\omega^2 r^2}{2c^2}\right), \tag{37}$$

where $y = q_3'$. Integrating it, we obtain

$$y = q_3' = \frac{K}{r}\,e^{-\frac{3\omega^2 r^2}{4c^2}} \approx \frac{K}{r}\left(1 - \frac{3\omega^2 r^2}{4c^2}\right), \tag{38}$$

where K is a constant of integration. Assuming $r = r_0$ and $y_0 = q_{3(0)}$ at the initial moment of time, we determine the constant: $K = y_0 r_0\left(1 + \frac{3\omega^2 r_0^2}{4c^2}\right)$. Integrating (38), we have

$$q_3 = K\left(\ln r - \frac{3\omega^2 r^2}{8c^2}\right) + L\,, \quad L = \mathrm{const.} \tag{39}$$

Determining the integration constant L from the initial conditions, we obtain the final expression for q_3:

$$q_3 = K\left[\ln\frac{r}{r_0} - \frac{3\omega^2}{8c^2}\left(r^2 - r_0^2\right)\right] + q_3(0)\,, \tag{40}$$

where $q_3(0)$ is the initial value of q_3. Substituting (40) into (34) we obtain the equation

$$q_2' = \frac{\omega \mathrm{v} K r}{c^2}\,, \tag{41}$$

which is easily integrated to

$$q_2 = \frac{\omega \mathrm{v} K}{2c^2}\left(r^2 - r_0^2\right). \tag{42}$$

Finally, we calculate the non-zero components of the magnetic strength chr.inv.-vector H^{*i}. Substituting the obtained formulae for q_3' (38) and q_2' (41) into the definition of H^{*i} (30), we obtain

$$\begin{aligned} &H^{*2} = \frac{1}{\sqrt{h}} H_{31} = q_3'(0)\left(1 - \frac{GM}{c^2 r} - \frac{\omega^2 r^2}{2c^2} + \frac{3\omega^2 r_0^2}{4c^2}\right), \\ &H^{*3} = \frac{1}{\sqrt{h}} H_{12} = -\frac{\omega \mathrm{v} r_0}{c^2}\,q_3'(0)\,. \end{aligned} \tag{43}$$

This is the solution for H^{*i}, the magnetic strength chr. inv.-vector, obtained from the chr.inv.-Maxwell equations in the rotating space of an orbiting body. The solution we have obtained shows that:

> A free electromagnetic field along the trajectory of an orbiting body ($\omega \neq 0$, $\mathrm{v} \neq 0$) cannot be zero, and is represented by purely magnetic "standing" waves (all components of the electric strength are $E^i = 0$).

This fundamental conclusion is easily obtained from the solution (43).

The linear velocity v of the orbiting body (the body moves in the $x^3 = z$-direction) produces effects in only the q_2-component of the three-dimensional observable vector potential (i. e. along the φ-direction).

The solution (43) exists only if the initial value of the derivative with respect to r of the z-component of the three-dimensional observable vector potential is $q_3'(0) \neq 0$.

The z-component $H^{*3} \neq 0$ if the reference body (in common with the observer) moves in the $x^3 = z$-direction at a linear velocity v and, at the same time, rotates orthogonally to it in the $x^2 = \varphi$-direction at an angular velocity ω. The component H^{*3} is positive, if v is negative. So H^{*3} is directed opposite to the motion of the observer (and his reference planet, the Earth for instance). The numerical value of H^{*3} is $\sim 8\times10^{-8}$ of H^{*2}. If the reference planet has its orbit "stopped" in the z-direction (a purely theoretical case), only $H^{*2} \neq 0$ is left because it depends on $\frac{GM}{c^2 r}$ and $\frac{\omega^2 r^2}{2c^2}$.

The stationary solution (43) of the chr.inv.-Maxwell equations describes standing magnetic waves in the φ- and z-directions. In such a case, as follows from the condition $E_i = 0$, the Pointing vector (the density of the impulse of the electromagnetic field) is $J^i_{(\mathrm{em})} = 0$ (see formula 28). On the other hand the Einstein equations (15–20) we have obtained for the rotating space of an orbiting body (the same space as that used for the Maxwell equation) have the density of the impulse of matter $J^i \neq 0$ (see formula 16 in the Einstein equations), which should be applicable to any distribution of matter, including electromagnetic fields. This implies that:

> In the rotating space of an orbiting body, electromagnetic fields don't satisfy the Einstein equations if there is no distribution of another substance (dust, gas or something else) in addition to the fields.

As follows from (25) we have obtained in the metric considered, $J^i \neq 0$ for an ideal liquid or gas. So, if an electromagnetic field is added by a gaseous medium (for instance), they can together satisfy the Einstein equations in the rotating space of an orbiting body. We therefore conclude that:

> Interplanetary/interstellar space where space bodies are orbiting, must be necessarily pervaded by electromagnetic fields with a concomitant distribution of substantial matter, such as a gaseous medium, for instance.

We have actually shown that space bodies cannot undergo orbital motion in empty space, i. e. if electromagnetic fields and other substantive media (e. g. dust, gas, etc.) are not present. What a bizarre result!

It should be noted that we have obtained this startling conclusion using no preliminary proposition or hypothesis. This conclusion follows directly from the requirement for Maxwell's equations and Einstein's equations to be both satisfied in the rotating space of an orbiting body. So this is the *actual condition for orbital motion*, according to General Relativity.

3 Preferred spatial directions as a result of the interaction of the space non-holonomity fields

In this section we have to consider three problems arising from the specific space structure we have obtained for orbital motion.

First problem. Refer to the chr.inv.-Einstein equations (15–20) we have obtained in the rotating space of an orbiting body. The most significant terms in the left side of the scalar equation (15) are the first two. They both have a positive sign. Hence the right side of equation (15) must also be positive, i. e. the right side must satisfy the condition,

$$\widetilde{\lambda} c^2 > \frac{\kappa}{2}\left(\rho c^2 + U\right). \tag{44}$$

Let's apply this condition to a particular case of the orbiting body spaces: the space within the corridor along which the Earth orbits in the Galaxy. As a matter fact, this space is governed by the metric (1). In this space we have, $\omega^2 = 4\times10^{-14}\,\mathrm{sec}^{-2}$, $M = M_\odot = 2\times10^{33}$ g, $r = 15\times10^{12}$ cm. We obtain, $\omega^2 + \frac{GM}{r^3} \simeq 8\times10^{-14}\,\mathrm{sec}^{-2}$. Therefore

$$\widetilde{\lambda} c^2 > 8\times10^{-14}\,\mathrm{cm}^{-2}, \qquad \widetilde{\lambda} > 10^{-34}\,\mathrm{cm}^{-2}. \tag{45}$$

As a result $\widetilde{\lambda} > 10^{-34}\,\mathrm{cm}^{-2}$ numerically equals $\frac{\omega^2}{2c^2}$ — the quantity which was proven in [7] to be the square of the dynamical "magnetic" strength of the field of the space non-holonomity. We therefore conclude that the $\widetilde{\lambda}$-field is connected to the non-holonomity field of the Earth's space.

We note that the Earth's space is non-holonomic due to the effect of a number of factors such as the daily rotation of the Earth, its yearly rotation around the Sun, its common rotation with the solar system around the centre of the Galaxy, etc. Each factor produces a field of non-holonomity, the algebraical sum of which gives the complete field of non-holonomity of the Earth.

Given the problem statement we are considering, the obtained numerical value $\widetilde{\lambda} > 10^{-34}\,\mathrm{cm}^{-2}$ characterizing the non-Newtonian force of repulsion is attributed to the non-holonomity field of the Earth's space which is caused by the Earth's rotation around the Sun. If other problem statements are considered, we can calculate the numerical values of $\widetilde{\lambda}$ characterizing the other factors of the Earth's space non-holonomity. The non-Newtonian forces of repulsion obtained therein are expected to be directed according to the acting factors (in different directions), so the numerical value of each $\widetilde{\lambda}$ has its own meaning, whilst their sum builds the common non-Newtonian repulsing force acting in the Earth's space.

Second problem. As follows from the scalar Einstein equation (16), the density of the impulse of the distributed matter in the $x^3 = z$-direction

$$J^3 = -\frac{2\omega^2 \mathrm{v}}{\kappa c^2} \tag{46}$$

has a negative numerical value. So the flow of the distributed medium that fills the space is directed opposite to the orbital motion. In other words, according to the theory, the orbiting body should meet a counter-flow by the medium: a "relativistic braking" should be expected in orbital motions. Because the orbiting bodies, e. g. the stars, the planets and the satellites, show no such orbital braking, we propose a mechanism that refurbishes the braking energy of the medium into another sort of energy — heat or radiations, for instance.

This conclusion finds verification in recent theoretical research which, by means of General Relativity, indicates that stars produce energy due to the background space non-holonomity [8, 9]. It is shown in papers [8, 9], that General Relativity, in common with topology, predicts that the most probable configuration of the background space of the Universe is globally non-holonomic. The global anisotropic effect is expected to manifest as the anisotropy of the Cosmic Microwave Background Radiation and the anisotropy of the observable velocity of light. Moreover, if the global non-holonomic background is perturbed by a local rotation or oscillation (local non-holonomic fields), the background field produces energy in order to compensate for the perturbation in it. Such an energy producing mechanism is expected to be operating in stars, in the process of transfer of radiant energy from the central region to the surface, which has verification in the data of observational astrophysics [9].

From the standpoint of our theory herein, the aforementioned mechanism producing stellar energy [8, 9] is due to a number of factors that build the background space non-holonomity field in stars, not only the globally non-holonomic field of the Universe. By our theory, the substantive distribution is also connected to the space non-holonomity so that the braking energy of the medium is related to the space non-holonomity field. So a star, being in orbit in the Galaxy and the group of galaxies, meets the non-holonomity fields produced by the rotations of the Galactic space, the Local Group of galaxies, etc. Then the braking energy of the medium that fills the spaces (the same as for the energy of the space non-holonomic field) transforms into heat and radiations within the star by the stellar energy mechanism as shown in [8, 9]. In other words, a star "absorbs" the energy of the non-holonomity fields of the spaces wherein it is orbiting, then transforms the energy into heat and radiations.

Employing this mechanism in an Earth-bound laboratory, we can obtain a new source of energy due to the fact that the Earth orbits in the non-holonomic fields of the space.

Third problem. A relative variation of the observable velocity of light in the z-direction we have obtained in [1] is

$$\frac{\Delta \dot{z}}{c} = 2\times10^{-4} \sin 2\widetilde{\omega}\tau\,, \tag{47}$$

where $\widetilde{\omega} = \omega\left(1 + \frac{\mathrm{v}}{c}\right)$, whilst given an Earth-bound laboratory the space rotation thereof is the sum of the Earth's rotations around the Sun and around the centre of the Galaxy. We see therefore, that we have a relative variation $\frac{\Delta \dot{z}}{c} \neq 0$ of the observable velocity of light only if both $\omega \neq 0$ and $\mathrm{v} \neq 0$. Hence the predicted anisotropy of the observable velocity of light depends on the interaction of two fields of non-holonomity that are represented in the laboratory space (within the framework of the considered problem statement).

The same is true for the flow of matter distributed throughout the space (46): $J^3 \neq 0$ only if both $\omega \neq 0$ and $\mathrm{v} \neq 0$. Thus the energy produced in a star due to the background space non-holonomity should be dependent not only on the absolute value of the non-holonomity (as the sum of all acting non-holonomic fields), but also on the interaction between the non-holonomic fields.

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