A Cosmological Model without Singularity and its Explanation for Evolution of the Universe and the natures of Huge Voids

Shi-Hao Chen

Institute of Theoretical Physics,

Northeast Normal University,

Changchun 130024, China.

shchen@nenu.edu.cn

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Abstract

The new conjectures are proposed that there are s-matter and v-matter which are symmetric and whose gravitational masses are opposite to each other. There are two sorts of symmetry breaking modes called V-breaking and S-breaking, respectively. In the V-breaking, v-particles get their masses and form v-galaxies etc., while s-fermions and s-gauge bosons are still massless and form s-SU(5) color-single states which loosely distribute in space and cause space to expand with an acceleration. The curvature factor K in the RW metric is regarded as a function of gravitational mass density in the comoving coordinates. In the S-breaking, space contracts and causes temperature to rise. When it reaches the critical temperature, masses of all particles are zero. Thus s-particles and v-particles transform from one to another so that the gravitational mass density is zero. Consequently space inflation occurs. After the reheating process, the state with the highest symmetry transits into the V-breaking. In the V-breaking, space first expands with a deceleration; then comes to static, and finally expands with an acceleration up to now. The cosmological constant is determined to be zero, although the energy density of the vacuum state is still large. There is no space-time singularity in the present model. There are the critical temperature, the highest temperature and the least scale in the universe. The new equations of structure formation have been derived. A huge v-voids is not empty, in which there must be s-matter with its bigger density, and which is equivalent to a huge concave lens. The density of hydrogen in the huge voids must be more less than that predicted by the conventional theory. The gravitation between two galaxies distant enough will be less than that predicted by the conventional theory. It is possible that a v-black hole with its big enough mass and density can transform into a huge white hole by its self-gravitation. Nucleosynthesis and CMBR are explained. Space-time is open or $K<0$ according to the present model. w can change from $w>0$ to $w<-1$.

Contents

I. ACTION, ENERGY-MOMENTUM TENSOR AND FIELD EQUATIONS

A. Conjectures and action

1. Conjectures

In order to solve the above problems, we propose the following conjectures.

Conjecture 1 *There are two sorts of matter which are called* $solid-matter$ *(*$s-matter$*) and* $void-matter$ *(*$v-matter$*), respectively. Both are symmetric and their contributions to the Einstein tensor are opposite each other. There is no other interaction between both except the interaction described by* (10) *between* $s-Higgs\ fields$ *and* $v-Higgs\ fields$*.*

Conjecture 2 $\lambda_{eff} = 0$, *where* λ_{eff} *is the effective cosmological constant.*

Conjecture 3 *The curvature factor* $K = K\left(\underline{\rho}_g\left(t, R\left(t\right)\right)\right)$ *in the Robertson -Walker metric is a monotone and finite function of* $\underline{\rho}_g$, $dK/d\underline{\rho}_g > 0$ *and* $K = 0$ *for* $\underline{\rho}_g = 0$, *here* $\underline{\rho}_g$ *is the gravitational mass density in the comoving coordinates.*

Conjecture 4 *When* $SU(5)$ *symmetry holds water and temperature is low, all particles in free states must exist in* $SU(5)$ *color single states.*

The other premise of the present model is the conventional $SU(5)$ grand unified theory (GUT). But it is easily seen that the present model does not rely on the special GUT.

Provided the conjecture 1 and such a coupling as (10) are kept in a GUT, the GUT can be accepted.

In fact, the only conjecture 1 is essential. The other conjectures are obviously consistent with the conventional theory.

All following inferences hold water when $S \rightleftarrows V$ and $s \leftrightarrows v$ due to the conjecture 1.

2. There is no contradiction between conjecture 1 and experiments and observations up to now.

(**1**) . $S - matter$ and $v - matter$ are asymmetric because of the symmetry spontaneously breaking.

Matter determines properties of space-time. Different breaking modes of Higgs fields correspond to different ground states. There are two sorts of breaking modes which are called $S - breaking$ and $V - breaking$. In the $S - breaking$, the expectation values of $s - Higgs$ fields are not zero and the expectation values of all $v - Higgs$ fields are zero. Consequently, the $s - SU(5)$ symmetry finally breaks into $s - SU(3) \times U(1)$, $s - particles$ can get their masses and form $s - atoms$, $s - observers$ and $s - galaxies$, and the $v - SU(5)$ symmetry is still strictly kept, all $v - fermions$ and $v - gauge$ bosons are massless and must form $v - SU(5)$ color-single states when temperature is low. There is no electroweak gauge interaction among the $v - SU(5)$ color-single states because the $v - SU(5)$ is a simple group. Consequently the $v - SU(5)$ color-single states cannot form $v - atoms$, $v - observers$ and $v - galaxies$, and must loosely distribute in space as the so-called dark energy. Thus, in the $S - breaking$ $s - matter$ is identified with the conventional matter forming the given world, and $v - matter$ can cause space to expand with an acceleration as dark energy and cannot be observed except by the repulsion. In contrast with the dark energy, the gravitational masses of $v - matter$ is negative in the $S - breaking$.

(**2**). There are only the repulsion between $s - matter$ and $v - matter$ when temperature is low.

The interaction (10) between the $v - Higgs$ fields and the $s - Higgs$ fields is repulsive, the masses of Higgs particles are all very large and the Higgs particles must decay fast at low temperature. Hence the interaction may be ignored when temperature is low. Thus There are only the repulsion between $s - matter$ and $v - matter$ when $T \ll T_{cr}$. Consequently, any bound state is composed of only $s - particles$ or only $v - particles$, there is no the transformation of $s-particles$ and $v-particles$ from one into another when $T \ll T_{cr}$, and if ρ_v is very large, ρ_s must be very little in the same region. Thus, in the $V-breaking$, there must be $\rho_s \ll \rho_v$ in a $v-galaxy$ so that ρ_s may be ignored.

(**3**) . The equivalence principle still holds for the ordinary particles.

In the $V-breaking$, $v-particles$ are identified as the ordinary particles to form the given world and there are only the $v-observers$, and there is no $s-observer$, hence the gravitational masses of $v-matter$ must be positive, i.e. $m_{vg}=m_v$, and the gravitational masses of $s-matter$ must be negative relatively to the $v-observers$, i.e. $m_{sg}=-m_s$, because of the conjecture 1. Thus the equivalence principle still holds for $v-matter$ (given matter), but is violated for $s-matter$. Thus a $v-photon$ falling in a gravitational field must have redshift, but a $s-particle$ (there is no $s-photon$ and there are only $s-SU(5)$ color single states) will have purple shift. This result does not contradict the experiments and observations up to now, because of the above reasons. In fact, it is too difficult that a $v-observor$ observes $s-particles$, because $\rho_s \ll \rho_v$ in a $v-galaxy$, there is only the repulsion between $s-matter$ and $v-matter$ and the $s-SU(5)$ color single states can only loosely distribute in space. In the other hand, there is no reason to demands demand unknown matter to satisfy the equivalence principle.

(**4**). ρ_s and ρ_v can transform from one into another when temperature is high enough, i.e., $T \sim T_{cr}$ (see later)..

When $T \sim T_{cr}$, the expectation values of all Higgs fields and the masses of all particles are zero and the interaction (10) between the $s-Higgs$ fields and the $v-Higgs$ fields is important. Consequently, ρ_s and ρ_v can transform from one into another by (10) so that $\rho_s=\rho_v$, $T_s=T_v \sim T_{cr}$ and the symmetry $v-SU(5)\times s-SU(5)$ holds in this case. This is a new case which is different from any given experiment and observation.

3. The conjectures 2-4 are consistent with the conventional theory

(1). $\lambda_{eff}=0$ is a necessary inference because we can explain evolution of space without λ_{eff}. On the basis, the cosmological constant problem is easily solved.

(2) . In contrast with the conventional theory, all $\underline{\rho}_g>0$, $=0$ and <0 are possible, hence the curvature factor $K>0$, $=0$ and <0 are all possible as well. Consequently K is regarded as a function of the gravitational mass density $\underline{\rho}_g$ in the comoving coordinates, i.e.

$K = K\left(\underline{\rho}_g\left(t, R\left(t\right)\right)\right)$. The evolving equations corresponding to K have been derived[9].

(3) .As is well known, the $SU(3)$ theory has proven that there can be the $SU(3)$ glue-balls whose masses are not zero. The $SU(5)$ color single states can be regarded as generalization of the $SU(3)$ glue-balls.

Sum up, in the $v-breaking$, the $s-particles$ have only the cosmological effects and cannot be observed. Consequently there is no contradiction between conjectures and experiments and observations up to now.

4. The inferences of the conjecture are consistent with the cosmological observations

Based on the conjecture and the $F-W$ dark matter model (or mirror dark matter model), the following inferences are consistent with the cosmological observations.

1. The evolution of the universe;

2. Large-scale structure formation;

3. The features of huge voids;

4. Primordial nucleosynthesis (it is necessary to consider simultaneously the conjecture and the F-W dark matter model);

5. Cosmic microwave background radiation (it is necessary to consider simultaneously the conjecture and the F-W dark matter model).

6. $w = p/\rho$ can change from $w > 0$ to $w < -1$.

In addition, the conjecture is necessary in order to solve the following issues.

1. The cosmological constant issue.

2. The space-time singularity issue.

5. New predictions and an inference and some guesses

a. New predictions 1.It is possible that huge voids is equivalent to a huge concave lens. The density of hydrogen and the density of helium in the huge voids predicted by the present model must be more less than that predicted by the conventional model.

2.The gravitation between two galaxies distant enough will be less than that predicted by the conventional theory.

3. A black hole with its mass and density big enough will transform into a white hole. The transformation of the cosmic ultimate

4. Space-time is open, i. e. $K<0$.

b. Some guesses 1.The universe is composed of infinite s-cosmic islands and v-cosmic islands

2.Mass redshifts

B. Action

The breaking mode of the symmetry is only one of the $S-breaking$ and the $V-breaking$ due to (10). In the $S-breaking$, there are only the $s-observators$. In the $V-breaking$, there are only the $v-observators$. Hence the actions should be written as two sorts of form, I_S in the $S-breaking$ and I_V in the $V-breaking$. Because of the conjecture 1, the structures of I_S and I_V are the same, i.e. $I_V \rightleftarrows I_S$ when $S \rightleftarrows V$ and $s \rightleftarrows v$. Thus, at the zero-temperature we have

$$I_S = I_g + I_{SM} = I_g + I_{VM} = I_V, \tag{1}$$

$$I_g = \frac{1}{16\pi G}\left(\int_\Sigma R\sqrt{-g}d^4x + 2\int_{\partial\Sigma} K\sqrt{\pm h}d^3x\right), \tag{2}$$

$$I_{SM} = \int d^4x\sqrt{-g}\mathcal{L}_{SM}, \qquad \mathcal{L}_{SM} = \alpha\mathcal{L}_s + \beta\mathcal{L}_v + V_0 + \frac{1}{2}(\alpha+\beta)V_{sv}, \tag{3}$$

$$I_{VM} = \int d^4x\sqrt{-g}\mathcal{L}_{VM}, \qquad \mathcal{L}_{VM} = \alpha\mathcal{L}_v + \beta\mathcal{L}_s + V_0 + \frac{1}{2}(\alpha+\beta)V_{vs}, \tag{4}$$

$$\mathcal{L}_s = \mathcal{L}_{sM}\left(\Psi_s, g(x), g(x)_{,\mu}\right) + V_s(\omega_s), \tag{5}$$

$$\mathcal{L}_v = \mathcal{L}_{vM}\left(\Psi_v, g(x), g(x)_{,\mu}\right) + V_v(\omega_v), \tag{6}$$

$$V_{sv}(\omega_s, \omega_v) = V_{vs}(\omega_s, \omega_v); \tag{7}$$

$$\omega_s \equiv \Omega_s,\ \Phi_s,\ \chi_s; \qquad \omega_v \equiv \Omega_v,\ \Phi_v,\ \chi_v,$$

Here α and β are two parameters and we finally take $\alpha=-\beta=1.V_0$ is a parameter which is so taken that $V_{s\min}(\varpi_s)+V_0=0.$ in the$S-breaking$ or $V_{v\min}(\varpi_v)+V_0=0$ in the V-breaking and at the zero-temperature..

The Higgs potentials in (5) − (7) is the following.

$$\begin{aligned}V_s = &-\frac{1}{2}\mu^2\Omega_s^2+\frac{1}{4}\lambda\Omega_s^4\\&-\frac{1}{2}w\Omega_s^2Tr\Phi_s^2+\frac{1}{4}a\left(Tr\Phi_s^2\right)^2+\frac{1}{2}bTr\left(\Phi_s^4\right)\\&-\frac{1}{2}\varsigma\Omega_s^2\chi_s^+\chi_s+\frac{1}{4}\xi\left(\chi_s^+\chi_s\right)^2,\end{aligned} \tag{8}$$

$$\begin{aligned}V_v = &-\frac{1}{2}\mu^2\Omega_v^2+\frac{1}{4}\lambda\Omega_v^4\\&-\frac{1}{2}w\Omega_v^2Tr\Phi_v^2+\frac{1}{4}a\left(Tr\Phi_v^2\right)^2+\frac{1}{2}bTr\left(\Phi_v^4\right)\\&-\frac{1}{2}\varsigma\Omega_v^2\chi_v^+\chi_v+\frac{1}{4}\xi\left(\chi_v^+\chi_v\right)^2,\end{aligned} \tag{9}$$

$$\begin{aligned}V_{sv} = &\frac{1}{2}\Lambda\Omega_s^2\Omega_v^2+\frac{1}{2}\alpha\Omega_s^2Tr\Phi_v^2+\frac{1}{2}\beta\Omega_s^2\chi_v^+\chi_v\\&+\frac{1}{2}\alpha\Omega_v^2Tr\Phi_s^2+\frac{1}{2}\beta\Omega_v^2\chi_s^+\chi_s,\end{aligned} \tag{10}$$

C. Equations of motion and energy-momentum tensors

$$\begin{aligned}T_{s\mu\nu} &= T_{sM\mu\nu}-g_{\mu\nu}V_s\\&= 2\frac{1}{\sqrt{-g}}\left[\frac{\partial\left(\sqrt{-g}\mathcal{L}_{sM}\right)}{\partial g^{\mu\nu}}-\left(\frac{\partial\left(\sqrt{-g}\mathcal{L}_{sM}\right)}{\partial g^{\mu\nu},_\sigma}\right),_\sigma\right]-g_{\mu\nu}V_s,\end{aligned} \tag{12a}$$

$$\begin{aligned}T_{v\mu\nu} &= T_{vM\mu\nu}-g_{\mu\nu}V_v\\&= 2\frac{1}{\sqrt{-g}}\left[\frac{\partial\left(\sqrt{-g}\mathcal{L}_{vM}\right)}{\partial g^{\mu\nu}}-\left(\frac{\partial\left(\sqrt{-g}\mathcal{L}_{vM}\right)}{\partial g^{\mu\nu},_\sigma}\right),_\sigma\right]-g_{\mu\nu}V_v.\end{aligned} \tag{12b}$$

From (11) we obtain

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R = -8\pi G\left(T_{s\mu\nu}-g_{\mu\nu}V_0-T_{v\mu\nu}\right)\equiv -8\pi GT_{Sg\mu\nu}, \tag{13a}$$

$$T_{Sg\mu\nu} \equiv T_{s\mu\nu}-g_{\mu\nu}V_0-T_{v\mu\nu}=T_{SMg\mu\nu}-g_{\mu\nu}V_{Sg} \tag{13b}$$

$$T_{SMg\mu\nu} \equiv T_{sM\mu\nu}-T_{vM\mu\nu},\qquad V_{Sg}=V_s+V_0-V_v, \tag{13c}$$

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R = -8\pi G\left(T_{v\mu\nu}-g_{\mu\nu}V_0-T_{s\mu\nu}\right)\equiv -8\pi GT_{Vg\mu\nu}, \tag{14a}$$

$$T_{Vg\mu\nu} \equiv T_{v\mu\nu}-g_{\mu\nu}V_0-T_{s\mu\nu}=T_{VMg\mu\nu}-g_{\mu\nu}V_{Vg}, \tag{14b}$$

$$T_{VMg\mu\nu} \equiv T_{vM\mu\nu}-T_{sM\mu\nu},\qquad V_{Vg}=V_v+V_0-V_s, \tag{14c}$$

in the $V-breaking$.

From (1) the total energy-momentum tensor density in the S-breaking which does not contain the energy-momentum tensor of gravitational and repulsive fields can be defined as

$$\begin{aligned} T_{S\mu\nu} &= \frac{2}{\sqrt{-g}}\left(\frac{\partial}{\partial\alpha}+\frac{\partial}{\partial\beta}\right)\left[\frac{\partial\left(\sqrt{-g}\mathcal{L}_S\right)}{\partial g^{\mu\nu}}-\left(\frac{\partial\left(\sqrt{-g}\mathcal{L}_S\right)}{\partial g^{\mu\nu}{}_{,\sigma}}\right)_{,\sigma}\right] \\ &\equiv T_{s\mu\nu}+T_{v\mu\nu}-g_{\mu\nu}\left(V_{sv}+V_0\right)=T_{SM\mu\nu}-g_{\mu\nu}V_S=T_{V\mu\nu}\equiv T_{\mu\nu}, \end{aligned} \tag{15a}$$

$$\begin{aligned} T_{SM\mu\nu} &= T_{sM\mu\nu}+T_{vM\mu\nu}=T_{VM\mu\nu}\equiv T_{M\mu\nu}, \\ V_S &= V_s+V_v+V_{sv}+V_0=V_V\equiv V. \end{aligned} \tag{15b}$$

In fact, $V_{v\min}=V_{sv\min}=0$ due $\langle\omega_v\rangle=0$ in the $S-breaking$, hence $V_{S\min}=V_{s\min}+V_0$.

It should be noticed from $(13)-(15)$ that the potential energy V_{sv} is different from other energies in essence. There is no contribution of V_{sv} to $R_{\mu\nu}$, i.e., there is no gravitation and repulsion of the potential energy V_{sv}. This does not satisfy the equivalence principle. But this does not cause any contradiction with all given experiments and astronomical observations because $V_{sv}=0$ in either of breaking mode.

It is proved that the necessary and sufficient condition of $T^{\mu\nu}_{;\nu}=0$ is I_M to be a scalar quantity[12]. I_S and I_V are all scalar quantities, hence

$$T^{\mu\nu}_{S;\nu}=T^{\mu\nu}_{V;\nu}=0. \tag{16}$$

D. The difference of motion equations of a v-particle and a s-particle in the same gravitational field

The geodesic equations of the present model are the same as the conventional equations, i.e.,

$$\frac{d^2x^\mu}{d\sigma^2}+\Gamma^\mu_{\alpha\beta}\frac{dx^\alpha}{d\sigma}\frac{dx^\beta}{d\sigma}=0. \tag{17}$$

The field equation can be rewritten as

$$R_{\mu\nu}=8\pi G\left[\left(T_{s\mu\nu}-\frac{1}{2}g_{\mu\nu}T_s\right)-\left(T_{v\mu\nu}-\frac{1}{2}g_{\mu\nu}T_v\right)\right], \tag{18}$$

in the $S-breaking$.

Consequently, we have

$$\ddot{x}^k\simeq-\Gamma^k_{00}\simeq-\frac{1}{2}\frac{\partial g_{00}}{\partial x^k},\quad \text{for } \rho_s, \tag{24a}$$

$$\overset{..}{x}^{k} \simeq \Gamma_{00}^{k} \simeq \frac{1}{2}\frac{\partial g_{00}}{\partial x^{k}}, \quad \text{for } \rho_v. \tag{24b}$$

$(24a)$ is the same as (3.2.9) in Ref. [13], and the equation $(24b)$ of motion of a $s-particle$ is different from that of a $v-particle$ in the same gravitational field.

Eq. $(24a)$ and $(24b)$ are consistent with observed data. The reasons are as follows.

A. In the $s-breaking$, in a $s-galaxy$ ρ_v must be very small and ρ_s must be large. Hence the equivalent principle still holds for $s-particles$, and the gravitational field, the equation $(24a)$ and trajectories of motion of $s-particles$ are still the same as those of the conventional theory in observed precision.

B. In the $s-breaking$, the equation $(24b)$ and trajectories of motion of $v-particles$ must be different from those of the conventional theory. But it is impossible to observe the $v-SU(5)$ color single states by a $s-observor$ in practice, because $v-SU(5)$ color single states cannot form dumpling and must loosely distribute in space, and there is only the repulsion between $s-matter$ and $v-matter$. In fact, $(24b)$ has only theoretical meanings.

C. In fact, only the cosmological effects of $v-matter$ are important and are consistent with the observed data up to now.

II. SPONTANEOUS BREAKING OF SYMMETRY AND THE GRAVITATIONAL MASS DENSITY OF THE VACUUM STATE

A. Spontaneous breaking of symmetry

III. EVOLVING EQUATIONS OF SPACE

A. Evolving equations when curvature factor k is regarded as a constant

Provided the cosmological principle is valid, the metric tensor is the Robertson-Walker metric which can be written

$$(ds)^2 = -(dt)^2 + R^2(t)\left\{\frac{(dr)^2}{1-kr^2} + (rd\theta)^2 + (r\sin\theta d\varphi)^2\right\}, \tag{25}$$

where k is the curvature factor. k is regarded an arbitrary real constant in the Friedmann model. When $r \longrightarrow \alpha r$, $R \longrightarrow R/\alpha$ and $k \longrightarrow k/\alpha^2$, (25) is unchanged. Thus, without losing generality, k may be taken as 1, 0 or -1. Here α must be a positive number, hence k cannot change from 1 into 0 or -1 by altering a.

Matter in the universe may approximately be regarded as ideal gas evenly distributed in the whole space when temperature is not very high. The energy-momentum tensor densities of the ideal gas are

$$T_{sM\mu\nu} = (\rho_s + p_s) U_{s\mu} U_{s\nu} + p_s g_{\mu\nu}, \tag{26}$$

Substituting (25) $-$ (26) and the RW metric into (13), we get the Friedmann equations in the $S - breaking$

$$\dot{R}^2 + k = \eta \left[(\rho_s + V_s + V_0) - (\rho_v + V_v)\right] R^2 = \eta \left[\rho_{Sg} + V_{Sg}\right] R^2 \equiv \eta \widetilde{\rho}_{Sg} R^2, \tag{27a}$$

$$\rho_{Sg} \equiv \rho_s - \rho_v, \;\; V_{Sg} \equiv V_s + V_0 - V_v, \quad \widetilde{\rho}_{Sg} = \rho_{Sg} + V_{Sg}, \quad \eta \equiv 8\pi G/3, \tag{27b}$$

$$\begin{aligned} \ddot{R} &= -\frac{1}{2}\eta \left[(\rho_s + 3p_s) - 2\left(V_s + V_0 - V_v\right) - (\rho_v + 3p_v)\right] R. \equiv -\frac{1}{2}\eta \left(\widetilde{\rho}_{Sg} + 3\widetilde{p}_{Sg}\right) R \\ &= -\frac{1}{2}\eta \left[\rho_{Sg} + 3p_{Sg} - 2V_{Sg}\right], \quad p_{Sg} \equiv p_s - p_v, \quad \widetilde{p}_{Sg} = p_{Sg} - V_{Sg}. \end{aligned} \tag{28}$$

Analogously, we get

$$\dot{R}^2 + k = \eta \left[(\rho_v + V_v + V_0) - (\rho_s + V_s)\right] R^2 = \eta \widetilde{\rho}_{Vg} R^2, \tag{29}$$

$$\ddot{R} = -\frac{1}{2}\eta \left[(\rho_v + 3p_v) - 2\left(V_v + V_0 - V_s\right) - (\rho_s + 3p_s)\right] R = -\frac{1}{2}\eta \left(\widetilde{\rho}_{Vg} + 3\widetilde{p}_{Vg}\right) R, \tag{30}$$

in the $V - breaking$.

B. The evolving equations when $K = K(\underline{\rho}_g\left(t, R\left(t\right)\right))$

The evolving equations corresponding to $K(\underline{\rho}_g\left(t, R\left(t\right)\right))$ has been derived[9]

$$\dot{R}^2 + 3K = 8\pi G \rho_g R^2 + \frac{2}{3}\frac{R\dot{R}\ddot{K}}{\dot{K}}, \tag{31}$$

$$\ddot{R} = \left[-4\pi G\left(\rho_g + p_g\right) + \frac{K}{R^2}\right] R - \frac{1}{3}\frac{\dot{R}\ddot{K}}{\dot{K}}. \tag{32}$$

$$\ddot{K} + \frac{3r^2 \dot{K}^2}{2\left(1 - Kr^2\right)} + 3\frac{\dot{R}\dot{K}}{R} = 0. \tag{33}$$

We discuss the evolving equations as follows[9].

1. When $\dot{K} \sim 0$, from (33) we have

$$\frac{\ddot{K}}{\dot{K}} = -3\frac{\dot{R}}{R}. \tag{34}$$

2. When $\dot{R} \longrightarrow 0$, from (31) – (32) we have

$$\begin{aligned} \dot{R} &= 0,\ K = \eta\rho_g R^2 \leq 0, \quad > 0 \text{ are all possible. But only } \leq 0. && \text{(35a)} \\ \ddot{R} &= -\frac{\eta}{2}\left(\rho_g + 3p_g\right) R \geq 0, \quad < 0 \text{ are all possible.} \\ &\simeq -\frac{\eta}{2}\left(\rho_g + \rho_{g\gamma}\right) R = -\frac{\eta R_1^3}{2R^2}\left(\rho_{gm1} + 2\rho_{g\gamma 1}\frac{R_1}{R}\right). && \text{(35b)} \end{aligned}$$

This is similar to the conventional theory only when $\rho_g > 0$. According to present model, ρ_g and $\rho_g + \rho_{g\gamma} = 0$ or < 0 are possible as well. Thus, the present model is different from the conventional theory.

3. When

$$\rho_g = \rho_{gm} + \rho_{g\gamma} = \frac{R_1^3}{R^3}\left(\rho_{gm1} + \rho_{g\gamma 1}\frac{R_1}{R}\right) = \frac{R_1^3}{R^3}\underline{\rho}_g = 0 \text{ so that } K\left(\underline{\rho}_g\right) = 0, \tag{36}$$

(31) – (32) becomes

$$\dot{R}^2 = \frac{2}{3}\frac{R\dot{R}\ddot{K}}{\dot{K}}, \tag{37a}$$

$$\ddot{R} = -\frac{\eta}{2}\rho_{g\gamma}R - \frac{1}{3}\frac{\dot{R}\ddot{K}}{\dot{K}} = -\frac{\eta}{2}\rho_{g\gamma}R - \frac{1}{2}\frac{\dot{R}^2}{R} < 0. \tag{37b}$$

This is because only when $\rho_{gm} < 0$, it is possible that $\rho_{gm} + \rho_{g\gamma} = 0$. Hence $\rho_{g\gamma} > 0$. It is seen that although $\rho_g = K = 0$, it is still possible $\dot{R} > 0$ and $\ddot{R} < 0$. In the case space expands with a deceleration. This is different from the conventional theory in which when $\rho_g = k = 0$, $\dot{R} = \ddot{R} = 0$ is necessary. It is seen that when $\rho_g \sim 0$ and $K \sim 0$, $\dot{K}$ must be considered.

4. Although K is a function of r when $K \sim 0$, ρ_g and R are still independent of r[9].

5. In the $S - breaking$, ρ_s can transform into ρ_v because of $\partial K/\partial t < 0$ when $\rho_s \sim \rho_v$. After reheating, in fact, $\partial V_g/\partial t \sim 0$. It is necessary that $\rho_s = \rho_{sm} + \rho_{s\gamma} \sim \rho_v$ at some a time, because $\rho_{sm} \propto R^{-3}$, $\rho_{s\gamma} \propto R^{-4}$, and $\rho_{sm} < \rho_v = \rho_{vm} \propto R^{-3}$. When $\rho_s \sim \rho_v$, $K \sim 0$, $\partial K/\partial t < 0$ is marked and the universe is matter-dominated so that $p_s - p_v$ may be ignored. Consequently we see

$$d\left[\left(\rho_s - \rho_v\right) R^3\right]/dt = R\left(dk/\eta dt\right) < 0. \tag{38}$$

This implies ρ_s can transform into ρ_v because of $\partial K/\partial t < 0$ when $\rho_s \sim \rho_v$. In fact, in this stage, $s - galaxies$ can be fast formed and (38) holds.

IV. TEMPERATURE EFFECT

A. Two sorts of temperature

B. The influences of finite temperature on the Higgs potential

1. *Critical temperatures and masses of the Higgs particles*

The critical temperature $T_{s,\varphi cr}$ is such a temperature at which the minima are degenerate.

In the $S - breaking$, when $T_s \geq \mu/\sqrt{\lambda} > T_{s,\varphi cr}$, $v_{\varphi v}(T_s, T_v) = v_{\varphi s}(T_s, T_v) = v_{\Omega v} = 0$. Thus the critical temperature $T_{\Omega cr} \equiv T_{cr}$ is determined by $(66c)$

$$T_{cr} = \frac{2\mu}{\sqrt{\lambda}} > T_{s,\varphi cr}, . \tag{39}$$

Thus, when $T_s \geq T_{cr}$,

$$v_{\Omega s}(T_s) = 0,\ V^{(1)T}_{eff\,\min}\left(\overline{\Omega}_s, T_s\right) = V^{(1)T}_{eff}(0, T_s) = 0, \tag{40}$$

C. ρ_s and ρ_v transform from one into another when $T_s \longrightarrow T_{cr}$ so that $\rho_s - \rho_v \longrightarrow 0$

D. Change of w from > 0 to < -1 and q

In the inflation period, $\rho_g = 0$ and $V_g = V_0$. (30) can be rewritten as

$$\frac{\ddot{R}}{R} = -\frac{\eta}{2}\left(V_0 - 3V_0\right). \tag{41}$$

After reheating, $V_g = 0$. In the $V - breaking$,

$$\begin{aligned}\frac{\ddot{R}}{R} &= -\frac{\eta}{2}\left[\left(\rho_{vm} + \rho_{v\gamma} + 3p_{vm} + 3p_{v\gamma}\right) - \left(\rho_{sm} + \rho_{s\gamma} + 3p_{sm} + 3p_{s\gamma}\right)\right] \\ &= -\frac{\eta}{2}\left[\rho + 3p\right],\end{aligned} \tag{42}$$

where

$$\begin{aligned}\rho &\equiv \rho_{vm} + \rho_{v\gamma}, \\ p &\equiv p_{vm} + p_{v\gamma} - \rho_{sm}/3 - \rho_{s\gamma}/3 - p_{sm} - p_{s\gamma},\end{aligned} \tag{43}$$

ρ is the conventional positive mass density, and p is the effective pressure density relative to ρ. When the evolution equation is in the form (42), w is defined as

$$w = p/\rho. \tag{44}$$

Thus, in the inflation period, from (41) we find

$$w = -1. \tag{45}$$

For (42) we have

$$w = \frac{p_{vm} + 3p_{v\gamma} - \rho_{sm}/3 - \rho_{s\gamma}/3 - p_{sm} - p_{s\gamma}}{\rho_{vm} + \rho_{v\gamma}} \tag{46}$$

We suppose that after reheating,

$$\rho_{vm} + \rho_{v\gamma} > \rho_{sm} \gtrsim 2\rho_{vm}. \tag{47}$$

The static masses of all color-single states are non-zero, hence $\rho_{s\gamma} = 0$. In the early period after reheating, temperature is very high so that the masses of particles may be neglected, $p_{vm} \sim \rho_{vm}/3$, $p_{v\gamma} \sim \rho_{v\gamma}/3$ and $p_{sm} \sim \rho_{sm}/3$. Consequently,

$$w \sim \frac{\rho_{vm} + \rho_{v\gamma} - 2\rho_{sm}}{3\left(\rho_{vm} + \rho_{v\gamma}\right)} > 0. \tag{48}$$

Considering $\rho_\gamma \propto R^{-4}$ and $\rho_m \propto R^{-3}$, when R is large enough, from (95) we have

$$w \sim \frac{\rho_{vm} - 2\rho_{sm}}{3\rho_{vm}} < \frac{\rho_{vm} - 4\rho_{vm}}{3\rho_{vm}} < -1. \tag{49}$$

It is seen that w can change from $w > 0$ to $w < -1$ according to the present model..

V. CONTRACTION OF SPACE, THE HIGHEST TEMPERATURE AND INFLATION OF SPACE

On the basis of the cosmological principle, if there is the space-time singularity, it is a result of space contraction. Thus, we discuss the contracting process and find the condition of space inflation. From the contracting process we will see that there is no space-time singularity in present model

We do not consider the couplings of the Higgs fields with the Ricci scalar R for a time. We will see in the following paper that the following conclusions still hold water when such couplings as $\xi R\Omega_s^2$ are considered. In fact, $\xi R\left(\overline{\Omega}_s^2-\overline{\Omega}_v^2\right)=0$ because there is the strict symmetry between $s-matter$ and $v-matter$ when $T\gtrsim T_{cr}$.

We chiefly discuss change of $\langle\Omega_a(T_a)\rangle$ and $\langle\varphi_a(T_a)\rangle$ as temperature, $a=s,v$, in the contracting process of space for short. When $\langle\chi_a(T_a)\rangle$ is considered as well, the inferences are still valid qualitatively.

A. Contraction of space, proof of non-singularity, the highest temperature and inflation of space

Proof. There no singularity of space-time in the present model. ■

1. The end of space contraction is in the most symmetric state in which $\langle\omega_v\rangle=\langle\omega_s\rangle=0$, $T_s=T_v$ and $\rho_s=\rho_v$ so that $\widetilde{\rho}_{Sg}=V_0$

This has been proved in section

2. There is no singularity in the present model on the basis of the cosmological principle.

If space does not contract because $\dot{R}>0$ or $\widetilde{\rho}_{Sg}=0$, it is necessary that there is no space-time singularity. Provided space contract because $\widetilde{\rho}_{Sg}=0$, T_s and T_v must rise. When $T_s\sim T_v\geq T_{cr}\equiv\mu/\sqrt{\lambda}$, $\langle\omega_v\rangle=\langle\omega_s\rangle=0$, the masses of all particles which originate from the couplings with ϖ_s and ϖ_v are zero. Consequently ρ_s and ρ_v can transform from one into another. Thus $\rho_s=\rho_v$, $T_s=T_v$ and $\widetilde{\rho}_{Sg}=V_0$, i.e., the most symmetric state comes into being. In the state, both the $s-SU(5)$ and the $v-SU(5)$ are strictly kept. In the case, from the conjecture 3 and the discussion about $(31)-(33)$, we may take $K=1$. Thus $(27)-(28)$ is reduced to

$$\dot{R}^2=-1+\eta V_0R^2, \tag{50a}$$

$$\ddot{R}=\eta V_0R. \tag{50b}$$

Consequently space inflation must occur and temperature will fast descend.

Let $R_{cr}=R(T_{cr})$. If

$$\dot{R}_{cr}^2=-1+\eta V_0R_{cr}^2\geq 0,\quad \text{i.e.}\quad R_{cr}\geq\sqrt{1/\eta V_0}, \tag{51}$$

R can continue to decrease with a deceleration or stop contracting. Hence there must be the least scale $R_{\min}\leq R_{cr}$, the critical temperature T_{cr}, the highest temperature $T_{\max}$ and the largest energy density $\rho_{\max}$,

$$R_{\min} = \sqrt{1/\eta V_0} \leq R_{cr}, \quad T_{cr} \equiv 2\mu/\sqrt{\lambda}, \tag{52a}$$

$$T_{\max} = T(R_{\min}) = T_{cr} R_{cr}/R_{\min} \geq T_{cr}, \tag{52b}$$

$$\rho_{\max} = \rho_{s\max} + \rho_{v\max} = 2\frac{\pi^2}{30} g^* T_{\max}^4, \quad \text{and} \quad \widetilde{\rho}_{\max} = \rho_{\max} + V_0. \tag{52c}$$

Thus, when R decreases to $R_{\min}$, and space inflation must occur,

$$R = \sqrt{\frac{1}{\eta V_0}} \cosh \sqrt{\eta V_0} (t - t_{FI}) = \sqrt{\frac{1}{\eta V_0}} \cosh H (t - t_{FI}), \quad \sqrt{\eta V_0} \equiv H, \tag{53a}$$

$$= \sqrt{\frac{1}{\eta V_0}} = R_{\min}, \quad \text{when } t = t_{FI} \tag{53b}$$

$$\sim \frac{1}{2}\sqrt{\frac{1}{\eta V_0}} \exp H (t - t_{FI}), \quad \text{when } H (t - t_{FI}) >> 1, \tag{53c}$$

where $\sqrt{\eta V_0} \equiv H$ is the Hubble constant at $t \gtrsim t_{FI}$. t_{FI} is just the last moment of the world in the $S - breaking$ and the initial moment of the world in the $V - breaking$. $R_{\min}$ and T_{cr} are two new important constants, and $T_{\max}$ and $\rho_{\max}$ are determined by R_{cr}. It is seen that all R, T and ρ must be finite. The meanings of the parameters are that when $T = T_{cr}$, $\langle\omega_s\rangle = \langle\omega_v\rangle = 0$ and $R = R_{cr}$, and when $R = R_{\min}$, $T = T_{\max}$ or $\rho = \rho_{\max}$ and $\dot{R} = 0$.

We know that the duration of inflation τ may be long enough for inflation. After τ, R has a large enough increase.

(51) is the condition of space inflation. Because the masses of all particles which originate from the couplings with $\langle\omega_s\rangle$ or $\langle\omega_v\rangle$ are zero and $\rho_s = \rho_v$ when $T \gtrsim T_{cr}$, we have

$$\rho_s R^4 = \rho_{scr} R^4 (T_{cr}) \equiv D_s = D_v = \rho_v R^4 = \rho_{vcr} R^4 (T_{cr}), \quad \rho_a = \frac{\pi^2}{30} g^* T_a^4,$$

$$\rho_{scr} = \rho_{vcr} = \rho_{cr} \equiv \frac{\pi^2}{30} g^* T_{cr}^4 = \frac{\pi^2}{30} g^* \frac{16\mu^4}{\lambda^2}, \quad T_a^4 R^4 = T_{cr}^4 R^4 (T_{cr}). \tag{54}$$

Thus, we can rewrite the condition of inflation (51) as

$$D_v = D_s \geq \left(\frac{K}{\eta}\right)^2 \frac{16\mu^4 g^*}{V_0^2 \lambda^2} = g^* \frac{1}{\eta^2} \left(\frac{4}{\mu}\right)^4 \equiv D_{cr}, \tag{55}$$

here $V_0 = \mu^4/4\lambda$ and $K = 1$ is considered. Thus, when $D_s \geq D_{cr}$, there must be space inflation.

If $R(T_{cr}) < \sqrt{1/\eta V_0}$ or $D_s < D_{cr}$, this implies that $\dot{R} = 0$ already occurs before R contracts to $R(T_{cr})$ or T_s rises to T_{cr}, i.e., $R_{\min} > R(T_{cr})$ and $T(R_{\min}) = T_{\max} < T_{cr}$. Consequently T_{cr} and $R(T_{cr})$ cannot be arrived and there still are $\langle\omega_s(T_s)\rangle \neq 0$ and $\langle\omega_v\rangle = 0$.

In the case, all $R_{\min}$, $T_{\max}$, ρ_g, ρ_s and ρ_v must still be finite because of the cosmological principle, i.e. there is no space-time singularity. In the case, it is necessary

$$\dot{R} = 0, \quad \ddot{R} > 0, \quad \text{when } R = R_{\min}, \tag{56}$$

because $R_{\min}$ is the end of contracting R. In the case, when $R \geq R_{\min}$, the evolving equations are still $(27) - (28)$ and space will expand still in the $S - breaking$ mode, but space inflation cannot occur.

To sum up, we see that in any case of the contracting process, there must be $R_{\min} > 0$ and the finite $T_{\max}$. Because of the cosmological principle, all ρ_s, ρ_v, $\widetilde{\rho}_{Sg} = \widetilde{\rho}_s - \widetilde{\rho}_v$ and $p \leqslant \rho/3$ are finite because of the cosmological principle. Hence $T_{Ss\mu\nu}$, $T_{Sv\mu\nu}$ and $T_{Ss\mu\nu} - T_{Sv\mu\nu}$ must be finite. Substituting the finite $T_{Ss\mu\nu} - T_{Sv\mu\nu}$ into the Einstein field equation (13), we see that $R_{\mu\nu}$ and $g_{\mu\nu}$ must be finite.

Thus, we have proved that there is no singularity in present model.

In fact, when $\widetilde{\rho}_g = \widetilde{\rho}_v - \widetilde{\rho}_s = V_0$, (50) is consistent with the Lemaitre model without singularity in which $\rho_g = 0$, $k = 1$ and the cosmological constant $\lambda_{eff} > 0$[16].

B. The result above is not contradictory to the singularity theorems

We first intuitively explain the reasons that there is no space-time singularity. It has been proved that there is space-time singularity under certain conditions[1]. These conditions fall into three categories. First, there is the requirement that gravity shall be attractive. Secondly, there is the requirement that there is enough matter present in some region to prevent anything escaping from that region. The third requirement is that there should be no causality violations.

Hawking considers it is a reasonable conjecture that $\rho_g > 0$ and $p_g \geq 0$[1]. But this conjecture is not valid. The gravitational mass density $\rho_g = \rho_s - \rho_v > 0$, $= 0$ or < 0 are all possible in the present model.

It is necessary $\rho_g = \rho_s - \rho_v = 0$ because ρ_s and ρ_v can transform from one to another when $T \gtrsim T_{cr}$. It is seen that ρ_g does not increase not only, but also decreases to zero when $T \gtrsim T_{cr}$. Hence the second condition is violated.

The key of non-singularity is that there are $s - matter$ and $v - matter$ with opposite gravitational masses and both can transform from one to another when $T \gtrsim T_{cr}$

We explain the reasons that there is no space-time singularity from the Hawking theorem as follows. S.W. Hawking has proven the following theorem[1].

The following three conditions cannot all hold:

(a) every inextendible non-spacelike geodesic contains a pair of conjugate point;

(b) the chronology condition holds on μ;

(c) there is an achronal set $\mathfrak{T}$ such that $E^{+}(\mathfrak{T})$ or $E^{-}(\mathfrak{T})$ is compact.

The alternative version of the theorem can obtained by the following two propositions.

Proposition 1[1]:

If $R_{ab}V^aV^b \geq 0$ and if at some point $p = \gamma(s_1)$ the tidal force $R_{abcd}V^cV^d$ is non-zero, there will be values s_0 and s_2 such that $q = \gamma(s_0)$ and $r = \gamma(s_2)$ will be conjugate along $\gamma(s)$, providing that $\gamma(s)$ can be extended to these values.

Proposition 2[1]:

If $R_{ab}V^aV^b \geq 0$ everywhere and if at $p = \gamma(v_1)$, $K^aK^bK_{[a}R_{b]cd[e}K_{f]}$ is non-zero, there will be v_0 and v_2 such that $q = \gamma(v_0)$ and $r = \gamma(v_2)$ will be conjugate along $\gamma(v)$ provided that $\gamma(v)$ can be extended to these values.

An alternative version of the above theorem is the following.

Space-time (μ, g) is not timelike and null geodesically complete if:

(1) $R^{ab}K_aK_b \geq 0$ for every non-spacelike vector $\boldsymbol{K}$.

(2) The generic condition is satisfied, i.e. every non-spacelike geodesic contains a point at which $K_{[a}R_{b]cd[e}K_{f]}K^cK^d \neq 0$, where $\boldsymbol{K}$ is the tangent vector to the geodesic.

(3) The chronology condition holds on μ (i.e. there are no closed timelike curves).

(4) There exists at least one of the following:

(A) a compact achronal set without edge,

(B) a closed trapped surface,

(C) a point p such that on every past (or every future) null geodesic from p the divergence $\widehat{\vartheta}$ of the null geodesics from p becomes negative (i.e. the null geodesics from p are focussed by the matter or curvature and start to reconverge).

This theorem is an alternative version of the above theorem. This is because if μ is timelike and null geodesically complete, (1) and (2) would imply (a) by above propositions 1 and 2, (1) and (4) would imply (c), and (3) is the same as (b).

In fact, R_{ab} is determined by the gravitational energy-momentum tensor T_{gab}. According to the conventional theory, $T_{gab} = T_{ab}$ so that the above theorem holds.

In contrast with the conventional theory, according to conjecture 1, in the $s-breaking$,

$$\begin{aligned} R_{\mu\nu} &= -8\pi G\left(T_{g\mu\nu}-\frac{1}{2}g_{\mu\nu}T_g\right) \\ &= -8\pi G\left[\left(T_{s\mu\nu}-T_{v\mu\nu}\right)-\frac{1}{2}g_{\mu\nu}\left(T_s-T_v\right)\right]. \end{aligned} \tag{57a}$$

Consequently, $R_{00}>0$, $=0$ and <0 are all possible. Thus, although the strong energy condition holds, i.e.

$$\left[\left(T_s^{ab}+T_v^{ab}\right)-\frac{1}{2}g^{ab}\left(T_s+T_v\right)\right]K_aK_b\geq 0, \tag{57b}$$

the conditions of propositions 1 and 2 and condition (1) do not hold. Hence (a) and (c) do not hold, but (b) still holds, and μ is timelike and null geodesically complete..

C. The process of space inflation

As mentioned before, the duration of space inflation is finite. Supposing $\lambda\sim g^4$, $g^2\sim 4\pi/45$ for $SU(5)$, and considering $m(\Omega_s)=\sqrt{2}\mu$, we can estimate $T_{\max}$,

$$T_{\max}\gtrsim\frac{2\mu}{\sqrt{\lambda}}\sim\frac{2\mu}{g^2}\sim\frac{\sqrt{2}m(\Omega_s)}{4\pi/45}=5m(\Omega_s). \tag{58}$$

The temperature will strikingly decrease in the process of inflation, but the potential energy $V\left(\varpi_s\sim\varpi_v\sim 0\right)\sim V_0$ cannot decrease to $V_{\min}\left(T_v\right)$ at once, because this is a super-cooling process.

We can get the expecting results by suitably choosing the parameters in $(8)-(10)$. In order to estimate $H=\sqrt{\eta V_0}$, taking $V_0\sim\mu^4/4\lambda$, from (59) we have

$$H=aT_{\max}^2,\quad a\equiv\sqrt{\eta\lambda}/8\sim g^2\sqrt{\eta}/8. \tag{59}$$

We can take $T_{\max}$ to be the temperature corresponding to GUT because the $SU(5)$ symmetry strictly holds water at $T_{\max}$.

Taking $T_{\max}\sim 5m\left(\Omega_s\right)\sim 5\times 10^{15}Gev$ and $\sqrt{\lambda}/8\sim g^2\sim 0.035$, we have $H^{-1}=10^{-35}s$. If the duration of the super-cooling state is $10^{-33}s\sim\left(10^8Gev\right)^{-1}$, $R_{\min}$ will increase $exp100\sim 10^{43}$ times. As mentioned before, the duration τ of inflation may be long enough, $\tau\sim 1/T_b$[15]. Taking $T_{\max}\sim 10^{15}Gev$ and $T_b\sim 10^8Gev$, we have $H^{-1}=10^{-35}s$ and $\tau\sim 10^{-33}s$ so that $R_{\min}$ will increase 10^{43} times. The result is consistent with the Guth's inflation model[17].

Before inflation, the world in the $S-breaking$ is in thermal equilibrating state. If there is no $v-matter$, because of contraction by gravitation, the world would become a thermal-equilibrating singular point, i.e., the world would be in the hot death state. As seen, it is necessary that there are both $s-matter$ and $v-matter$ and both the $S-breaking$ and the $V-breaking$.

VI. EXPANSION OF SPACE AFTER INFLATION

A. The reheating process

From the decaying process we see it is necessary $\alpha > (1-\alpha)$. Let $\rho_v' = \rho_s'$ before the transition, it is necessary after transition that

$$\rho_v = \rho_v' + \alpha V_0 > \rho_s = \rho_s' + (1-\alpha)V_0. \tag{60}$$

This is the reheating process, after which, the $v-particles$ get their masses, but the $s-gauge$ bosons and the elementary $s-fermions$ are still massless since $s-SU(5)$ is not broken. Both $v-matter$ and $s-matter$ can exist in the form of plasma for a short period, because T_s and T_v must be very high in the initial period after reheating.

B. Change of gravitational mass density in comoving coordinates

We take the order of time to be $t_0 > t_1 \geq t_2 > t_3 > t_{FI} = 0$.

Hence ρ_v/ρ_s must decrease as R increases because $\rho_m \propto R^{-3}$ and $\rho_\gamma \propto R^{-4}$. In the case, $V_g = 0$ and $(29)-(30)$ reduces to

$$\dot{R}^2 + k = \eta\left(\rho_{vm} + \rho_{v\gamma} - \rho_{sm}\right)R^2 = \eta\rho_g R^2, \tag{61a}$$

$$\ddot{R} \simeq -\frac{\eta}{2}\left(\rho_{vm} + 2\rho_{v\gamma} - \rho_{sm}\right)R = -\frac{\eta}{2}\left(\rho_{mg} + 2\rho_{v\gamma g}\right)R, \tag{61b}$$

where p_{vm} and p_{sm} are neglected and $p_{v\gamma} = \rho_{v\gamma}/3$ is considered.

Suppose when $t = t_3$ (e.g. $t_3 \sim 10^4 \sim 10^5 a$), $v-atoms$ have formed, $v-photons$ have decoupled, $s-SU(5)$ color single states have formed, $\rho_{sm}(t_3) = x\rho_{vm}(t_3)$, $\rho_{v\gamma}(t_3) = y_3\rho_{vm}(t_3)$ and

$$\begin{aligned} \rho_v \ &= \ \rho_{v\gamma}(t_3) + \rho_{vm}(t_3) > \rho_{sm}(t_3) > \rho_{vm}(t_3), \\ \text{or} \ \ y_3 + 1 \ &> \ x > 1. \end{aligned} \tag{62}$$

After the photons decoupled, the number n_{vN} of the $v - nucleons$ and the number $n_{v\gamma}$ of the $v - photons$ are invariant and $n_{vN0}/n_{v\gamma 0} \sim 5 \times 10^{-10}$ when space expansion. The number n_s of the $s - colour$ single states is invariant as well. Let $\underline{\rho}_{Vg}(t, R(t)) = \underline{\rho}_{Vg}(R(t))$, then $\rho_{sm} \propto R^{-3}$, $\rho_{vm} \propto R^{-3}$ and $\rho_{v\gamma} \propto R^{-4}$. Thus the gravitational mass density $\underline{\rho}_{Vg}(t)$ in comoving coordinates is changeable,

$$\underline{\rho}_g(t) = \underline{\rho}_{vm}(t_0)\left(1 - x + y_0 R(t_0)/R(t)\right), \tag{63}$$

where $y_0 = \rho_{v\gamma 0}/\rho_{vm0}$ and $\underline{\rho}_{vm}(t_3) = \underline{\rho}_{vm}(t_0)$ is considered. Let $\rho_{Vg}(t_2) = 0$, then considering the conjecture 3, we have

$$\rho_g(t_2) = K(t_2) = 0, \quad \frac{R(t_3)}{R(t_2)} = (x-1)/y_3, \quad \text{or} \quad \frac{R(t_0)}{R(t_2)} = (x-1)/y_0. \tag{64}$$

Thus when $t > t_2$, $\rho_{Vg}(t) < 0$ and $K(t) < 0$. x is invariant and y is changeable. For example, we may take $y_3 = 1$ and $y_0 = 1/6000$.

C. Space expands with a deceleration

From (63) – (64) we see when $0 < t < t_2$, $\rho_{Vg}(t) > 0$ so that $K\left(\underline{\rho}_g\right) > 0$. From we have

$$\dot{R}^2 + K = \eta\rho_{Vg}R^2 = \eta\frac{R^3(t_3)}{R}\rho_{vm}(t_3)\left[(1-x) + \frac{y_3 R(t_3)}{R}\right], \tag{65a}$$

$$\begin{aligned}\ddot{R} &= -\frac{\eta}{2}\left(\rho_{Vg} + \rho_{v\gamma}\right) \\ &= -\frac{\eta}{2}\frac{R^3(t_3)}{R^2}\rho_{vm}(t_3)\left[(1-x) + 2\frac{y_3 R(t_3)}{R}\right].\end{aligned} \tag{65b}$$

In the case, $(1-x) + y_3 R(t_3)/R > 0$. Hence $(1-x) + 2y_3 R(t_3)/R > 0$ so that $\ddot{R} < 0$, i.e., space must expand with a deceleration in the period.

D. Space expands with an acceleration

We consider the expanding process of space. After reheating, $V_{Vg} \sim 0$. Based on the discussion about (31) – (33) we may conclude when $t \gg t_3$, say $t \geq t_1$, so that $R(t) \gg R(t_3)$,

$$\rho_{Vg}(t) \sim \rho_{vm}(t_3)\left(-x + 1 + yR(t_3)/R(t)\right) \ll 0,$$

$\dot{K} \sim 0$, $K < 0$ and K can be taken as -1. Thus, in the $V - breaking$, from $(29) - (30)$ we have

$$\dot{R}^2 = 1 + \eta\rho_g R^2 = 1 - \eta\frac{C_0}{R}\left(x - 1 - \frac{y_0 R_0}{R}\right)$$

$$\dot{a}^2 = H_0^2\left(1 + \Omega_{g0}\right)\left[1 - \frac{1}{\left(1 + \Omega_{g0}\right)}\left(\frac{\Omega_{gm0}}{a} - \frac{\Omega_{v\gamma0}}{a^2}\right)\right], \tag{66a}$$

$$\ddot{R} = \frac{\eta}{2}\frac{C_0}{R^2}\left(x - 1 - 2\frac{y_0 R_0}{R}\right), \quad \ddot{a} = \frac{H_0^2}{2}\left(\frac{\Omega_{gm0}}{a^2} - 2\frac{\Omega_{v\gamma0}}{a^3}\right), \tag{66b}$$

where $\rho_g = \rho_{Vg}$ for simplicity, $C_0 = \rho_{m0}R_0^3$, $a = R/R_0$, $\dot{a}_0^2 = H_0^2 = \eta\rho_c = \eta\rho_{gc}$, $\Omega_{gm0} = \left(\rho_{sm0} - \rho_{vm0}\right)/\rho_c = \left(x - 1\right)\rho_{vm0}/\rho_c$, $\Omega_{v\gamma0} = \rho_{v\gamma0}/\rho_c = y_0\rho_{vm0}/\rho_c$, $\Omega_{g0} = \left(\rho_{sm0} - \rho_{vm0} - \rho_{v\gamma0}\right)/\rho_c$, $H_0^2 R_0^2 = 1/\left(1 + \Omega g_0\right)$. It is obvious that when $R_0/R < \left(x - 1\right)/2y_0$, $\dot{R} > 0$ and $\ddot{R} > 0$, i.e., space will expand with an acceleration.

E. To determine $a\left(t\right)$

It is difficult to uniformly describe the three evolving stages space since $K\left(t\right)$ is difficultly determined. Considering $K = -1$ is applicable to all cases $\rho_g > 0$, $\rho_g = 0$, and $\rho_g < 0$, as a crude approximation for $\rho_g > 0$ (thereby $K > 0$) and $\rho_g = 0$ (thereby $K = 0$), we describe expansion of space by $(66a)$ in which $K = -1$. In fact, when $\eta\rho_g R^2 \gg 1$, K may be ignored. Because when $\rho_g > 0$ and $K > 0$, space expands with a deceleration, and when $\rho_g < 0$ and $K < 0$, space expands with an acceleration, the period of $\rho_g = K = 0$ can be approximately solved. The result is qualitatively consistent with $(66a)$. As mentioned before, when $t \leq t_1$, $\ddot{R}\left(t\right) < 0$ so that space expands with a deceleration. From $(66a)$ we have

$$\begin{aligned} t \ = \ & t_0 - \frac{1}{H_0\sqrt{1 + \Omega_{g0}}}\{\sqrt{1 - M + \Gamma} - \sqrt{a^2 - Ma + \Gamma} \\ & + \frac{M}{2}\ln\frac{2 - M + 2\sqrt{1 - M + \Gamma}}{2a - M + 2\sqrt{a^2 - Ma + \Gamma}}\}, \end{aligned} \tag{67}$$

where $M = \Omega_{gm0}/\left(1 + \Omega_{g0}\right)$, $\Gamma = \Omega_{v\gamma0}/\left(1 + \Omega_{g0}\right)$.

Taking $\Omega_{v\gamma0} = 0.001$, $\Omega_{gm0} = 0.3\Omega_{v\gamma0} + 2\sqrt{\Omega_{v\gamma0}}$, $H_0^{-1} = 9.7776 \times 10^9 h^{-1} yr$[8] and $h = 0.8$, we get $a\left(t\right)$. $a\left(t\right)$ is shown by the curve B in the figure 1 and describes evolution of the cosmos from $14 \times 10^9 yr$ ago to now. Taking $\Omega_{v\gamma0} = 0.05$, $\Omega_{gm0} = 2\sqrt{\Omega_{v\gamma0}}$, we get the $a\left(t\right)$ which is shown by the curve A in the figure 1 and describes evolution of the cosmos from

$13.7 \times 10^9 yr$ ago to now. Provided $\Omega_{gm0} \leqslant 2\Omega_{v\gamma0} + 2\sqrt{\Omega_{v\gamma0}}$ (the condition $\dot{a}^2 > 0$), we can get a curve of $a(t)$ which describes evolution of the cosmological scale.

From the two curves we see that the cosmos must undergo a period in which the cosmos expands with a deceleration in the past and present period in which the cosmos expands with an acceleration.

Ignoring $\Omega_{v\gamma0}$, $\Omega_{gm0} \longrightarrow -\Omega_{gm0}$ and taking $a \sim 0$, we can reduce (67) to the corresponding formula (3.44) in Ref. [8]

F. The relation between redshift and luminosity distance

Considering $k = -1$, from (25) and (66a) we have

$$\int_a^1 \frac{cda}{R\dot{a}} = -\int_r^0 \frac{dr}{\sqrt{1+r^2}}, \tag{68}$$

$$\begin{aligned} H_0 d_L = H_0 R_0 r(1+z) = & \frac{2c}{\left(\Omega_{gm0} - 2\Omega_{v\gamma0}\right)^2 - 4\Omega_{v\gamma0}} \cdot \\ & \{2\left(1+\Omega_{g0}\right) - \left(1+z\right)\Omega_{gm0} \\ & - \left[2\left(1+\Omega_{g0}\right) - \Omega_{gm0}\right]\sqrt{1 - \left(\Omega_{gm0} - 2\Omega_{v\gamma0}\right)z + \Omega_{v\gamma0}^2 z^2}\}, \end{aligned} \tag{69}$$

where $z = (1/a) - 1$ is the redshift caused by R increasing. Provided $\Omega_{gm0} \longrightarrow -\Omega_{gm0}$, (69) is consistent with the corresponding formula (3.81) in Ref. [8]. Ignoring $\Omega_{v\gamma0}$, $\Omega_{gm0} \longrightarrow -\Omega_{gm0}$ we reduce (69) to

$$H_0 d_L = \frac{2c}{\Omega_{gm0}^2}\left\{2 + \Omega_{gm0}\left(1-z\right) - \left[2+\Omega_{gm0}\right]\sqrt{1-\Omega_{gm0} z}\right\}, \tag{70a}$$

which is consistent with (3.78) in Ref. [8]. Approximating to Ω_{m0}^1 and z^2, we obtain

$$H_0 d_L = z + \frac{1}{2}z^2\left(1 + \frac{1}{2}\Omega_{gm0}\right). \tag{70b}$$

Taking $\Omega_{v\gamma0} = 0.001$, $\Omega_{gm0} = 0.3\Omega_{v\gamma0} + 2\sqrt{\Omega_{v\gamma0}}$ and $H_0^{-1} = 9.7776 \times 10^9 h^{-1} yr$[8] and $h = 0.8$, from (69) we get the $d_L - z$ relation which is shown by the curve A in the figure 2; Taking $\Omega_{v\gamma0} = 0.05$, $\Omega_{gm0} = 2\sqrt{\Omega_{v\gamma0}}$ we get the $d_L - z$ relation which is shown by the curve B in the figure 2.

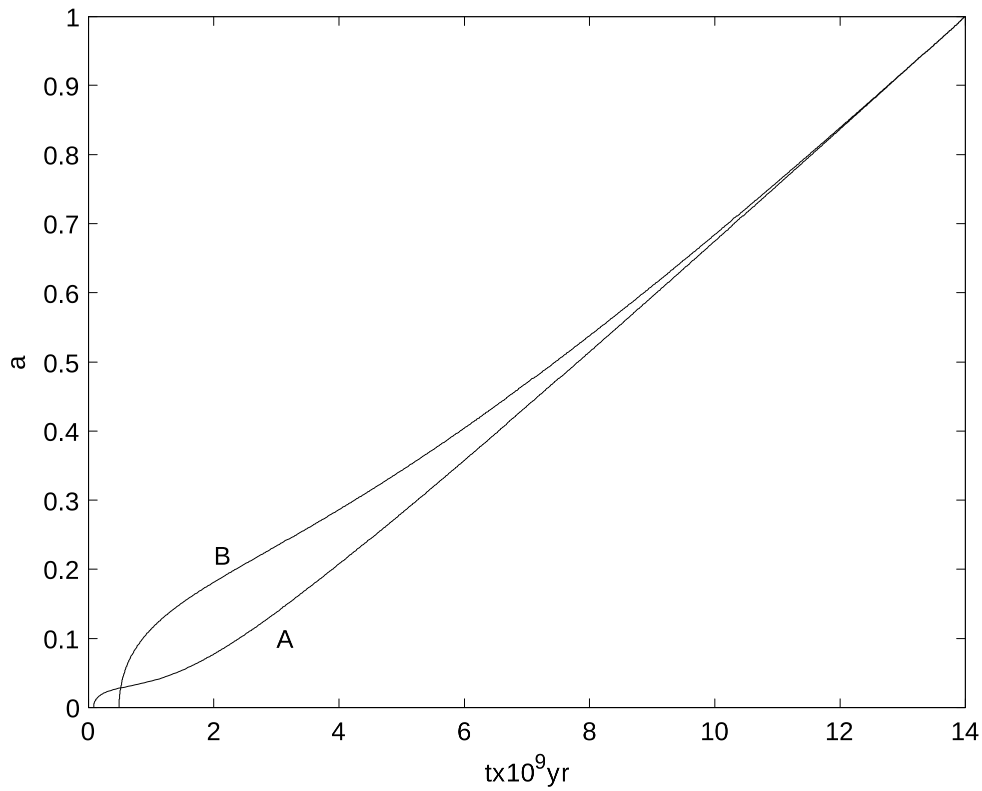

FIG. 1: The curve A describes evolution of $a(t)$ from $14\times 10^9 yr$ ago to now; The curve B describes evolution of $a(t)$ from $13.7\times 10^9 yr$ ago to now.

VII. DYNAMICS OF V-STRUCTURE FORMATION AND THE DISTRIBUTIVE FORM OF THE S-SU(5) COLOR SINGLE STATES

Defining the comoving spatial coordinates

$$\mathbf{x}(t)=a\left(t\right)\mathbf{r}\left(t\right), \qquad \delta\mathbf{v}\left(t\right)=a\left(t\right)\mathbf{u}\left(t\right), \tag{71}$$

we have $\nabla_x=\nabla_r/a$. Let

$$\delta_{vk}=\delta_{vk}\left(t\right)\exp\left(-i\mathbf{k}_v\cdot\mathbf{r}\right), \qquad \delta_{sk}=\delta_{sk}\left(t\right)\exp\left(-i\mathbf{k}_s\cdot\mathbf{r}\right), \tag{72a}$$

$$c_v^2=\frac{\partial p_v}{\partial\rho_v}, \qquad c_s^2=\frac{\partial p_s}{\partial\rho_s}, \tag{72b}$$

we can get

$$\left(\frac{\partial}{\partial t}+\mathbf{v}_{v0}\cdot\boldsymbol{\nabla}\right)^2\delta_{vk}+2\frac{\dot{a}}{a}\dot{\delta}_{vk}=4\pi G\left(\rho_{v0}\delta_{vk}-\rho_{s0}\delta_{sk}\right)-\frac{c_v^2k_v^2}{a^2}\delta_{vk}. \tag{73}$$

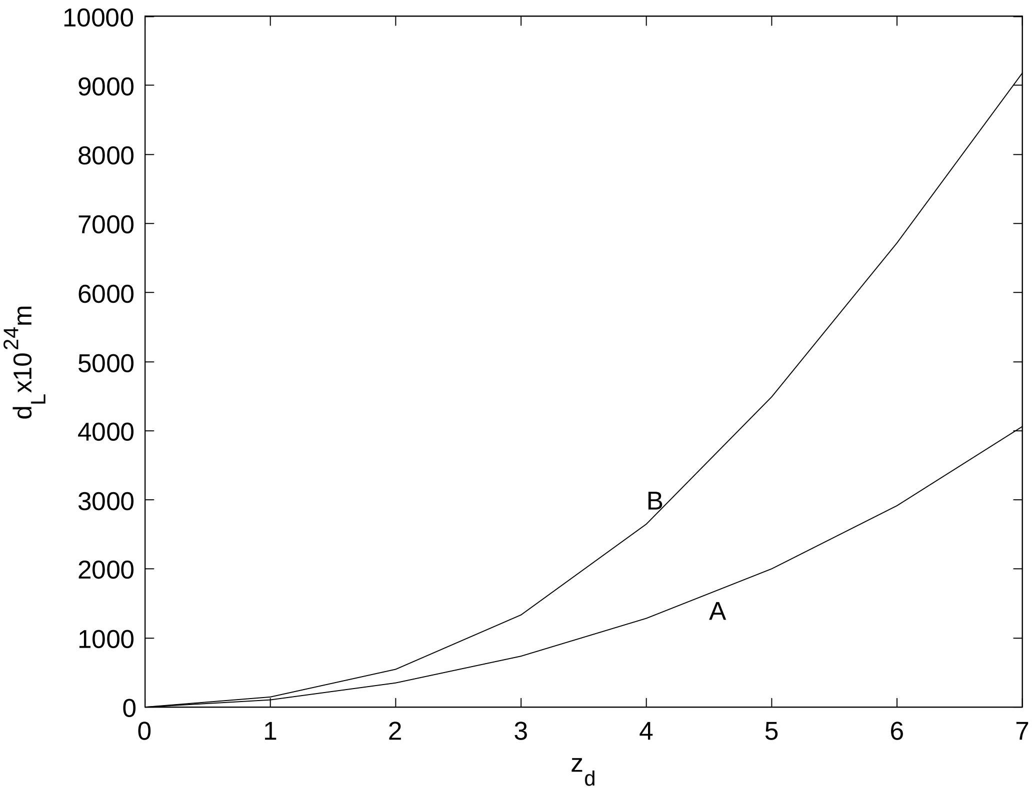

FIG. 2: The curve A describes the $d_L - z$ relation when $\Omega_{v\gamma 0} = 0.001$and $\Omega_{m0} = 0.3\Omega_{v\gamma 0} + 2\sqrt{\Omega_{v\gamma 0}}$; The curve B describes the $d_L - z$ relation when $\Omega_{v\gamma 0} = 0.05$and $\Omega_{m0} = 2\sqrt{\Omega_{v\gamma 0}}$

$$\left(\frac{\partial}{\partial t} + \mathbf{v}_{s0} \cdot \boldsymbol{\nabla}\right)^2 \delta_{sk} + 2\frac{\dot{a}}{a}\dot{\delta}_{sk} = 4\pi G \left(\rho_{s0}\delta_{sk} - \rho_{v0}\delta_{vk}\right) - \frac{c_s^2 k_s^2}{a^2}\delta_{sk}. \tag{74}$$

It is necessary that $\delta_{sk} < 0$ when $\delta_{vk} > 0$ because there is only repulsion between $s - matter$ and $v - matter$. Consequently,

$$\rho_{v0}\delta_{vk} - \rho_{s0}\delta_{sk} = \rho_{v0}\delta_{vk} + \rho_{s0} \mid \delta_{sk} \mid, \tag{75a}$$

$$\rho_{s0}\delta_{sk} - \rho_{v0}\delta_{vk} = \rho_{s0}\delta_{sk} + \rho_{v0} \mid \delta_{vk} \mid . \tag{75b}$$

According to the present model, there must be $\dot{a}/a = \left(-K/a^2 + \eta\rho_g\right)^{1/2} \sim 0$, because $\rho_v = \rho_{vm} + \rho_{v\gamma}$, $\rho_{vm} \propto R^{-3}$, $\rho_{v\gamma} \propto R^{-4}$, $\rho_s = \rho_{sm} > \rho_{vm}$, and $\rho_{sm} \propto R^{-3}$ so that $\rho_g = \rho_v - \rho_s = 0$ and $K = 0$. There possibly is $\delta_{vk}(t) > \delta_{sk}(t)$ when $\rho_v = \rho_s$, because $s - SU(5)$ color single states in the $V - breaking$ can be regarded as ideal gas without collision. The ideal gas has the effect of free flux damping for clustering. Ignoring δ_{sk} in (73), for $\dot{a}/a \sim 0$ and

$(4\pi G\rho_{v0} - c_v^2 k_v'^2) > 0$, from (73) we get

$$\ddot{\delta}_{vk}(t) = \left(4\pi G\rho_{v0} - c_v^2 k_v'^2\right)\delta_{vk}, \qquad \delta_{vk}(t) = \exp\left(t/\tau\right) \ , \tag{76}$$

where $k_v' = k_v/a$, $\tau = 1/\sqrt{4\pi G\rho_{v0} - c_v^2 k_v'^2}$. We see that $\delta_{vk}(t)$ will exponentially grow for long-wavelength. We cannot get the result as (76) for δ_{sk} from (74), because the velocity v_{s0} of a $s - SU(5)$ color single state is invariant because there is no collision and is very big. Let the duration in which $\dot{R} \sim 0$ be $\triangle t$, the distance l to be damped out is $l = v_{s0}\triangle t$. The perturbation whose size is less than l cannot form. Thus $s - SU(5)$ color single states can only form superclusterings. When $\rho_{s0} > \rho_{v0}$, $\rho_{s0}\delta_{sk} - \rho_{v0}\delta_{vk} > 0$ is possible. Consequently, the $s - SU(5)$ color single states possibly form superclusterings, because when $\left(\dot{a}/a\right)$ is large, the perturbation will slowly grow in power rules.

From the above mentioned, we see that the $s - SU(5)$ color single states must loosely distribute in space or form $s - superclustering$, i.e., huge $v - voids$, in which $\rho_s \gg \rho_v$.

To sum up, because of the following two reasons, the perturbation δ_{vk} will grow faster or earlier than that determined by the conventional theory.

1. There is such a stage in which $\rho_s - \rho_v \sim 0$ and $K(\rho) \sim 0$ so that $\dot{R}/R = \dot{a} \sim 0$, because the gravitational masses of $s - matter$ and $v - matter$ are opposite and $K(\rho)$ is changeable. Consequently, from (73) and (76) we see that $\delta_{vk}(t)$ will exponentially grow for long-wavelength in the stage.

2. From (73), (75) and (76) we see that $\delta_{vk}(t)$ can grow faster than that determined by (76) because $\rho_{v0}\delta_{vk} + \rho_{s0} \mid \delta_{sk} \mid > \rho_{v0}\delta_{vk}$. The origin is the repulsion between $s - matter$ and $v - matter$.

VIII. SOME GUESSES, NEW PREDICTIONS AND AN INFERENCE

A. Some guesses

1. The universe is composed of infinite s-cosmic islands and v-cosmic islands

From this we present a new cosmic model as follows.

The universe is composed of infinite $s - cosmic$ islands and and $v - cosmic$ islands. $\langle\omega_v\rangle = 0$ and $\langle\omega_s\rangle = \langle\omega_s\rangle_0$ in $s - cosmic$ islands, and $\langle\omega_s\rangle = 0$ and $\langle\omega_v\rangle = \langle\omega_v\rangle_0$ in the the $v - cosmic$ islands.

A $s-cosmic$ island or a $v-cosmic$ island must be finite. There must be a transitional region ($T-region$) between a $s-cosmic$ island and a $v-cosmic$ island. In the $T-region$, it is necessary $\langle\omega_s\rangle$ and $\langle\omega_v\rangle$ change from $\langle\omega_s\rangle = \langle\omega_s\rangle_0$ and $\langle\omega_v\rangle = 0$ into $\langle\omega_s\rangle = 0$ and $\langle\omega_v\rangle = \langle\omega_v\rangle_0$, respectively. Consequently, the expectation values $\langle\omega_s\rangle_T$ and $\langle\omega_v\rangle_T$ inside the $T-region$ must satisfy

$$0 <\mid \langle\omega_s\rangle_T \mid<\mid \langle\omega_s\rangle_0 \mid, \quad 0 <\mid \langle\omega_v\rangle_T \mid<\mid \langle\omega_v\rangle_0 \mid . \tag{77}$$

There must be only $v-cosmic$ islands neighboring a $s-cosmic$ island. This is because that if two $s-cosmic$ islands are neighboring, they must form one new larger $s-cosmic$ island.

It is obvious that if there is only one sort of breaking, it is impossible that such cosmic islands exist.

Based on the following reasons, the probability is very little that a $v-observer$ accepts messages from a $s-cosmic$ island.

1. The probability must be very small that a $s-particle$ (a quark, a lepton or a photon) in the $s-cosmic$ island comes into the $v-cosmic$ island, because a $s-particle$ in a $s-cosmic$ island is $s-SU(5)$ non-color single state. If a $s-particle$ comes into the $v-cosmic$ island, it would still be non-color single state and would get very big mass. This is impossible due to color confinement. But a bound state of the $s-particles$, e.g. $\left(u\overline{u} \mp d\overline{d}\right)/\sqrt{2}$ which is a color single state in both $V-breaking$ and $S-breaking$, possibly comes into the $v-cosmic$ island. It is hardly funded by a $v-observer$ because the boson $\left(u\overline{u} \mp d\overline{d}\right)/\sqrt{2}$ is a $s-colour$ single state in the $v-cosmic$ island which is a particle of dark energy. .

2. The probability must be very small that a $v-particle$ in the $s-cosmic$ island come into the $v-cosmic$ island as well. The $v-particle$ (a fermion or a gauge boson) in the $s-cosmic$ island must be massless. If the massless $v-particle$ comes into the $v-cosmic$ island, it would get its mass. Thus its static mass will change from $m_0 = 0$ to $m_0 > 0$ so that it must suffer a strong-repulsive interaction, hence it hardly comes into the $v-cosmic$ island.

3. Higgs particles in the $s-cosmic$ island must decay fast into fermions or gauge bosons, hence they cannot come to the $v-cosmic$ island.

4. $T-regions$ is so big that the probability through which a particle passes is very small..

The probability must be very small that particles leave the $v-cosmic$ island because of the same reasons.

A $v-cosmic$ islands and a $s-cosmic$ island can influence on each other by the Higgs potential in the $T-region$ between both.

As a consequence a $v-observer$ in the $v-cosmic$ island can regard the $v-cosmic$ island as the whole cosmos. It is possible that Some cosmic islands are forming or expanding, and the other cosmic islands are contracting.

Thus, according to the present model the cosmos as a whole is infinite and its properties are always unchanging, and there is no starting point or end of time.

2. Mass redshifts

Hydrogen spectrum is

$$\omega_{nk} = (E_n - E_k)/\hbar = -\frac{\mu e^4}{2\hbar^3}(\frac{1}{n^2} - \frac{1}{k^2}), \quad \mu = \frac{mM}{m+M}, \tag{78}$$

where m is the mass of an electron, and M is the mass of a proton. According the unified model, $m \propto v_e$, the mass of a quark $m_q \propto v_q$, where v_e and v_q are the expectation values of the Higgs fields coupling with the electron and the quark, respectively. $M \propto m_q$.

If there are some galaxies inside a $T-region$, from (77) we see that the mass m_T of an electron and the mass M_T of a proton inside the $T-region$ must be

$$m_T < m, \quad M_T < M.$$

Thus we have

$$\mu_T < \mu, \quad \triangle\, \omega_{nk} = \omega_{nk} - \omega_{nkT} = -\frac{(\mu - \mu_T)e^4}{2\hbar^3}(\frac{1}{n^2} - \frac{1}{k^2}) < 0. \tag{79}$$

The sort of red-shifts is called $mass\ redshift$. The mass redshift is essentially different from the cosmological red-shift mentioned before. Thus, the photons coming from the star in a $T-region$ must have larger red-shift than that determined by the Hubble formula at the same distance. Thereby we guess that some quasars are just the galaxies in the $T-region$ of our cosmos island.

An ordinary $s-galaxy$ and a $s-quasar$ can be neighboring, because a $T-region$ must be neighboring to an ordinary region.

B. New predictions

1. It is possible that huge voids is equivalent to a huge concave lens. The density of hydrogen and the density of helium in the huge voids predicted by the present model must be more less than that predicted by the conventional model.

A. A $v - void$ must be huge, because there is no other interaction among the $s - SU(5)$ color single states except the gravity and the masses of the $s - SU(5)$ color single states are very small.

B. When $v - photons$ pass through such a huge $v - void$, the $v - photons$ must suffer repulsion from ρ_s' and are scattered by ρ_s' as they pass through a huge concave lens. Consequently, the galaxies behind the huge $v - void$ seem to be darker and more remote.

C. Both density of matter and density of dark matter in huge voids must be more lower than those predicted by the conventional theory. Specifically, the density of hydrogen in the huge voids must be more less than that predicted by the conventional theory. Right or mistake of the predict can be confirmed by the observation of distribution of hydrogen.

It is seen that the present model can well explain the characters of some huge voids. This is a decisive prediction which distinguishes the present model from other models.

2. The gravitation between two galaxies distant enough will be less than that predicted by the conventional theory.

There must be $s - matter$ between two $v - galaxies$ distant enough, hence the gravitation between the two $v - galaxies$ must be less than that predicted by the conventional theory due to the repulsion between $s - matter$ and $v - matter$. When the distance between the two $v - galaxies$ is small, the gravitation is not influenced by $s - matter$, because ρ_s must be small when ρ_v is big.

3. A black hole with its mass and density big enough will transform into a white hole

Let there be a $v - black$ hole with its mass and density to be big enough so that the critical temperature T_{cr} can be reached in the $V - breaking$. If its mass is so big that its temperature $T_v \gtrsim 2\mu/\sqrt{\lambda}$ since the black hole contracts by its self-gravitation, then the expectation values of the Higgs fields inside the $v-black$ hole will change from $\varpi_v = \varpi_{v0}$ and $\varpi_s = 0$ into $\varpi_v = \varpi_s = 0$. Consequently, inflation must occur. After inflation, the highest symmetry will transit into the $V-breaking$ or the $S-breaking$. No matter which breaking appears, the energy of the black hole must transform into both $v-energy$ and $s-energy$. Thus, a $v-observer$ will find that the black hole disappears and a white hole appears.

In the process, part of $v-energy$ transforms into $s-energy$. A $v-observer$ will consider the energy not to be conservational because he cannot detect $s-matter$ except by repulsion. The transformation of black holes is different from the Hawking radiation. This is the transformation of the vacuum expectation values of the Higgs fields. There is no contradiction between the transformation and the Hawking radiation or another quantum effect, because both describe different processes and based on different conditions (the density and mass of the black hole must be large enough so that its temperature $T_v \gtrsim 2\mu/\sqrt{\lambda}$). According to the present model, there still are the Hawking radiation or other quantum effects of black holes. In fact, the universe is just a huge black hold. The universe can transform from the $S-breaking$ into the $V-breaking$ because of its contraction or expansion. This transformation is not quantum effects.

Let there be a $v-cosmic$ island neighboring on a $s-cosmic$ island. It is possible that the $v-cosmic$ island transforms into a $s-cosmic$ island after it contracted. In this case, a $s-observer$ in the $s-cosmic$ island must observe a very huge white hole.

C. The transformation of the cosmic ultimate

As mentioned before, in the $V-breaking$, when $\rho_s > \rho_v$, space will expand with an acceleration. It seems that the universe will alwayse expand withan acceleration. This is impossible. In the expanding process of the universe, galaxies can be continue to exist and $v-matter$ will gather so that a huge $v-black$ hole with its mass and density big enough can be formed after long enough time, because the repulsion between s-matter and v-matter and the gravitation among $v-particles$. After the temperature of the black hole reaches the critical temperature T_{cr}, the expectation values of all Higgs fields will tend to zero and the local space will expand. In the case, both $V-breaking$ and $s-breaking$ are possibly realized. If the density of $v-matter$ around the huge $v-black$ hole is little enough, the $S-breaking$ will is realized. Consequently the $V-breaking$ transforms into the $S-breaking$ and the $v-world$ transforms the $s-world$. If the density of $v-matter$ around the huge $v-black$ hole is very large, the $V-breaking$ will is realized. This is because the transformation of symmetry breaking must cause the transformation of existing form of matter. $V-matter$ whose temperature is low around the huge v-black hole will prevent the transformation of the $V-breaking$ into the $S-breaking$. After the average density of v-matter is little because space expands and a huge $v-black$ hole with its mass and density big enough formed, the transformation of the $V-breaking$ into the $S-breaking$ can occur.

It is seen that in the both cases that the universe is little enough because space contracts or is large enough because space expands, it will occur that one sort of breaking transforms into the other and the world transforms the other world.

D. An inference :$\lambda_{eff} = \lambda = 0$, although $\rho_0 \neq 0$

The effective cosmological constant $\lambda_{eff} = \lambda + \rho_{g0}$. The conventional theory can explain evolution with a small λ_{eff}. Such a small λ_{eff} cannot be derived from a elementary theory. According to the conventional quantum field theory, $\lambda_{eff} = \lambda + \rho_0$, $\rho_0 \ggg \lambda_{eff}$, In fact, ρ_0 is divergence. According to the conventional gravitational theory, $\rho = \rho_g = \rho$ $(c = 1)$. Consequently, the issue of the cosmological constant appears.

$\rho_0 = 0$ can be obtained by some supersymmetric model, but it is not a necessary result. On the other hand, the particles predicted by the supersymmetric theory have not been found, although their masses are not large.

$\rho_0 = 0$ is a necessary result of our quantum field theory without divergence[6]. In this theory, $\rho_0 = 0$ is naturally obtained without normal order of operators, there is no divergence of loop corrections, and dumpling dark matter is predicted[7].

According to the present model, $\lambda_{eff} = \lambda = 0$, although ρ_0 is still very big according to the conventional quantum field theory.

Proof: $\lambda_{eff} = \lambda = 0$, although $\rho_0 \neq 0$.

Applying the conventional quantum field theory to the present model, we have $\rho_0 = \rho_{s0} + \rho_{v0}$. Both ρ_{s0} and ρ_{v0} must be two constants. According to the conjecture 1, $s-particles$ and $v-particles$ are strictly symmetric in essence. Hence

$$\rho_{s0} = \rho_{v0} = \rho_0/2.$$

According to the conjecture 1, the gravitational mass of $s-matter$ is opposite to that of $v-matter$. i.e., $\rho_{gs}=-\rho_{gv}$ when $\rho_s=\rho_v$. Hence we have

$$\rho_0 = \rho_{s0}+\rho_{v0}=2\rho_{s0}\neq 0, \tag{80a}$$

$$\rho_{g0} = \rho_{sg0}+\rho_{vg0}=0. \tag{80b}$$

Thus, there is no the fine tuning problem, even if $\lambda_{eff}\neq 0$.

$\lambda_{eff}=0$ is a necessary inference, because evolution of the cosmos can be explained by the present model without λ_{eff}. Consequently, although $\rho_0\neq 0$, we have still

$$\lambda_{eff}=0=\lambda+\rho_{g0}=\lambda. \tag{81}$$

This is an direct inference of the present model, and independent of a quantum field theory. Thus, the cosmological constant issue has been solved.

For the vacuum state in the $S-breaking$ or the $V-breaking$, the Einstein field equation is reduced to

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=-8\pi G\left(T_{s0\mu\nu}-T_{v0\mu\nu}\right)=-8\pi G\left(T_{v0\mu\nu}-T_{s0\mu\nu}\right)=0. \tag{82}$$

This is a reasonable result.

IX. PRIMORDIAL NUCLEOSYNTHESIS

A. F-W dark matter model

The $F-W$ dark matter model[7] is a necessary inference of the quantum field theory without divergence. The $F-W$ dark matter model is similar with the mirror dark matter model.

According to the mirror dark matter model, it is impossible that the density of matter is equal to that of dark matter in order to explain the primordial nucleosynthesis and $CMBR$. This is too difficultly understood, because matter and mirror matter are symmetric and both can transform from one into another when temperature is high enough.

In contrast with the mirror dark matter model, according to the $F-W$ matter model, $F-matter$ (ordinary matter) and $W-matter$ (dark matter) are not only symmetric, but also $\rho_{vF}=\rho_{vW}$. If the total density of matter and dark energy is ρ_t and the ratio of the density of dark energy ρ_{de} to ρ_t is 0.73, $(\rho_{vF}+\rho_{vW})/\rho_t = 2\rho_{vF}/\rho_t = 0.27$. Considering only $F-baryon$ matter is visible and the radio of the density ρ_{vFB} to ρ_t is $\rho_{vFB}/\rho_t = 0.04$, dark matter can be classified into the following three sorts: invisible $F-matter$ for a time whose density is $\rho_{vFu} = (0.27/2-0.4)\,\rho_t = 0.095\rho_t$, invisible $W-baryon$ matter whose density is $\rho_{vWB} = 0.04\rho_t$, and invisible $W-non-baryon$ matter whose density is $\rho_{vWu} = 0.095\rho_t$. ρ_{vWB} can form dark galaxies and can be observed, ρ_{vWu} and ρ_{vFu} cannot form any dumpling. The $vFu-particles$ is possibly observed in future. ρ_{vF} and ρ_{vW} can transform from one into another when temperature is high enough.

According to the present cosmological model, there are $s-matter$ and $v-matter$ which are symmetric in principle. After symmetry spontaneously breaking, $s-matter$ and $v-matter$ are no longer symmetric. In the $V-breaking$, $v-matter$ corresponds visible matter and dark matter, $s-matter$ corresponds to so-called dark energy and must exist in the form of the $s-SU(5)$ color single states. The masses of all color single states are non-zero. But the masses are different from each other. Some masses of color single states (their density are denoted by ρ_{sl}) are possibly less than $1Mev$ so that they may be ignored when temperature $T \gtrsim 1Mev$, and the others (their density are denoted by ρ_{sm}) are larger than $1Mev$. ρ_{sm} and ρ_{sl} can be determined based on observation.

When the $F-W$ dark matter model and the present cosmological model are simultaneously considered, the primordial nucleosynthesis and CMBR can be explained.

B. Primordial nucleosynthesis

According to the $F-W$ matter model[7] which is similar with the mirror dark matter model, the mechanism of primordial nucleosynthesis is the same as the conventional theory. But the mechanism of space expansion of the present model is different from that of the conventional theory. For short, we consider only influence of space expansion on the primordial nucleosynthesis and $CMBR$.

The primordial helium abundance Y_4 is determined by n_n/n_p[8],

$$Y_4 = 2/\left[1+(n_n/n_p)^{-1}\right], \tag{83a}$$

$$n_n/n_p = exp\,(-\triangle m/kT_1)\,, \quad \triangle m = m_n - m_p, \tag{83b}$$

where n_n/n_p is the neutron-proton ratio in the unit comoving volume at the freeze-out temperature T_1. T_1 is determined by $\Gamma_1 = \Gamma(T_1)$ and $H_1 = \eta\rho_g(T_1)$, here .Γ is the interaction rate experienced by a particle.

As mentioned above,

$$\rho_{vFm} = \rho_{vWm}, \quad \rho_{vF\gamma} = \rho_{vW\gamma}, \; \rho_v = 2\rho_{vFm} + 2\rho_{vF\gamma}, \quad \rho_s = \rho_{sm} + \rho_{sl},$$

and in the $V-breaking$, $T_1 = T_{v1}$ and in general $T_{v1} \neq T_{s1}$. Since the masses of all $s-color$ single states are non-zero, it is possible there are some $s-color$ single states with their masses $m_{sm} \gtrsim 1Mev$ and the others with their masses m_{sl} and $1Mev > m_{sl} > 1ev$. Thus, when $T_s \gtrsim 1Mev$, m_{sl} may be ignored so that $\rho_{sl} \propto T_s^4$, and when $T_s \lesssim 1ev$, $\rho_s = \rho_{sm} + \rho_{sl} \propto T_s^3$.

Considering $m_p \sim m_n \sim 1Gev$, $m_e = 0.511Mev$, $m_\gamma = 0$ and $m_{\nu i}$, $i = e$, μ and τ, are regarded as zero, $g_e = 7/2$, $g_\gamma = 2$ and $g_{\nu i} = 7/4$ so that $g^* = 10.75$. When $T \sim T_{v1} \sim T_{s1} \sim 1Mev$, m_e may be ignored and the universe is dominated by ρ_{sl} and $\rho_{s\gamma}$, we have

$$\begin{aligned} H_1^2 &= \frac{\dot{R}^2(T_1)}{R^2(T_1)} = \eta\rho_g(T_1) = \eta\left[\rho_v(T_{v1}) - \rho_s(T_{s1})\right] \\ &= \eta\left[\left(\rho_{vFm} + \rho_{vWm} + \rho_{vF\gamma} + \rho_{vW\gamma}(T_{v1})\right) - \left(\rho_{sm} + \rho_{sl}(T_{s1})\right)\right] \\ &\simeq \eta\left[\rho_{vF\gamma} + \left(\rho_{vW\gamma}(T_{v1}) - \rho_{sl}(T_{s1})\right)\right] \\ &= \eta\left[\frac{\pi^2}{30}g^*T_{v1}^4 + \left(\frac{\pi^2}{30}g^*T_{v1}^4 - \rho_{sl}(T_{s1})\right)\right]. \end{aligned} \tag{84}$$

$$\rho_{sl}(T_s)/\rho_{sl}(T_{s1}) \propto T_s^4/T_{s1}^4 = (R_1/R)^4 = T_v^4/T_{v1}^4, \quad \text{when } T_v \gtrsim T_{vdec}, \tag{85}$$

where T_{vdec} is the $v-photon$ decoupling temperature (see the following). ρ_{sl} and ρ_{sm} are two parameters which should be determined by observations. $\rho_{sl}(T_{s1})$ can be so chosen that

$$\frac{\pi^2}{30}g^*T_{v1}^4 - \rho_{sl}(T_{s1}) \sim 0, \tag{86a}$$

$$H_1^2 \sim \eta\frac{\pi^2}{30}g^*T_{v1}^4. \tag{86b}$$

For the freeze-out temperature T_{v1} is determined by Γ_1 and H_1. Γ_1 in the present model is the same as that in the conventional theory. $(86b)$ is the same as that in the conventional theory as well. Hence the present model can explain the primordial nucleosynthesis and Y_4 as the conventional theory. For example, taking the rough approximation $\Gamma_1 = H_1$, considering $(86b)$, we get the equation to determine T_{v1}

$$\Gamma_1(T_{v1}) \sim G_F^2T_{v1}^5 = H_1 = \left[\eta\left(\rho_v(T_{v1}) - \rho_s(T_{s1})\right)\right]^{1/2} \simeq \left(\eta\frac{\pi^2}{30}g_v^*T_{v1}^4\right)^{1/2}. \tag{87}$$

This result and n_n/n_p and Y_4 corresponding to this are the same as those of the conventional theory[19].

It is seen that although ordinary matter and dark matter are completely symmetric so that $\rho_{vF} = \rho_{vW}$, we can still obtained the result of conventional theory, provided the F-W dark matter model and the present model are simultaneously considered. This is different from the mirror dark matter model.

X. COSMIC MICROWAVE BACKGROUND RADIATION ($CMBR$)

A. The recombination temperature T_{rec}

It is the same as the conventional theory that there are the inflation and big bang processes in the present model. Hence there must be the cosmic microwave background radiation ($CMBR$).

The recombination temperature of the present model is the same as that of the conventional theory, because it is independent of s-matter in the V-breaking. From the following formulas[19] we can determine the recombination temperature T_{rec},

$$\frac{1-\chi}{\chi^2} = 1.1 \times 10^{-8} \xi T_v^{3/2} \exp\left(B/T_v\right), \quad A \equiv T_v/Tv0.$$

where $\chi = n_e/n = n_p/n$, $n = n_p + n_H$ to be number density and $B = 13.6ev$ is the ionization potential of hydrogen. Taking $\xi \sim 5 \times 10^{-10}$ and $\chi = 0.1$, considering $n_e = n_p$, $n_\gamma = \left(\zeta\left(3\right)/\pi^2\right) g_\gamma T^3 = \left(2.4/\pi^2\right) T^3$, $n = \xi n_\gamma$, $T_v = Tv0\left(T_v/Tv0\right)$ and $Tv0 = 2.35 \times 10^{-4} ev$, we have[19]

$$T_{rec} = 3423.5K = 0.295ev. \tag{88a}$$

$$(1 + z_{rec}) = T_{rec}/Tv0 = 1255. \tag{88b}$$

B. The temperature T_{eq} of matter-radiation equality

In contrast with the conventional theory, according to the $F-W$ dark matter model, $F-matter$ and $W-matter$ are completely symmetric so that not only there are $F-photon$ (ordinary photons), but also $W-photons$ (dark-matter photons). $\rho_{v\gamma} = \rho_{vF\gamma} + \rho_{vW\gamma} = 2\rho_{vF\gamma}$,

$\rho_{vm} = \rho_{vFm} + \rho_{vWm} = 2\rho_{vFm}$. From this we can estimate the temperature T_{eq} of matter-radiation equality as follows.

When only the photons and the three species of neutrinos are considered (here the three species of neutrinos are regarded as massless)., we have[18]

$$\rho_{vF\gamma} = \rho_{vW\gamma} = \frac{\pi^2}{30} g_\gamma^* \left(\frac{kT_v}{\hbar c}\right)^4 . \tag{89a}$$

$$g_\gamma^* = 2 + \frac{7}{8} \times 6 \times \left(\frac{4}{11}\right)^{4/3} = 3.36. \tag{89b}$$

Thus, considering $T_{v0} = T_0 = 2.728K = 2.35 \times 10^{-4} ev$, we get

$$\begin{aligned} \rho_{vr0} &= 2\rho_{vFr0} = 2 \times \left[\frac{3.36}{2} \times \frac{\pi^2}{30} \times 2 \times \left(2.35 \times 10^{-13} Gev\right)^4\right] \\ &= 6.7425 \times 10^{-51} Gev^4. \end{aligned} \tag{90}$$

Observation shows that the total density of matter and dark matter is $\rho_0 = \Omega_0 \rho_c = 0.27\rho_c$. According to the $F - W$ model, this implies

$$\begin{aligned} \rho_{v0} &= 2\rho_{vFm0} + 2\rho_{vFr0} \simeq \rho_{vm0} = \Omega_0 \rho_c \\ &= 1.8789 \times 10^{-26} h^2 \Omega_0 \cdot kg \cdot m^{-3} = 9.238 \times 10^{-48} Gev^4, \quad \text{when } h = 0.65. \end{aligned} \tag{91}$$

where $h = 0.5 - 0.8$, $\rho_{vm0} = \rho_{vFm0} + \rho_{vWm0}$, and $\rho_{vr0} = \rho_{vF\gamma 0} + \rho_{vWr0} = 2\rho_{vF\gamma 0} = 2\rho_{r0}$.

From $(90) - (91)$ T_{veq} can be determined

$$\rho_{vmeq}(T_{veq}) = \rho_{vm0}\left[R_0/R_{eq}(T_{veq})\right]^3 = \rho_{v\gamma 0}\left[R_0/R_{eq}(T_{veq})\right]^4 = \rho_{v\gamma eq}(T_{veq}), \tag{92a}$$

$$\begin{aligned} \frac{R_0}{R_{eq}} &= \frac{T_{veq}}{T_{v0}} = \frac{\rho_{vm0}}{\rho_{v\gamma 0}} = \frac{\Omega_0 \rho_c}{2\rho_{vFr0}} = (1 + z_{eq}) = 1370, \\ T_{veq} &= 0.32 ev, \ \text{when } h = 0.65, \end{aligned} \tag{92b}$$

$$\begin{aligned} \frac{R_0}{R_{eq}} &= \frac{T_{veq}}{T_{v0}} = \frac{\rho_{vm0}}{\rho_{v\gamma 0}} = 1272, \\ T_{veq} &= 0.295 ev = T_{rec}, \ \text{when } h = 0.624. \end{aligned} \tag{92c}$$

According to the conventional theory, $\rho_{\gamma 0} = \rho_{vr0}/2$, $\rho_0 = \rho_{v0}$, hence if $h = 0.65$ and $\Omega_0 = 0.27$,

$$T'_{eq} = T_0 R_0 / R'_{eq} = \left(1 + z'_{eq}\right) T_0 = \left(\rho_{m0}/\rho_{r0}\right) T_0 = 2\left(\rho_{m0}/\rho_{vr0}\right) T_0 = 0.64 ev = 2T_{veq}. \tag{93}$$

It is seen that T'_{eq} is remarkably different from T_{veq}. When $T_v \sim T_{veq}$, the universe is not matter-dominated.

C. Decoupling temperature

Let when $T_v = T_{veq}$, $T_s = T_{sq}$, $\rho_{sm}(T_{sq}) = t_{mq}\rho_{vm}(T_{veq})$ and the masses of all s-color single states cannot be ignored, i.e. $\rho_{sm}(T_{sq}) = \rho_s(T_{sq})$. Considering

$$\frac{T_{sq}}{T_s} = \frac{R}{R_{eq}} = \frac{T_{veq}}{T_v}, \tag{94}$$

$$\begin{aligned} \rho_{vm} &= A\Omega_{m0}\rho_c, \quad A \equiv \frac{Tv}{Tv0}, && (95a) \\ \rho_{v\gamma} &= \left(\frac{T_{v0}}{Tveq}\right) A^4\Omega_{m0}\rho_c, && (95b) \\ \rho_{sm} &= t_{mq}^3 A\Omega_{m0}\rho_c, && (95c) \end{aligned}$$

Ignoring K, considering $H_0 = \sqrt{\eta\rho_c} = 65km\cdot(s\cdot Mpc)^{-1} = 1.4\times10^{-42}Gev$, $\Omega_{vm0} = 0.27$, and $T_{v0}/Tveq = (2.35\times10^{-4})/0.32 = 0.734\times10^{-4}$,we get

$$\begin{aligned} H^2 &= \eta\rho_g = \eta\left(\rho_{vm} + \rho_{v\gamma} - \rho_{sm}\right) \\ &= 0.27\times1.4^2\times10^{-82}A^3\left(1 - t_{mq} + 0.734\times10^{-3}A\right)Gev. \end{aligned} \tag{96}$$

$$\Gamma = n_{vFe}\sigma_{th} = \chi\xi n_{vF\gamma}\sigma_{th} = \frac{2.4}{\pi^2}\xi T_{v0}^3\sigma_{th}\chi A^3 = 5.4\times10^{-36}\xi\chi A^3 Gev, \tag{97}$$

$$\frac{1-\chi}{\chi^2} = 1.1\times10^{-8}\xi T_v^{3/2}\exp\frac{13.6}{T_v} = 3.96\times10^{-14}\xi A^{3/2}\exp\frac{57872}{A}, \tag{98}$$

where $T_v = T_{v0}(T_v/T_{v0}) = 2.35\times10^{-4}A$ is considered. Only for comparison of the present model with the conventional theory, we use the same equation (98) and the same crude approximation $\Gamma = H$ to evaluate the decoupling temperature. Taking $\Gamma = H$, and $t_{mq} = 1.5$, from (97) – (98) we have

$$\begin{aligned} A^{3/2} &= \xi^{-1}1.347\times10^{-7}\left(1 - t_{mq} + 0.734\times10^{-3}A\right)^{1/2} \\ &\quad + \xi^{-1}7.185\times10^{-28}\times\left(1 - t_{mq} + 0.734\times10^{-3}A\right)\times\exp\frac{57872}{A} \end{aligned} \tag{99}$$

Taking $t_{mq} = 1.5$ and $\xi = 5\times10^{-10}$, we get

$$1 + z_{dec} = 1097, \quad T_{vdec} = 0.258ev, \quad \chi = 0.004. \tag{100}$$

Taking $t_{mq} = 1.5$ and $\xi = 3\times10^{-10}$, we get

$$1 + z_{dec} = 1108, \quad T_{vdec} = 0.260ev, \quad \chi = 0.0068, \tag{101}$$

Taking place of (96) by the equation in the conventional theory

$$H^2 = \eta\rho_g = \eta\rho_{vm} = 0.27 \times 1.4^2 \times 10^{-82} A^3 Gev, \tag{102}$$

we have

$$\begin{aligned} 1 + z_{dec} &= 1121, \quad T_{vdec} = 0.263ev, \quad \chi = 0.007, \\ \text{when } t_{mq} &= 1.5, \ \ \xi = 5 \times 10^{-10}, \end{aligned} \tag{103}$$

$$\begin{aligned} 1 + z_{dec} &= 1132, \quad T_{vdec} = 0.266ev, \quad \chi = 0.012, \\ \text{when } t_{mq} &= 1.5, \ \ \xi = 3 \times 10^{-10}. \end{aligned} \tag{104}$$

z_{dec} is not susceptible for change of t_{mq} in the scope $1.1 - 1.7$.

Considering

$$\frac{\rho_{vmdec}}{\rho_{vmeq}} = \left(\frac{T_{vdec}}{T_{veq}}\right)^3, \quad \frac{\rho_{v\gamma dec}}{\rho_{v\gamma eq}} = \left(\frac{T_{vdec}}{T_{veq}}\right)^4, \quad \rho_{vmeq} = \rho_{v\gamma eq}, \tag{105}$$

we have

$$\frac{\rho_{v\gamma dec}}{\rho_{vmdec}} = \frac{T_{vdec}}{T_{veq}} = \frac{0.258}{0.32} = 0.81. \tag{106}$$

It is seen from (106) that in the decoupling stage, $\rho_{vmdec} \sim \rho_{v\gamma dec}$ and the universe is not matter-dominated. This is different from the conventional theory.

D. Space-time is open, i. e. $K < 0$.

The first peak of the $CBMR$ power spectra is the evidence of existence of the elementary wave. The elementary wave began at reheating ($T = T_{reh}$) and ended at recombination after 3.8×10^5 years ($T = T_{rec}$) according to the conventional theory. Let the temperature of reheating is T_{reh}. In the period T_{reh} descends into T_{rec}, baryons exist in plasma. The sound speed of plasma is $c_s = \partial p/\partial\rho = \sqrt{5T_b/3m_p}$. Let the period in which T_{reh} descends into T_{rec} is $\triangle t_{hc}$ according to the present model and that according to the conventional theory is $\triangle t'_{hc} = 3.8 \times 10^5 a$, there must be

$$\triangle t_{hc} > \triangle t'_{hc}. \tag{107}$$

The reasons are as follows.

That (86) holds implies

$$\rho_{vFr}\left(T_{v1}\right)+\left(\rho_{vWr}\left(T_{v1}\right)-\rho_{sl}\left(T_{s1}\right)\right)\sim\rho_{vFr}\left(T_{v1}\right)=\rho_{\gamma}\left(T_{1}\right), \tag{108}$$

where $\rho_m(T_v)$ and $\rho_\gamma(T_v)$ are the mass density in the conventional theory. It is necessary that when $T_v \geq T_{v1}$, (86) or (179) still holds. This is because $\rho_{sl}(T_s) \propto R^{-4}$, $\rho_{vF\gamma}(T_v) = \rho_{vW\gamma}(T_v) \propto R^{-4}$ and $\rho_{v\gamma}(T_v) \gg \rho_{vm}(T_v)$ and $\rho_{sl}(T_s) \gg \rho_{sm}(T_s)$ when $T_v \geq T_{v1}$. When $T_v < T_{v1}$, it is necessary that $\rho_{vW\gamma}(T_v) < \rho_{sl}(T_s)$. This is because $\rho_{vF\gamma}(T_v) = \rho_{vW\gamma}(T_v) \propto R^{-4}$ still holds, but $\rho_{sl}(T_s) \propto R^{-3}$ (due to $1Mev > m_{sl} \gtrsim 1ev$) when $T_v < T_{v1}$. Hence when $T_v < T_{v1}$,

$$H^2\left(T_v\right)=\eta\rho_g\left(T_v\right)<\eta\left(\rho_m\left(T\right)+\rho_\gamma\left(T\right)\right)=\eta\rho_g'\left(T\right)=H'^2\left(T\right). \tag{109}$$

This implies (107) to hold. On the other hand, the sound speed $c_{vs} = \partial p_v/\partial\rho_v$ is determined by only p_v and ρ_v or T_v and m_p, and is independent of ρ_s. Hence $c_{vs} \sim c_s'$ when T_{reh} descends into T_{rec}, here c_s' is the sound speed in the conventional theory when $T_{reh} \geq T \geq T_{rec}$. Thus when temperature descends from T_{reh} descends into T_{rec}, the propagating distance of the elemintary sound wave must be longer according to the present model than that according to the conventional theory.

Based on $\triangle t'_{hc} = 3.8 \times 10^5 a$, space-time is flat or $K = 0$ as the conventional theory, but based on $\triangle t_{hc} > \triangle t'_{hc}$ and $c_s = c_s' = \partial p/\partial\rho$, space-time is open or $K < 0$ as the the present model. This is consistent with the present model according which $K < 0$ when $\rho_g = \rho_v - \rho_s < 0$ in present stage. We will discuss the issue in detail in the following paper.

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