SOME PROBLEMS IN THE THEORY OF EARLY UNIVERSE EVOLUTION

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We continue consideration of physical characteristics of early Universe. Here our attention is concentrated on the three topics: thermodynamics, relic helium, energy of physical vacuum.

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1. THERMODYNAMICS

Zero cycle. First of all it is needed to emphasize that the notion of temperature may be introduced for ensembles of Hamiltonian (or Lagrangian) dynamical systems only. For bi-Hamiltonian system (ether) such a notion (as well as energy) does not exist. However after the Big Bang (in the first cycle) when Lagrangian fields and particles arisen physical temperature appears. In zero cycle ensemble of quanta f is characterized by fundamental parameter T_f which enters in Gibbs distribution function $e^{-\varepsilon/T_f}$ [1-3], where $\varepsilon=\overline{\varphi}\varphi$ fourth component of 4-momentum of quantum f (in connection with this formula we might call T_f as a non-physical "temperature" of quasi Lagrangian subsystem f of bi-Hamiltonian system $(\dot{f}, f)$). In the normal state f mean size of quantum f is determined by the relation $\lambda_f=1/T_f$ (we use the system where fundamental constants $c=h=1$) λ_f is connected with maximal size of ensemble $R_{\max}^{(0)}=1/\sqrt{G}T_f^2$ (G is gravitational constant) by means of formula $\lambda_f=R_{\max}^{(0)}/(N_f^{(0)})^{1/3}$, where $N_f^{(0)}=1/G^{3/2}T_f^3$ is the number of quanta f in ensemble. At the collapse of ensemble the size R and size of quantum λ decrease so that the relation $\lambda=R/(N_f^{(0)})^{1/3}$ takes place (T_f stays constant like at the "isothermal" compression). It is important to emphasize that Universe in zero cycle is collapsed because separate quanta f (each individual field $f(x)$) is constructed in that point at which f is attached: this is the main property of bi-Hamiltonian system (in general theory of dynamical systems such manifolds are called attractors). In zero cycle entropy of Universe is zero: $S=0$ (there are no interactions besides the gravitational one, therefore each quantum f may be in one state only). And if Universe in this cycle to characterize by physical temperature, so it must be equal zero ("cold" cycle).

First cycle. At compression of our ensemble size of each quantum f will be, after all, equaled $\lambda_{\dot{f}}=1/T_{\dot{f}}$ where $T_{\dot{f}}$ is fundamental parameter (analogous of T_f) by which condensed state $\dot{f}$ of our system is characterized. Hereby the size of ensemble in whole (Universe) is $R_{\min}^{(0)}=1/\sqrt{G}T_f\left|T_{\dot{f}}\right|$ ($T_{\dot{f}}$ is negative magnitude). In this moment total quantum transition (irreversible confluence) $f\to\dot{f}$ is beginning. It is so called Big Bang. Hereby the energy $T_f-T_{\dot{f}}\cong\left|T_{\dot{f}}\right|$ is secreted. It spends in main for the Universe space expansion. It is important to emphasize that the Universe expands because the process of pushing out of inner points $x,\dot{x}$ of each spaceuscule $\left(\dot{f}(\dot{x}), f(x)\right)$ takes place. Inside the spaceuscule some discontinuum (isomorphic to the Cantor's perfect manifold Π) stays only (in general theory of dynamical systems such manifolds are called repelers). It is important to emphasize also that pushing out of spaceuscule points has pulsating character determined by excitation spectrum of degenerate parameters $\chi(\dot{x})$ of condensed state $e^{i\chi(\dot{x})}\dot{f}(\dot{x})$ (that is very strong degenerate one due to the switching on of interactions described by parameters χ. Interesting to note: in [4] vibrations of electromagnetic field Whittecker identifies with vibrations of space-idea underlined his ether theory). Einstein paid his attention on the paradox in cosmology: (at small mass matter $\sqrt{\eta}M^{(0)}<<M^{(0)}$) wave equations are getting relativistic theory (GR). However in Universe theory is non relativistic matter. Relative velocities in $\dot{\theta},\dot{\varphi}=V<<c$ and connecting with them energies of motion are small in the suggested theory there are two kinds of motion: radial (total super relativistic) motion with velocity $V>>c$ and relative with $V<<c$. Total Universe energy ($\sqrt{\eta}M^{(0)}$) is hence dark energy, so paradox is explained. Thus quantum $\dot{f}$ may stands in many different states labeled $\dot{f}, e^{i\chi_1}\dot{f}, e^{i\chi_2}\dot{f},\ldots$ and marked by different values of degeneration parameters χ. Quantity of such states corresponding to one quantum $\dot{f}$ (and also one fundamental particle) usually calls as specific entropy and denotes S. We have to calculate this magnitude. In expo-

nent $e^{i\chi}$ phase χ is a usual Lagrangian field pulsations of which have ultrarelativistic character. Density of such pulsations we denote n_γ. At the pure thermodynamic approach this magnitude depends on temperature like $n_\gamma = T^3$. Now we determine physical temperature T by the formula $T = T_{\dot{f}} / \eta^a$ where $a(R)$ is some function of Universe radius (or time evolution t). Then the specific entropy is written

$$S = \frac{n_\gamma}{n_{\dot{f}}} = \frac{n_\gamma R^3}{N_f^{(0)}} = \frac{(TR)^3}{N_f^{(0)}} \qquad (1)$$

(obviously number of condensed states $\dot{f}$ coincides with number of normal states f and equals to number of fundamental particles in the Universe). Hereby formula for entropy of Universe in whole is written

$$S_U = SN_f^{(0)} = VT^3, \qquad (2)$$

where V is volume of Universe. If, beginning from $T = T_{\dot{f}}$ and $R = R_s$ (the end of the de-Sitter's stage), Universe expansion would be adiabatic (Gamov hypothesis), so $S = \text{const} = \eta$ (because $T_{\dot{f}} R_s = (\eta N_f^{(0)})^{1/3}$). However [1-3], from obvious inequality $\rho_\gamma \le \rho_c$ where $\rho_c = T_{\dot{f}}^4 / \eta$ and $\rho_\gamma = T^4 = T_{\dot{f}}^4 / \eta^{4a}$ it follows that $a \ge \frac{1}{4}$, i.e. at the end of de-Sitter's stage temperature $T = T_{\dot{f}} / \eta^{1/4}$, but not $T_{\dot{f}}$. Writing current radius of Universe in analogous form $R = R_s \eta^b$ where $b(R)$ (like $a(R)$) is some function of R (or t) we get

$$S / S_{equ} = \eta^{3(b-a)} \qquad (3)$$

(here $S_{equ} = \eta$ is the equilibrium specific entropy). Hence entropy of Universe in whole is $S_U = N_\gamma \eta^{3(b-a)}$, where $N_\gamma = \eta N_f^{(0)}$ is the number of photons (relic radiation) in Universe. It is essential that b and a depend on time evolution t by different manner, and therefore adiabatic condition ($b = a$) was fulfilled in past not always. Question about adiabatic regime of Universe expansion has been already discussed in literature [1-3]. One considers that this regime was set long after the Big Bang when temperature decreased lower than $4000\,\text{K}$ (ionization energy of H-atom), i.e. in atomic era. It is needed for this that the system " $p + e$ " had bound state and interaction (force) between p and e was potential. It is shown in [1-3] that these conditions took place not always. All depends on phase state of configuration space of Universe. There exist three phase states of space: Lebesgue's continuum, Bohr's compact and discontinuum [1-3]. Only in Lebesgue's continuum system " $p + e$ " has bound states (energy binding $\varepsilon < 0$) and its angular momentum in it is not quantized) [1-3]. It turns out that at $T > 4000\,K$ (post de-Sitter's stage) $b \ne a$. Independent estimations of functions b and a [1-3] show that in the end of the de-Sitter's stage (R_s), hadron era (R_H) lepton era (R_L) and atomic era (R_a) b had the numerical values 0, 1/3, 2/3, 1 and a was equaled to 1/4, 1/2, 3/4, 1. Consequently in these eras ratio $S / S_{equ} = \eta^{3(b-a)}$ has values $10^{-9}, 10^{-6}, 10^{-3}, 1\, (\eta = 10^{12})$. Entropy S achieving its maximal value η in atomic era holds this value at further expansion of Universe (so only after atomic era adiabatic regime takes place). Before atomic era Universe had lower entropy. With this fact lower entropy of Universe space is connected: after the de-Sitter's stage configuration space was exist in the Bohr's compact phase (see also [1-3]). The signs (relics) of that epoch conserved near to our time. In this epoch taking about one year special material structures characterized by lower entropy were arisen. The most interesting from them are, we consider, various forms of living matter [1-3].

2. RELIC HELIUM

Usually one considers that creation of cosmic He^4 is a result of nucleon-synthesis or nucleon-fusion [5]. We consider that cosmic He^4 appeared as a result of disintegration of super dense body of Universe at its expansion. Due to the quantum correlation between spin and isospin and switching on the strong interaction between nucleons the bound conglomerates may remain but not only individual nucleons will be. Nucleon skeleton (see [1-3]) is described by the representation $D_i(1/2) \otimes D_s(1/2)$ of the group $SU_i(2) \otimes SU_s(2)$ (i and s are isotopic and usual spin indices; $\otimes$ is the direct product). Two-particle conglomerates are described by the representation

$$(D_i(1/2) \otimes D_s(1/2)) \times (D_i(1/2) \otimes D_s(1/2)) = (D_i(1/2) \times D_i(1/2)) \otimes (D_s(1/2) \times D_s(1/2))$$

($\times$ is the Kronecker multiplication). As $D(1/2) \times D(1/2) = D(0) + D(1)$, so we have

$$(D_i(0) + D_i(1)) \otimes (D_s(0) + D_s(1)) = D_i(0) \otimes D_s(0) + D_i(1) \otimes D_s(1) + D_i(1) \otimes D_s(0) + D_i(0) \otimes D_s(1).$$

Due to the Pauli exception principle only two latter terms are realizable in the Nature; hereby states $D_i(0) \otimes D_s(1)$ correspond to the deuteron d. Proceeding from these states we build four nucleons conglomerates. They are described by the representation

$$(D_i(1) \otimes D_s(0) + D_I(0) \otimes D_s(1)) \times (D_i(1) \otimes D_s(0) + D_i(0) \otimes D_s(1)) = \left(D_i(0) + D_i(1) + D_i(2)\right) \otimes D_s(0) + 2D_i(1) \otimes D_s(1) + D_i(0) \otimes (D_s(0) + D_s(1) + D_s(2))$$

He^4 is an isosinglet with usual spin $s = 0,1,2$. It is described by the representation $2D_i(0) \otimes D_s(0)$, $D_i(0) \otimes D_s(1)$ and $D_i(0) \otimes D_s(2)$. At strong interaction switching on the latters correspond to the bound states of four nucleons (He^4). The rest are states of four nucleons without bound states. Number of possible states with isospin i and usual spin s is $(2i+1)(2s+1)$. Using this formula we get that the total number of states consisting of four nucleons is 36. Number of states for He^4 is 10. Ratio 10/36=0.27 gives the percentage of He^4 in the Universe. Cosmic observations give the same number [5].

3. ENERGY OF PHYSICAL VACUUM

Here a contribution of physical vacuum (zero vibrations of the Lagrangian particle fields) into energy of Universe is calculated. In quantized field theory energy of *physical vacuum* is determined by the expression $P_0 = \left\langle 0 \left| \int T_{00}(\vec{X}, t) d^3 X \right| 0 \right\rangle$, see [6], where $T_{\mu\nu}$ is the total energy-momentum tensor of all quantized fields and 0 is the state of physical vacuum. Magnitude P_0 may be expressed as the following sum

$$\sum_{s,m} (-1)^{2s} (2s+1) \frac{1}{i} \frac{\partial^2}{\partial t^2} D_m^+(0,t)\big|_{t=0} \int d^3 X , \qquad (4)$$

where $D_m^+(X)$ is the Pauli-Jordan function of positive frequency, s and m are spin and mass of particle. In the local theory (point-like particles) energy density of vacuum is given by the sum (see [6])

$$\rho^{vac} = \sum_{s,m} \left[\pm (2s+1) \int d^3 p \sqrt{\vec{p}^{\,2} + m^2} \right], \qquad (5)$$

where signs "+" and "–"are for bosons and fermions correspondingly. It is obviously infinite magnitude. However in the bilocal field theory (non-point, smearing particles [1-3]) particles have the space-time structure described by the function $\theta(I) \frac{\sin\sqrt{I}}{\sqrt{I}}$ where $I = (pY)^2 - p^2 Y^2$, $\theta(I)$ is the Heaviside function and $Y = (Y_0, \vec{Y})$ are the inner space-time coordinates of particle. In the case of physical vacuum these variables are free (see [1-3]; for massless particles structure function is $\cos(p, Y)$). For smearing particles the Pauli-Jordan function $D_m^+(X,Y)$ is given in [1-3]. Using this function the expression for energy density of vacuum is written in the form of sum of integrals

$$\pm (2s+1) \int d^3 p \sqrt{\vec{p}^{\,2} + m^2} \, \frac{\sin \sqrt{(pY)^2 - p^2 Y^2}}{\sqrt{(pY)^2 - p^2 Y^2}} , \qquad (6)$$

(here we took into account that for free particles $p^2 = m^2$; for massless particles we have the sum $\sum \left[\pm 2 \int d^3 p |\vec{p}| \cos pY \right]$ because there are only two chiral states). We else may choose the system in which $\vec{Y} = 0$ and therefore $(pY)^2 - p^2 Y^2 = \vec{p}^{\,2} Y_0^2$. In result the expression for ρ^{vac} is the sum of terms

$$\begin{aligned} &\pm (2s+1) \int d^3 p \sqrt{\vec{p}^{\,2} + m^2} \, \frac{\sin |\vec{p}| Y_0}{|\vec{p}| Y_0} \\ &= \mp (2s+1) \frac{4\pi}{Y_0^4} (mY_0)^2 K_2(mY_0) , \end{aligned} \qquad (7)$$

where K_2 is the Macdonald's function. So for bosons ρ^{vac} is a negative magnitude and for fermions it is a positive one. At the limit of small mY_0 this gives $\mp (2s+1) 8\pi / Y_0^4$ (at $m=0$ when the structure function is $\cos\{pY\}$ we have $\mp 48\pi / Y_0^4$). In another limit $mY_0 \to \infty$ we have $m^{3/2} e^{-mY_0} / Y_0^{5/2}$. To estimate the numerical value of ρ^{vac} we resort to the following consideration. So far as at the Universe expansion the ratio R/λ where λ is a free length and R is radius of the Universe) is invariant (see above) so we have to consider that $Y_0 \sim R$. Obviously the physical vacuum appeared together with particle appearance after the so called de-Sitter's stage when the radius R of the Universe has been $R_s = c^{7/2} h^{3/2} / G^{1/2} T_f^{5/3} T_{\dot{f}}^{1/3}$. At this stage Y_0 had the minimal value equaled to the fundamental "length" $1/k$. At the Lebesgue phase (space for elementary particles is always the Lebesgue one) $Y_0 = R / kR_s$ and hence

$$\begin{aligned} \rho^{vac} &= \sum_{s\,m} \mp (2s+1) 4\pi k^4 hc \left(\frac{R_s}{R} \right)^4 \left(\frac{mcR}{hkR_s} \right)^2 \\ &\times K_2 \left(\frac{mcR}{hkR_s} \right). \end{aligned} \qquad (8)$$

At small masses ($mc^2 << khc \sim 1 Gev$) and $R \sim R_s$ (just after the de-Sitter's stage) we have

$$\begin{aligned} &\mp (2s+1) 8\pi k^4 hc \left(\frac{R_s}{R} \right)^4 = \mp (2s+1) 8\pi k^4 hc \left(\frac{T}{T_{\dot{f}}} \right)^4 \\ &= \mp (2s+1) \sigma_{vac} T^4 / c. \end{aligned} \qquad (9)$$

Here the condition $RT = R_s T_{\dot{f}}$ is used (see above), $\sigma_{vac} = 8\pi k^4 hc^2 / T_{\dot{f}}^4$ and $T_{\dot{f}} \sim 10^{15} \, eV$ (see above). From this it follows that for nucleon vacuum $\rho^{vac} \sim 10^{45} eV / cm^3$ (that is compatible with the density of nuclear matter). Nowadays $R \sim 10^{27} cm$, $R / R_s \sim 10^{18}$ and hence $\rho^{vac} \sim e^{-10^{18}} eV / cm^3$ for nucleon vacuum that is, of course, negligible small magnitude. More over at $m=0$ we have the strict equality $\rho^{vac} = \rho_F^{vac} + \rho_B^{vac} = 0$ because there are two neutrinos with chiralities 1/2 and two states of photon with chiralities 1. Note that charge and spin densities of physical vacuum are strictly zero because integrals $\int d^3 p \frac{\sin |\vec{p}| Y_0}{|\vec{p}| Y_0} = 0$ and $\int d^3 p \cos \left| |\vec{p}| Y_0 \right| = 0$.

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НЕКОТОРЫЕ ПРОБЛЕМЫ В ТЕОРИИ ЭВОЛЮЦИИ РАННЕЙ ВСЕЛЕННОЙ

С.С. Санников-Проскуряков

Продолжаем рассмотрение физических характеристик ранней Вселенной. Сосредотачиваем внимание здесь на трех вопросах: термодинамика, реликтовый гелий, энергия физического вакуума.

ДЕЯКІ ПРОБЛЕМИ У ТЕОРІЇ ЕВОЛЮЦІЇ РАННЬОГО ВСЕСВІТУ

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Продовжуємо розгляд фізичних характеристик раннього Всесвіту. Зосереджуємо увагу тут на трьох питаннях: термодинаміка, реліктовий гелій, енергія фізичного вакууму.