RELATIVISTIC ELASTICITY IN THE 3D-BRANE UNIVERSE MODEL. PART 3.

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Abstract. The 3D-brane universe model is the name of a new non-Einsteinian theory of gravity. In the two previous papers, nonlinear relativistic elastic media were considered within this theory. The first paper comprises the derivation of differential equations of motion, while the second one comprises the derivation of boundary conditions for them in the case of perfect contact. Here, we consider the case of ideal slip and derive the boundary conditions for this case.

1. Introduction.

The main concept of the 3D-brane universe model is that our physical universe M is a 3D-manifold equipped with a time-dependent Riemannian metric

$$g_{ij}=g_{ij}(t,x^1,x^2,x^3),\quad 1\leqslant i,j\leqslant 3. \tag{1.1}$$

The four-dimensional spacetime M_4 is not a physical continuum in the new theory. It is just a mathematical abstraction that serves as a bridge connecting the new theory with Einstein's relativity. As in the Lorentz ether theory (also known as the Lorentz–Larmor–Poincaré ether theory, see [1]) and the Robertson–Mansouri–Sexl theory (see [2]), there is a preferred class of coordinates in the 3D-brane universe model, which are called comoving coordinates. Furthermore, there is a class of preferred global time variables in this theory, which are called membrane time, or brane time for short (see the monograph [3] in Russian or its English translation [4]). More references can be found in e-prints [5–20] and conference abstracts [21–39].

A nonlinear relativistic elastic medium was considered in [18]. Its Lagrangian density was given by the following formula:

$$\mathcal{L}_{\text{mat}}=-\rho\,c_{\text{br}}^2\sqrt{g_{00}-\frac{|\mathbf{v}|^2}{c_{\text{br}}^2}}-\mathcal{F}(y,J,\mathbf{v},\mathbf{u}) \tag{1.2}$$

Using (1.2), the differential equations of motion for relativistic elastic media were derived. They consist of the equation for the rest mass density

$$\frac{\partial\rho}{\partial t}+\sum_{k=1}^{3}c_{\text{gr}}\,\rho\,b_k^k+\sum_{i=1}^{3}\nabla_i(\rho\,v^i)=0 \tag{1.3}$$

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and the equations for the components of the momentum covector density

$$\frac{\partial p_n}{\partial t}+\sum_{k=1}^{3} c_{\text{gr}}\,p_n\,b^k_k+\sum_{m=1}^{3}\nabla_m\Pi^m_n=f_n+\mathcal{F}_n. \tag{1.4}$$

The quantities p_n and Π^m_n in (1.4) are given by the formulas

$$p_n=\frac{\rho\,v_n}{\sqrt{g_{00}-\dfrac{|\mathbf{v}|^2}{c^2_{\text{br}}}}}\,, \qquad\qquad \Pi^m_n=\frac{\rho\,v_n\,v^m}{\sqrt{g_{00}-\dfrac{|\mathbf{v}|^2}{c^2_{\text{br}}}}}\,. \tag{1.5}$$

The quantities Π^m_n in (1.5) are components of the momentum flux density tensor. The quantities f_n and $\mathcal{F}_n$ in (1.4) correspond to the densities of bulk forces:

$$f_n=-\frac{1}{2}\,\frac{\rho\,c^2_{\text{br}}\,\nabla_n g_{00}}{\sqrt{g_{00}-\dfrac{|\mathbf{v}|^2}{c^2_{\text{br}}}}}\,. \tag{1.6}$$

The quantities f_n in (1.6) are components of the gravity force density. As for $\mathcal{F}_n$, they are given by a more complicated formula:

$$\mathcal{F}_n=\sum_{i=1}^{3}\left(-\frac{\partial}{\partial t}\left(\frac{\delta\mathcal{F}}{\delta w^i}\right)_{\substack{g,\dot{g},\mathbf{g}\\ \mathbf{b},y}}-c_{\text{gr}}\left(\frac{\delta\mathcal{F}}{\delta w^i}\right)_{\substack{g,\dot{g},\mathbf{g}\\ \mathbf{b},y}}\sum_{q=1}^{3}b^q_q+\left(\frac{\delta\mathcal{F}}{\delta y^i}\right)_{\substack{g,\dot{g},\mathbf{g}\\ \mathbf{b},w}}\right)J^i_n. \tag{1.7}$$

The quantities $\mathcal{F}_n$ in (1.7) are components of the elastic stress force density.

Two nonlinear relativistic media were considered in [20]. Their Lagrangian densities were given by the following formulas analogous to (1.2):

$$\mathcal{L}^-_{\text{mat}}=-\rho^-\,c^2_{\text{br}}\sqrt{g_{00}-\frac{|\mathbf{v}|^2}{c^2_{\text{br}}}}-\mathcal{F}^-(y,J,\mathbf{v},\mathbf{u}), \tag{1.8}$$

$$\mathcal{L}^+_{\text{mat}}=-\rho^+\,c^2_{\text{br}}\sqrt{g_{00}-\frac{|\mathbf{v}|^2}{c^2_{\text{br}}}}-\mathcal{F}^+(y,J,\mathbf{v},\mathbf{u}). \tag{1.9}$$

Using (1.8) and (1.9), the boundary conditions at the interface of the two media were derived in [20]. They are written as follows:

$$\sum_{s=1}^{3}\Bigl(\mathcal{B}^+_m\,v^s_+-\mathcal{C}^{s+}_m\Bigr)n_s\,\Bigr|_{\sigma}=\sum_{s=1}^{3}\Bigl(\mathcal{B}^-_m\,v^s_--\mathcal{C}^{s-}_m\Bigr)\,n_s\,\Bigr|_{\sigma}. \tag{1.10}$$

The quantities $\mathcal{B}^\pm_m$ and $\mathcal{C}^{s\pm}_m$ in (1.10) are related to the Lagrangian densities (1.8) and (1.9) through a multistep algorithm based on the calculus of variations. The reader can find this algorithm in [20].

The boundary conditions (1.10) correspond to the case of perfect contact where the velocity vector $\mathbf{v}$ is continuous at the interface of the media:

$$v^i_+\Bigr|_{\sigma}=v^i_-\Bigr|_{\sigma}. \tag{1.11}$$

The case of ideal slip is opposite to (1.11). In this case,

$$\sum_{i=1}^{3} v_{+}^{i}\,n_i\,\Bigr|_{\sigma}=\sum_{i=1}^{3} v_{-}^{i}\,n_i\,\Bigr|_{\sigma}. \tag{1.12}$$

Relation (1.12) means that only the normal component of the velocity vector $\mathbf{v}$ is continuous across the interface. The main goal of the present paper is to derive the boundary conditions analogous to (1.10) for the case of ideal slip (1.12).

2. Dynamical variables of elastic media.

Following [20], we consider two elastic media with Lagrangian densities (1.8) and (1.9). We assume that they both were melted and then frozen in some static 3D-space with the static Riemannian metric

$$\eta_{ij}=\eta_{ij}(y^1,y^2,y^3),\quad 1\leqslant i,j\leqslant 3. \tag{2.1}$$

Upon being solidified, the media fill two static domains Ω_+ and Ω_- in the static space with coordinates y^1, y^2, y^3. Then these media are immersed in the real universe M, which is described by some comoving coordinates x^1, x^2, x^3, some brane time t, and the metric (1.1). The immersion is described by the functions

$$\begin{cases} x^1=x^1_+(t,y^1,y^2,y^3),\\ x^2=x^2_+(t,y^1,y^2,y^3),\\ x^3=x^3_+(t,y^1,y^2,y^3),\end{cases}\qquad \begin{cases} x^1=x^1_-(t,y^1,y^2,y^3),\\ x^2=x^2_-(t,y^1,y^2,y^3),\\ x^3=x^3_-(t,y^1,y^2,y^3).\end{cases} \tag{2.2}$$

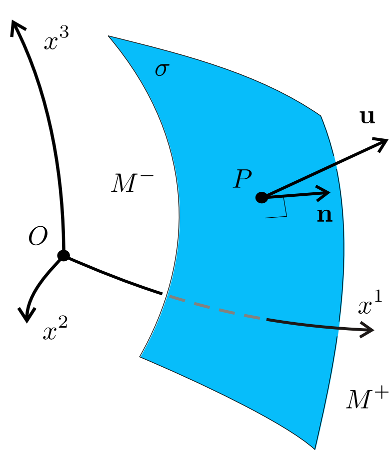

Fig. 2.1

The functions (2.2) map the domains Ω_+ and Ω_- onto two moving domains M^+ and M^- separated by the moving interface σ (see Fig. 2.1). These functions are assumed to be differentiable. They produce two Jacobian matrices

$$M^r_{m+}=\frac{\partial x^r_+}{\partial y^m}, \tag{2.3}$$

$$M^r_{m-}=\frac{\partial x^r_-}{\partial y^m}. \tag{2.4}$$

The matrices (2.3) and (2.4) are assumed to be continuously extendable onto the boundaries of the domains Ω_+ and Ω_-.

The mappings produced by the functions (2.2) are assumed to be invertible. Their inverse mappings are given by

$$\begin{cases} y^1=y^1_+(t,x^1,x^2,x^3),\\ y^2=y^2_+(t,x^1,x^2,x^3),\\ y^3=y^3_+(t,x^1,x^2,x^3),\end{cases}\qquad \begin{cases} y^1=y^1_-(t,x^1,x^2,x^3),\\ y^2=y^2_-(t,x^1,x^2,x^3),\\ y^3=y^3_-(t,x^1,x^2,x^3).\end{cases} \tag{2.5}$$

The mappings (2.5) produce two Jacobian matrices inverse to (2.3) and (2.4):

$$J^i_{j+} = \frac{\partial y^i_+}{\partial x^j}, \qquad\qquad J^i_{j-} = \frac{\partial y^i_-}{\partial x^j}. \tag{2.6}$$

The matrices (2.6) are continuously extendable onto the interface σ. However, their values on σ do not necessarily coincide. We can treat them as a single matrix-valued function J defined in the union of the domains M^+ and M^- with a discontinuity at the interface σ.

As in [18] and [20], we choose the functions (2.5) to be the dynamical variables of our media.

3. Variations of the dynamical variables.

The dynamical variables given by the functions (2.5) are independent within the bulk of their domains M^+ and M^-. However, their values at the interface σ are not independent.

Generally speaking, the domains Ω_+ and Ω_- in the static space may be completely disjoint. However, their boundaries have certain parts that are mapped onto the interface σ by means of the functions (2.2). By changing the coordinates in Ω_+ and Ω_- and subsequently cutting and gluing the static space itself, we can make these parts of the boundaries flat and bring them into contact (see Fig. 3.1). By the same actions, we can additionally provide the following equality in the case of perfect contact:

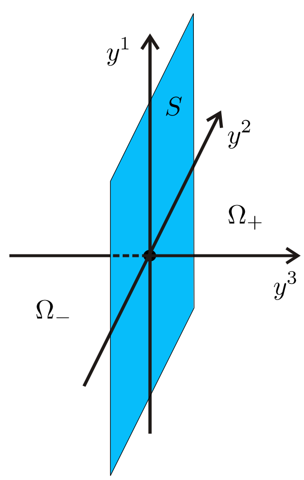

Fig. 3.1

$$y^i_+\Big|_{\sigma,t=t_0} = y^i_-\Big|_{\sigma,t=t_0}. \tag{3.1}$$

Applying (2.2) to (3.1), we obtain

$$x^i_+\Big|_{S,t=t_0} = x^i_-\Big|_{S,t=t_0}. \tag{3.2}$$

Afterwards, from (1.11) and (3.2), taking into account $v^i_+ = \dot{x}^i_+$ and $v^i_- = \dot{x}^i_-$, we derive the following relation for all instants of time:

$$x^i_+\Big|_S = x^i_-\Big|_S. \tag{3.3}$$

Finally, applying the backward transformation functions (2.5) to (3.3), we extend the initial relation (3.1) to all instants of time:

$$y^i_+\Big|_\sigma = y^i_-\Big|_\sigma. \tag{3.4}$$

Relation (3.4) was implicitly used in [20]; here, it has been rigorously proved. It shows that the number of independent dynamical variables at the interface σ in the case of perfect contact is three instead of six.

The case of ideal slip is more complicated. The domains Ω_+ and Ω_- are brought into contact at the plane S given by the equation $y^3 = 0$ (see Fig. 3.1). This plane is mapped onto the interface σ by the forward transformation functions (2.2). Therefore, the relation (3.4) is replaced by less restrictive relations in this case:

$$y^3_+\Big|_\sigma = 0, \qquad\qquad y^3_-\Big|_\sigma = 0. \tag{3.5}$$

Let $X = (x^1, x^2, x^3) \in \sigma$ be some arbitrary point on the interface σ. Applying the backward transformation functions (2.5) to it, we get two points:

$$Y_+ = (y^1_+, y^2_+, 0) \in S, \qquad\qquad Y_- = (y^1_-, y^2_-, 0) \in S \tag{3.6}$$

In general, the points Y_+ and Y_- in (3.6) do not coincide.

In order to pass to variations, we introduce a small parameter $\varepsilon \to 0$ into the argument lists of the functions (2.2) and (2.5). Even for $\varepsilon \neq 0$, these functions implement mutually inverse transformations. Therefore, we write

$$\begin{aligned}
&x^i_+(\varepsilon, t, y^1_+(\varepsilon, t, x^1, x^2, x^3), y^2_+(\varepsilon, t, x^1, x^2, x^3), y^3_+(\varepsilon, t, x^1, x^2, x^3)) = x^i,\\
&x^i_-(\varepsilon, t, y^1_-(\varepsilon, t, x^1, x^2, x^3), y^2_-(\varepsilon, t, x^1, x^2, x^3), y^3_-(\varepsilon, t, x^1, x^2, x^3)) = x^i.
\end{aligned} \tag{3.7}$$

We differentiate (3.7) with respect to ε and then substitute $\varepsilon = 0$. Moreover, we set x^1, x^2, x^3 to be the coordinates of the point $X \in \sigma$. This yields

$$\begin{aligned}
&x^{i\,\prime}_{\varepsilon+}(0, t, Y_+) + \sum_{k=1}^{3} M^i_{k+}(0, t, Y_+)\, y^{k\,\prime}_{\varepsilon+}(0, t, X) = 0,\\
&x^{i\,\prime}_{\varepsilon-}(0, t, Y_-) + \sum_{k=1}^{3} M^i_{k-}(0, t, Y_-)\, y^{k\,\prime}_{\varepsilon-}(0, t, X) = 0.
\end{aligned} \tag{3.8}$$

For comparison with (7.8) in [18] and with (6.2) in [20], we write

$$\hat{y}^k_\pm = y^k_+ + \varepsilon h^k_\pm(t, x^1, x^2, x^3) + \ldots, \tag{3.9}$$

where

$$h^k_\pm(t, x^1, x^2, x^3) = y^{k\,\prime}_{\varepsilon\pm}(0, t, x^1, x^2, x^3). \tag{3.10}$$

In the case of perfect contact, the functions (3.10) are arbitrary smooth functions with compact support in the bulk of the domains $M^\pm$ whose values coincide on the interface σ due to (3.4). In our present case of ideal slip, the functions $h^1_\pm(t, x^1, x^2, x^3)$ and $h^2_\pm(t, x^1, x^2, x^3)$ are also arbitrary functions within the bulk of the domains $M^\pm$, but their values at the interface σ do not necessarily coincide:

$$h^1_+(t, X) \neq h^1_-(t, X), \qquad\qquad h^2_+(t, X) \neq h^2_-(t, X), \tag{3.11}$$

where $X \in \sigma$.

The case of $h^3_\pm(t, x^1, x^2, x^3)$ is more complicated. The values of these two functions at the interface σ are not independent. In order to reveal their dependence, we apply the notation (3.10) to (3.8) and write the relation

$$\begin{gathered} x^{i\,\prime}_{\varepsilon\pm}(0,t,Y_\pm)+M^i_{1\pm}(0,t,Y_\pm)\,h^1_\pm(t,X)+\\ +\,M^i_{2\pm}(0,t,Y_\pm)\,h^2_\pm(t,X)+M^i_{3\pm}(0,t,Y_\pm)\,h^3_\pm(t,X)=0. \end{gathered}\tag{3.12}$$

Note that $M^i_{1\pm}(0,t,Y_\pm)$ and $M^i_{2\pm}(0,t,Y_\pm)$ are the components of the vectors

$$\boldsymbol{\tau}_1=\begin{Vmatrix} M^1_{1\pm}(0,t,Y_\pm)\\ M^2_{1\pm}(0,t,Y_\pm)\\ M^3_{1\pm}(0,t,Y_\pm)\end{Vmatrix},\qquad\qquad \boldsymbol{\tau}_2=\begin{Vmatrix} M^1_{2\pm}(0,t,Y_\pm)\\ M^2_{2\pm}(0,t,Y_\pm)\\ M^3_{2\pm}(0,t,Y_\pm)\end{Vmatrix}\tag{3.13}$$

tangent to the interface σ at the point X. Therefore, we can exclude $h^1_\pm(t,X)$ and $h^2_\pm(t,X)$ from (3.12) using the components of the unit vector $\mathbf{n}$ normal to σ. Since the scalar products $(\boldsymbol{\tau}_1,\mathbf{n})$ and $(\boldsymbol{\tau}_2,\mathbf{n})$ for the vectors (3.13) are zero, we derive

$$\sum_{i=1}^{3}x^{i\,\prime}_{\varepsilon\pm}(0,t,Y_\pm)\,n_i=-\left(\sum_{i=1}^{3}M^i_{3\pm}(0,t,Y_\pm)\,n_i\right)h^3_\pm(t,X).\tag{3.14}$$

Both $x^i_+(\varepsilon,t,Y_+)$ and $x^i_-(\varepsilon,t,Y_-)$ are the coordinates of two points on the same surface $\sigma(\varepsilon)$ slightly deviated from the interface σ. Therefore,

$$\sum_{i=1}^{3}x^{i\,\prime}_{\varepsilon+}(0,t,Y_+)\,n_i=\sum_{i=1}^{3}x^{i\,\prime}_{\varepsilon-}(0,t,Y_-)\,n_i.\tag{3.15}$$

The above relations (3.14) and (3.15) prove that the variations $h^3_+(t,x^1,x^2,x^3)$ and $h^3_-(t,x^1,x^2,x^3)$ from (3.9) are not independent at the interface σ. If we denote

$$h(t,X)=\sum_{i=1}^{3}x^{i\,\prime}_{\varepsilon+}(0,t,Y_+)\,n_i=\sum_{i=1}^{3}x^{i\,\prime}_{\varepsilon-}(0,t,Y_-)\,n_i,\tag{3.16}$$

then we can express both $h^3_+(t,X)$ and $h^3_-(t,X)$, where $X\in\sigma$, through the function $h(t,X)$. Thus, we conclude that, in the case of ideal slip, there are five independent variations at the interface σ. These are the functions from (3.11) and (3.16).

Remark. Despite (3.5), the variations of the functions $y^3_+(t,x^1,x^2,x^3)$ and $y^3_-(t,x^1,x^2,x^3)$ therein are not zero at the interface σ since the interface $\sigma=\sigma(\varepsilon)$ itself depends on ε when varying. The same is true for (3.4). But in this case $y^i_+(\varepsilon,t,X)=y^i_-(\varepsilon,t,X)$, i. e., y^i_+ and y^i_- change coherently at σ when varying.

4. Boundary conditions.

The three boundary conditions in (1.10) derived in [20] are associated with three independent variations $h^i_+(t,X)=h^i_-(t,X)$ at the interface σ. In the case of ideal slip, we have four independent variations in the relation (3.11). The boundary conditions associated with them are written as follows:

$$\sum_{s=1}^{3}\Bigl(\mathcal{B}^\pm_m\,v^s_\pm-\mathcal{C}^{s\pm}_m\Bigr)n_s\,\Bigr|_\sigma=0,\quad m=1,\,2.\tag{4.1}$$

In order to derive the fifth boundary condition associated with the fifth independent variation $h(t,X)$ in (3.16), we express $h^3_\pm(t,X)$ through $h(t,X)$ using (3.14):

$$h^3_\pm(t,X)=-\biggl(\,\sum_{i=1}^{3}M^i_{3\pm}(0,t,Y_\pm)\,n_i\biggr)^{-1}h(t,X). \tag{4.2}$$

Applying (4.2) to the integral (12.4) in [20], we derive

$$\begin{aligned}&\biggl(\,\sum_{i=1}^{3}M^i_{3+}\,n_i\biggr)^{-1}\,\sum_{s=1}^{3}\Bigl(\mathcal{B}^+_3\,v^s_+-\mathcal{C}^{s+}_3\Bigr)n_s\Bigr|_\sigma=\\ &=\biggl(\,\sum_{i=1}^{3}M^i_{3-}\,n_i\biggr)^{-1}\,\sum_{s=1}^{3}\Bigl(\mathcal{B}^-_3\,v^s_--\mathcal{C}^{s-}_3\Bigr)\,n_s\Bigr|_\sigma.\end{aligned} \tag{4.3}$$

Note that the formulas (4.1) and (4.3) are less universal than the formula (1.10). They are bound to our very specific transformations of the domains Ω_+ and Ω_- with the coordinates y^1, y^2, y^3 in them (see Fig. 3.2). The metric (2.1) becomes discontinuous at the plane $y^3=0$ under these transformations; however, this does not influence the ultimate result.

5. Conclusions.

The boundary conditions (4.1) and (4.3) for the case of ideal slip are the main result of the present paper. Along with the condition in (1.12), they can be applied to the equations (1.3) and (1.4) for relativistic nonlinear elastic media derived in [18] within the framework of the 3D-brane universe model (see [3] or [4]).

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7. Dedication.

This paper is dedicated to my sister Svetlana Abdulovna Sharipova.

References

1. *Lorentz ether theory*, Wikipedia, Wikimedia Foundation, Inc., San Francisco, USA.
2. *Test theories of special relativity*, Wikipedia, Wikimedia Foundation, Inc., San Francisco, USA.
3. Sharipov R. A., *3D-brane universe model,* Monograph, Part 1, Russian edition, Ufa, 2024; ISBN 978-5-600-04170-7; see also ResearchGate publication No. 383040427, 2024.
4. Sharipov R. A., *3D-brane universe model,* Monograph, Part 1, English edition, Ufa, 2025; ISBN 978-5-6053179-0-6; see also ResearchGate publication No. 390542259, 2025.
5. Sharipov R. A., *A note on electromagnetic energy in the context of cosmology*, e-print viXra: 2207.0092.
6. Sharipov R. A., *A three-dimensional brane universe in a four-dimensional spacetime with a Big Bang*, e-print viXra:2207.0173.
7. Sharipov R. A., *Lagrangian approach to deriving the gravity equations for a 3D-brane universe*, e-print viXra:2301.0033.

8. Sharipov R. A., *Hamiltonian approach to deriving the gravity equations for a 3D-brane universe*, e-print viXra:2302.0120.
9. Sharipov R. A., *Energy conservation law for the gravitational field in a 3D-brane universe*, e-print viXra:2303.0123.
10. Sharipov R. A., *Speed of gravity can be different from the speed of light*, e-print viXra:2304.0225.
11. Sharipov R. A., *On superluminal non-baryonic matter in a 3D-brane universe*, e-print viXra:2305.0113.
12. Sharipov R. A., *3D-brane gravity without equidistance postulate*, e-print viXra:2306.0104.
13. Sharipov R. A., *Lagrangian approach to deriving the gravity equations in a 3D-brane universe without equidistance postulate*, e-print viXra:2307.0039.
14. Sharipov R. A., *Superluminal non-baryonic particles in a 3D-brane universe without equidistance postulate*, e-print viXra:2307.0072.
15. Sharipov R. A., *Energy conservation law for the gravitational field in a 3D-brane universe without equidistance postulate*, e-print viXra:2308.0175.
16. Sharipov R. A., *Decay of a superbradyon into a baryonic particle and its antiparticle*, e-print viXra:2403.0041.
17. Sharipov R. A., *Relativistic hardening and softening of fast moving springs*, ResearchGate publication No. 379537924, 2024; DOI: 10.13140/RG.2.2.10991.24488.
18. Sharipov R. A., *Relativistic elasticity in the 3D-brane universe model. Part 1.*, ResearchGate publication No. 388315101, 2025; DOI: 10.13140/RG.2.2.28837.61920; see also Erratum to *Relativistic elasticity in the 3D-brane universe model. Part 1.*
19. Sharipov R. A., *Boundary conditions in Lagrangian field theories*, ResearchGate publication No. 393645020, 2025; DOI: 10.13140/RG.2.2.14737.34403.
20. Sharipov R. A., *Relativistic elasticity in the 3D-brane universe model. Part 2.*, ResearchGate publication No. 409335444, 2026; DOI: 10.13140/RG.2.2.33441.98400.
21. Sharipov R. A., *On the dynamics of a 3D universe in a 4D spacetime*, Conference abstracts book "Ufa autumn mathematical school 2022" (Fazullin Z. Yu., ed.), vol. 2, pp. 279–281; DOI: 10.33184/mnkuomsh2t-2022-09-28.104.
22. Sharipov R. A., *The universe as a 3D brane and the equations for it*, Conference abstracts book "Fundamental mathematics and its applications in natural sciences 2022" (Gabdrakhmanova L. A., ed.), p. 37; DOI: 10.33184/fmpve2022-2022-10-19.30.
23. Sharipov R. A., *The universe as a 3D-brane and the gravity field in it*, Conference abstracts book "Complex analysis, mathematical physics, and nonlinear equations", March 13-17, Lake Bannoe 2023 (Garifullin R. N., ed.), pp. 129–130.
24. Sharipov R. A., *The universe as a 3D-brane and its evolution*, Conference abstracts book of the second All-Russia youth conference "Modern physics, mathematics, digital and nanotechnologies in science and education (ФМЦН-23)" dedicated to the 80th anniversary of Prof. R. S. Sinagatullin, April 18-20, Ufa 2023 (Vasilyeva L. I., Kudasheva E. G., Kudinov I. V., Izmailov R. N., Kosarev N. F., Gess D-L. Z., eds.), pp. 142–143.
25. Sharipov R. A., *The universe as a 3D-brane and the equation of its evolution*, Conference abstracts book of the ninth interregional school-conference of students and young scientists "Theoretical and experimental studies of nonlinear processes in condensed media", April 26-27, Ufa 2023 (Zakiryanov F. K., Gabdrakhmanova L. A., Kharisov A. T., eds.), p. 16.
26. Sharipov R. A., *3D-brane universe model*, Conference abstracts book of the International scientific and practical conference "Spectral theory of operators and related topics" dedicated to the 75th anniversary of Prof. Ya. T. Sultanaev (Vildanova V. F., Garifullin R. N., Kudasheva E. G., eds.), 2023, pp. 38–39.
27. Sharipov R. A., *3D-brane universe without equidistance postulate*, Conference abstracts book "Ufa autumn mathematical school 2023" (Fazullin Z. Yu., ed.), vol. 2, pp. 153–156.
28. Sharipov R. A., *3D-brane universe model*, Conference abstracts book of the 14th Int. Conf. "Fundamental mathematics and its applications in natural sciences 2023" dedicated to the 75th anniversary of Profs. Ya. T. Sultanaev and M. Kh. Kharrasov (Khabibullin B. N., Ekomasov E. G., Gabdrakhmanova L. A., Zakiryanov F. K., Kharisov A. T., eds.), p. 18.
29. Sharipov R. A., *Energy conservation law for the gravitational field in the 3D-brane universe model*, Conference abstracts book "Complex analysis, mathematical physics, and nonlinear equations", March 11-15, Pavlovka-Ufa (Garifullin R. N., ed.), 2024, pp. 72–73.

30. Sharipov R. A., *Decay of a superbradyon into a baryonic particle and its antiparticle*, Conference abstracts book of the second All-Russia youth conference "Modern physics, mathematics, digital and nanotechnologies in science and education (ФМЦН-24)" dedicated to the 70th anniversary of Prof. R. M. Asadullin, April 17-19, Ufa 2024 (Vasilyeva L. I., Kudasheva E. G., Kudinov I. V., Izmailov R. N., Kosarev N. F., Gess D-L. Z., eds.), pp. 100–101.
31. Sharipov R. A., *Relativistic hardening and softening of fast moving springs*, Conference abstracts book of the tenth interregional school-conference of students and young scientists "Theoretical and experimental studies of nonlinear processes in condensed media", April 25-26, Ufa 2024 (Zakiryanov F. K., Gabdrakhmanova L. A., Kharisov A. T., eds.), p. 8.
32. Sharipov R. A., *Relativistic hardening and softening of moving springs*, Conference abstracts book "Ufa autumn mathematical school 2024" (Fazullin Z. Yu., ed.), vol. 2, pp. 187–190.
33. Sharipov R. A., *Decay of a superbradyon*, Conference abstracts book of the 15th international conference "Fundamental mathematics and its applications in natural sciences 2024" dedicated to the 300th anniversary of Russian Academy of Sciences (Khabibullin B. N., Ekomasov E. G., Gabdrakhmanova L. A., Zakiryanov F. K., Kuzhaev A. F., eds.), p. 18.
34. Sharipov R. A., *Elastic media in the 3D-brane universe model*, Conference abstracts book "Complex analysis, mathematical physics, and nonlinear equations", March 17-21, Pavlovka-Ufa (Garifullin R. N., Kordyukov Yu. A., Musin I. Kh., Khabibullin B. N., eds.), 2025, pp. 54–55.
35. Sharipov R. A., *Motion of relativistic elastic media in the 3D-brane universe model*, Conference abstracts book "Ufa autumn mathematical school 2025" (Fazullin Z. Yu., ed.), vol. 1, pp. 173–175.
36. Sharipov R. A., *Relativistic elastic media in the 3D-brane universe model*, Conference abstracts book of the 16th international conference "Fundamental mathematics and its applications in natural sciences 2025" (Khabibullin B. N., Ekomasov E. G., Gabdrakhmanova L. A., Zakiryanov F. K., Kharisov A. T., eds.), p. 5.
37. Sharipov R. A., *Boundary conditions in Lagrangian field theories*, Conference abstracts book "Complex analysis, mathematical physics, and nonlinear equations", March 9-13, Pavlovka-Ufa (Garifullin R. N., Kordyukov Yu. A., Musin I. Kh., Khabibullin B. N., eds.), 2026, p. 53.
39. Sharipov R. A., *Boundary conditions in Lagrangian field theories*, Conference abstracts book of the twelfth interregional school-conference of students and young scientists "Theoretical and experimental studies of nonlinear processes in condensed media", April 28-29, Ufa 2026 (Zakiryanov F. K., Gabdrakhmanova L. A., Kharisov A. T., eds.), pp. 9–10.

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