V. BURDYUZHA , O. LALAKULICH ,
Yu. PONOMAREV , G. VERESHKOV

PREPRINT

4

FAMILON MODEL OF DARK MATTER

FAMILON MODEL OF DARK MATTER

Vladimir Burdyuzha [1], Ol'ga Lalakulich [2], Yuri Ponomarev [1], Grigori Vereshkov [2]

[1] Astro Space Center of Lebedev Physical Institute, Russian Academy of Sciences, Moscow
[2] Institute of Physics, Rostov State University, Rostov/Don, Russia

Abstract

If the next fundamental level of matter occurs (preons) then dark matter must consist of familons containing a "hot" component from massless particles and a "cold" component from massive particles. During evolution of the Universe this dark matter was undergone to late-time relativistic phase transitions temperatures of which were different. Fluctuations created by these phase transitions have had a fractal character. In the result of the structurization of dark matter (and therefore the baryon subsys-lem) has taken place and in the Universe some characteristic scales which have printed this phenomenon arise naturally. Familons are collective excitations of nonperturbative preon condensates which could be produced during more early relativistic phase transition. For structurization of dark matter (and baryon component) three generations of particles are necessary. The first generation of particles has produced the observed baryon world. The second and third generations have produced dark matter from particles which have appealed when symmetry among generations was spontaneously broken.

Фамилонная модель тёмной материи

В.Бурдюжа, О.Лалакулич, Ю.Пономарёв, Г.Верешков

Если следующий фундаментальный уровень материи имеет место, тогда тёмная материя должна состоять из фамилонов, содержащих горячую компоненту из безмассовых частиц и холодную компоненту из массивных частиц. В течении эволюции Вселенной такая тёмная материя должна была подвергнуться нескольким фазовым переходам, температуры которых были различны. Флуктуации, порождённые этими фазовыми переходами, имели фрактальный характер. В результате структуризация тёмной материи (и следовательно барионной подсистемы) имела место и во Вселенной несколько характеристических шкал, которые отпечатали этот феномен, возникли естественно. Фамилоны (псевдо- Голстоуновские бозоны), как коллективные возбуждения непертурбативных преонных конденсатов, были образованы в течении более раннего релятивисткого фазового перехода. Для структуризации тёмной материи (и для объяснения иерархии масштабов барионной компоненты) три поколения частиц необходимо. Первое поколение частиц образует наблюдаемый барионный мир. Второе и третье поколение образует тёмную материю из частиц, которые возникли когда симметрия между поколениями была спонтанно нарушена.

Using the preon structure of matter the familon model of dark matter (DM) proposed by Schramm et al [1] and Frieman et al [2] is reanimated. This model has more physical and cosmological consequences if the next structure level of matter is involved. Our interest to the preon model of elementary particles was also induced by the fact of possible leptoquarks resonance in HERA experiment and the possibility to research a pair production of scalar leptoquarks at the FERMILAB TEVATRON [3]. The standard model is not expected to be a complete theory (it does not explain the number of fermion families, their mass hierarchy and does not provide a unified description of all gauge symmetries). Although, of course, the standard model describes very well nature in term of the fundamental fermions and their interactions via gauge bosons. Compositeness models postulate a new strong dynamics that bind constituents (preons) and, of course, a sure motivation to these models is absent till now.

At first important cosmological and physical consequences enumerate. If DM consist of familons then in this medium late-time phase transitions were possible and fluctuations created by these phase-transitions have had a fractal character. These fractal fluctuations could develop into the fractal large- scale structure (LSS) of the baryon component (the fractal structure of the baryon component is not observed on all scales [4]). In the Universe these phase transitions have also produced some characteristic scales. Besides understanding of three generations of elementary particles is become naturally. The observed baryon world and DM may be realized only then when three generations of particles occur. The first generation of particles has produced the baryon world. The second and third generations have produced dark matter. The structurization of dark matter (and the baryon component) has been produced particles appeared when the symmetry among generations was spontaneously broken.

The preon structure of matter was introduced by Pati and Salam [5] and was studied by many authors [6]. The structure of preon nonperturbative vacuum arising in the result of the correlation of non-Abelian fields on two scales ($\Lambda_{mc} \gg 1 \ TeV$ is the confinement scale of metacolour and $\Lambda_c \sim 150 \ MeV$ is the QCD scale) has been researched. We have detected that in the spectrum of excitations of heterogenic nonperturbative preon vacuum pseudo-Goldstone modes of familon type arise. Familons are created when the symmetry

of quark-lepton generations is spontaneously broken and their nonrezo masses are the result of superweak interactions with quark condensates. Physics of the spontaneously broken symmetry of generations (production of familons) was considered in [7]. The distinguishing characteristic of these particles is the availability of the residual $U(1)$ symmetry and possibility of it spontaneous breaking for temperature $\frac{\Lambda_{mc}}{\Lambda_c^2} \sim 10^{-3} \ eV$ in the result of relativistic phase transitions.

We have proposed that these relativistic phase transitions (RPT) had the direct relation to the production of primordial perturbations in DM the evolution of which leads to fractal baryon large scale structure. Note other time that the idea of RPT in the cosmological gas of pseudo- Goldstone bosons in connection with LSS problems was formulated in [1-2]. Here we have investigated by quantitatively the preon-familon model of these RPT.

In the beginning the astrophysical motivation of our theory is discussed more detail. Observational data show that some baryon objects such as the quasar on $z \sim 4.9$ and the galaxy on $z \sim 6.68$, CO lines on $z \sim 4.43$ and $z \sim 4.69$ [8] were produced as minimum on redshifts $z \sim 6 \div 8$. This is the difficulty for the standard CDM and ΛMDM models to produce their (the best fit is $z \sim 2 \div 3$ [9] and observations provide the support of this). If early baryon cosmological structures produced on $z > 10$ then the key role must play DM particles with nonstandard properties.

Probably DM consists of ideal gas particles with $m \approx 0$ practically noninteracting with usual matter (till now they do not detected because of their superweak interaction with baryons and leptons). In the standard cosmological model DM (here CDM) contains 25% of the total density that is

$$\Omega_0 = \Omega_\Lambda + \Omega_{CDM} + \Omega_\nu + \Omega_b = 0.7 + 0.25 + 0.02 + 0.03 = 1.$$

Certainly a characteristic moment of the most of cosmological structures formation finishing remains the same ($z \sim 2 \div 3$) and the appearence of baryon structures on high z ($z > 4$) was the result of statistical outburst evolution of the spectrum of DM density perturbations. Early cosmological baryon structures are connected to statistical outbursts in the sharply nonlinear physical system which is RPT (the production of inhomogeneities).

Note again that we have investigated the idea in which the baryon component of matter repeats the structure of DM owing to gravitation. That is relativistic phase transitions have produced DM fractal fluctuations in which baryons have subsequently clustered. The fractal

structure of the baryon component was studied in [4] starting from the article [10] in which authors have suggested that the Universe up to some Mpc has the fractal structure (the fractal structure was observed up to 50 Mpc [11] and the sharp transition to homogeneity is predicted at 300 Mpc [4]). Only the critical phenomenom like to a phase transition creates fractal structures.

A new theory of DM must combine the properties of superweak interaction of DM particles with baryons and leptons and intensive interaction of these particles each other. Such interactions are provided by nonlinear properties of DM medium. This is the condition for realization of RPT.

The familon symmetry is experimentally observed (the different generations of quarks and leptons participate in gauge interactions the same way). Breaking of this symmetry gives masses of particles in different generations. A hypothesis about spontaneous breaking of familon symmetry is natural and the creation of Goldstone bosons is inevitably. The properties of any pseudo-Goldstone bosons as and pseudo-Goldstone bosons of familon type depends on physical realization of Goldstone modes. These modes can be arisen from fundamental Higgs fields or from collective excitations of a heterogenic nonperturbative vacuum condensate more complex than quark-gluon one in QCD. The second possibility can realize the theory in which quarks and leptons are composite that is the preon model of elementary particles. If leptoquarks will be detected then two variants of explanations may be. If leptoquarks resonanse will be narrow and high then theses leptoquarks come from GUT or SUSY theories. The low and wide resonanse can be explained by composite particles only (preons).

The simplest boson-fermion preon model consists of left-handed fermion preons U_L^α, D_L^α and scalar preons of quark ($\Phi_a^{i\alpha}$) and lepton (χ_l^α) types. In this model the interior structure of elementary particles is:

$$u_{La}^i = U_L^\alpha \Phi_a^{+i\alpha} \quad u_{La}^i = (u_L^i, c_L^i, t_L^i)$$

$$d_{La}^i = D_L^\alpha \Phi_a^{+i\alpha} \quad d_{La}^i = (d_L^i, s_L^i, b_L^i) \tag{1}$$

$$\nu_{Ll}^i = U_L^\alpha \chi_l^\alpha \quad \nu_{Ll}^i = \nu_{L_e}, \nu_{L_\mu}, \nu_{L_\tau}$$

$$l_{Ll}^i = D_L^\alpha \chi_l^\alpha \quad l_{Ll}^i = (e_L, \mu_L, \tau_L)$$

In case of leptoquarks our model gives:

$$(LQ)_{al} = \Phi_a^{i\alpha}\chi_l^\alpha \tag{2}$$

here and in the following i is color index of QCD, $a,b,c = 1,2,3; l,m,r = 1,2,3$ are numbers of quark and lepton generations, α is metacolor index corresponding to new metachromodynamics interaction linking preons in quarks and leptons.

Inside quarks and leptons metagluon fields $G_{\mu\nu}^\omega$ and scalar preon fields are in the confinement state like to the confinement of quarks and gluons inside hadrons. This effect is provided by the existence of nonperturbative metagluon and preon condensates:

$$\langle 0 \mid \frac{\alpha_{mc}}{\pi} G_{\mu\nu}^\omega G_\omega^{\mu\nu} \mid 0 \rangle \sim \Lambda_{mc}^4 \tag{3}$$

$$\langle 0 \mid \Phi_a^{+i\alpha}\Phi_b^{i\alpha} \mid 0 \rangle = V_{ab} \sim -\Lambda_{mc}^2 \tag{4}$$

$$\langle 0 \mid \chi_l^{+\alpha}\chi_m^\alpha \mid 0 \rangle = V_{lm} \sim -\Lambda_{mc}^2 \tag{5}$$

here Λ_{mc} is the energetic scale of preon confinement, V_{ab}, V_{lm} are the condensate matrixes. Condensates (3) and (4) together with gluon and quark condensates ($\langle 0 \mid \frac{\alpha_s}{\pi}G_{\mu\nu}^a G_a^{\mu\nu} \mid 0 \rangle$; $\langle 0 \mid \bar{q}_L q_R + \bar{q}_R q_L \mid 0 \rangle$) provide the mechanism of mass quarks production of all third generations. It is shown on the diagram 1
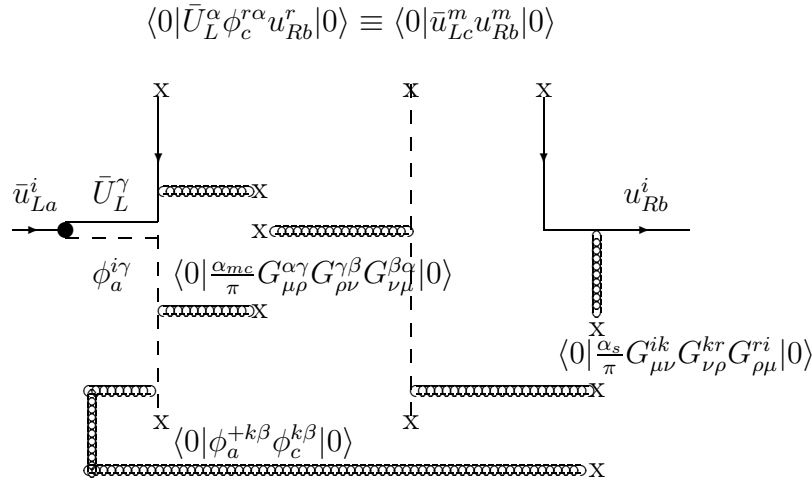
$$\langle 0|\bar{U}_L^\alpha \phi_c^{r\alpha} u_{Rb}^r|0\rangle \equiv \langle 0|\bar{u}_{Lc}^m u_{Rb}^m|0\rangle$$

Diagram 1

in which $G_{\mu\nu}^{ik} = \lambda_n^{ik} G_{\mu\nu}^{in}$, λ_n^{ik} is Gell-Mann matrices; $G_{\mu\nu}^{\alpha\beta} = \lambda_\omega^{\alpha\beta} G_{\mu\nu}^\omega$, $\lambda_\omega^{\alpha\beta}$ is an analogue of Gell-Mann matrices for metacolour. As it can see from diagram (1) the main contribution in the effect of familon symmetry vacuum breaking is formed by the preon condensates (4).

The theory of preons predicts the complex structure of heterogenic nonperturbative vacuum and familons are collective excitations of these condensates. These excitations are the

result of local processes of weaking and rebuilding of correlations among fields entering in condensates:

$$M_{ab}^{(u)} = \langle 0 \mid \Phi_a^{\alpha k}\Phi_c^{\alpha k}\bar{U}_L^\beta \Phi_c^{\beta_i} q_{R_b}^i \mid 0\rangle \qquad (6)$$

$$M_{ab}^{(d)} = \langle 0 \mid \Phi_a^{\alpha k}\Phi_c^{\alpha k}\bar{D}_L^\beta \Phi_c^{\beta_i} q_{R_b}^i \mid 0\rangle \qquad (7)$$

$$M_{lm}^{(l)} = \langle 0 \mid \chi_l^\alpha \chi_r^\alpha \bar{D}_L^\beta \chi_r^\beta l_{Rm} \mid 0\rangle \qquad (8)$$

Also it is necessary to note the pecular properties of the first generation of quarks. Their masses are exclusively produced by the interaction with the quark-gluon condensate. The production of second and third generations of quark masses is outside limits of the QCD. But this fact may be natural in the preon model. Scalar preon condensates of the first generation are efficiently suppressed and they do not carry contribution in (6-8). This situation may be explained in the model containing composite scalar preons (the scale more than Λ_{mc}). In this preon - subpreon model [12] the initial familon symmetry $SU_F(3) \to SU_F(2)$ is broken on scale $\Lambda_{smc} \gg \Lambda_{mc}$ and then on more low scale the symmetry $SU_F(2) \to U(1)$ is broken also. Therefore here we will discuss the chiral-familon symmetry of second and third generations only (the discussion of the familon symmetry was in detail given in the article [7]). 3 types of nonperturbative condensates correspond to 3 type of familon fields and a number of familons of every type equals 8. In each type 2 familon fields arise as the local perturbation of a condensate energy density. The rest 6 familon fields arise as the result of rebuilding of a condensate.

Thus, in the frame of preon theory DM is interpreted as the system of familon collective excitations of heterogenic nonperturbative vacuum. This system consists of 3 subsystems:

1) familons of up-quark type;

2) familons of down-quark type;

3) familons of lepton type.

On stages of the cosmological evolution when $T \ll \Lambda_{mc}$ the heavy unstable familons are absent. Small masses of familons are the result of superweak interactions of Goldstone fields with nonperturbative vacuum condensates and therefore familons acquire status of pseudo-Goldstone bosons. The value of these masses is limited by the astrophysical and laboratory magnitudes [13]:

$$\begin{cases} m_{astrophysical} & \sim \quad 10^{-3} \div 10^{-5} \ eV \\ m_{laboratory} & \leq \quad 10 \ eV \end{cases} \qquad (9)$$

The effect of familons mass production corresponds formally mathemathically the appearence of mass terms in the Lagrangian of Goldstone fields. From general considerations one can propose that massive terms may arise as with "right" as and with "wrong" signs. The sign of the massive terms predetermines the destiny of residual symmetry of Goldstone fields. In the case of "wrong" sign for low temperatures $T < T_c \sim m_{familons} \sim 0.1 \div 10^5 \ K$ a Goldstone condensate produces and the symmetry of familon gas breaks spontaneously.

The representation about physical nature of familon excitations described above is formalized in a theoretical-field model. As example we discuss the model only one familon subsystem corresponding to up- quarks of second and third generations. The chiral-familon group of the model is $SU_L(2) \times SU_R(2)$. The familon excitations are described by eight measure (on number of matrix components (6)) reducible representation of this group factorized on two irreducible representations (F, f_a); (ψ, φ_a) which differ each other by sign of space chirality. In this model the interaction of quark fields with familons occurs. However in all calculations quark fields are represented in the form of nonperturbative quark condensates. From QCD and the experiment the connection between quark and gluon condensates is known:

$$\langle 0 \mid \bar{q}q \mid 0 \rangle \approx \frac{1}{12m_q} \qquad \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \approx \frac{3\Lambda_c^4}{4m_q} \tag{10}$$

here: $q = t, c$; $m_c \sim 1.5 \ Gev$; $m_t \sim 175 \ Gev$; $\Lambda_c \sim 150 \ Mev$.

The spontaneous breaking of symmetry $SU_L(2) \times SU_R(2) \to U(1)$ is produced by vacuum shifts $\langle \psi \rangle = v$; $\langle f_3 \rangle = u$. The numerical values $v, u \sim \Lambda_{mc}$ are unknown. They can be found by experimentally if our theory corresponds to reality. Parameters u and v together with the value of condensates (10) define numerical values of basic magnitudes characteristing the familon subsystem. After breaking of symmetry $SU_L(2) \times SU_R(2) \to U(1)$ light pseudo-Goldstone fields contain the real pseudoscalar field with the mass:

$$m_{\varphi'}^2 = \frac{1}{6(u^2 + v^2)} \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \tag{11}$$

the complex pseudoscalar field with the mass:

$$m_\varphi^2 = \frac{1}{24v^2} \frac{m_t}{m_c} \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \tag{12}$$

and the complex scalar field the mass square of which is negative:

$$m_f^2 = -\frac{1}{24u^2} \frac{m_t}{m_c} \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \tag{13}$$

7

The complex field with masses (12-13) is the nontrivial representation of residual symmetry of $U(1)$ group, but the real field (11) is the sole representation of this group. We propose that cosmological DM consists of particles with these masses and their analogies from the down- quark-familon and lepton-familon subsystems.

The negative mass square of complex scalar field means that for

$$T < T_{c(up)} \sim \mid \bar{m}_f \mid \sim \frac{\Lambda_{mc}}{\Lambda_c^2} \sqrt{m_t/m_c} \tag{14}$$

pseudo-Goldstone vacuum is unstable that is when $T = T_{c(up)}$ in gas of pseudo-Goldstone bosons should be RPT in the state with spontaneous breaking $U(1)$ symmetry. Two other familon subsystems can be studied by the same methods. Therefore DM consisting of pseudo-Goldstone bosons of familon type is a many component heterogenic system evolving complex thermodynamical way.

In the phase of breaking symmetry every complex field with masses (12-13) splits on two real fields with different masses. That is the familon subsystem of up-quark type consists from five kinds of particles with different masses. Analogous phenomenon takes place in the down-quark subsystem. The breaking of residual symmetry is when

$$T_{c(down)} \sim \frac{\Lambda_{mc}}{\Lambda_c^2} \sqrt{m_b/m_s} \tag{15}$$

In low symmetric phase this subsystem consists also of five kinds particles with different masses. In our theory the lepton-familon subsystem can be undergone to RPT also but leptonic condensates are elements of new physics which may come in the future and probably their discussion is prematurely.

The relativistic phase transitions in familon subsystems must be described in the frame of temperature quantum field theory. It is important to underline that sufficiently strong interactions of familons each other provide the evolution of familon subsystem through state of local equilibrium type. Our estimates have shown that the transition in nonthermodynamical regime of evolution occurs on stage after RPT even if RPT took place for temperature $\sim 10^{-3} \; eV$. The thermodynamics of a familon system may be formulated in the approximation of self-coordinated field. The methods of RPT theory which will be used by us are similar to ones of our article [14]. The unequilibrium Landau functional of states $F(T, \eta, m_A)$ depends on order parameter η and five effective masses of particles $m_A, \; A = 1, 2, 3, 4, 5$:

$$F(T, \eta, m_A) = -\frac{1}{3} \sum_A J_2(T, m_A) + U(\eta, m_A) \tag{16}$$

8

here J_2 is the characteristic integrals (similar integrals used for the description of RPT in [15]). The conditions of the extremum of this functional on effective masses give the equation of connection $m_a = m_a(\eta, T)$ which defines formally the typical functional Landau $F(T, \eta)$. The condition of minimum of this functional on the parameter of order η

$$\frac{d^2 F}{d\eta^2} = \frac{\partial^2 F}{\partial \eta^2} + \sum_A \frac{\partial^2 F}{\partial \eta \partial m_A}\left(\frac{\partial m_A}{\partial \eta}\right) > 0 \tag{17}$$

is concordanced with the equation of state $\partial F/\partial \eta = 0$ that allows: a) to establish the kind of RPT, b) to find the thermodynamical boundary of stability phases, c) to calculate values of observed magnitudes (energy density, pressure, thermal capacity, sound velocity et al.) in each phase. More detail the thermodynamics of the familon system has been discussed in [16].

We have detected that RPT in familon gas is one of the first kind with wide region of phases coexistence. Therefore in epoch of RPT or more exactly in the region of phases coexistence the Universe had a block-phase structure containing domains of different phases. The numerical modelling of this RPT has shown that average contrast of density in the block-phase structure is $\delta\epsilon/\epsilon \sim 0.1$. This structure is illustrated on diagram 2 in some conditional dimensionless units.
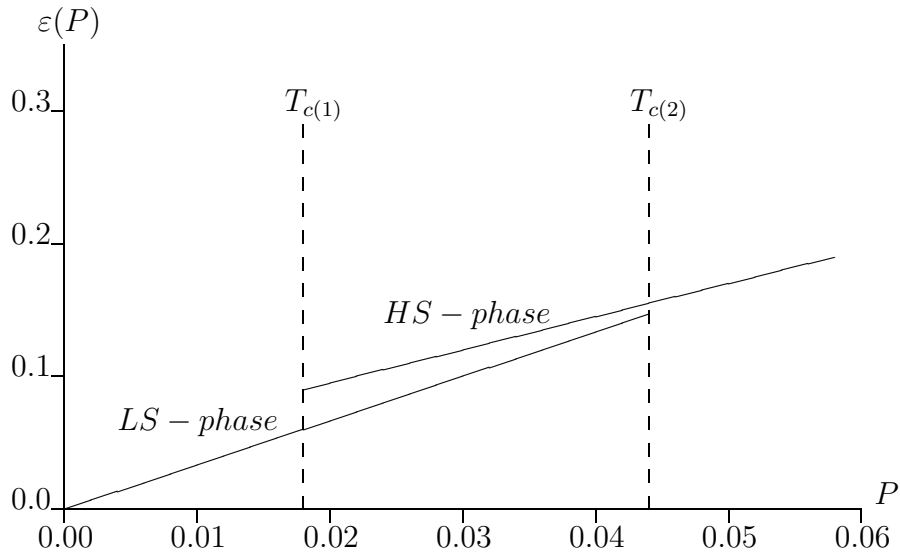

Diagram 2

The size of domains and masses of baryon and dark matter inside domains are defined by distance to horison of events $L_{horiz.}$ at the moment of RPT. As it is seen from (14-15) numerical values of these magnitudes which are important for LSS theory depend on a value of the unknown today parameter of the preon confinement Λ_{mc}.

9

If inhomogeneties appearing during RPT in familon gas have the relation to observable scales of LSS (10 Mpc) then $\Lambda_{mc} \sim 10^5 \, TeV$. More detail estimates today is premature but it is necessary to note that suggested theory contains as minimum two phase transitions and therefore two characteristic scales of baryon LSS. Now it would be a speculation to define exactly magnitude of these scales (probably galaxies and clusters of galaxies) since we do not know familon masses.

Numerical estimates of inhomogeneities parameters arising as the result of strong inter-action of domains LS and HS phases in region of their contact show that the density contrast may mount to $\delta\epsilon/\epsilon \sim 1$ on the scale $L \sim 0.1 L_{horison}$ at the moment of the phase transition and besides effects connected with fragmentation of DM medium may be superimposed at the spectrum of the CMB radiation.

Note that D.Schramm et al [1] have even proposed some laboratory tests for verification of the late-time phase transitions model (the neutrino-schison model). Their model as and our one can potentially generate structures (baryon and DM) at redshifts $z > 10$. Besides, if the fractal structure of the baryon component of will be proved finally then the late-time phase transitions model becomes automatically the main one for the production of the baryon LSS. Since only phase transitions realize a fractal structure for seeds. Probably during evolution of baryon structures their fractal distribution is smoothed down and it is not observed on large scales although there is general agreement about the existence of fractal galactic structures at moderate scales [4,17].

Finally note,that for structurization of DM (and baryon component) three generations of particles are necessary obligatory. In the preon model only for availability of the second and third generations of particles fractal distributed dark matter from familons is produced (the first generation of particles produces the baryon world which is observed). Recent search of familons by CLEO collaboration gave the negative result [18]. Last publications on research of DM can be found in [19].

REFERENCES

1.C.T.Hill, D.N.Schramm and J.N.Fry, Comments of Nucl. and Part. Phys. 19 (1989) 25.

2.J.A.Frieman, C.T.Hill and R.Watkins, Phys. Rev. D46 (1992) 1226.

3.C.Adloff et al., Z. Phys. C74 (1997) 191; J.Breitweg, Z. Phys. C74 (1997) 207; M.Kramer et al., Phys. Rev. Lett. 79 (1997) 341; T.Affolder et al., Phys. Rev. Lett. 87 (2001) 231803.

4.P.Bak and K.Chen, Phys. Rev. Lett. 86 (2001) 4215; K.K.S.Wu, O.Lahav and M.J.Rees, Nature 397 (1999) 225.

5.J.C.Pati and A.Salam, Phys. Rev. D10 (1974) 275.

6.H.Terazawa, Y.Chikashige and K.Akama, Phys. Rev. D15 (1977) 480; H.Terazawa, Phys. Rev. D22 (1980) 184; E.Eichten et al., Rev. Mod. Phys. 56 (1984) 579; K.D.Lane et al., Phys. Rep. 278 (1977) 291.

7.J.L.Feng et al., Phys. Rev. D57 (1998) 5875.

8.A.Omont et al., Nature 382 (1996) 428; H-W.Chen, K.M.Lanzetta and S.Pascarelle, Nature 398 (1999) 586.

9.P.Madau, in Proceeding of Nobel Symposium Particle Physics and the Universe and Preprint N 1333 (1999) of Space Telescope Science Institute.

10.P.H.Coleman, L.Pietronero and R.H.Sanders, Astron. Astrophys. 200 (1988) L32.

11.V.J.Martinez and P.Coles, Astrophys. J. 437 (1994) 550.

12.O.E.Evnin, hep-ph/9711433.

13.D.E.Groom et al. (Particle Data Group), Eur. Phys. Jour. C15 (2000) 1; http://pdg.lbl.gov (page 15).

14.G.M.Vereshkov and V.V.Burdyuzha, Int. J. Modern. Phys. A.10 (1995) 1343.

15.V.V.Burdyuzha, O.D.Lalakulich, Yu.N.Ponomarev, G.M.Vereshkov, Phys. Rev. D 55 (1997) 7340 R; Astronomy Reports 42 (1997) 711.

16.V.V.Burdyuzha, O.D.Lalakulich, Yu.N.Ponomarev, G.M.Vereshkov, Preprint of Yukawa Inst. for Theoretical Physics (YITP-98-51); hep-ph/9907531.

17.L.Guzzo et al., Astrophys.J.Lett. 382 (1991) L5.

18.R.Ammar et al., Phys.Rev.Lett. 87 (2001) 271801.

19.V.Sahni, astro-ph/0403324; R.Chen et al., astro-ph/0403352; K.Adashe, G.Servant, hep-ph/0403143; J.W.Moffat, hep-ph0403266.