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SCALAR FIELD POTENTIAL DISTRIBUTION FOR A CLOSED RADIALLY EXPANDING NULL STRING IN PLANE Z = 0

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In this article, we have received, the general view of distribution of potential scalar field for "thick" null string radially expanding in plane $z = 0$. Conditions on potential of a scalar field at which, within the limits of compression of a scalar field in one-dimensional object, the stress energy tensor components of a scalar field coincide with components stress energy tensor of the closed null string moving on the same trajectory are found.
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INTRODUCTION

Now string theory is a promising direction in the development of modern physics. Because fundamentally gives the opportunity to resolve the contradictions between quantum mechanics and general relativity. The idea of string holography successfully develops, whereby quantum field theory on the p-brana can be the equivalent of the string theory in the full dimensional space. Moreover, in the classical limit of string theory arises generalized theory of gravity (supergravity), under which it is possible to reproduce the results essentially quantum field theory on the p-brane in a purely classical manner [1, 2].

Besides studying of string theory allows us to understand the deepest moments of the birth of the Universe in order to understand why it occurred, and what lies ahead of her? But it is impossible to imagine studying the evolution of the Universe without studying the properties of its components. That's why this article is a studying of null strings, which are an integral part of both the string theory and the universe in general [3].

Objective of article:

- Construct the general view of distribution of potential scalar field for "thick" null string radially expanding in plane $z = 0$.
- Find conditions on potential of a scalar field at which, within the limits of compression of a scalar field in one-dimensional object, the stress energy tensor components of a scalar field coincide with components stress energy tensor of the closed null string moving on the same trajectory.

The components of the energy-momentum tensor for a null string have the following form [4]:

$$T^{mn}\sqrt{-g} = \gamma \int d\tau d\sigma x^m_{,\tau} x^n_{,\tau} \delta^4\left(x^l - x^l(\tau,\sigma)\right), \tag{1}$$

where the indices m,n,l take on the values 0,1,2,3, the functions $x^m = x^m(\tau,\sigma)$ determine the trajectory of a null string, τ and σ are the parameters on the light surface of the null string, $x^m_{,\tau} = \partial x^m / \partial\tau$, $g = |g_{mn}|$, g_{mn} is the metric tensor of the environment, $\gamma = const$. In the cylindrical system of coordinates, $x^0 = t$, $x^1 = \rho$, $x^2 = \theta$, $x^3 = z$, the functions $x^m(\tau,\sigma)$, that determine the trajectory of a closed null string, radially expanding in a plane $z = 0$, have the following form:

$$t = \tau,\ \rho = \tau,\ \theta = \sigma,\ z = 0,\ \tau \in [0,+\infty). \tag{2}$$

Using the symmetry of the trajectory (2), the general expression of the quadratic form, which describes the motion under consideration null string can be presented as

$$dS^2 = e^{2\nu}(dt)^2 - A(d\rho)^2 - B(d\theta)^2 - e^{2\mu}(dz)^2, \tag{3}$$

where ν,μ,A,B depend on the variables t,ρ,z.

Since trajectory (2) must be one of the solutions of the motion equations of a null string, additional restrictions imposed on the metric functions can be obtained, whose fulfillment provides the constancy of a trajectory of the null string specified by (2).

The motion of a null string in the pseudo-Riemannian space is determined by the system of equations [3]

$$x^m_{,\tau\tau} + \Gamma^m_{pq} x^p_{,\tau} x^q_{,\tau} = 0, \tag{4}$$

$$g_{mn} x^m_{,\tau} x^n_{,\tau} = 0,\ g_{mn} x^m_{,\tau} x^n_{,\sigma} = 0, \tag{5}$$

where Γ^m_{pq} are the Christoffel symbols. Putting down the first of Eqs. (5) for (2), one can make sure that it has form $e^{2\nu} - A = 0$. Consequently,

$$e^{2\nu} = A, \tag{6}$$

whereas the rest of equations of system (4), (5) for (2), (3) under condition (6) are reduced to the single equation $\nu_{,\rho} + \nu_{,t} = 0$, which yields

$$\nu = \nu(\eta, z), \tag{7}$$

where $\eta = t - \rho$. Analyzing the system of Einstein equations and using conditions (6), (7), the dependence of functions of the quadratic form (3) can be redefined as

$$\mu = \mu(\eta, z),\ B = B(\eta, z). \tag{8}$$

In this case, the Einstein system itself is reduced to the equations

$$-\mu_{,\eta\eta} - \frac{B_{,\eta\eta}}{2B} - (\mu_{,\eta})^2 + \left(\frac{B_{,\eta}}{2B}\right)^2 + 2\nu_{,\eta}\left(\mu_{,\eta} + \frac{B_{,\eta}}{2B}\right) = \chi\gamma \frac{e^{2\nu-\mu}}{\sqrt{B}} \delta(\eta)\delta(z), \tag{9}$$

$$\nu_{,zz} + \frac{B_{,zz}}{2B} + (\nu_{,z})^2 - \left(\frac{B_{,z}}{2B}\right)^2 - \mu_{,z}\nu_{,z} - \frac{B_{,z}}{2B}(\mu_{,z} - \nu_{,z}) = 0, \tag{10}$$

$$\frac{B_{,\eta z}}{B}+2\nu_{,\eta z}-\frac{1}{2}\frac{B_{,\eta}}{B}\frac{B_{,z}}{B}-\frac{B_{,\eta}}{B}\nu_{,z}-\frac{B_{,z}}{B}\mu_{,\eta}-2\mu_{,\eta}\nu_{,z}=0\,, \tag{11}$$

$$\frac{B}{e^{2\mu}}\left(2\nu_{,zz}+3(\nu_{,z})^2-2\nu_{,z}\mu_{,z}\right)=0\,,\quad (\nu_{,z})^2+\nu_{,z}\frac{B_{,z}}{B}=0\,. \tag{12}$$

With the use of the obtained conditions (6) – (8), expression (3) can be presented in the form

$$dS^2=e^{2\nu}\left((dt)^2-(d\rho)^2\right)-B(d\theta)^2-e^{2\mu}(dz)^2\,, \tag{13}$$

where ν,μ,B depend on the variables η,z .

Later, using the result of [5], we consider the components of the zero-string energy-momentum tensor as the limit of a "thick" distribution, in which we choose as a real massless scalar field, because the task at hand, we consider the scalar zero object.

1. SYSTEM OF EINSTEIN EQUATIONS FOR THE «THICK» PROBLEM

The components of the energy-momentum tensor for a real massles scalar field have the form

$$T_{\alpha\beta}=\varphi_{,\alpha}\varphi_{,\beta}-\frac{1}{2}g_{\alpha\beta}L\,, \tag{14}$$

where $L=g^{\alpha\beta}\varphi_{,\alpha}\varphi_{,\beta}$, $\varphi_{,\alpha}=\partial\varphi/\partial x^{\alpha}$, φ is the scalar field potential, and this indices α,β take on the values 0,1,2,3. To provide the self-consistency of the Einstein equations constructed for (13), (14), we demand that

$$T_{\alpha\beta}=T_{\alpha\beta}(\eta,z)\rightarrow\varphi=\varphi(\eta,z)\,. \tag{15}$$

Putting down Eq. (14) for (13), (15), we obtain

$$T_{00}=(\varphi_{,\eta})^2+\frac{e^{2(\nu-\mu)}}{2}(\varphi_{,z})^2,\ T_{11}=(\varphi_{,\eta})^2-\frac{e^{2(\nu-\mu)}}{2}(\varphi_{,z})^2,$$

$$T_{22}=-\frac{Be^{-2\mu}}{2}(\varphi_{,z})^2,\ T_{33}=\frac{1}{2}(\varphi_{,z})^2,\ T_{01}=-(\varphi_{,\eta})^2,\ \ T_{03}=-T_{13}=\varphi_{,\eta}\varphi_{,z}\,. \tag{16}$$

The system of Einstein equations for (13), (16) can be presented as follows

$$2\nu_{,\eta}\mu_{,\eta}+2\nu_{,\eta}\frac{B_{,\eta}}{2B}-\mu_{,\eta\eta}-(\mu_{,\eta})^2-\frac{B_{,\eta\eta}}{2B}+\left(\frac{B_{,\eta}}{2B}\right)^2=\chi(\varphi_{,\eta})^2\,, \tag{17}$$

$$\nu_{,zz}+\frac{B_{,zz}}{2B}+(\nu_{,z})^2-\left(\frac{B_{,z}}{2B}\right)^2-\nu_{,z}\mu_{,z}-\frac{B_{,z}}{2B}(\mu_{,z}-\nu_{,z})=-\frac{1}{2}\chi(\varphi_{,z})^2\,, \tag{18}$$

$$\frac{-B_{,\eta z}}{B}-2\nu_{,\eta z}+\frac{1}{2}\frac{B_{,z}}{B}\frac{B_{,\eta}}{B}+\frac{B_{,\eta}}{B}\nu_{,z}+\frac{B_{,z}}{B}\mu_{,\eta}+2\mu_{,\eta}\nu_{,z}=2\chi\varphi_{,\eta}\varphi_{,z}\,, \tag{19}$$

$$2\nu_{,zz}+3(\nu_{,z})^2-2\nu_{,z}\mu_{,z}=-\frac{\chi}{2}(\varphi_{,z})^2,\ (\nu_{,z})^2+\nu_{,z}\frac{B_{,z}}{B}=\frac{\chi}{2}(\varphi_{,z})^2. \qquad (20)$$

Let us consider system (17) – (20) for the distribution of the scalar field already concentrated inside a “thin” ring, with the variables η and z taking values in the interval

$$\eta\in[-\Delta\eta;\Delta\eta],\ z\in[-\Delta z;\Delta z], \qquad (21)$$

where $\Delta\eta$ and Δz are small positive constants that determine the “thickness” of the ring,

$$\Delta\eta<<1,\ \Delta z<<1. \qquad (22)$$

With a further contraction of this “thin” ring into a one-dimensional object (null string),

$$\Delta\eta\to 0,\ \Delta z\to 0. \qquad (23)$$

The space, where such a “thick” null string moves and for which the variables η and z take on values in the interval

$$\eta\in(-\infty;+\infty),\ z\in(-\infty;+\infty), \qquad (24)$$

can be conditionally divided into three regions:

- region I, for which (Fig. 1)

$$\eta\in(-\infty;-\Delta\eta)\cup(\Delta\eta;+\infty),\ z\in(-\infty;+\infty), \qquad (25)$$

- region II, for which (Fig. 1)

$$\eta\in[-\Delta\eta;\Delta\eta],\ z\in(-\infty;-\Delta z)\cup(\Delta z;+\infty), \qquad (26)$$

- region III, for which (Fig. 1)

$$\eta\in[-\Delta\eta;\Delta\eta],\ z\in[-\Delta z;\Delta z]. \qquad (27)$$

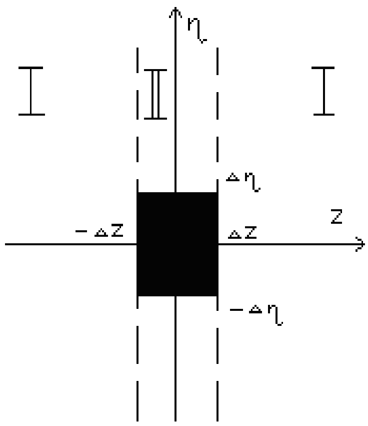


Fig. 1. Schematic section of space by the plane $\theta=const$ and decomposition of the space on 3 regions (25) – (27) depend on the variables z,η . Region III marked in black.

Since the contraction of the scalar field into a string mast result in the asymptotic coincidence of system (17) – (20) with the system for a closed null string (9) – (12) we obtain for the regions I, II (Fig. 1).

$$\varphi \to 0, \; \varphi_{,z} \to 0, \; \varphi_{,\eta} \to 0, \qquad (28)$$

for the region III, in the general case,

$$\frac{\varphi_{I,II}}{\varphi_{III}} \le 1, \quad \frac{\left(\varphi_{,z}\right)_{I,II}}{\left(\varphi_{,z}\right)_{III}} \le 1, \quad \frac{\left(\varphi_{,\eta}\right)_{I,II}}{\left(\varphi_{,\eta}\right)_{III}} \le 1 \cdot \qquad (29)$$

where $\varphi_{I,II}$ are values of the scalar field potential in the regions I, II (Fig. 1), φ_{III} are values of the scalar field potential in the region III (inside the "thin" ring), equality is realized on the boundary.

Comparing the system of Einstein equations for a closed null string (9) – (12) with system (17) – (20), we may conclude that, under the contraction of the scalar field into a string of the required configuration, i.e., at $\Delta\eta \to 0$, $\Delta z \to 0$

$$\left(\varphi_{,z}\right)^2\Big|_{\eta\to 0,\, z\to 0} \to 0, \; \left(\varphi_{,\eta}\right)^2\Big|_{\eta\to 0,\, z\to 0} \to \infty, \; \left(\varphi_{,z}\varphi_{,\eta}\right)\Big|_{\eta\to 0,\, z\to 0} \to 0. \qquad (30)$$

According to (28), the scalar field potential in region I at any fixed value of $\eta = \eta_0 \in \left(-\infty; -\Delta\eta\right) \cup \left(\Delta\eta; +\infty\right)$ and all values of $z \in \left(-\infty; +\infty\right)$

$$\varphi\left(\eta_0, z\right) \to 0, \qquad (31)$$

Considering the scalar field potential distribution at any fixed value of $\eta = \eta_0 \in \left[-\Delta\eta; \Delta\eta\right]$, (regions II and III), if $z \in \left(-\infty; -\Delta z\right) \cup \left(\Delta z; +\infty\right)$ (region II), must be realized

$$\varphi\left(\eta_0, z\right) \to 0, \qquad (32)$$

whereas, for $z \in \left[-\Delta z; \Delta z\right]$ (region III)

$$\frac{\varphi(\eta_0, z)_{III}}{\varphi(\eta_0, z)_{II}} > 1 \cdot \qquad (33)$$

2. SCALAR FIELD POTENTIAL DISTRIBUTION FOR A «THICK» NULL STRING

For the conditions (31)–(33) it is suitable to present the scalar field potential distribution in the form

$$\varphi\left(z, \eta\right) = -\ln\left[\alpha\left(\eta\right) + \lambda\left(\eta\right) f\left(z\right)\right], \qquad (34)$$

where the functions $\alpha\left(\eta\right)$ and $\lambda\left(\eta\right)$ are symmetric with respect to the inversion of η to $-\eta$:

$$\alpha\left(\eta\right) = \alpha\left(-\eta\right), \; \lambda\left(\eta\right) = \lambda\left(-\eta\right). \qquad (35)$$

The function $\alpha\left(\eta\right) + \lambda\left(\eta\right) f\left(z\right)$ is bounded

$$0 < \alpha\left(\eta\right) + \lambda\left(\eta\right) f\left(z\right) \le 1, \qquad (36)$$

and the scalar field potential specified by (34), in accordance with (36), can assume values from

$$\varphi = 0 \text{, при } \alpha(\eta) + \lambda(\eta) f(z) = 1, \quad (37)$$

to

$$\varphi \to \infty \text{, при } \alpha(\eta) + \lambda(\eta) f(z) \to 0, \quad (38)$$

Moreover, according to (31) and (37), in region I,

$$\alpha(\eta) \to 1,\ \lambda(\eta) \to 0. \quad (39)$$

Since, according to (32), the scalar field potential tends to zero in region II, the following condition must be met at $\eta \in [-\Delta\eta; \Delta\eta]$ and any fixed value of $z = z_0 \in (-\infty; -\Delta z) \cup (\Delta z; +\infty)$

$$\alpha(\eta) + \lambda(\eta) f(z_0) \to 1. \quad (40)$$

In region III, for the same values of $\eta \in [-\Delta\eta; \Delta\eta]$ and at $z = z_0 \in [-\Delta z; \Delta z]$

$$0 < \alpha(\eta) + \lambda(\eta) f(z_0) < 1. \quad (41)$$

Equation (40) implies that, for all $z \in (-\infty; -\Delta z) \cup (\Delta z; +\infty)$ the values of the function $f(z)$ tends to constant

$$f(z) \to f_0 = const. \quad (42)$$

Moreover $f_0 \neq 0$, while the functions $\alpha(\eta)$ and $\lambda(\eta)$ are interconnected

$$\lambda(\eta) = (1 - \alpha(\eta)) / f_0. \quad (43)$$

Substituting (43) into (42) we obtain for region III

$$0 < \alpha(\eta) + (1 - \alpha(\eta)) f(z) / f_0 < 1, \quad (44)$$

This together with (38) and (44) mean that, at $\varphi \to \infty$

$$\alpha(\eta) \to 0,\ f(z) \to 0. \quad (45)$$

Thus, the functions $\alpha(\eta)$ and $f(z)$ in the expression for the scalar field potential (34) are bounded and, for any $z \in (-\infty; +\infty)$ and $\eta \in (-\infty; +\infty)$, take on values in the intervals

$$0 \le \alpha(\eta) \le 1,\ 0 \le f(z) \le f_0. \quad (46)$$

The distribution for the function $f(z)$ at $z \in (-\infty; -\Delta z) \cup (\Delta z; +\infty)$ is determined by Eq (42), at $z \to 0$, and, according to (45)

$$f(z) \to 0. \quad (47)$$

Differentiating (34), with regard for (43), over z and η we obtain

$$\varphi_{,\eta} = -\frac{\alpha_{,\eta}(1 - f(z)/f_0)}{\alpha(\eta) + (1 - \alpha(\eta)) f(z)/f_0},\ \varphi_{,z} = -\frac{(1 - \alpha(\eta)) f_{,z}/f_0}{\alpha(\eta) + (1 - \alpha(\eta)) f(z)/f_0}. \quad (48)$$

Using (39), (40), (41) for (48) we obtain, that in regions I, II: $\varphi_{,z} \to 0$, $\varphi_{,\eta} \to 0$, which coincides with (28). In region III (рис.1), at $z \to 0$, with regard for (47), the first of Eqs. (48) can be presented in the form

$$\varphi_{,\eta} = -\alpha_{,\eta} / \alpha(\eta), \tag{49}$$

This, according to (30), at $\Delta\eta \to 0$, $\Delta z \to 0$, yields

$$\left|\alpha_{,\eta} / \alpha(\eta)\right| \to \infty. \tag{50}$$

With regard for (48), the second of Eqs. (58) at $\eta \to 0$ can be presented as

$$\varphi_{,z} = -f_{,z} / f(z), \tag{51}$$

According to (30), at $\Delta z \to 0$, $\Delta\eta \to 0$

$$f_{,z} / f(z) \to 0. \tag{52}$$

On the other hand, considering Eqs. (48) in some small neighborhood of the circle $\eta = 0, z = 0$, i.e., inside the region, where the scalar field is concentrated with $\frac{f(z)}{f_0} << 1$ and $\alpha(\eta) << 1$ (according to (37), (38)), we can put down

$$\varphi_{,z}\varphi_{,\eta} = \frac{\alpha_{,\eta} / \alpha(\eta) \cdot f_{,z} / f(z)}{\left(1 + \frac{1}{f_0}\frac{f(z)}{\alpha(\eta)}\right)\left(1 + f_0\frac{\alpha(\eta)}{f(z)}\right)}, \tag{53}$$

Then, according to (37), the following condition must be satisfied at $\Delta z \to 0$, $\Delta\eta \to 0$

$$\left(\alpha_{,\eta} f_{,z}\right) / \left(\alpha(\eta) f(z)\right) \to 0. \tag{54}$$

As an example, the functions $\alpha(\eta)$ and $f(z)$ satisfying the found conditions can be chosen as follows:

$$\alpha(\eta) = \exp\left\{-\frac{1}{\varepsilon + (\xi\eta)^2}\right\}, \tag{55}$$

$$f(z) = f_0 \exp\left\{-\mu\left(1 - \exp\left\{-\frac{1}{(\varsigma z)^2}\right\}\right)\right\}, \tag{56}$$

where the constants ξ and ς determine the size ("thickness") of the ring with the scalar field concentrated inside with respect to the variables z and η, respectively. Namely, as follows from (55), (56), at

$$\Delta z \to 0,\ \xi \to \infty;\ \Delta\eta \to 0,\ \varsigma \to \infty, \tag{57}$$

while the positive constants ε and μ provide the fulfillment of conditions (47), (50), (52), at $z \to 0$, $\eta \to 0$, $\Delta z \to 0$, $\Delta\eta \to 0$. Namely, at

$$\Delta z << 1,\ \varepsilon << 1;\ \Delta\eta << 1,\ \mu >> 1, \qquad (58)$$

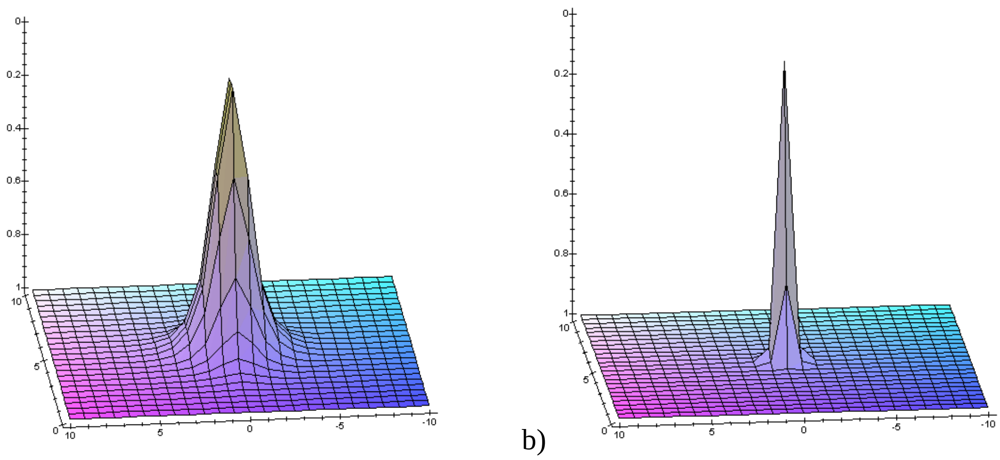
With a further contraction into a one-dimensional object (null string), i.e., at $\Delta z \to 0$, $\Delta\eta \to 0$

$$\varepsilon \to 0,\ \mu \to \infty. \qquad (61)$$

Using (43), (55), (56) for (34) we obtain the expression for one of the possible distributions of the potential of the massless scalar field, whose components of the energy-momentum tensor asymptotically coincide with those of a closed null string under contraction into a one-dimensional object.

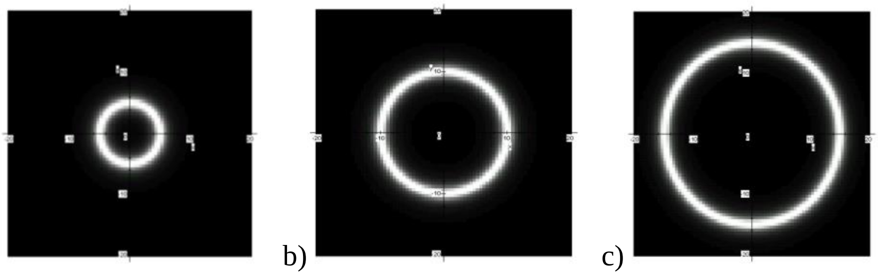
Fig. 2 presents the distributions of the function $\alpha(\eta) + (1-\alpha(\eta)) f(z) / f_0$ in the region $\eta \in [-10;10]$, $z \in [-10;10]$, for the functions $\alpha(\eta)$, $f(z)$, specified by Eqs. (55), (56), corresponding to the following choice of the constants a) $\xi = \varsigma = \mu = 1$; б) $\xi = \varsigma = \mu = 4$. One can see from these figures that, with increasing values of the constants ξ, ς, the region of the non-unity function $\alpha(\eta) + (1-\alpha(\eta)) f(z) / f_0$ (i.e., the region, where the scalar field is concentrated, and the scalar field potential isn't tend to zero) contracts, which corresponds to a decrease of the "thickness" of the ring with the scalar field concentrated inside.

Fig. 3 – 5 present different space-time sections (depends on t, ρ, θ) for a closed «thick» null string radially expanding in a plane $z = 0$ in region $\eta \in [-10;10]$, $z \in [-10;10]$, for the functions $\alpha(\eta)$, $f(z)$, defined by the equalities (55), (56). Note that in the presented Fig. 3 – 5, black shows an area in which $\varphi \to 0$.



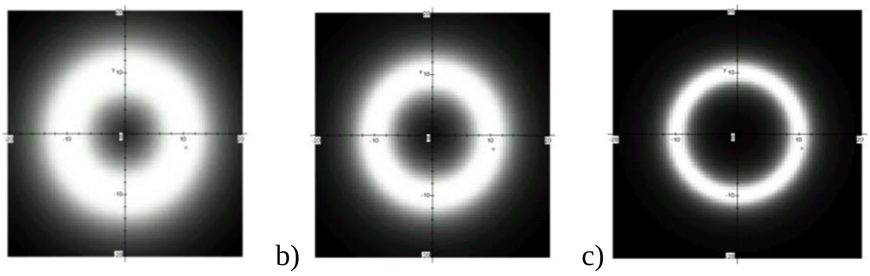
a) b)

Fig. 2. The distributions of the function $\alpha(\eta) + (1-\alpha(\eta)) f(z) / f_0$, where, $\eta \in [-10;10]$, $z \in [-10;10]$ at: a) $\xi = \varsigma = \mu = 1$, b) $\xi = \varsigma = \mu = 4$.



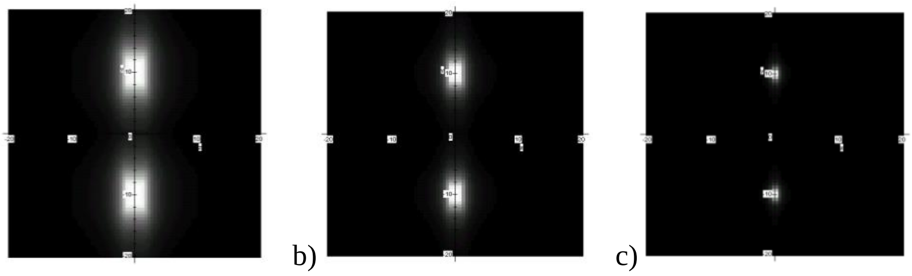
a) b) c)

Fig. 3. Scalar field potential distribution specified by (34), (55), (56) with depends on t, at $\varepsilon = 0.01$, $\xi = 1.3$, $\mu = 4$, $\varsigma = 1.3$, $z = 0.01$, $\rho \in (0,20)$: a) $t = 5$, b) $t = 10$, c) $t = 15$.



a) b) c)

Fig. 4. Scalar field potential distribution specified by (34), (55), (56) with respect to ρ at $\varepsilon = 0.01$, $\mu = 4$, $\varsigma = 1.3$, $z = 0.01$, $\rho \in (0,20)$, $t = 10$: a) $\xi = 0.2$, b) $\xi = 0.3$, c) $\xi = 0.6$.



a) b) c)

Fig. 5. Scalar field potential distribution specified by (34), (55), (56) on the surface $\theta = const$; $\varepsilon = 0.01$, $\mu = 4$, $\varsigma = 1.3$, $z = 0.01$, $\rho \in (0,20)$, $t = 10$: a) $\xi = 0.3$, b) $\xi = 0.5$, c) $\xi = 1.3$.

From the Fig. 3 – 5 immediately follows that with increasing values of the variable t (Fig. 3) radius of the "thick" null string increases (null string extends radially in a plane $z = 0$), and with increasing values of the constants ξ, ς (Fig. 4, 5) region decreases, where scalar field potential isn't tend to zero. In other words, the "thickness" of the ring, where the scalar field is concentrated, decreases.

CONCLUSIONS

In this article, we have received, the general view of distribution of potential scalar field for "thick" null string radially expanding in plane $z = 0$. Conditions on potential of a scalar field at which, within the limits of compression of a scalar field in one-dimensional object, the stress energy tensor components of a scalar field coincide with components stress energy tensor of the closed null string moving on the same trajectory are found.

The example of the potential distribution of a scalar field, corresponds to the conditions obtained. The next stage of the proposed work will be the integration of the Einstein equations for the scalar field obtained distribution and the analysis of the gravitational field produced by radially expanding null string.

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Леляков О. П. Розподіл потенціалу скалярного поля для замкненої нуль струни, що радіально розширюється / О. П. Леляков, О. С. Усачев, Р. О. Бабаджан // Вчені записки Таврійського національного університету імені В. І. Вернадського. Серія : Фізико-математичні науки. – 2013. – Т. 26 (65), № 2. – С. 69-78.

У роботі запропоновано загальний вигляд розподілу потенціалу безмасового дійсного скалярного поля для «розмазаної» нуль-струни, що радіально розширюється в площині $z = 0$. Знайдено умови на потенціал скалярного поля, при яких, при стисканні скалярного поля в одновимірний об'єкт, компоненти тензора енергії-імпульсу скалярного поля асимптотичне збігаються з компонентами тензора енергії-імпульсу замкненої нуль-струни яка прямує по тієї ж траєкторії.

Ключові слова: нуль-струна, скалярне поле, космологія.

Леляков А. П. Распределение потенциала скалярного поля для радиально расширяющейся замкнутой нуль-струны / А. П. Леляков, А. С. Усачев, Р. А. Бабаджан // Ученые записки Таврического национального университета имени В. И. Вернадского. Серия : Физико-математические науки. – 2013. – Т. 26 (65), № 2. – С. 69-78.

В работе предложен общий вид распределения потенциала вещественного безмассового скалярного поля для «размазанной» нуль-струны радиально расширяющейся в плоскости. Найдены условия на потенциал скалярного поля, при которых, в пределе сжатия в одномерный объект, компоненты тензора энергии-импульса скалярного поля асимптотически совпадают с компонентами тензора энергии-импульса замкнутой нуль-струны движущейся по той же траектории.

Ключевые слова: нуль-струна, скалярное поле, космология.

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