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# ON THE ORIGIN OF FUNDAMENTAL SCALAR FIELDS

The geometrical and physical aspects of origin of cosmic scalar fields are considered together.

**1. Introduction.** The global 'inexplainable' phenomena, dark energy and dark matter, can be reduced to fundamental scalar-type background fields, and in such a case the main challenge consists in identification of those without invoking any exotic particles and fields unknown to modem experiment. But where 'the fundamental scalar fields' come from?

**2. Geometrical issues.** Unlike $U(1)\times SU(2)_L\times\times SU(3)$-Standard Model (SM), gravity has no internal symmetries but only those of space-time. They may be generally described by the spacetime deformation tensor $D_{\mu\nu}=\mathrm{L}_\xi(g_{\mu\nu})$ being the Lie derivative $\mathrm{L}_\xi$ of metric tensor $g_{\mu\nu}$ with respect to some timelike field $\xi^\mu=\xi u^\mu$, $u^\mu u_\mu=1$: $\mathrm{L}_\xi(g_{\mu\nu})=\xi_{\mu;\nu}+\xi_{\nu;\mu}=D_{\mu\nu}$. Taking into account of the appropriate Ricci identity including the Riemannian curvature tensor, $\xi_{\mu;\nu\alpha}-\xi_{\mu;\alpha\nu}=\frac{1}{2}R^\beta{}_{\mu\nu\alpha}\xi_\beta$, we deduce from that for any $\{u^\mu\}$-congruence the master-identity [1] connecting the Ricci tensor $R_{\mu\nu}$ with scalar field $\xi=(\xi_\alpha\xi^\alpha)^{1/2}$:

$$R_{\alpha\beta}u^\alpha u^\beta=-\xi^{-1}\Box\xi+u_{\alpha;\beta}u^{\alpha;\beta}+\xi^{-1}f_\alpha u^\alpha, \quad (1)$$

$$f^\mu=-\frac{1}{2}\left(D^\alpha{}_\alpha\right)^{;\mu}+D^{\mu\alpha}{}_{;\alpha},\ \Box\xi\equiv\xi_{;\alpha}{}^{;\alpha}.$$

By applying relation between $u_{\alpha;\beta}u^{\alpha;\beta}$ and $u_{\alpha;\beta}u^{\beta;\alpha}$ this can be reduced to the Ehlers identity known also as 'the Raychaudhuri equation' [2]. A preference of (1) consists in its explicit dependence from geometrical scalar field $\xi=\xi(x^\mu)$ to be appropriate for description of redshift, temperature and other characteristics of physical systems. Moreover, $\xi$ induces the existence of some physical scalar counterpart $\phi$ to be presented in the form of ansatz: $\xi=\xi(\phi(x^\mu))$.

For the particular Killing, conformal or space-conformal symmetries we have [3]: $D_{\mu\nu}=0$, $D_{\mu\nu}=\Omega(x^\alpha)g_{\mu\nu}$ or $D_{\mu\nu}=\Psi(x^\alpha)h_{\mu\nu}$, $h_{\mu\nu}=g_{\mu\nu}-u_\mu u_\nu$, correspondingly. In the Killing case, $f^\mu=0$, $u_{\alpha;\beta}=-\dot u_\alpha u_\beta$ (here $\dot u_\alpha$ – fouracceleration), and fundamental identity (1) reduces to

$$R_{\alpha\beta}u^\alpha u^\beta=-\xi^{-1}\Box\xi+u_{\alpha;\beta}u^{\alpha;\beta}=-\xi^{-1}\Box\xi+\dot u_\alpha\dot u^\alpha=$$

$$=-\xi^{-1}\xi_{;\alpha\beta}(g^{\alpha\beta}-u^\alpha u^\beta)=-\xi^{-1}h^{\alpha\beta}\xi_{;\alpha\beta}.$$

So, we have obtained the Hawking-Ellis relation [2]: $R_{\alpha\beta}u^\alpha u^\beta=-\xi^{-1}h^{\alpha\beta}\xi_{;\alpha\beta}$, which has been used for the remarkable non-variational deduction of the

Einstein equations. In static case the Killing-vector modulus and scalar potential are connected by $\xi = e^{-\phi}$ (with our choice of positive $\phi$). In fact this is the first manifestation of the direct relation between the fundamental geometrical and physical scalar fields of type $\xi = \xi(\phi(x^{\mu}))$ which may be extended to gravity as a whole. Now we get $-\xi^{-1}h^{\alpha\beta}\xi_{;\alpha\beta} = \Delta\phi = R_{\mu\nu}u^{\mu}u^{\nu}$, and so, the Poisson equation of Newtonian gravity follows by equating the congruence invariant $-R_{\mu\nu}u^{\mu}u^{\nu}$ to matter density $4\pi G\rho$. This reduces the master-identity (1) to the scalar field equation: $\Delta\phi = -4\pi G\rho$. A general relation of the Ricci tensor to the complete EMT ('scalar field + matter' energy-momentum tensor $T_{\mu\nu}$) may be easy obtained under some subsidiary condition. So, for the divergence-free case $T^{\mu\nu}{}_{;\nu} = 0$ we get the habitual Einstein equations: $G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \kappa T_{\mu\nu}$, but the other viable variants (for example, with an energy conservation condition $(T^{\mu\nu}u_{\mu})_{;\nu} = 0$) are possible as well [4].

The difference between the habitual and proposed approaches consists in the statement that not only $\xi = \xi(\phi(x^{\mu}))$ but all the geometry is induced by some fundamental scalar field $\phi$, and the rest of matter may be conceived as a sort of exited states of the same field. So, for metric tensor we accept $g_{\mu\nu} = g_{\mu\nu}(\phi(x^{\alpha}))$. This means that the definite scalar field (in form of EMT) can never be removed from the field equations due to physical reasons. At first such ansatz has been proposed by Papapetrou [5] (for one, and then for two generating scalar fields), and we go on to elaborate this idea for our task – to identify the global phenomena, dark energy (DE) and dark matter (DM). As we shall see DE proves to be a neutral composition of quasi-static electric fields generated by all fermions in the Universe, and DM represents the tachyon neutrino-antineutrino conglomerate. The fundamentality of such fields is justified on the basis of *antiscalar approach* to gravity.

**3. DE as a composition of electric fields generated by fermions.** We begin with the fundamental Papapetrou solution [5] of the Einstein equations for minimal antiscalar field (ASF) $\phi$ with the following metric ansatz, $g_{\mu\nu} = g_{\mu\nu}(\phi(x^{\alpha}))$, $\xi = e^{-\phi}$, $c = 1$:

$$ds^2 = e^{-2\phi}dt^2 - e^{2\phi}(dr^2 + r^2 d\Omega^2) =$$
$$= e^{-2GM/r}dt^2 - e^{2GM/r}(dr^2 + r^2 d\Omega^2)\,. \quad (2)$$

Antiscalarity means the polarity [6] or sign of energy-momentum tensor of scalar field (SF) in the Einstein equations opposite that of EMT of usual matter. The last of (2) is specified for gravitating mass $M$. This solution is more realistic than the Schwarzschild one by many reasons. It contains all the 'crucial effects' and leads to correct formulae of lensing. There are no black holes (BH) but for the compact objects with a scale of order of gravitational radius $2GM/c^2$ we get the usual results of BH-thermodynamics [7]. Antiscalarity satisfies the thermodynamic stability conditions and is justified by electrostatic origin of background scalar field [8].

Really, (2) reduces to the static Majumdar-Papapetrou solution of the Einstein-Maxwell equations [9] under 'balance condition' $e_i = \pm\sqrt{G}M_i$ for interacting charges $e_i$ or masses $M_i$, correspondingly. Moreover, the known minimal SF solution [10] with scalar charge $q$ transforms into the ASF metric (2) under mapping $q > iq$, $|q| > M$. All this means [8] that no another scalar charge (source of scalar field) besides mass can exist, and scalar fields produced by masses reduce to composition of electric fields produced by charges. So, SF represents the neutral composition $\phi \sim \phi_+ + \phi_-$ (f.i. $\phi = (\phi_+ + \phi_-)/\sqrt{2}$) of quasi-static electric fields [8] generated by all fermions of the Universe [7] and 'visible' only gravitationally. And vice versa, the arbitrarily small disbalance between $\phi_+$ and $\phi_-$ becomes apparent as quasi-static electric fields or charges.

Now from Schwinger's conjecture [11] that quasi-static fields do have their own carriers, we conclude: these carriers ('statons') should behave only as sub-quantum super-tachyon objects (to imitate the instant action of static fields). If they possess of negligible masses $\mu$ appreciable only for cosmological scales, we extend the minimal scalar EMT generating the ASF-solution (2) to general $T^{scalar}_{\mu\nu}$ of tachyon ($\mu^2 < 0$) nature with a traditional positive $\Lambda$-term (the last, however, changes its sign at once due to antiscalarity):

$$T_{\mu\nu}^{scalar} = \frac{1}{4\pi}[\phi_\mu \phi_\nu - \frac{1}{2} g_{\mu\nu}(\phi_\alpha \phi^\alpha - \mu^2 \phi^2 - \Lambda / 4\pi G)], \quad (3)$$

$$G_{\mu\nu} = \kappa T_{\mu\nu} = 8\pi G(-T_{\mu\nu}^{scalar} + T_{\mu\nu}^{matter}), \quad (4)$$

where $\phi_\mu = \phi_{;\mu} = \phi_{,\mu} = \partial_\mu \phi \equiv \partial\phi / \partial x^\mu$, $\mu^2 = -m^2 < 0$, and negative sign of $T_{\mu\nu}^{scalar}$ in the Einstein equations means antiscalarity. Then neglecting the tensor $T_{\mu\nu}^{matter}$ (including DM), but taking into account the integrability condition (to be manifestation of indissolubility of $\Lambda$ and mass – terms),

$$|\Lambda| = -(2/3)\mu^2 > |\mu| = m \approx 10^{-33} eV \approx 10^{-65} g, \quad (5)$$

and using the corresponding (tachyon) Klein-Gordon equation, $\partial_\mu(\sqrt{-g} g^{\mu\nu})\partial_\nu \phi - m^2 \sqrt{-g}\phi = 0$, we get the cosmological ASF-solution [8] to be appropriate for description of DE [12]:

$$ds^2 = dt^2 - a^2(\phi(t))(dr^2 + r^2 d\Omega^2) =$$

$$= dt^2 - \exp\{-|\Lambda|(t-t_0)^2\}(dr^2 + r^2 d\Omega^2), \quad (6)$$

From that it follows an equation of state for DE [12]: $p = w\varepsilon$, $\varepsilon = T_0^0$, $p = -\frac{1}{3}T_i^i$,

$$w = \frac{-3\Lambda(t-t_0)^2/2 + 1}{3\Lambda(t-t_0)^2/2}. \quad (7)$$

Asimptotically at $t \to \infty$ it goes to the de Sitter state $w = -1$. When $w < -1/3$, we obtain the accelerated phase for the Universe. After a definite time $t_0$, the expansion will always change to contraction. There are no more phantom fields with $w < -1$ in equation of state (7).

The local (2) and cosmological (6) effects may be jointed in metric:

$$ds^2 = e^{-2\phi}dt^2 - e^{2\phi}a^2(\phi(t))(dr^2 + r^2 d\Omega^2),$$

$$e^{\pm 2\phi} \approx 1 \pm 2\phi. \quad (8)$$

In particular for both the crucial effects and DE we get the solution

$$ds^2 = e^{-2GM/r}dt^2 -$$

$$- e^{2GM/r}\exp\{-|\Lambda|(t-t_0)^2\}(dr^2 + r^2 d\Omega^2). \quad (9)$$

We suppose that DM effects may be included later into $\phi$ of (8): $\phi = \phi_{Newton}(r) + \phi_{sin}(r)$.

It stands to reason the nature of such dark energy scalar field (SF1) described by (5-9) as a neutral composition of quasi-static electric fields remains to be the same: $\phi \sim \phi_+ + \phi_-$.

**4. DM as the tachyon neutrinos background.** DM is usually believed to be composed of some heavy particles (wimp's, etc.) or to be the sea of pseudo-scalar axions or of neutrinos. Axions and wimp's are unobservable today. The thermal neutrinos generated in reactions of type $e^+ + e^- \leftrightarrow \nu + \bar{\nu}$ at the temperatures $T \approx 1MeV$ now represent relict at $T_0(\nu) = (4/11)^{1/3}T(\gamma) \approx 2.1^\circ K$ with $T_0(\gamma) \approx 2.73^\circ K$ for CMB, and contribution of those to critical density $\varepsilon_{cr} \sim (10^{-3}eV)^4 \approx 10^{-29} g/cm^3$ is only about 1%. The recent estimations of condensate of massive *non-relativistic* neutrinos $\nu$ and antineutrinos $\bar{\nu}$ of three generations explain a bulk of DM [13] if the minimal neutrino masses $m_\nu \approx 1.5eV$. But the modern data reduce those down to $m_\nu \approx (10^{-2} - 10^{-3})eV$, and a problem remains to be urgent.

Another situation arises if neutrinos respond to tachyon representation of the Lorentz group [14] with the corresponding Dirac equation [15]. In fact this is inevitable way to match the finiteness of neutrino masses with chirality (all neutrinos $\nu$ are left and antineutrinos $\bar{\nu}$ are right). The tachyon mass-shell $p_\mu p^\mu = -m_\nu^2 c^2$ means $E / m_\nu c^2 = (u^2/c^2 - 1)^{-1/2}$, i.e. the speeds $u > c$ are very close to $c$ even for neutrinos with minimal energies $E > 0.1MeV$ detected today.

In general the tachyon neutrinos cannot be canonically quantized and so cannot produce the thermal Fermi distribution or the Cooper pairs condensate. It may be noted [16] that in attempt to quantize the scalar tachyons one can produce only the Fermi distribution of those. We suppose instead that neutrino background may be represented as a scalar conglomerate (not a condensate) $\Phi = \Phi(\nu, \bar{\nu})$ produced with bicomplex Hermitian spinors $\Psi$ by means of the following ansatz:

$$\Psi = \nu + i\overline{\nu} \Rightarrow \Phi = \Psi^{+}\Psi = \nu^2 + \overline{\nu}^2 = \phi_{dm} \quad (10)$$

to be applied to each generation of neutrino. This is similar to the Born approach to quantum mechanics but $\Phi$ is here normalized to be of dimension of scalar potential. The right side of (10) has been computed with the usual Dirac spinors: $\nu = \psi(\nu) = \psi_L = P_L\psi = \frac{1}{2}(1-\gamma^5)\psi$ and $\overline{\nu} = \psi(\overline{\nu}) = \psi_R = P_R\psi = \frac{1}{2}(1+\gamma^5)\psi$. From that we have $\nu^2 = \nu^{+}\nu = \psi_L^{+}\psi_L$ and $\overline{\nu}^2 = \overline{\nu}^{+}\overline{\nu} = \psi_R^{+}\psi_R$, but unlike for the Dirac-conjugate spinors, $\overline{\psi} = \psi^{+}\gamma^0$, the mixed terms rule out: $\nu^{+}\overline{\nu} = \psi_L^{+}\psi_R = 0$, $\overline{\nu}^{+}\nu = \psi_R^{+}\psi_L = 0$. So, for the tachyon-type neutrino sector of SM one should be used only such type Hermitian spinors with no breaking of chiral invariance as required.

We can define a pseudo-scalar conglomerate as well, $\Phi = \Psi^{+}\gamma^5\Psi = -\nu^2 + \overline{\nu}^2$, due to the Dirac $\gamma$-matrices relations: $\gamma^5 P_L = -P_L$ and $\gamma^5 P_R = P_R$. But scalar $\Phi(\nu, \overline{\nu})$ in (10) may be preferable (if densities of $\nu$ and $\overline{\nu}$ prove to be equal) due to symmetry $\nu \leftrightarrow \overline{\nu}$. So, the following Lagrangian for the second fundamental gravitating tachyon scalar field (SF2)

$$L^{DM} = \tfrac{1}{2}[\nabla_\mu \Phi \nabla^\mu \Phi + m_\nu^2 \Phi^2] \quad (11)$$

with a corresponding tachyon EMT (see (4)):

$$T_{\mu\nu}^{matter} = T_{\mu\nu}^{baryon} + T_{\mu\nu}^{DM},$$

$$T_{\mu\nu}^{DM} = \tfrac{1}{4\pi}\{\Phi_\mu \Phi_\nu - \tfrac{1}{2} g_{\mu\nu}(\Phi_\alpha \Phi^\alpha + m_\nu{}^2 \Phi^2) \quad (12)$$

may be appropriate for the minimal (without unnecessary cosmological-type term) self-sufficient description of DM. Taking the values $\varepsilon = T_0^0$ and $p = -\frac{1}{3}T_i^i$, one obtains from (12) the appropriate tachyon-type equation of state, $p = w\varepsilon$, and by variation of (11) with respect to $\Phi$ we get the corresponding tachyon Klein-Gordon equation for DM: $\nabla_\mu \nabla^\mu \Phi - m_\nu^2 \Phi = 0$.

**5. Some estimations.** DM and DE have the similar energy densities ($\varepsilon_{DM} \approx 0.23\varepsilon_{cr}$, $\varepsilon_{DE} \approx 0.73\varepsilon_{cr}$) but with extremely different energy scales defined by typical masses of carriers of two underlying scalar fields - specifically, with neutrino masses $m_\nu \approx (10^{-2} - 10^{-3})eV$ for DM, and with $m \approx 10^{-33}eV$ (stipulated by cosmological constant) for DE.

A 'natural' number density corresponding to critical energy density of order $(10^{-3}eV)^4$ (factor 2.3 may be omitted for brevity) produced by 'particles' with mass-energy scale of order $10^{-3}eV$ is about $(10^{-3}eV)^3 \approx 1.25\times10^5 cm^{-3}$. Correspondingly, the effective number density of DM neutrinos related to a medial global value $\varepsilon_{DM} \approx 0.23\varepsilon_{cr}$ and mass-energy scale $(10^{-3} - 10^{-2})eV$ will be about $2.9\times(10^4 - 10)eV$.

There is a way [18] to estimate a scale for self-gravitating DM 'halo'. A sphere of radius $R$ with typical local DM energy density $\varepsilon_{dm}$ has a gravitational radius $2G\varepsilon_{dm}(4\pi R^3/3c^2)$. This is equal to $R$ when $R = (8\pi G\varepsilon_{dm}/3c^2)^{-1/2}$. For example for the critical density $\varepsilon_{cr} \sim 10^{-29} g/cm^3$ it follows the Hubble radius of the Universe $R \sim 10^{28} cm$.

For typical 'local' DM halo densities in galaxies [19] $\varepsilon_{dm}$ is about $(10^{-25} - 10^{-23})g/cm^3$, so the associated maximal $R$ is $(10^{25} - 10^{24})cm \approx (3-0.3)Mpc$. Such large space scales could be appropriate for DM tachyon neutrinos conglomerate. The expected astronomical observations [20] should confirm the smooth DM density effects at the maximally accessible scales [17] but no expressive cusp or sub-haloes effects for dark tachyon neutrinos background (unlike for the baryon matter) are possible.

The estimations above can also be applied to axially symmetric 'haloes'. This is especially of interest because in such a case DM can approximately be described by logarithmic potential of type $\Phi = \phi_{dm} \approx \ln(r/r_0)$ to be appropriate for description of saturation effect of rotation curves in galaxies and clusters [17].

For definiteness let us consider a class of oblate cylindrical or conic-like objects ('haloes' of spiral galaxies) with approximately the same order of medial thickness or depth $D$. Then the associated gravitational radius $R$ of such objects may be evaluated as $2G\varepsilon_{dm}D(\pi R^2/c^2)$ which is equal to $R$ when $R=(2\pi GD\varepsilon_{dm}/c^2)^{-1}$. It follows from here that $\varepsilon_{dm}R=(2\pi GD/c^2)^{-1}\approx const$. This includes the empirical law recently exposed for array of about 1000 spiral galaxies [19].

**6. Conclusion.** The last estimates are of geometric nature and maybe remind a calculation for inside of BH. But it is worth to emphasize that the applied antiscalar approach (AA) to gravity (to be following from the Papapetrou ansatz and unremovable character of SF) is very restrictive. So, the habitual vacuum Einstein equations, together with BH and GW (gravitational waves propagating with speed of light) solutions, being tolerant in standard General Relativity, are out of scope of AA. Moreover, there are no such type solutions in AA at all. So, the 'gravitational radius' is not a scale having any relation to the habitual 'BH horizons' but it is simply an independent natural scale relating to the dimensional unites, and nothing more.

Unlike the customary approaches we do not take by hands any *ad hoc* scalar fields to get DE but *deduce* the fundamental scalar field (SF1) from general geometrical and physical principles, and only on the last step identify it with DE. Being of electrostatic origin with a mass-scale of order $m\approx 10^{-33}eV$ such DE has a corresponding 'back-reaction' on the electrodynamics which is however insignificant due to utterly small mass-scale indicated here. But of course this is a matter of principle and as such should be considered separately.

As for SF2 we believe the neutrinos to be the only realistic constituents compatible with DM, and for the *massive* neutrinos to be always left (and antineutrinos – right) they should inevitably respond to the tachyon representations of the Lorentz group. These free neutrino and antineutrino fields together can naturally compose the second fundamental effectively scalar background field which should be classic (not quantized) and capable of accumulation as stated above.

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**Резюме**

Ғарыштық скалярлық өрістерінің пайда болуының геометрлік мен физикалық қасиеттері бірге көрсетілген.



**Резюме**

Геометрические и физические аспекты происхождения космических скалярных полей рассмотрены совместно.


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