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DARK MATTER, LARGE NUMBERS, AND THE LARGE SCALE STRUCTURE IN THE UNIVERSE

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Abstract

We found that there exists a large number A, $A = 10^{19}$, in the universe, from which there are some correspondences between length scales and mass scales in the universe; since then and from the restraint condition A: $v_s \sim 0.1c - 0.01c$ (v_s is the sound velocity in dark matter medium), one type of fermions with mass $\sim 10^{-1}eV$ in a degenerate state would be preferable as a candidate of dark matter, which is not in contradiction with the observed results about the large scale celestial bodies in the universe. Under the restrict condition A the bosons can be the candidate of dark matter only in a universe with a low energy phase transition during the evolution, and the mass of bosons is still near by $10^{-1} - 10^{-2}eV$, and the absolute value of the chemical potential of bosons is still near by $10^{-5} - 10^{-4}eV$ as that of fermions.

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1 Large number A ($A = 10^{19}$)

1.1 The fundamental physical constants

It is well known that the fundamental physical constants are the velocity of light c, the gravitation constant G, and the Planck constant $\hbar$, from which a length scale r_{pl} (Planck length) and a mass scale m_{pl} (Planck mass) can be deduced:

$$r_{pl} \sim \sqrt{\frac{\hbar G}{c^2}} \sim 10^{-33} cm, \tag{1}$$

$$m_{pl} \sim \sqrt{\frac{\hbar c}{G}} \sim 10^{19} GeV, \tag{2}$$

and

$$r_{pl} \sim \frac{G m_{pl}}{c^2}. \tag{3}$$

In the universe, if we adopt the Planck length as the fundamental length r_0 ($r_o \equiv r_{pl}$), then $r_1 = A \cdot r_0 \sim 10^{-14} cm$ is the length scale of a nucleon (n), $r_2 = A^2 \cdot r_0 \sim 10^5 cm$ is the length scale of a black hole collapsed from a star, $r_3 = A^3 \cdot r_0 \sim 10^{24} cm$ is near by the scale of supercluster. As for the mass scale, if we adopt the nucleon mass (m_n) as the fundamental mass scale m_0 ($m_0 \equiv m_n$), then $m_1 = A \cdot m_0 \sim 10^{19} Gev$ is the Planck mass, $m_3 = A^3 \cdot m_0 \sim 1 M_\odot$ is the stellar mass scale, $m_4 = A^4 \cdot m_0 \sim 10^{19} M_\odot$ is the total mass corresponding to the superstructure[1]-[4] in the universe (SSU).

It is obviously that

$$\frac{m_{i+1}}{r_i} = const., \quad i = 0, 1, 2, 3 \tag{4}$$

Since $m_1 = m_{pl}$ and $r_o = r_{pl}$, from eqs(3),(4) we have

$$r_2 \sim \frac{G m_3}{c^2}, \tag{5}$$

$$r_3 \sim \frac{G m_4}{c^2}. \tag{6}$$

These are the relationships between the mass of celestial bodies and their corresponding black hole radii (BHR).

1.2 Nucleons and the "strong gravitation"

Basis on the above analysis, we can see that r_0 is corresponding to m_1, r_2 is corresponding to m_3, and r_3 is corresponding to m_4, but there exists a anomaly, i.e. r_1 is corresponding to m_0 and the scale of m_2 is not existing in the universe indeed. Suppose the relationship between r_1 and m_0 is formally like Eq(5), i.e.

$$r_1 \sim \frac{\tilde{G}m_0}{c^2}, \tag{7}$$

but from eqs(3),(4),

$$r_1 \sim \frac{Gm_2}{c^2}, \tag{8}$$

so a result of

$$\frac{\tilde{G}}{G} \sim A^2 \sim 10^{38} \tag{9}$$

can be deduced, it just right is the ratio of the strong interaction force between two nucleons to the gravitation interaction force between them. So, a nucleon is like a black hole under a "strong gravitation" interaction with a "strong gravitation constant" $\tilde{G}$, which is confined for the "strong signals".

1.3 The free stream scales (FSS)

Up to now, from the cosmology, we know the main compositions of the universe are baryons (b) and dark matter (d), however in the universe the baryons mainly are the nucleons; on the other hand, from the particle physics, we know the stable particles are protons, electrons, neutrinos, and photons. At the present era, electrons and photons only make up a few portion of the total mass of the universe, since then the candidate of dark matter naturally is neutrino ν. Therefore we are confronted with a two-compositions ($b + \nu$) universe. In this universe it would exist two FSS: M'_F and M_F",

$$M'_F \sim \frac{m_{pl}^3}{m_n^2}, \tag{10}$$

$$M_F" \sim \frac{m_{pl}^3}{m_\nu^2}. \tag{11}$$

From Eq(10), it is obviously that

$$M_F' \sim A^3 \cdot m_0 = m_3. \tag{12}$$

As for the M_F", it might logically be equal to m_4:

$$M_F" \sim A^4 \cdot m_0 = m_4, \tag{13}$$

so from eqs (11) and (13), we have

$$m_\nu = A^{-0.5} \cdot m_n \sim 10^{-1} eV. \tag{14}$$

This result is like that in Ref[5], and means that a neutrino celestial body with the total mass corresponding to SSU could be some time collapsed to a black hole with a length scale of r_3. May be, this sort of celestial bodies will play an important role on Hubble constant, the large scale stream, and the increment of perturbations in the universe.

1.4 summary

(1) All of the corresponding relationships discussed above can be synthesized as follows:

r_i	m_i	BHR	FSS
	m_0	$r_1 \sim \frac{Gm_0}{c^2}$	
r_0	m_1	$r_0 \sim \frac{Gm_1}{c^2}$	$m_1 \sim \frac{m_{pl}^3}{m_p^2}$
r_1			
r_2	m_3	$r_2 \sim \frac{Gm_3}{c^2}$	$m_3 \sim \frac{m_{pl}^3}{m_\pi^2}$
r_3	m_4	$r_3 \sim \frac{Gm_4}{c^2}$	$m_4 \sim \frac{m_{pl}^3}{m_\nu^2}$

(2) May be there exists some unification between the strong interaction and the gravitational interaction.

(3) The dark matter particles (DMP) could not be the neutrinos, but could be a sort of hot DMP with mass $\sim 10^{-1} eV$ related to SSU.

2 DMP

We discuss some weakly interacting massive particles in a RWF universe, which are either fermions (f) or bosons (b) and have a mass of m_f or m_b with the chemical potential of μ_f or μ_b respectively. If the cosmic dark matter is composed of them, we will further research the mass region and the matter state of such particles following Ref[6] and according to SSU[1]-[4] as the main clues.

3 Fermions as DMP

3.1 Premises

(1) These f-particles are relativistic, when they are decoupling from the cosmic hot soup, and are stable since then during the evolution of the universe.

(2) At the present era, f-particles are the main composition of the universe, which portion is

$$\Omega_f = \frac{\rho_f}{\rho_c}, \tag{15}$$

where ρ_f is the present average density of f-particles, and ρ_c is the present critical density of the universe. From now on, all physical quantities will adopt the present values unless there are any declares.

(3) Since there exists the large scale structure in the universe, the f-particles can not be in a relativistic state at the present time, or else the large scale structure in the universe will be broken by the free stream. So, we arrange that the average thermal velocity of f-particles is less than 0.1c ($\bar{v} < 0.1c$).

$$\bar{v} = \sqrt{\frac{2kT_f}{m_f}} \cdot \int_0^\infty \frac{ZdZ}{exp(Z-\gamma)+1} / \int_0^\infty \frac{\sqrt{Z}dZ}{exp(Z-\gamma)+1}, \tag{16}$$

where $\gamma \equiv \frac{\mu_f}{kT_f}$, and the T_f is f-particles temperature; but the sound velocity v_s in f medium is

$$v_s = \sqrt{\frac{10}{9}\frac{kT_f}{m_f} \cdot \int_0^\infty \frac{Z^{\frac{3}{2}}dZ}{exp(Z-\gamma)+1} / \int_0^\infty \frac{\sqrt{Z}dZ}{exp(Z-\gamma)+1}}. \tag{17}$$

From calculations we know that $\frac{v}{v_s} \sim 1$, so $v_s < 0.1c$.

(4) From the observations [1]-[4] of SSU, we know the scale of that has being been $1\% - 10\%$ of horizon, it will be as well to adopt that $v_s = 0.01c - 0.1c$ (restrict condition A) following Ref[6].

(5) The temperature of fermions T_f can be estimated as follows

$$T_f = \frac{kT_{fo}T_{\gamma o}}{m_f c^2 + kT_{\gamma o}}, \tag{18}$$

in which $T_{\gamma o}$ is the microwave background temperature, $T_{\gamma o} = 2.7^o K$; T_{fo} is the f-particles temperature when $m_f = 0$. When $m_f c^2 \gg kT_{\gamma o}$,

$$T_f \doteq \frac{kT_{fo}T_{\gamma o}}{m_f c^2}. \tag{19}$$

(6) As for the T_{fo}, if the fermions are neutrinos, then $T_{fo} = 1.9^o K$; if the fermions are decoupled before the neutrino decoupling, then $T_{fo} < 1.9^o K$; if there exists a low energy phase transition (LEPT) in the universe, then $T_{fo} > 1.9^o K$ and in eqs(18),(19), $T_{\gamma o}$ is substituted by $(\frac{11}{4})^{\frac{1}{3}} \cdot T_{fo}$. The LEPT means that a phase transition had occurred in the universe after the neutrino decoupling.

3.2 Deduction

For the average density of f-particles, it can be expressed as

$$\rho_f = \frac{g m_f^{\frac{5}{2}} (kT_f)^{\frac{3}{2}}}{2^{\frac{1}{2}}\pi^2\hbar^3} \cdot \int_0^\infty \frac{\sqrt{Z}dZ}{exp(Z-\gamma)+1}, \tag{20}$$

where g is the variety number of f-particles. If $\rho_c = \frac{3H_{100}^2}{8\pi G}$, $H_{100} = 100km \cdot sec^{-1} \cdot Mpc^{-1}$, then

$$\rho_f = \Omega_f \rho_c h^2, \tag{21}$$

where $h = \frac{H_o}{H_{100}}$, H_o is the Hubble constant. Make

$$J_a \equiv \int_0^\infty \frac{Z^a dZ}{exp(Z-\gamma)+1}, \tag{22}$$

from eqs(19),(20),(21), get

$$m_f = \frac{\Omega_f h^2}{J_{\frac{1}{2}} g} \cdot \frac{2^{\frac{1}{2}} \pi^2 \hbar^3 c^3 \rho_c}{k^3 (T_{fo} T_{\gamma o})^{\frac{3}{2}}}; \tag{23}$$

from eqs(17),(18), get

$$m_f v_s = \sqrt{\frac{10}{9} \frac{T_{fo} T_{\gamma o} J_{\frac{3}{2}}}{J_{\frac{1}{2}}}} \cdot \frac{k}{c}. \tag{24}$$

From eqs(23),(24),(19), we know, after giving the values of T_{fo} and γ, the values of m_f (from Eq(23)), v_s (from Eq(24)), T_f (from Eq(19)), and μ_f (from γ) can be deduced. The influence of Ω_f, h, g on m_f and etc. can be synthetically considered in a factor w, $w \equiv \frac{g}{\Omega_f h^2}$. We need not to consider the distinct values of them but need to consider the value of w only. If $g = 1$, $\Omega_f = 1$, $h = 1$, then $w = 1$; if $g = 6$, $\Omega_f = 0.3$, $h = 0.5$, then $w = 80$, therefore we shall be discussing in a range of $w = 1 - 80$.

3.3 Results

(1) The matter state of f-particles

Taking $T_{fo} = 1.9^o K$ and $v_s/c = 0.01, 0.1$, from eqs(23),(24),(19) the calculated results are as follows

w	v_s/c	$m_f(eV)$	$T_f(^oK)$	$\mu_f(eV)$	γ
1	0.01	0.17	2.5×10^{-3}	2.6×10^{-5}	120
1	0.1	0.031	1.4×10^{-2}	4.7×10^{-4}	380
40	0.01	0.069	6.4×10^{-3}	1.1×10^{-5}	19
40	0.1	0.012	3.6×10^{-2}	1.9×10^{-4}	60
80	0.01	0.057	7.7×10^{-3}	0.9×10^{-5}	13.5
80	0.1	0.010	4.4×10^{-2}	1.6×10^{-4}	43

Taking $T_{fo} = 0.19^oK$, from eqs(23),(24),(19) the calculated results are

w	v_s/c	$m_f(eV)$	$T_f(^oK)$	$\mu_f(eV)$	γ
1	0.01	0.17	2.5×10^{-4}	2.6×10^{-5}	1200
1	0.1	0.031	1.4×10^{-3}	4.7×10^{-4}	3800
40	0.01	0.069	6.4×10^{-4}	1.1×10^{-5}	190
40	0.1	0.012	3.6×10^{-3}	1.9×10^{-4}	600
80	0.01	0.057	7.7×10^{-4}	0.9×10^{-5}	135
80	0.1	0.010	4.4×10^{-3}	1.6×10^{-4}	430

It is clearly that the dark matter fermions are in a degenerate state as the whole, and m_f, μ_f are constants for different T_{fo} ($T_{fo} \leq 1.9^oK$) and same w, v_s. The values of m_f and μ_f are about $10^{-1} - 10^{-2}eV$ and $10^{-5} - 10^{-4}eV$ respectively. At the degenerate state, eqs (20),(23),(19),(24) become to

$$\rho_f = \frac{g m_f^{\frac{5}{2}} (kT_f)^{\frac{3}{2}}}{2^{\frac{1}{2}} \pi^2 \hbar^3} \cdot \frac{2}{3} \gamma^{\frac{3}{2}}, \tag{25}$$

$$m_f^4 = \frac{2}{3^{\frac{1}{2}}} \cdot \frac{\pi^2 \hbar^3 \rho_c}{w v_s^3} = function(w, v_s), \tag{26}$$

$$\frac{T_f}{T_{fo}} \doteq \frac{kT_{\gamma o}}{m_f c^2} = function(w, v_s), \tag{27}$$

$$\mu_f = \frac{3}{2} (\frac{m_f v_s c}{k})^2 \frac{T_f}{T_{fo}} \frac{1}{T_{\gamma o}} = function(w, v_s). \tag{28}$$

(2) The value of μ_f during evolution

According to the isoentropic hypothesis in the evolution of the universe, the entropy per f-particle (S/N) is a constant:

$$\begin{aligned} S/N &= \frac{k}{3} \cdot \{ \int_0^\infty Z^{\frac{3}{2}} (Z + \frac{2m_f c^2}{kT_f})^{\frac{3}{2}} \frac{dZ}{exp(Z-\gamma)+1} \\ &+ 3 \int_0^\infty (Z + \frac{m_f c^2}{kT_f}) \sqrt{Z(Z + \frac{2m_f c^2}{kT_f})} \frac{(Z-\gamma)dZ}{exp(Z-\gamma)+1} \} \div \\ &\int_0^\infty \frac{dZ}{exp(Z-\gamma)+1} \cdot (Z + \frac{m_f c^2}{kT_f}) \sqrt{Z(Z + \frac{2m_f c^2}{kT_f})}. \end{aligned}$$

Under the relativistic condition, $S/N = \frac{k}{3} \cdot \frac{4J_3 - 3J_2\gamma}{J_2}$; under the non-relativistic condition, $S/N = \frac{k}{3} \cdot \frac{5J_{\frac{3}{2}} - 3J_{\frac{1}{2}}\gamma}{J_{\frac{1}{2}}}$. It is obvious that under the relativistic condition there are two situations for μ_f[7] typically: the first is $\gamma > 20$(degenerate state), in this time there only exist either fermions or antifermions $\bar{f}$; the second is $\gamma = 0$, then the particle number of f is equal to that of $\bar{f}$. From calculations we know for $\gamma > 20$ the non-relativistic fermions or antifermions deduced from relativistic particles will still be near by a degenerate state; but for $\gamma = 0$, the value of γ for non-relativistic fermions or antifermions will not still be equal to zero but will translate to $\gamma = -1.62$ after the deducing. The results for $T_{fo} = 1.9^oK$ and $\gamma = -1.62$ are as follows

w	v_s/c	$m_f(eV)$	$T_f(^oK)$	$\mu_f(eV)$
1	2.8×10^{-7}	926	4.8×10^{-7}	-6.7×10^{-11}
80	2.2×10^{-5}	11.6	3.8×10^{-5}	-5.3×10^{-9}

Since the values of v_s/c are too small, it suggests that there may exist LEPT, for example the photon cooling process in Ref[8].

(3) LEPT

The LEPT can be described by taking $T_{fo} > 1.9^oK$ and substituting $T_{\gamma o}$ by $(\frac{11}{4})^{\frac{1}{3}} \cdot T_{fo}$, for $\gamma = -1.62$ the calculated results are as follows

w	v_s/c	$m_f(eV)$	$T_f(^oK)$	$\mu_f(eV)$	$T_{fo}(^oK)$
1	0.01	0.35	0.25	-3.5×10^{-5}	27
1	0.1	0.062	4.3	-6.0×10^{-4}	47
80	0.01	0.12	0.083	-1.2×10^{-5}	9
80	0.1	0.021	1.4	-2.0×10^{-4}	16

In this situation, f-particles are near by a high temperature state, and m_f is still about $10^{-1} - 10^{-2}eV$, and the absolute value of μ_f is still about $10^{-5} - 10^{-4}eV$.

(4) High temperature approximation ($\gamma < -4$)

At this state and with LEPT, eqs(20),(24) become to

$$\rho_f = \frac{g m_f^{\frac{5}{2}} (kT_f)^{\frac{3}{2}}}{2^{\frac{1}{2}} \pi^2 \hbar^3} \cdot \frac{\sqrt{\pi}}{2} exp(\gamma) \tag{29}$$

$$m_f = (\frac{5}{3})^{\frac{1}{2}}(\frac{11}{4})^{\frac{1}{6}} \cdot \frac{T_{fo}}{v_s} \cdot \frac{k}{c} = function(T_{fo}, v_s). \tag{30}$$

From eqs(23),(24), we have

$$m_f^4 = (\frac{10\pi}{3})^{\frac{3}{2}} \frac{\hbar^3 \rho_c}{w \cdot exp(\gamma)} \tag{31}$$

3.4 Summary

(1) If there does not exist a LEPT in the universe and the dark matter fermions are neutrinos indeed, they will be in a degenerate state, and there occurs the large lepton number problem [9], because from Eq(21) the number density of neutrino is about 10^4; or else the dark matter fermions are composed of another particles, such as gravitinos[10] and etc. In this situation, m_f is not sensitive with the value of w, because $m_f \propto w^{-\frac{1}{4}}$ from Eq(26).

(2) If there exists a LEPT, the large lepton number problem could be overcome, and the neutrinos could be DMP but with a negative chemical potential. In this situation, the mass of any dark matter fermions is approximately not relative to the value of w (see Eq(30)).

(3) From eqs(26),(31) and the data in section 3.3(1),3.3(3), we can see that if $\gamma > -4$ and $v_s = const$, then m_f is nearly invariable for different states of matter. So, basis on the observations of SSU, there may exist one type of fermions as hot dark matter with the particle mass $m_f = 10^{-1} - 10^{-2} eV$ for restrict condition A.

4 Bosons as DMP

4.1 Bosons are relativistic as their decoupling

At this condition the equations in section 3 can still be used, but in all of these equations the foot sign f (fermions) must be substituted by b (bosons), and the term $[exp(Z-\gamma)+1]$ must be substituted by $[exp(Z-\gamma)-1]$; besides, there are three points to be explained: (1) The values of g for bosons usually are 1 or 2, and the value of Ω_b usually is near 1 [11], so we shall be discussing in a range of $w = 1 - 10$. (2) The chemical potential of bosons is negative, i.e. $\gamma \leq 0$. (3) When the bosons isoentropically evolute from relativistic

particles to non-relativistic particles, their value of γ will translate from $\gamma = 0$ to $\gamma = -1.245$.

4.1.1 The calculated results without LEPT

Since $\gamma \leq 0$, it is well known that $m_b = m_{bmin}$, $T_b = T_{bmax}$, $v_s = v_{smax}$, when $\gamma = 0$. Taking $T_{b0} = 1.9^oK$, for $\gamma = 0, -1.245, -20$, we obtain the calculated results as follows:

w	v_s/c	$m_b(eV)$	$T_b(^oK)$	$\mu_b(eV)$	γ
1	2.7×10^{-6}	65.7	6.7×10^{-6}	0	0
10	2.7×10^{-5}	6.57	6.7×10^{-5}	0	0
1	4.6×10^{-7}	531	8.3×10^{-7}	-8.9×10^{-11}	-1.245
10	4.6×10^{-6}	53.1	8.3×10^{-6}	-8.9×10^{-10}	-1.245
1	3.0×10^{-15}	8.3×10^{10}	5.3×10^{-15}	-9.2×10^{-18}	-20
10	3.0×10^{-14}	8.3×10^{9}	5.3×10^{-14}	-9.2×10^{-17}	-20

It is obviously that the sound velocity in b medium is too low, so, without LEPT, for the formation of SSU no direct influence is from bosons, this is not like the influence from fermions in section 3, because the value of γ of fermions can be larger than zero.

4.1.2 The calculated results with LEPT

Taking $\gamma = -1.245$, $v_s/c = 0.01, 0.1$, get

w	v_s/c	$m_b(eV)$	$T_b(^oK)$	$\mu_b(eV)$	$T_{bo}(^oK)$
1	0.01	0.29	0.22	-2.4×10^{-5}	23.4
1	0.1	0.052	4.0	-4.3×10^{-4}	41.5
10	0.01	0.17	0.13	-1.3×10^{-5}	13.2
10	0.1	0.029	2.3	-2.4×10^{-4}	23.4

In such condition for the formation of SSU the effect from bosons is like that from fermions, and the mass and the chemical potential of bosons are all like that of fermions.

4.2 Bosons are non-relativistic as their decoupling

At this time, the temperature of bosons is not related to that of microwave background. For convenience' sake Eq(19) can be rewritten in a

form

$$T_b \doteq \frac{kT_{bo}T_{\gamma o}}{Km_bc^2}, \tag{32}$$

where $K > 1$, from which eqs(23),(24) become to

$$m_b = K^{\frac{3}{2}} \cdot \frac{\Omega_b h^2}{J_{\frac{1}{2}} g} \cdot \frac{2^{\frac{1}{2}}\pi^2\hbar^3c^3\rho_c}{k^3(T_{bo}T_{\gamma o})^{\frac{3}{2}}}; \tag{33}$$

$$m_b v_s = \sqrt{\frac{10}{9}\frac{T_{bo}T_{\gamma o}J_{\frac{3}{2}}}{K \cdot J_{\frac{1}{2}}}} \cdot \frac{k}{c}. \tag{34}$$

For K=100, the results are as follows:

w	v_s/c	$m_b(eV)$	$T_b(^oK)$	$\mu_b(eV)$	γ
1	2.7×10^{-10}	6.6×10^4	6.7×10^{-11}	0	0
10	2.7×10^{-9}	6.6×10^3	6.7×10^{-10}	0	0
1	4.6×10^{-11}	5.3×10^5	8.3×10^{-12}	-8.9×10^{-16}	-1.245
10	4.6×10^{-10}	5.3×10^4	8.3×10^{-11}	-8.9×10^{-15}	-1.245
1	3.0×10^{-19}	8.3×10^{13}	5.3×10^{-20}	-9.2×10^{-23}	-20
10	3.0×10^{-18}	8.3×10^{12}	5.3×10^{-19}	-9.2×10^{-22}	-20

Comparing these results with that in section 4.1.1, we can see that $m_b \uparrow$, $T_b \downarrow$, $\mu_b \downarrow$, $v_s/c \downarrow$, so, for the formation of SSU the influence of such particles is far less.

4.3 Boson condensation

Under a giving number density of bosons ($n_b = const.$), when the chemical potential of bosons tends to zero, the temperature of bosons will tend to T_o. From Ref[12],

$$T_o = \frac{3.31}{w^{\frac{2}{3}}} \cdot \frac{\hbar^2}{m_b^{\frac{5}{3}}k} \cdot \rho_c^{\frac{2}{3}}, \tag{35}$$

From Eq(32), get

$$\frac{T_b}{T_o} \doteq (\frac{k}{\hbar c})^2 \cdot \frac{T_{bo}T_{\gamma o}}{3.31 \cdot K} \cdot (\frac{m_b w}{\rho_c})^{\frac{2}{3}}. \tag{36}$$

If $\frac{T_b}{T_o} = 1, w = 1, K = 1, T_{bo} = 1.9^o K$, then $m_b = 65.6eV$;
if $w = 1, K = 1, T_{bo} = 1.9^o K, m_b = 0.1eV$, then $\frac{T_b}{T_o} = 1.3 \times 10^{-2}$;
if $w = 1, K = 1, T_{bo} = 1.9^o K, m_b = 10^{-5}eV$, then $\frac{T_b}{T_o} = 2.9 \times 10^{-5}$.

It is clearly that without LEPT for bosons with mass $m_b < 65.6eV$ there can appear boson condensation. Under this state, in b medium the sound velocity v_s is zero, so they will be no influence on the formation of SSU.

4.4 Summary

If there exists LEPT, and if DMP are relativistic as their decoupling, either fermions or bosons are the candidate of dark matter, and the ranges of their mass and chemical potential are much the same, which are $\sim 10^{-1} - 10^{-2}eV$ and $\sim 10^{-5} - 10^{-4}eV$ respectively.

5 The fermions in a degenerate state

In this section we discuss the effects of the dark matter fermions in a degenerate state on galaxies, superclusters, the large scale stream and etc. in the universe.

5.1 The rotational velocity distribution in S galaxies

From refs(13),(14), we know that the flatness of the rotational velocity distribution in spiral galaxies can be explained in a two-compositions model of baryons and fermions (neutrinos) in a degenerate state. According to the normalization equations in Ref[14], a range of $m_f \sim 10^{-1} - 10^{-2}eV$ corresponds to the normalized parameter $m \to 0$, and the dark matter content in the galactic region will decrease to a minimum of $\frac{2+n}{3n}$, when $n \to \infty$, this minimum is $\frac{1}{3}$. In other words, the results of $m_f \sim 10^{-1} - 10^{-2}eV$ obtained in this paper are not in contradiction with the observed results about the rotational velocity distribution in S galaxies, so long as the edge scale of galactic halo is far larger then the scale of galaxies. Besides, according to the normalized equations in Ref[14], if we extend the scale of two-compositions celestial bodies from galaxies to superclusters, then the up-limit of fermion mass $< m >_f$ will decrease from $20eV$ to $0.2eV$.

5.2 The filament with supercluster scale

From Ref[15], we know that the filament with supercluster scale in the universe can also be explained in a two-compositions model of baryons and fermions (neutrinos) in a degenerate state. That is another circumstantial evidence of this paper.

6 Discussion

(1) Starting from Planck mass m_{pl} and Planck length r_{pl}, the mass scale and the length scale observed in the universe are: $m_o = A^{-1} \cdot m_{pl} \sim 1GeV$ (nucleon mass), $m_3 = A^2 \cdot m_{pl} \sim 1M_\odot$ (stellar mass), $m_4 = A^3 \cdot m_{pl} \sim 10^{19}M_\odot$ (SSU mass); $r_1 = A \cdot r_{pl} \sim 10^{-14}cm$ (nucleon radius), $r_2 = A^2 \cdot r_{pl} \sim 10^5 cm$ (BHR of stellar), and the predictive scales are: $m_d = A^{-1.5} \cdot m_{pl} \sim 10^{-1}eV$ (the mass of DMP); $r_3 = A^3 \cdot r_{pl} \sim 10^{24}cm$ (BHR of SSU).

(2) There are two scales for free stream: $M'_F \sim 1M_\odot$ (stellar mass), $M"_F \sim 10^{19}M_\odot$ (SSU mass). The former is generally observed in the universe, and the latter would be a typical scale in future observations for Hubble constant and the law about the increment of cosmic perturbations.

(3) From SSU, It would be inferred that there at least exists one type of hot dark matter composed of weakly interacting particles with mass $\sim 10^{-1} - 10^{-2}eV$ and chemical potential $\sim 10^{-5} - 10^{-4}eV$ (absolute value), and if they are fermions, they could be in a degenerate state.

(4) Whether fermions or bosons are DMP, LEPT could exist in the universe; but if the origination of the large scale magnetic fields relates to the magnetic moment of DMP[16], the existence of LEPT is much possible.

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