Cosmoparticle physics of family symmetry breaking

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The models of gauge theory with family symmetry breaking, reproducing the observed properties of quarks and leptons, provide the unified description for the main candidates of dark matter particles: neutrino with the mass 20ev as hot dark matter, archions (axions, being simultaneously singlet Majorons and familons) as cold dark matter, and unstable neutrino with mass 100ev, decaying on lighter neutrino and archions with the lifetime 10^{16}s as unstable dark matter. The mechanisms for baryosynthesis and inflation are also provided by the models. The choice between these cosmological models, depending on the unknown a priori scale of the horizontal symmetry breaking can be made unambiguously in the combination of search for rare archion decays and astronomical studies of the dark matter in the Universe.

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. 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, ascribing to the hierarchy of the horizontal symmetry breaking the observed hierarchy of masses and the mixing between quark and lepton families.

The problem of fermion families (generations) remains one of the central problems of particle physics. The standard $SU(3)*SU(2)*U(1)$ model, so as its possible 'vertical' extensions (in the framework of one generation) of the type $SU(5)$, $SO(10)$ etc., does not contain any deep physical grounds both for the existence of mass hierarchy between generations and the observed weak mixing of quarks and leptons owing to arbitrary Yukawa couplings. 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 [1], is reasonable to be considered with left-handed quark and lepton components transforming as $SU(3)_H$ triplets, and the right-handed ones transforming as antitriplets. Their mass terms transform as $3*3 = \bar{3} + 6$ and consequently may arise as a result of $SU(3)$ breaking only. (Generalization on the case of n generations, $SU(n)$, is trivial.)

In this approach the hypothesis is reasonable, that the structure of these matrices is determined by the pattern of horizontal symmetry breaking (i.e., by the structure of vacuum expectation values (VEV) of horizontal scalars, maintaining $SU(3)$ breaking) and the mass hierarchy between generations is related to a definite hierarchy in this breaking (the hypothesis of horizontal hierarchy - HHH) [2,3].

The simpliest realisation of HHH invokes the introduction of additional superheavy fermions, acquiring their masses via direct coupling with horizontal scalars. The ordinary quark and lepton masses are induced by their "see-saw" mixing [3] with these heavy fermions.

The concept of grand unification (GUT) is another argument in favor of chiral G symmetry. In the GUT models left-handed quarks and leptons are put together with antiparticles of their right-handed component into the same irreducible representations of GUT group G_{GUT} . So in the framework of $G_{GUT} * G_H$ symmetry left-handed and right-handed components must transform as conjugated representations of G_H, i.e., G_H symmetry must be chiral.

One may hope, that complete unification of horizontal and vertical symmetries will be achieved on the base of unifying fundamental symmetry G, including $G_{GUT} * G_H$ in the course of superstring theory development. Though the most elaborated simpliest variant of realistic superstring model $E_8 * E_8'$ [4,5] does not leave any room inclusion of horisontal symmetry, such inclusion is possible within the frame of wider class of superstring models, c.f., in $SO(32)$ or in heterotic string models with direct compatification to 4-dimentional spacetime [6]. In the latter case [6] a wide class of GUT groups with the rank smaller than 22 is possible. The analysis of broken horizontal symmetry, given in the present paper, may be useful for the choice of realistic models from this variety of possibilities.

Here we do not consider supersymmetric extensions of the model, in which a nimber of new particles are predicted, extending the hidden sector of the theory. Properties of such particles depend critically on details of supersymmetry breaking and need special detailed study.

To build the realistic model of broken horizontal symmetry, rather wide set of parameters is to be introduced. But: i) the number of these parameters is smaller than in the realistic models without horizontal symmetry; ii) the bulk of these parameters is fixed by the experimental data on the quark and lepton properties, and, finally, iii) the set of new nontrivial physical phenomena, predicted by the model, provides in principle complete check of the model and determination of all the parameters. These new phenomena arise at a high energy scale of horizontal symmetry breaking $> 10^5 - 10^6$GeV, which can not be achieved even in the far future at accelerators. However combination of experimental searches of their indirect effects in the processes with known particles with the analysis of their cosmological and astrophysical effects makes it possible to study physics, predicted at this scale.

The proposed model satisfies the following naturality conditions:

a) natural suppression of flavour changing neutral currents (FCNC) [7]. There are absent light scalar $SU(2) * U(1)$ doublets, transforming according to nontrivial representations of G_H (vertical-horizontal fields) and leading to unacceptably strong FCNC. Yukawa couplings, responsible for quark and lepton mass generation, include the only standard $SU(2) * U(1)$ Higgs doublet, though left-handed and right-handed fermion components transform as conjugate representations of horizontal symmetry group. The price for it is the introduction of additional superheavy fermions, maintaining the hidden sector of the theory. Quark and lepton masses are induced by mixing with these heavy fermions. That is the so called 'see-saw' mechanism [8] is realized not only for neutrinos, but for all the quarks and leptons either. Besides that, our approach provides natiral explanation of the hierarchy of electroweak and GUT scales on base of mechanisms suggested for GUT with one generation,c.f., by means of supersymmetric extensions of $SU(5)$, $SO(10)$ etc. [9]. Quark and lepton mass generation by means of vertical-horizontal fields would have needed unnatural fine tuning of their parameters even in the supersymmetric case;

b) natural horizontal hierarchy. The observed mass hierarchy of families (c.f., $m_e : m_\mu : m_\tau = 1 : 200 : 4000$ etc.) is explained by much more moderate hierarchy of horizontal symmetry breaking. The parameters of such breaking are proportional to m for quarks and leptons. So there is no need in special mechanisms to protect the hierarchy from loop corrections;

c) natural solution for QCD CP-violation problem [10]. Through there is the only Higgs doublets present, the theory provides natural inclusion of $U(1)$ Peccei-Quinn symmetry [10], being associated with heavy Higgs fields, breaking G at scale. Breaking of this global U(1) symmetry results in the existence of pseudo-Goldstone boson α of invisible axion type with interaction scale v_H [11]. α has both flavour-diagonal and flavour-nondiagonal coupling with quarks and leptons, i.e., is simultaneously familon [12,13]. Finally, it is related to neutrino Majorana mass generation, being in fact Majoron of singlet type [14].

The model inevitable consequences are:

a) flavour changing neutral transitions, related to axion and horizontal gauge bosons interactions;

b) the existence of neutrino Majorana mass and of the neutrino mass hierarchy of different families;

c) the instability of heavier neutrino relative to axion decay on lighter neutrino;

d) the existence of metastable superheavy fermions.

The presented model may be cheched in the combination of laboratory tests (the search for neutrino mass, for neutrino oscillations and for $2\beta_{0\nu}$ decay, the study of $\tilde{K}^0 - K^0$ and $\tilde{B}^0 - B^0$ transitions, the search for axion decays $\mu \to ea$, $K \to \pi a$ etc.) and of analysis of cosmological and astrophysical effects of its predictions. The latter includes study of axion emission effects on stellar evolution, investigation of primordial axion field and massive unstable neutrino effects on the dynamics of cosmological large scale structure formation, as well as the analysis of the mechanisms of inflation and baryogenesis, based on the hidden sector of the model.

Consider $SU(2)*U(1)$ model with local chiral horizontal symmetry $SU(3)_H$ [1,15] between the families (1). Quarks and leptons are put into the following representations of $SU(2)*U(1)*SU(3)_H$:

$$f_{L\alpha}:\begin{pmatrix}u\\d\end{pmatrix}_{L\alpha}(2,1/3,3),\qquad \begin{pmatrix}\nu\\e\end{pmatrix}_{L\alpha}(2,-1,3)$$
$$f_R^\alpha: u_R^\alpha(1,4/3,\bar{3}),\qquad d_R^\alpha(1,-2/3,\bar{3}),\qquad e_R^\alpha(1,-2,\bar{3}) \tag{2}$$

where we retain family ($SU(3)_H$) index: $\alpha=1,2,3$.

We can choose scalars, breaking the horizontal symmetry, as $SU(3)_H$ sextets and triplets. All of them are to be $SU(2)*U(1)$ singlets, to prevent electroweak symmetry breaking of $SU(3)_H$ scale. To generate realistic quark and lepton mass matrices at least three such 'horizontal' scalars are needed. At least one of them with the greatest VEV is to be sextet: $\xi^{(0)}_{\alpha,\beta}$ $\alpha,\beta=1,2,3.$ Otherwise, triplet fields only don't generate realistic mass matrices. For the other two scalars $\xi^{(1)}$ and $\xi^{(2)}$ may be concretize further their $SU(3)$ content, mentioning only those cases, when sextet and triplet representations result in different consequences.

Let us introduce additional fermions in the form [3,15]

$$F_L^\alpha: U_L^\alpha(1,4/3,\bar{3});\qquad D_L^\alpha(1,-2/3,\bar{3});\qquad E_L^\alpha(1,-2,\bar{3})$$
$$F_{R\alpha}:\qquad U_{R\alpha}(1,4/3,3);\qquad D_{R\alpha}(1,-2/3,3);\qquad E_{R\alpha}(1,-2,3);\qquad N_{R\alpha}(1,0,3) \tag{3}$$

Note, that these fermions cancel the $SU(3)_H$ anomaly of quarks and leptons (2). The most general Yukawa coulings allowed by the symmetry are

$$g_f\bar{f}_{L\alpha}F_{R\alpha}\phi^0+G_F^{(n)}\bar{F}_L^\alpha F_{R\beta}\bar{\xi}^{(n)\alpha\beta}+G_\eta\bar{F}_L^\alpha f_R^\alpha\eta+h.c.;n=0,1,2 \tag{4}$$

for quarks and leptons [3,15] ($f=u,d,e;F=U,D,E$) and

$$g_\nu\bar{\nu}_{L\alpha}N_{R\alpha}\phi^0+G_N^{(n)}N_{R\alpha}CN_{R\beta}\bar{\xi}^{(n)\alpha\beta}+h.c. \tag{5}$$

for neutrinos [15,16]. Here ϕ^0 is the neutral component of the standard $SU(2)*U(1)$ Higgs doublet $(2,-1,1)$ $(\langle\phi^0\rangle=v=(\sqrt{8}G_F)=250\mathrm{GeV})$ and η is real $SU(2)*U(1)*SU(3)_H$ singlet scalar $(\langle\eta\rangle=\mu/G_\eta)$

Yukawa couplings (4),(5) are invariant relative to global axial $U(1)_H$ transformations:

$$f_L\to f_L exp(i\omega),\qquad f_R\to f_R exp(-i\omega),\qquad F_L\to F_L exp(-i\omega)$$
$$F_R\to F_R exp(i\omega),\qquad \phi\to\phi,\qquad \xi^{(n)}\to\xi^{(n)}exp(2i\omega);\qquad n=0,1,2 \tag{6}$$

This $U(1)$ symmetry will be maintaned also by the Higgs potential, provided that there are trilinear couplings such as $\Lambda\xi^{(0)}_{\alpha\beta}\xi^{(1)\alpha}\xi^{(1)\beta}+h.c.$ etc. These couplings are not induced by any other (gauge or Yukawa) interactions. So their absence in the Lagrangian is natural [15,16]

The analysis of the Higgs potential (see [2,15,16] for details) shows, that the VEV matrix can obtain the form:

$$V_H =< \xi^{(0)} + \xi^{(1)} + \xi^{(2)} >= \begin{pmatrix} r_1 & p_1 & p_3 \\ +(-)p_1 & r_2 & p_2 \\ +(-)p_3 & +(-)p_2 & r_3 \end{pmatrix} \tag{7}$$

(where '+' and '-' signs correspond to sextet and triplet - and , respectively) with the natural 5-10 fold hierarchy of their values:

$$r_1 > p_1 > r_2 > p_2 > p_3 > r_3 \tag{8}$$

Inserting the scalar VEVs into Yukawa couplings (4),(5) one obtains full 6*6 fermion mass matrices:

$$\begin{array}{c} \\ \tilde{f}_L \\ \tilde{F}_L \end{array} \begin{array}{c} f_R \quad F_R \\ \begin{pmatrix} 0 & g_f v \\ \mu & M_F \end{pmatrix} \end{array}; \qquad \begin{array}{c} \\ \tilde{\nu}_L \\ \tilde{N}_R \end{array} \begin{array}{c} \nu_R \quad N_R \\ \begin{pmatrix} 0 & g_\nu v \\ g_\nu v & M_N \end{pmatrix} \end{array} \tag{9}$$

Here $M_F = \Sigma\langle\xi^{(n)}\rangle G_F^{(n)}$, $F = U, D, E, N$; and $N_L = C\tilde{N}_R$, $\nu_R = C\tilde{\nu}_L$. Note, that only sextet scalars contribute into Majorana mass matrix M_N. So, one has Dirac "see-saw" mechanism of the quark and lepton mass generation and ordinary Majorana "see-saw" mechanism for neutrino mass term where $N_{R\alpha}$ play the role of right-handed neutrino. The quark and lepton mass matrices obtained from the block-diagonalization of (9) will have the form:

$$m_f = g_f v \mu M_F^{-10}; \qquad f = u,d,e; \qquad m_\nu = (g_\nu v)^2 M_N^{-1} \tag{10}$$

So the mass hierarchy between the families appears to be inverted with respect to hierarchy of $SU(3)_H * U(1)_H$ symmetry breaking:

$$SU(3)_H * U(1)_H[v_H \sim r_1] \to SU(2)_H * U(1)'_H[v'_H \sim p_1] \to U(1)''_H[v''_H \sim p_2] \to I \tag{11}$$

where. Here the intermediate $SU(2)_H * U(1)'_H$ horizontal symmetry is maintained between the second and the third generations of quarks and leptons: and the remaining global $U(1)''_H$ is appropriate to the third generation only. The considered case is called the inverse hierarchy model in contrast with the direct hierarchy model, in which the quark and lepton mass hierarchy is parallel with hierarchy of $SU(3)_H * U(1)_H$ symmetry breaking [15,17]. The global $U(1)_H$ ($U(1)^{"}_H$) symmetry breaking results in the existence of massless Goldstone boson, a, named archion, having both flavour diagonal and flavour nondiagonal couplings with quarks and leptons and thus being familon of the type [13,18]. For sextet $\xi^{(1)}$ and $\xi^{(2)}$ its main couplings with e.g.charged leptons have the form

$$-ia(g_{\tau\tau}\bar{\tau}\gamma_5\tau + g_{\tau\mu}\bar{\tau}\gamma_5\mu + g_{\tau e}\bar{\tau}\gamma_5 e + g_{\mu\mu}\bar{\mu}\gamma_5\mu + g_{\mu e}\bar{\mu}\gamma_5 e + g_{ee}\bar{e}\gamma_5 e) + h.c \tag{12}$$

where

$$g_{\tau\tau} = m_\tau/v^{"}_H, \qquad g_{\tau\mu} \approx m^l_{23}/v_H",$$

$$g_{\tau e} \approx m^l_{13}/v^{"}_H, \qquad g_{\mu\mu} < m_\mu/v'_H,$$

$$g_{ee} < (m_e/m_\tau)(m_l/v''_H)$$

$$g_{e\mu} < (m_\mu/m_\tau)^{1/2}(m^l_{12}/v''_H)$$

For triplet $\xi^{(1)}$ and $\xi^{(2)}$ flavour nondiagonal coupling are scalars. In the tree approximation the couplings of a with quarks are similar to (12). In our minimal $SU(2) * U(1) * SU(3)_H$ model is the particle of the arion type [19]. It has no couplings $a\gamma\gamma$ and agg induced by triangle diagrams. Its interactions with the ordinary matter are suppressed sufficiently to remove the strong astrophysical restrictions [20] on the scale $v_H^{"}$. So the flavour changing decays may go with noticeable probability [15], e.g.

$$\mu \to ea, \qquad \tau \to \mu a, \qquad K \to \pi a, \qquad B \to K(K^*)a, \qquad D \to \pi(p)a \tag{13}$$

The search of such decays could provide the valuable information about the structure of fermion mass matrices.

In any realistic extension of our scheme, c.f. in $SU(5) * SU(3)_H$ model triangle diagrams owing to the inevitable presence of additional heavy fermions (GUT) induce $a\gamma\gamma$ and agg vertices, so that $U(1)_H^{"}$ turns to be Peccei-Quinn symmetry [10] and archion becomes the invisible axion of nearly hadronic type [21]. The scale $v_H^{"} = v_{PQ}$ is then restricted from below by astrophysical estimations of stellar energy losses due to archion emission: $v_{PQ} > 10^6$GeV (sun and red giants [22,20,15] and $v_{PQ} > 10^{10}$GeV (supernova SN1987A [23]. The latter restriction seems to be taken with caution.

According to (10) the hierarchy of neutrino Majorana masses is similar to the ordinary quark and lepton mass hierarchy: $m_{\nu_e} : m_{\nu_\mu} : m_{\nu\tau} \sim m_e : m_\mu : m_\tau$. For sextet $\xi^{(1)}$ and $\xi^{(2)}$ neutrino mass matrix m_ν (10) is nondiagonal and archion decays are possible with the lifetimes $\tau(\nu_H \to \nu_L a = 16\pi/g_{HL}^2 m_H$, where $g_{HL} = g_{\nu_H \nu_L} = m_{HL} v_{PQ}$.

For "small" scale of family symmetry breaking $v_{PQ} \sim 10^6$GeV the predicted effect of Majorana masses of neutrino is rather close to the modern sensitivity of $2\beta_{0\nu}$ searches.

Since the archion couplings to fermions of the lightest family (u, d, e) are suppressed, the existing constraints on the respective scale are weakened to $v_{PQ} > 10^6$GeV, making the model of archion rather close to the model of hadronic axion [21]. However, it turns out [24], that archion model escapes the serious problem of primordial superheavy stable Q quarks, predicted in the model of hadronic axion [24,21,25]. One can estimate the frozen concentration of Q quarks and respective Q hadrons in the Universe and find it contradicting [24] 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.

Since the mass of neutrino $m_\nu \sim v_{PQ}^{-1}$, its lifetime $\tau \sim v_{PQ}^5$ and the density of primordial axion field [26] $\rho_a = \bar{\rho} \sim v_{PQ}$, at larger v_{PQ} axion field is to dominate in the Universe, massive stable neutrino dominancy corresponds to smaller v_{PQ}, and, finally, the smallest possible v_{PQ} correspond to cosmological models with massive unstable neutrino [28,29,24]. So changing the parameter v_{PQ} one reproduces all the main types of cosmological models of the formation of the structure of the Universe. In our approach continuous change of v_{PQ} 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.

The total cosmological density ρ_{tot} and the baryon density ρ_B being fixed, relationship [15,24]

$$\rho_a^{prim}(v_{PQ}) + \Sigma\rho_{\nu_i}^{prim}(v_{PQ}) + \rho_a^{dec}(v_{PQ}) + \Sigma\rho_{\nu_i}^{dec}(v_{PQ}) + \rho_B = \rho_{tot} \tag{15}$$

turns to be an equation relative to v_{PQ}.

The solutions of this equation define a discrete set of cosmological models with different types of dark matter, forming the structure of the Universe. In general, there are six different dark matter scenarios [15,24] which may be realized in the framework of the considered model.

1. Cold dark matter (CDM) scenario. The cosmological evolution of axion field after Peccei-Quinn symmetry breaking follows basically in our approach general features of the standard model of'invisible' axions [26]. $SU(3)_H * U(1)_H$ symmetry breaking leads $U(1)_H''$ 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 [30]. Stochastic distribution of the axion field: $\theta = a/v_{PQ}$ may lead to its change on 2π along a closed path, resulting in the appearance of string structure, decaying rapidly after the axion mass swiches on at $T < 800$MeV [31]. Then axion field oscillations with the averaged amplitude $\bar{\theta} \sim 1$ start in the Universe. In the standard model of invisible axion the density decreases in the course of expansion as $\rho_a \sim a^{-3}$, where a is the scale factor, and the modern axion mass density is equal to [26]:

$$\rho_a = (v_{PQ}/4 \cdot 10^{12} GeV)\rho_{cr}, \qquad \rho_{cr} = \frac{3H^2}{8\pi G} \tag{16}$$

According to [31] intensive axion emission by decaying axion cosmic string structure result in the growth of the modern cosmological axion density up to

$$\rho_a = (v_{PQ}/2 \cdot 10^{10} GeV)\rho_{cr} \tag{17}$$

Comparing these predictions with the total cosmological density, taken to be equal to ρ_{cr}, one obtains the upper limit on v_{PQ}. However, within the frame of inflational cosmology the situation is possible, when the axion field in the observed part of the Universe has an amplitude $\theta << 1$ [27]. Exponential expansion of the region with $\theta << 1$ provides also the absence of axion strings in this region, so that there is no increase of the axion density due to axion emission of such strings.

Cosmological upper limits on the scale v_{PQ} seem to be absent in this case, so that this scale may have reached even planckean values $v_{PQ} \sim m_{pl}$. But in our model the scale v_{PQ} may be constrained even in this case, taking into account the condition on the absence of phase transition at the inflational stage. Based on the chaotic inflation scenario, in order to avoid the peaks in density fluctuations one should exclude the possibility of horizontal symmetry phase transitions at the inflationary stage, what leads to the restriction $v_{PQ} < 210^{10}$GeV [32].

It was recently shown [37], that the initial distribution ofθ 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 80length in the form of infinite string, stretching out the region of the considered size [38]. So the archioles form the fractal structure, causing inhomogeneities at all the scale. Putting aside the small scale evolution of archioles, estimations [37] 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 [24] 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 may in this case induce fractal distribution of baryonic charge.

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 $(t_U < \tau(\nu_\tau \to \nu_\mu a))$:

$$\rho_{\nu_\tau} = \frac{6,6 \cdot 10^{13} GeV}{v_{PQ}} (g^2/G)\rho_{cr}, g^2/G \sim 10^{-4} - 10^{-6} \tag{18}$$

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):

$$\rho^{rel}_{\nu_\mu + a} = \frac{(v_{PQ}/10^{10} GeV)^{3/2}}{x(g^2/G)^{1/2}} \rho_{cr} \tag{19}$$

where $x \sim 1$ is neutrino mixing parameter.

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

$$\rho_{\nu_\mu} = \frac{0,6 \cdot 10^{12} GeV}{v_{PQ}} (g^2/G)\rho_{cr} \tag{20}$$

5. Relativistic hierarchial decay (HD) scenario. The dominancy in the modern Universe of relativistic archions ρ_a^{dec} and ν_e, from decay of $\nu_m u$ 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:

$$\rho^{rel}_{\nu_e + a} = \frac{(v_{PQ}/10^{8} GeV)^{3/2}}{(g_2/G)^{1/2}} \rho_{cr} \tag{21}$$

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:

$$\rho_{\nu_e} = \frac{3,3 \cdot 10^{10} GeV}{v_{PQ}} (g^2/G)\rho_{cr} \tag{22}$$

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

$$\rho_a = \frac{9 \cdot 10^4 GeV}{v_{PQ}} \rho_{cr} \tag{23}$$

So the archion model provides the unique physical basis for CDM (primordial axion condensate) UDM (stable ν_τ), relativistic and nonrelativistic UDM and HD scenarios, being realized as the solutions of the Eq (15). The complete set of the solutions of the Eq. (15) can be realized subject to v_{PQ} for $g^2/G \sim (1,5 - 40)10^{-6}$. On the other hand the set of cosmological and astrophysical constraints leaves only two small intervals near i) $v_{PQ} \sim 10^6$GeV, in which only HD scenarios 5 and 6 can be realized, and ii) $v_{PQ} \sim 10^{10}$GeV where scenarios CDM and HDM or their mixture are possible provided that the archioles problem is solved. The UDM scenarios 3 and 4 are excluded from SN1987A restrictions on v_{PQ}.

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 $\nu_\tau \rightarrow \nu_\mu a$ 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, $\nu_\mu \rightarrow \nu_e a$ 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 [33], the phase space restrictions on the mass of halo particles [34] can be weakened or even completely removed in the case of Bose gas.

The second possibility $v_{PQ} \sim 10^{10}$GeV corresponds to more conservative "standard" CDM model of large scale structure formation with possible modificaton to mixed CDM + HDM scenario. Note that HD scenario also provides effective mixtire of CDM + HDM, so that the both possibilities provide natural basis for refined mixed CDM + HDM model of large scale structure formation. The acount for archioles problem seem to reduce the space of free parameters of the model to the only possibility of HD scenario.

The recent indications on the existence of the anysotropy of microwave thermal background, claimed in COBE experiment [35] seem to favour such mixed scenario. They also 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 [36] 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. Such unified approach to cosmological and particle phenomena is the brightest feature of new science - cosmoparticle physics, forming last years in the confrontation of particle theory and cosmology. 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 that overdetermined system of equations relative to these parameters can be deduced from the set of tests of the predictions of the model considered. 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 inpossible.

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