Cosmoparticle physics of family symmetry breaking

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The foundations of both particle theory and cosmology are hidden at super energy scale and can not be tested by direct laboratory means. Cosmoparticle physics is developed to probe these foundations by the proper combination of their indirect effects, thus providing definite conclusions on their reliability. One may consider the set of astrophysical data as the result of the great particle physics experiment, taken place in the past of the Universe and to develop the methods of cosmoarcheology to look for the traces of hypothetical particles and fields, reflected in these data. The general set of restrictions on the possible parameters of new physics may be found [1], but this information is generally negative, saying what new physics should not be. However, though the standard model of strong, weak and electromagnetic interactions does not meet direct contradictions with the results of high energy physics experiments, it contains some internal inconsistencies, to remove which we should extend the standard model, as well as there is esthetical motivation for theories of everything, invoking new physical phenomena. On the other hand there are at least three places in the modern cosmology, appealing for the new physics and finding its grounds outside the physics, proved in laboratories,- inflation, baryosynthesis and nonbaryonic dark matter. Cosmological and astrophysical tests turn to be complementary to laboratory searches of rare processes, induced by new physics, as it can be seen in the case of gauge theory of broken symmetry of quark and lepton families.

The identity of quark and lepton families:

$$(u, d, e, \nu_e); \qquad (c, s, \mu, \nu_\mu); \qquad (t, b, \tau, \nu_\tau) \tag{1}$$

relative to strong and electroweak interactions strongly suggests the existence of 'horizontal' symmetry between these generations. The concept of local horizontal symmetry $SU(3)_H$, first proposed in [2], provides the "horizontal" fundamental symmetry grounds for the observed symmetry, mass hierarchy and mixing between the families of quarks and leptons [3]. The model [3] assumes the local gauge symmetry between quarks and leptons to be $SU(3)_C * SU(2)_L * U(1) * G_H$, thus putting together the symmetry of the standard model of strong $(SU(3)_C)$ and electroweak $(SU(2)_L * U(1))$ interactions and the "horizontal" gauge symmetry of families (G_H). The model ascribes the observed mass hierarchy of families to the hierarchy of "horizontal" symmetry breaking. It means, in particular, that left and right-handed quark and leptons fields should belong to different representation of G_H, what in the case of three families dictates the unique choice of $G_H = SU(3)_H$. The "horizontal" symmetry breakdown is maintained by the hierarchy of vacuum expectation values (v.e.v.) of "horizontal" Higgs fields $\langle\xi_i\rangle, i = 0, 1, 2$. These fields are directly coupled to additional heavy fermions, whose mixing with quarks and leptons provides the "see-saw" mechanism of the mass generation for quarks and leptons. So, the model ascribes the quark and lepton mass scale to the scale of electroweak symmetry breaking $v = 174$GeV, and the mass hierarchy of families reflects the hierarchy of $SU(3)_H$ symmetry breaking. The vacuum expectation values for "horizontal" Higgs field are practically put by hands into the model, but their ratio turns to be proportional to the square root of the fermion family ratio, so that the observed family mass hierarchy of 3–4 orders of the magnitude (c.f. $m_\tau : m_e = 3,5 : 10^3$) is reproduced by the v.e.v. ratio of the order, not exceeding α^{-1}, being stable to radiative corrections. The self consistency of the model needs the horizontal "triangle" anomaly to be canceled due to the proper choice of heavy fermion sector. Such cancellation involves the existence of heavy partners of neutrinos, so that the Dirac "see-saw" mechanism for quark and charged lepton mass generation is inevitably accompanied in the considered model by the Majorana "see-saw" mechanism for neutrino masses.

The natural assumption on the form of "horizontal" Higgs potential results in the existence of the additional global $U(1)_H$ symmetry. The latter may be identified at the last step of horizontal symmetry breaking with the Peccei–Quinn symmetry [4] and its breaking leads to the prediction of Goldstone boson a of invisible axion type [5]. In the considered model the Goldstone boson has flavor nondiagonal coupling with quarks and leptons (including neutrino), being simultaneously familon and Majoron of the singlet type, and called "archion". It turns out [6], that archion model escapes the serious problem of primordial superheavy stable Q quarks, predicted in the model of hadronic axion [5,6,7]. One can estimate the frozen concentration of Q quarks and respective Q hadrons in the Universe and find it contradicting [6] the upper limits on such concentration, following from the search for anomalous nuclei (so called "crazy isotopes"). So the theory should introduce the mechanism of superheavy quark instability. But the inclusion of the hadronic axion model into GUT models leads inevitably to the existence of superheavy lepton, coupled to axion. Then, the mixing of superheavy quark Q with the light (ordinary) quarks, inducing Q instability, would lead to the existence at the tree level of the axion coupling to leptons, so that axion is not hadronic. In view of these troubles of the model of hadronic axion the model of archion is of special interest, since it naturally provides both superheavy quark instability and the suppression of the axion coupling to leptons.

Two groups of new parameters have been introduced in the model:

- v.e.v.s of "horizontal" Higgs fields $\langle\xi_i\rangle$ (F'', F', F)
- Yukawa couplings of fields ξ_i to additional fermions (p_i, $i = 1, 2, 3$)

However, the amount of free parameters is actually smaller, as compared with the standard model, due to the relationships between the parameters imposed both by the symmetry and by the reproduction of observed mass matrices for quarks and leptons

$$F : F' : F" \simeq 1 : 30 : 200 \quad (2)$$

The structure of mass matrices of quarks and leptons is explained in the considered model by the hierarchy of horizontal symmetry breaking (1), and not by the great difference in Yukawa couplings for different generations as it is in the standard model.

The remaining free parameters are fixed by the following system of laboratory and cosmological restrictions:

a) The data on $\mu \to ea$ and $K \to \pi a$ decays lead to the lower bound $F > 4 \cdot 10^5 GeV$ [8].

b) The astrophysical estimations of stellar energy losses due to archion emission (for stars of the main sequence and red giants) give rise to the next lower bound $F \geq 10^6$GeV [6]. This bound turns to be by two orders of the magnitude weaker, than in the case of invisible axions owing to suppression of archion coupling to fermions of lightest family (u, d, e).

c) Archion emission can influence the time scale and energetics of neutrino flux from collapsing stars. Analysis of such a possible influence for SN1987 excludes the interval $10^6 GeV \leq F \leq 3 \cdot 10^9 GeV$ [6,9].

d) Generation of density perturbations in the phase transitions with family symmetry breaking at the inflational stage has been analyzed in [10]. The observed isotropy of relic radiation and astronomical restrictions on the concentration of primordial black holes in the Universe make it possible to exclude in the model of multicomponent chaotic inflation the values of the scale of family symmetry breaking $F > 10^{11}$GeV.

e)As it was shown in [11], that the initial distribution of θ changing on 2π around the string implies the inhomogeneity of the amplitude of coherent axion field oscillations relative to the true vacuum, being proportional to $\theta - \theta_{vac}$, where $\theta_{vac} = 2\pi n$ with n being integer. The large scale distribution of these primordial inhomogeneities named archioles, reflects the vacuum axion walls-surrounded-by-strings structure, formed when the axion mass is "switched on" at $T \sim 800$MeV. Owing to superweak self-interaction of invisible axion the vacuum walls-strings structure and archioles split and their successive evolution goes separately. The vacuum walls-surrounded-by-strings structure is known to disappear rapidly due to gravitational radiation, and the large scale structure of archioles freezes out at the radiation dominancy stage. Archioles reflect the original Brownian nature of axion strings, having at each scale about 80% of string length in the form of infinite string, stretching out the region of the considered size [12]. So the archioles form the fractal structure, causing inhomogeneities at all the scale. Putting aside the small scale evolution of archioles, estimations [11] show, that the large scale inhomogeneities induced by archioles can not be smaller than $\delta \sim 10^{-2}(F/10^{10}GeV)$ causing the serious trouble for the cosmological models with even small axionic dark matter admixtures at $F > 10^8$GeV in view of the observed isotropy of relic radiation. According to [6] at $F < 10^8$GeV coherent axion field oscillations are thermalized due to $aN(\tilde{N}) \to \pi N(\tilde{N})$ reactions, so that the archioles structure dissipates. Primordial axion field distribution can in this case induce fractal distribution of baryonic charge. So the troublesome problem of primordial inhomogenity of energy density distribution of coherent archion field oscillation (the arhioles problem) may be resolved for small scales F, thus putting the constraint $F < 10^8$GeV.

f) Since the mass of neutrino is proportional to p/F, its lifetime $\tau \sim F^5$ and the density of primordial axion field [13] $\rho_a = \bar{\rho} \sim F$, at larger F axion field is to dominate in the Universe, massive stable neutrino dominancy corresponds to smaller F, and, finally, the smallest possible F correspond to cosmological models with massive unstable neutrino [14,15,6]. So changing the parameter F one reproduces all the main types of cosmological models of the formation of the structure of the Universe. In our approach continuous change of F results in continuous transition from one to another form of dark matter, dominating in the Universe, and in definite predictions of the model for each type of dark matter, corresponding to the combination of respective cosmological, astrophysical and physical constraints. Indeed, due to the presence in the model of the Majorana neutrino masses with the hierarchy [3]

$$m_{\nu_e} : m_{\nu_\mu} : m_{\nu_\tau} \simeq m_e : m_\mu : m_\tau \tag{3}$$

of archion and of neutrino transitions with archion emission

$$\nu_\tau \rightarrow \nu_\mu a; \qquad \nu_\mu \rightarrow \nu_e a \tag{4}$$

the total cosmological density ρ_{tot} and baryon density ρ_B being fixed, relationship [16,6]

$$\rho_a^{prim} + \sum \rho_{\nu_i}^{prim} + \rho_a^{dec} + \rho_B = \rho_{tot} \tag{5}$$

turns to be an equation relative to F and couplings p_i (assumed to be of the same of the magnitude for all generations). The solutions of this equation define a discrete set of cosmological models with different types of dark matter, (see [16,6]). The solutions exist only if $p \leq 1,5 \cdot 10^{-4}$. For larger values of p the predicted dark matter density exceeds the total cosmological density.

The discrete set of solutions of the Eq.(2.4), depending on F and p reproduces in a quantitatively definite way all the main types of popular dark matter scenarios CDM, HDM, mixed CDM+HDM, relativistic and nonrelativistic UDM. They are:

1. Archion coherent oscilations dominancy as CDM. The cosmological evolution of archion field after Peccei-Quinn symmetry breaking follows basically in our approach general features of the standard model of 'invisible' axions. $SU(3)_H * U(1)_H$ symmetry breaking leads F to be in fact Peccei-Quinn symmetry of only one quark-lepton generation, what resolves automatically the cosmological θ-domain problem in the axion theory [17]. The modern archion mass density is equal to:

$$\rho_a = (F/4 \cdot 10^{12} GeV)\rho_{cr}, \qquad \rho_{cr} = \frac{3H^2}{8\pi G} \tag{6}$$

Accounting for intensive archion emission by decaying archion cosmic string structure result in the growth of the modern cosmological axion density up to

$$\rho_a = (F/2 \cdot 10^{10} GeV)\rho_{cr} \tag{7}$$

2. Hot dark matter (HDM) scenario. The dominancy of ν_τ with the standard concentration $n_\nu = 3/11 n_\gamma$ and the mass $m_{\nu_\tau} = 20$eV and the llifetime exceeding the age of the Universe, t_U, $(t_U < \tau(\nu_\tau \to \nu_\mu a))$:

$$\rho_{\nu_\tau} = \frac{6,6 \cdot 10^{13} GeV}{F} p\rho_{cr} \tag{8}$$

3. Relativistic unstable dark matter (UDM) scenario. The dominance in the Universe of relativistic archions and ν_μ, being the products of $\nu_\tau \to \nu_\mu a$ decay of with the mass $m_{\nu_\tau} = 50 - 100$eV and lifetime $\tau(\nu_\tau \to \nu_\mu a) = 4 \cdot 10^{15} - 10^{16}$s $(m_{\nu_\mu} < 5$eV):

$$\rho^{rel}_{\nu_\mu + a} = \frac{(F/10^{10} GeV)^{3/2}}{p^{1/2}} \rho_{cr} \tag{9}$$

4. Nonrelativistic UDM scenario. The dominancy of nonrelativistic ν_μ with the mass $\sim$ 10eV, both primordial and from $\nu_\tau \to \nu_\mu a$ decay of ν_τ with mass $\sim$ 100eV and the lifetime $\sim 10^{15}$s, provided that $\tau(\nu_\mu \to \nu_e a) > t_U$:

$$\rho_{\nu_\mu} = \frac{0.6 \cdot 10^{12} GeV}{F} p\rho_{cr} \tag{10}$$

5. Relativistic hierarchial decay (HD) scenario. The dominancy in the modern Universe of relativistic archions ρ_a^{dec} and ν_e, from decay of ν_{mu} with the mass $m_{\nu_\mu} = 50 - 100$eV and lifetime $\tau(\nu_\mu \to \nu_e a) = 4 \cdot 10^{15} - 10^{16}$s, under the condition of rapid decay of ν_τ with the mass $m_{\nu_\tau} \sim (1-10)$keV, $\tau(\nu_\tau \to \nu_\mu a) <$ $(10^8 - 10^{10})$s:

$$\rho^{rel}_{\nu_e + a} = \frac{(F/10^{8} GeV)^{3/2}}{p^{1/2}} \rho_{cr} \tag{11}$$

6. Nonrelativistic HD scenario. The dominancy of nonrelativistic or semirelativistic archions, originated from both early ν_τ decay and succesive ν_μ decays, provided that $m_a > m_{\nu_e}$. Or, in the other case $(m_a < m_{\nu_e})$ the dominancy of nonrelativistic ν_e both primordial and from ν_τ and ν_μ decays:

$$\rho_{\nu_e} = \frac{3,3 \cdot 10^{10} GeV}{F} p\rho_{cr} \tag{12}$$

In the former case the main contribution into the inhomogeneous dark matter (in rich galaxy clusters and halos of galaxies) is maintained by both primordial thermal archion background and nonrelativisic archions from early ν_τ decays

$$\rho_a = \frac{9 \cdot 10^{4} GeV}{F} \rho_{cr} \tag{13}$$

Putting together restrictions a, b, c, d, e, f the space of the model parameters is reduced to the only possible narrow window in the vicinity of

$$F = F_6 = 10^6 GeV \qquad and \qquad p = 5 \cdot 10^{-7} - 5 \cdot 10^{-6} \tag{14}$$

This solution corresponds to hierarchical decay scenario, sharing the qualitative advantages of CDM, HDM and UDM models. It was also shown that the model [3] contains physical grounds for inflation and baryosynthesis and may be viewed as quantitatively definite phenomenology for theories of everything [18].

In the hierarchical decay scenario (HDS) formation of the large scale structure takes place as a result of the stages of dominancy of unstable massive neutrinos and their relativistic decay products. In the period from the $t_0 = 10^6(1keV/m_{\nu_\tau})^2$s. to $\tau_{\nu_\tau}(\nu_\tau \to \nu_\mu a) = 10^{10}(1keV/m_{\nu_\tau})^3$s. the Universe is ν_τ dominating. The mass of ν_τ are disposed in the range $m_{\nu_\tau} = 1 - 10$keV (according to (2.13)) Their decay at $t = \tau_{\nu_\tau}$ leads to the period of relativistic ν_μ and a dominancy and to the following period of ν_μ dominancy with the mass $m_{\nu_\mu} = 0,1 - 1$keV. At $t = \tau_{\nu_\mu}(\nu_\mu \to \nu_e a) = 10^{16}(1keV/m_{\nu_\tau})^3$s. $\nu_\mu \to \nu_e a$ decays slow down the rate of the structure evolution and, thus, provide its survival to the present time.

So the UDM scenario is realized in this case. In the modern Universe the dominant DM types are thermal primordial archions [6] with the mass $m_a = 3$eV and number density $n_a = 0,6 n_\nu$ and archions from the ν_τ and ν_μ decays, as well as ν_e with the mass $m_{\nu_e} = 1$eV, both primordial and from ν_μ decays.

Note that HD scenarios 5 and 6 combine the attractive features of HDM, CDM and UDM models. It makes HD scenarios appealing physically relevant theoretical basis for detailed models of the cosmological large scale structure formation and for comparison of the predictions of such models with the astronomical data. Indeed in the HD scenarios the dominancy of ν_τ with the mass (1-10)keV in the period $(10^8 - 10^{10})$s induces short wave fluctuations in the spectrum of density perturbations of ν_μ with the mass (50-100)eV. ν_μ from $\nu_\tau \to \nu_\mu a$ decays enhance in this spectrum (by the factor of 2) the long wave component, inherent to HDM models, providing the formulation of clear cell structure of voids and superclusters. Finally, $\nu_\mu \to \nu_e a$ decays at $t \sim (10^{15} - 10^{16})$s slow down the rate of the evolution of the structure and provide its survival to the present time. The primordial thermal archion background, being in these models the coldest component of the modern dark matter play the important role in the evolution of the shortest wavelength part of density perturbations, inducing, in particular, the formation of massive halos outside the visible parts of galaxies. One should take in mind, that according to [19], the phase space restrictions on the mass of halo particles [20] can be weakened or even completely removed in the case of Bose gas.

Quantitative analysis of HD scenario was initiated recently by us with Doroshkevich and Berezhiani on base of the linear theory of the evolution of the spectrum of density perturbations, given by

$$P(k,t_f) = (b(t_i)/b(t_f))^2 T^2(k,t_f) P(k,t_i) \tag{15}$$

where $P(k,t_i)$ is the spectrum of initial perturbations and $T(k,t_f)$ is the transfer function, which describes the evolution of the spectrum in the considered DM model, $b(t)$ specifies the linear growth law of long wavelength perturbations. The evaluation of the transfer function assumes in general the solution of kinetic Vlasov equation in the gravitation field for the considered dark matter model. Here, instead, we"ll approximate the transfer functions by reasonable modification of the standard transfer functions for CDM and HDM models, given in [21]:

$$T_{CDM}(k) = \frac{ln(1+2,34q)}{2,34q}(1+3,89q+(16,1q)^2+(5,46q)^3+(6,71q)^4)^{-1/4}; \quad (16)$$

$$T_{HDM}(k) = \exp(-0,16(kR_{f\nu}) - (kR_{f\nu})^2/2)(1+1.6q+(4.0q)^{3/2}+(0.92q)^2)^{-1} \quad (17)$$

$$q = k/\Omega_\nu h^2 (Mpc)^{-1} \qquad R_{f\nu} = 2.6(\Omega_\nu h^2)^{-1}Mpc; \qquad \Omega_\nu h^2 = 0.31 m_\nu/(30eV)$$

where $h = H_0/100km/s/Mpc$ and H_0 is the present Hubble constant.

The evolution of perturbations in the hierarchical decay scenario proceeds according to the following scheme:

The period of dominancy of ν_τ induces short wave fluctuations in the spectrum of density perturbations, inherent to CDM model (more precisely, to warm dark matter). In this period derelativization of ν_μ provides their perturbations to share the same form of the spectrum, so that the short wave fluctuations retain after $\nu_\tau \to \nu_\mu a$ decays. In addition to these density fluctuations the ones of ν_μ from ν_τ decays enhance the long wave component of the spectrum. ν_μ decays slow down the rate of the evolution of the structure and provide its survival to the present time. Hierarchy of lifetimes of ν_τ and ν_μ which inevitably follows from the hierarchy (1) leads to the respective hierarchy of the scales. Thus, the transfer function to the period of $\nu_\mu \to \nu_e a$ decay will be the sum of two transfer functions: the one of the primordial $\nu_{\mu 1}$ and the one of $\nu_{\mu 2}$ from $\nu_\tau \to \nu_\mu a$ decays.

$$T_{HDS}(k) = (T^2_{\nu_{\mu 1}}(k) + T^2_{\nu_{\mu 2}}(k))^{1/2}/\sqrt{2} \quad (18)$$

We will denote these functions $T_{\nu_{\mu 1}}$ and $T_{\nu_{\mu 2}}$, respectively. Before the derelativization of primordial $\nu_{\mu 1}$ at $t_{\nu_{\mu 1}} = 10^8(1keV/m_{\nu_\tau})^2$ the perturbations in the gas of ν_τ evolve similar to the HDM and the transfer function has the form (17). In the period from the moment $t_{\nu_{\mu 1}}$ to the moment $\tau_{\nu_\tau} = 10^{10}(1keV/m_{\nu_\tau})^3$, when ν_τ decay, the derelativization of $\nu_{\mu 1}$ takes place inducing ν_τ scale fluctuations in there perturbations and the transfer function will be T_* in this period. After ν_τ decays until the moment of ν_μ decays the perturbations in the primordial $\nu_{\mu 1}$ evolve according to the CDM scenario and transfer functions of this period has the form (16). Thus, the resulting transfer function for the primordial $\nu_{\mu 1}$at the moment of ν_μ decays $t = \tau_{\nu_\mu}$ is the product of the three functions:

$$T_{\nu_{\mu 1}} = T^{\nu_\tau}_{HDM} T_* T_{CDM} \quad (19)$$

with the following parameters, determined at $t = \tau_{\nu_\mu}$ as

$$\Omega_{\nu_\tau} h^2 = 10.3(m_{\nu_\tau}/1keV); \qquad R_{f\nu_\tau} = 3 \cdot 10^{-2}(1keV/m_{\nu_\tau})^3 \quad (20)$$

To specify the form of the transfer function T_*, consider now the mechanism of the shortwave fluctuation generation in the gas of derelativized primordial $\nu_{\mu 1}$ at the stage of unstable ν_τ dominancy. At this stage the perturbations in the gas of primordial grow at the scales $R > R_{\nu_{\mu 1}}$ according to the following equation [22]

$$\ddot{\delta}_{\nu_{\mu 1}} + 4\dot{\delta}_{\nu_{\mu 1}}/3t \approx 4\pi G \rho_{\nu_\tau} \delta_{\nu_\tau} = 2\delta_{\nu_\tau}/3t^2 \qquad (21)$$

where $R_{\nu_{\mu 1}}$ is the Jeans length of $\nu_{\mu 1}$, $\delta_{\nu_{\mu 1}}$ and δ_{ν_τ} are density contrasts in the gas of $\nu_{\mu 1}$ and ν_τ respectively. The solution of (12) is [22]

$$\delta_{\nu_{\mu 1}}(\theta) = \delta_{\nu_\tau}(t_{\nu_{\mu 1}})(\theta^{2/3} + 2\theta^{-1/3} - 3) \qquad (22)$$

where $\theta = t/t_{\nu_{\mu 1}}$.

The Jeans length of relict $\nu_{\mu 1}$ is given by

$$R_{\nu_{\mu 1}}(t) = \langle v \rangle_{\nu_{\mu 1}} t \approx cT_{\nu_{\mu 1}} t/m_{\nu_\mu} = ct_{\nu_{\mu 1}}^{2/3} t^{1/3} \qquad (23)$$

For scales $R > R_{\nu_{\mu 1}}(t)$ the perturbations in the $\nu_{\mu 1}$ grow according to (22), until the R exceeds the $R_{\nu_{\mu 1}}(t)$, growing with time according to (23). Since the scale factor grows in this period as $\propto t^{2/3}$, it means that the properties of ν_τ gas fluctuations are shared by $\nu_{\mu 1}$ gas on less and less massive scales. The smallest mass scale of $\nu_{\mu 1}$ perturbations corresponds to the length $R = R_{\nu_{\mu 1}}(\tau_{\nu_\tau})$.

Thus, one can find, that the transfer function T_* for the gas of primordial ν_μ can be writed as follow:

$$\begin{array}{lll} T_* = ((kR^H_{\nu_{\mu 1}})^{-2} + 2kR^H_{\nu_{\mu 1}} - 3)^{1/2} & for & k > R^{-1}_{\nu_{\mu 1}}(\tau_{\nu_\tau}) \\ T_* = \quad 4,5(1keV/m_{\nu_\tau}) & for & k < R^{-1}_{\nu_{\mu 1}}(\tau_{\nu_\tau}) \end{array} \qquad (24)$$

Here $R^H_{\nu_{\mu 1}}$ is the size of the horizon at the moment $t_{\nu_{\mu 1}}$. At the moment of ν_μ decay $t = \tau_{\nu_\mu}$, the scales in the Eq.(24) are equal to

$$\begin{array}{l} R^H_{\nu_{\mu 1}} = \quad 10^{-2}(1keV/m_{\nu_\tau})^2 Mpc. \\ R_{\nu_{\mu 1}} = 4,6 \cdot 10^{-2}(1keV/m_{\nu_\tau})^3 Mpc. \end{array} \qquad (25)$$

Assuming that the $\nu_\tau \rightarrow \nu_\mu a$ decay proceeds instantaneously at $t = \tau_{\nu_\tau}$ we can use Eq.(17) for the transfer function of $T_{\nu_{\mu 2}}$, with the proper correction for the scale. Namely, we must renormalize the scale, because $\nu_{\mu 2}$ from ν_τ decays turn to be nonrelativistic in the moment $t_{\nu_{\mu 2}} = 10^{12}(1keV/m_{\nu_\tau})^2$s., but the derelativization of primordial $\nu_{\mu 1}$ take place at $t_{\nu_{\mu 1}} = 10^8(1keV/m_{\nu_\tau})^2$s. Finally, we have the following parameters for $T_{\nu_{\mu 2}}$ in the Eq.(17):

$$\begin{array}{l} R_{f\nu_{\mu 2}} = \quad 22(1keV/m_{\nu_\tau})^3 Mpc. \\ \Omega_{\nu_{\mu 2}} h^2 = 1,03 \cdot 10^{-2}(m_{\nu_\tau}/1keV) \end{array} \qquad (26)$$

As we can see, the hierarchy (1) induces similar hierarchy of scale in the hierarchical decay scenario.

Let us note, that the main HDS parameters (the mass of the unstable ν_τ) is severely constrained by the condition of the sufficient growth of small initial perturbations. Based on this condition the data on the anisotropy of the thermal microwave background exclude $m_{\nu_\tau} > 2$keV.

Semiquantitative analysis of the obtained spectrum of density fluctuations together with estimations of typical scales of the large scale structure and superlarge scale structure, arising in HDS makes it possible to conclude, that the cosmological structure, expected in the considered scenario should be close to the observed one.

The recent indications on the existence of the anysotropy of microwave thermal background, claimed in COBE experiment [23] also seem to favour such mixed scenario. Moreover, analysis of the data, obtained in Relict1 experimental searches for large scale anysotropy of relic radiation seem to favour unstable dark matter models of large scale structure formation. All the existing data and their analysis [24] also seem to favour "flat" Harrison-Zeldovich spectrum, predicted by simple one-field inflational models (by chaotic inflational scenario, in particular). Such a scenario can find its grounds in the framework of the presented model, since the singlet Higgs field η, determining the flavour independent mass term $\mu = G_\eta \langle \eta \rangle$ may self consistently play the role of inflaton at $\langle \eta \rangle \sim m_{pl}$ and $G_\eta < v_{PQ}/m_{pl}$. The predicted spectrum of density fluctuations practically coincides with the "flat" one at $v_{PQ} < 10^{10}$GeV.

Even at the presented level of "horizontal" $SU(2)*U(1)*SU(3)_H$ gauge unification the model provides the mechanism for baryogenesis without GUT-induced baryon nonconservation. The meshanism combines (B+L) nonperturbative electroweak nonconservation at high temperatures with $\Delta L = 2$ nonequilibrium transitions, induced by Majorana neutrino interactions. Estimations [25] show, that the mechanism can, in principle, reproduce the observed baryon assymetry of the Universe for the allowed parameters of the model. So the proposed model provides unified fundamental basis for theoretical description both of the structure of elementary particles and of the structure of the Universe. Unifying the separate results of studies of partial problems of cosmology and particle physics, the proposed model seems to be the first step on the way towards realistic unified description of unique fundamental grounds of the micro- and macro- world structure on the basis of flavourdynamics.

Our way to the highlights of the theory, based on the detailed elaboration of its 'low energy' basis, may give valiable recomendations for the choice of realistic variant of the complete unified 'theory of everything' (superstring theory, for example), what seems to be of sure importance in view of the existing theoretical uncertainties in the searches for fundamental grounds of physics and cosmology.

The important epistemological aspect of the presented studies is to be pointed out. We have demonstrated the principal possibility of detailed study of multiparameter "hidden" sector of particle theory. The example of the QFD with low energy scale of family symetry breaking implies the hope, that multiparameter model of superhighenergy physics, being elaborated in details, will lead to the amount of indirect effects, accesible to experimental and observational tests, exceeding the number of independent parameters of the theory. So the general approach to the experimental test of the theory, based on the overdetermined system of equations for unknown theoretical parameters, can be realized in the framework of cosmoparticle physics. The analysis of the combination of effects, predicted by the theory provides its detailed study in the case, than direct experimental test is impossible.

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