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

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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 can contract and causes temperature to rise. When it reaches the critical temperature, masses of all particles are zero so that 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. A formula is obtained which well describes the relation between a luminous distance and its redshift. The equations of structure formation have been derived, on which, galaxies can form earlier than the conventional theory. The universe is composed of infinite s-cosmic islands and v-cosmic islands. 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 densities of hydrogen and helium 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 $w \sim -1$. 
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I. INTRODUCTION

We consider that it is impossible to solve the singularity issue of space-time and the issue of the cosmological constant in the frame of the conventional theory, so that new conjectures are necessary. On the basis of a new essential conjecture, we can solve the two issues, well explain evolution of the universe and the characters of huge voids, and give new predictions and some guesses.

As is now well known, there is space-time singularity under certain conditions\textsuperscript{[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. Because of the theorems, there must be space-time singularity in the conventional theory. On the other hand, there should be no space-time
singularity in physics. Hence this problem must be solved.

Recent astronomical observations show that the universe expanded with a deceleration earlier while is expanding with an acceleration now. This implies that there is dark energy. 0.73 of the total energy density of the universe is dark energy density[2]. What is dark energy? Many possible answers have been given. One possible interpretation is in terms of the effective cosmological constant \( \lambda_{\text{eff}} = \lambda + \rho_{g0} \), here \( \lambda \) and \( \rho_{g0} \) are respectively the Einstein’s cosmological constant and the gravitational mass density of the vacuum state. According to the equivalent principle, \( \rho_{g0} = \rho_0 \), \( \rho_0 \) is the mass density of the vacuum state, hence \( \lambda_{\text{eff}} \) may written as \( \lambda + \rho_0 \). \( \lambda_{\text{eff}} \) cannot be derived from basic theories[3] and \( \rho_0 \gg \lambda_{\text{eff}} \). Hence the interpretation is unsatisfactory. Alternatively, dark energy is associated with the dynamics of scalar field \( \phi (t) \) that is uniform in space[4]. This is a seesaw cosmology[5]. Thus, discussion about the universe expansion with an acceleration is still open to the public.

\[ \rho_{g0} = \rho_0 \gg 0 \] originates from the conventional quantum field theory and the equivalent principle. \( \rho_0 \gg \lambda_{\text{eff}} \) and the singularity issue imply that the conventional theory is not self-consistent. \( \rho_0 = 0 \) is a necessary result of our quantum field theory without divergence[6]. In this theory, there is no divergence of loop corrections, and dumpling dark matter is predicted[7]. It is different from the supersymmetric quantum field theory in which \( \rho_0 = 0 \) can be obtained in only some models but is not necessary. Thus, issue of the cosmological constant is open as well.

Huge voids in the cosmos have been observed[8]. The model in which the hot dark matter (e.g. neutrinos) is major can explain the phenomenon, however, it cannot explain the structure with middle and small scales. Hence this is an open problem as well.

We consider that all important existing forms of matter, dark matter and dark energy, to be presented. Hence the basic problems, e.g. divergence problem in quantum field theory, cosmological constant and space-time singularity problems in cosmology, should be solved based on the important existing forms of matter. We have constructed a quantum field theory without divergence by dark matter. We construct a model of the universe without singularity in the paper by dark energy.

We consider the following conditions 1 and 2 to be necessary in order to solve the singularity and the cosmological constant problems in the basis of the classical cosmology and the frame of the conventional quantum field theory. The third condition is necessary to cause the space inflation.
**Condition 1** There are two sorts of matter which are symmetric, whose gravitational masses are opposite to each other and whose energies are all positive.

The two sorts of matter are called $s$–matter and $v$–matter, respectively. The condition implies that if $\rho_s = \rho_v$, $\rho_{gs} = -\rho_{gv}$.

**Condition 2** When temperature is high enough, the thermal equilibrium between the two sorts of matter can come into being, $\rho_s$ and $\rho_v$ can transform from one into another so that $\rho_g = \rho_{gs} + \rho_{gv} = \rho_s - \rho_v = 0$.

**Condition 3** $\rho_g = \rho_s - \rho_v = 0$ and $V = V_0 = V_{\text{max}} > 0$ when $T \geq T_{\text{cr}}$, here $T_{\text{cr}}$ is the critical temperature.

The conditions 1 and 2 cannot be realized in the conventional theory. In order to uniformly solve the above four problems on one basis, we present new conjectures (see section 2) and construct a cosmological model on the basis of the conjectures\textsuperscript{[9]}.

The basic idea of the present model is the conjecture 1, which realizes the conditions Consequently there is no singularity of space-time and $\rho_{g0} = 0$ is proven, although $\rho_0$ is still very large. Thus, there is no the fine tuning problem, even if $\lambda_{\text{eff}} \neq 0$. There are two sorts of breaking modes which are called $S$–breaking and $V$–breaking due to the conjecture 1. $\rho_g > 0$, $= 0$ or $< 0$ are all possible due to the conjecture 1. Hence the curvature factor $k$ in the $RW$ metric should be changeable. We consider $k$ to be a function of $\rho_g$, $\rho_g$ is the gravitational mass density in comoving coordinates, i.e., $K = K \left( \rho_g (t, R(t)) \right)$. The evolving equations corresponding to $K$ have been derived\textsuperscript{[9]}.

An important basis of the present model is the temperature effect on expectation values of Higgs fields.

The present model have the following results.

According to the present model, the evolving process of space is as follows.

In the $S$–breaking, space contracts $\longrightarrow$ temperature $T$ rises to the highest temperature $T_{\text{max}}$ and the highest symmetry comes into being $\longrightarrow$ space inflation $\longrightarrow$ reheating process $\longrightarrow$ the state with the highest symmetry transits to the state with the $V$–breaking and space expands with a deceleration $\longrightarrow$ then comes to static $\longrightarrow$ finally expands with an acceleration up to now.

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

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There are the critical temperature $T_{cr}$, the highest temperature $T_{\text{max}}$, the least scale $R_{\text{min}}$ and the largest energy density $\rho_{\text{max}}$ in the universe. $R_{\text{min}}$ and $T_{cr}$ are two new important constants, $T_{\text{max}}$ and $\rho_{\text{max}}$ are determined by $R(T_{cr})$.

A formula comes out which well describes the relation between a luminosity distance and its redshift.

The new predictions of the present model are as follows.

$V − huge$ voids in the $V − breaking$ are not empty, but there is $s − matter$ with its density $\rho_s \gg \rho_c$ in them. Their effects are similar to those of huge concave lenses for $v − photons$. In huge voids, both matter and dark matter are even shorter in the huge void. Thus the density of hydrogen in the huge voids must be more less that that predicted by the conventional theory. Right or mistake of the predict can be confirmed by the observation of distribution of hydrogen.

When the distance between two $v − galaxies$ is very large, the gravitation between both will be less than that predicted by the conventional theory, because there must be $s − matter$ between both.

We generalize equations governing nonrelativistic fluid motion to present model. The equations of structure formation have been derived. According to the equations, galaxies can form earlier and easier than that in the conventional theory.

On the basis of this model, we have three guesses.

The universe is composed of infinite $s − universal$ islands and $v − universal$ islands.

Some huge redshifts (e.g. the big redshifts of quasi-stellar objects) are explained as the mass redshifts which is caused by less mass $m_e'$ of an electron than given $m_e$.

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. Of course, the effects of quantum mechanics, e.g. Hawking radiation, must be considered. But there is no contradiction between the transformation and quantum mechanics.

It seems that there are some difficulties in the present model, e.g., it seems that this model is not consistent with primordial nucleosynthesis and the $CMBR$ data. It is a misunderstanding. In fact, in a broad scope of parameters, the primordial nucleosynthesis and $CMBR$ can be explained based on the $F − W$ dark matter model (or the mirror dark matter model) and this cosmological model.

The first peak of the $CBMR$ power spectra is the evidence of existence of the elementary
wave. The elementary wave began at reheating and ended at recombination after \( \Delta t_{hc}' \equiv 3.8 \times 10^5 \) years according to the conventional theory. But according to the present model, it is necessary that \( \Delta t_{hc} > \Delta t_{hc}' \), because the sound speed \( c_s \sim c'_s \) and \( H = \eta \rho_g < H' = \eta \rho'_g = \eta \rho' \), here \( \Delta t_{hc} \) is the period in which \( T_{reh} \) descends into \( T_{rec} \), \( c_s \), \( \Delta t_{hc}' \) and \( H' \) are the physical quantities in the conventional theory. Consequently, space-time is open or \( K < 0 \) according to the present model.

In section 2, action, energy-momentum tensor and field equations are presented; In section 3, spontaneous breaking of symmetry and the gravitational mass density of the vacuum state are discussed; In section 4, evolving equations of space are derived out; In section 5, temperature effects are considered; In section 6, the inflation process and change of \( w \) and \( q \) are discussed; In section 7, contraction of space, the highest temperature and inflation of space are considered; In section 8, expansion of space after inflation is discussed; In section 9, existing and distributive forms of \( s - SU(5) \) color single states in the \( V - \text{breaking} \) are discussed; In section 10, dynamics of \( v - \text{structure} \) formation and the distributive form of the \( s - SU(5) \) color single states are got; In section 11, some guesses, new predictions and an inference are given; In section 12, the primordial nucleosynthesis is discussed; In section 14, cosmic microwave background radiation is explained; Section 14 is the conclusions; Section 15 is discussion about conjecture 1.

II. ACTION, ENERGY-MOMENTUM TENSOR AND FIELD EQUATIONS

A. 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 \((s - \text{matter})\) and void – matter \((v - \text{matter})\), 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 \( s - \text{Higgs fields} \) and \( v - \text{Higgs fields} \).

Conjecture 2 \( \lambda_{eff} = 0 \), where \( \lambda_{eff} \) is the effective cosmological constant.

Conjecture 3 The curvature factor \( K = K \left( \rho_g (t, R(t)) \right) \) in the Robertson -Walker metric is a monotone and finite function of \( \rho_g \), \( dK/d\rho_g > 0 \) and \( K = 0 \) for \( \rho_g = 0 \), here \( \rho_g \) 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, only the conjecture 1 is essential. The other conjectures are obviously consistent with the conventional theory.

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

**B. Explanation for the conjectures**

1. 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 $\rho_v$ is very large, $\rho_s$ 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 $\rho_s$ 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 $v$–$observer$ 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. $\rho_s$ and $\rho_v$ 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, $\rho_s$ and $\rho_v$ 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.

In addition, conjecture 1 is necessary in order to solve the following issues.
1. The cosmological constant issue.

2. The space-time singularity issue.

2. 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 $\lambda_{eff}$. On the basis, the cosmological constant problem is easily solved.

(2). In contrast with the conventional theory, all $\rho_g > 0, = 0$ 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 $\rho_g$ in the comoving coordinates, i.e. $K = K\left(\rho_g(t, R(t))\right)$. 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. In contrast with the $SU(3)$ glue-balls, there is no the interaction similar with $U(1)$ gauge interaction among the $SU(5)$ color single states because $SU(5)$ is a single group.

Sum up, in the $\nu$–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.

3. The inferences of the conjectures 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 and the relation between distance and redshift;

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 $w < -1$. 

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Based on the conjectures, there are predictions to be confirmed.

C. 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 $s$-observers. In the $V$-breaking, there are only the $v$-observers. 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. $I_V \cong I_S$ when $S \cong V$ and $s \cong v$. Thus, at the zero-temperature we have

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

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

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

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

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

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

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

where the meanings of the symbols are as follows. $g = \det(g_{\mu\nu}), g_{\mu\nu} = \text{diag}(-1,1,1,1)$ in flat space. $R$ is the scalar curvature. Here $\alpha$ and $\beta$ are two parameters and we finally take $\alpha = -\beta = 1$. $V_0$ is a parameter which is so taken that $V_{s\text{min}} (\varpi_s) + V_0 = 0$ in the $S$-breaking or $V_{v\text{min}} (\varpi_v) + V_0 = 0$ in the $V$-breaking at the zero-temperature, $\varpi = \langle \omega \rangle$. $\mathcal{L}_{sM}$ ($\mathcal{L}_{vM}$) is the Lagrangian density of all $s$-fields ($v$-fields) and their couplings of the SU(5) GUT except the Higgs potentials $V_s$, $V_v$ and $V_{sv}$. $\Psi_s$ and $\Psi_v$ represents all $s$-fields and all $v$-fields, respectively. $\mathcal{L}_s$ and $\mathcal{L}_v$ do not contain the contribution of the gravitational and repulsive fields. It is seen that the set of equation (1) – (7) is unchanged when the subscripts $s \cong v$ and $S \cong V$. This shows the symmetry between $s$-matter and $v$-matter.
Gibbons and Hawking pointed out\textsuperscript{[10]} that in order to get the Einstein field equations, it is necessary

\[ I'_g = \frac{1}{16\pi G} \int \Sigma R \sqrt{-g} d^4x \rightarrow I_g = \frac{1}{16\pi G} \left( \int \Sigma R \sqrt{-g} d^4x + 2 \int_{\partial \Sigma} K \sqrt{\pm h} d^3x \right). \]

This is because it is not necessary that \( \delta \Gamma^\alpha_{\mu\nu} = 0 \) in \( \delta I'_g \) on the boundary \( \partial \Sigma \). Hence \( I'_g \) is replaced by \( I_g \) in (2). \( \Sigma \) is a manifold with four dimensions. \( \partial \Sigma \) is the boundary of \( \Sigma \). \( K = tr K^i_j \). \( K_{ij} = -\nabla_i n_j \) is the outer curvature on \( \partial \Sigma \). \( n_j \) is the vertical vector on \( \partial \Sigma \). \( h = |h_{ij}| \), and \( h_{ij} \) is the induced outer metric on \( \partial \Sigma \). When \( \partial \Sigma \) is space-like, \( \sqrt{\pm h} \) takes positive sign. When \( \partial \Sigma \) is time-like, \( \sqrt{\pm h} \) takes negative sign.

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

\[ V_s = -\frac{1}{2} \mu^2 \Omega^2_s + \frac{1}{4} \lambda \Omega^4_s \]
\[ -\frac{1}{2} w \Omega^2_s Tr \Phi^2_s + \frac{1}{4} a \left( Tr \Phi^2_s \right)^2 + \frac{1}{2} b Tr \left( \Phi^4_s \right) \]
\[ -\frac{1}{2} \xi \Omega^2_s \chi_s^+ \chi_s + \frac{1}{4} \xi \left( \chi_s^+ \chi_s \right)^2, \quad (8) \]

\[ V_v = -\frac{1}{2} \mu^2 \Omega^2_v + \frac{1}{4} \lambda \Omega^4_v \]
\[ -\frac{1}{2} w \Omega^2_v Tr \Phi^2_v + \frac{1}{4} a \left( Tr \Phi^2_v \right)^2 + \frac{1}{2} b Tr \left( \Phi^4_v \right) \]
\[ -\frac{1}{2} \xi \Omega^2_v \chi_v^+ \chi_v + \frac{1}{4} \xi \left( \chi_v^+ \chi_v \right)^2, \quad (9) \]

\[ V_{sv} = \frac{1}{2} \Lambda \Omega^2_s \Omega^2_v + \frac{1}{2} \alpha \Omega^2_s Tr \Phi^2_v + \frac{1}{2} \beta \Omega^2_v \chi^+_s \chi_v \]
\[ + \frac{1}{2} \alpha \Omega^2_v Tr \Phi^2_s + \frac{1}{2} \beta \Omega^2_v \chi^+_s \chi_s, \quad (10) \]

where \( \Omega_a, \Phi_a = \sum_{i=1}^{24} \left( T_i/\sqrt{2} \right) \varphi_{ai} \) and \( \chi_a \) are respectively 1, 24 and 5 dimensional representations of the \( SU(5) \) group, \( a = s, v \), here the couplings of \( \Phi_a \) and \( \chi_a \) are ignored for short\textsuperscript{[11]}.

We do not consider the terms coupling to curvature scalar, e.g. \( \xi R \Omega^2 \), for a time. In fact, \( \xi R \left( \langle \Omega^2_s \rangle - \langle \Omega^2_v \rangle \right) \sim 0 \) when temperature \( T \) is high enough due to the symmetry between \( s \) − matter and \( v \) − matter.

For short, we take \( \alpha = w \) in the paper. We will see in the following paper that when \( \alpha > w \), the duration \( \tau \) of inflation can be long enough without the slow approximation.
D. Equations of motion and energy-momentum tensors

By the conventional method, from (2) we can get

\[ \delta I_g = \frac{1}{16\pi G} \int \left( R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R \right) \delta g^{\mu\nu} \sqrt{-g} d^4x. \]  

(11a)

Considering \( \alpha = -\beta = 1 \), from (3) we have

\[ \delta I_{SM} = \int \frac{1}{\sqrt{-g}} \left[ \frac{\partial L_{SM} \sqrt{-g}}{\partial g^{\mu\nu}} - \left( \frac{\partial L_{SM} \sqrt{-g}}{\partial g^{\mu\nu}_{\sigma}} \right)_{,\sigma} \right] \delta g^{\mu\nu} \sqrt{-g} d^4x 
- \int \left\{ \frac{1}{\sqrt{-g}} \left[ \frac{\partial L_{sM} \sqrt{-g}}{\partial g^{\mu\nu}} - \left( \frac{\partial L_{sM} \sqrt{-g}}{\partial g^{\mu\nu}_{\sigma}} \right)_{,\sigma} \right] - \frac{1}{2} g_{\mu\nu} (V_s + V_0) \right\} \delta g^{\mu\nu} \sqrt{-g} d^4x 
+ \int \left\{ \frac{1}{\sqrt{-g}} \left[ \frac{\partial L_{vM} \sqrt{-g}}{\partial g^{\mu\nu}} - \left( \frac{\partial L_{vM} \sqrt{-g}}{\partial g^{\mu\nu}_{\sigma}} \right)_{,\sigma} \right] - \frac{1}{2} g_{\mu\nu} V_v \right\} \delta g^{\mu\nu} \sqrt{-g} d^4x 
= \int \frac{1}{2} (T_{s\mu\nu} - g_{\mu\nu} V_0 - T_{v\mu\nu}) \delta g^{\mu\nu} \sqrt{-g} d^4x, \]  

(11b)

where

\[ T_{s\mu\nu} = T_{sM\mu\nu} - g_{\mu\nu} V_s \]
\[ = 2 \frac{1}{\sqrt{-g}} \left[ \frac{\partial (\sqrt{-g} L_{sM})}{\partial g^{\mu\nu}} - \left( \frac{\partial (\sqrt{-g} L_{sM})}{\partial g^{\mu\nu}_{\sigma}} \right)_{,\sigma} \right] - g_{\mu\nu} V_s, \]  

(12a)

\[ T_{v\mu\nu} = T_{vM\mu\nu} - g_{\mu\nu} V_v \]
\[ = 2 \frac{1}{\sqrt{-g}} \left[ \frac{\partial (\sqrt{-g} L_{vM})}{\partial g^{\mu\nu}} - \left( \frac{\partial (\sqrt{-g} L_{vM})}{\partial g^{\mu\nu}_{\sigma}} \right)_{,\sigma} \right] - g_{\mu\nu} V_v. \]  

(12b)

From (11) we obtain

\[ R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -8\pi G (T_{s\mu\nu} - g_{\mu\nu} V_0 - T_{v\mu\nu}) \equiv -8\pi G T_{sg\mu\nu}, \]  

(13a)

\[ T_{sg\mu\nu} \equiv T_{s\mu\nu} - g_{\mu\nu} V_0 - T_{v\mu\nu} = T_{SMg\mu\nu} - g_{\mu\nu} V_s \]  

(13b)

\[ T_{SMg\mu\nu} \equiv T_{s\mu\nu} - T_{vM\mu\nu}, \quad V_s = V_0 - V_v, \]  

(13c)

in the \( S - breaking \). It is seen from (13c) that \( V_s \) is independent of \( V_v \). In fact, \( V_{v\text{min}} (\bar{\omega}_v) = 0 \) due \( \langle \omega_v \rangle = 0 \) in the \( S - breaking \), hence

\[ V_{s\text{min}} (\bar{\omega}_s, \bar{\omega}_v) = V_{s\text{min}} + V_0 - V_{v\text{min}} = V_{s\text{min}} + V_0. \]  

(13d)

\( T_{sg\mu\nu}, T_{SMg\mu\nu} \) and \( V_s \) are the gravitational energy-momentum tensor density, the gravitational energy-momentum tensor density without the Higgs potential and the gravitational...
potential density of the Higgs fields in the $S$ – breaking, respectively. Analogously, from (2) and (4) we obtain

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -8\pi G (T_{\mu\nu} - g_{\mu\nu} V_0 - T_{s\mu\nu}) \equiv -8\pi G T_{Vg\mu\nu},$$

(14a)

$$T_{Vg\mu\nu} \equiv T_{\mu\nu} - g_{\mu\nu} V_0 - T_{s\mu\nu} = T_{VMg\mu\nu} - g_{\mu\nu} V_g,$$

(14b)

$$T_{VMg\mu\nu} \equiv T_{vM\mu\nu} - T_{sM\mu\nu}, \quad V_g = V_v + V_0 - V_s,$$

(14c)

in the $V$ – breaking.

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

$$T_{S\mu\nu} = \frac{2}{\sqrt{-g}} \left( \frac{\partial}{\partial \alpha} + \frac{\partial}{\partial \beta} \right) \left[ \frac{\partial (\sqrt{-g} L_s)}{\partial g^{\mu\nu}} - \left( \frac{\partial (\sqrt{-g} L_S)}{\partial g^{\mu\nu}}, \sigma \right) \right],$$

$$\equiv T_{s\mu\nu} + T_{v\mu\nu} - g_{\mu\nu} (V_{sv} + V_0) = T_{SM\mu\nu} - g_{\mu\nu} V_S = T_{V\mu\nu} \equiv T_{\mu\nu},$$

(15a)

$$T_{SM\mu\nu} = T_{sM\mu\nu} + T_{vM\mu\nu} = T_{VM\mu\nu} \equiv T_{M\mu\nu},$$

$$V_S = V_s + V_v + V_{sv} + V_0 = V_V \equiv V.$$

(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 pointed out that only (13) is applicable in the $S$ – breaking, and only (14) applicable in the $V$ – breaking.

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 $\dot{T}_{\mu\nu} = 0$ is $I_M$ to be a scalar quantity[12]. $I_S$ and $I_V$ are all scalar quantities, hence

$$T_{S,\mu\nu} = T_{V,\mu\nu} = 0.$$
E. 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.,
\[
\frac{d^2 x^\mu}{d\sigma^2} + \Gamma^\mu_{\alpha\beta} \frac{dx^\alpha}{d\sigma} \frac{dx^\beta}{d\sigma} = 0.
\]
(17)
The field equation can be rewritten as
\[
R_{\mu\nu} = 8\pi G \left[ T_{s\mu\nu} - \frac{1}{2} g_{\mu\nu} T_s \right] - \left( T_{v\mu\nu} - \frac{1}{2} g_{\mu\nu} T_v \right),
\]
(18)
in the $S$–breaking.

In order to compare the equation of motion of a $s$–particle and the equation of motion of a $v$-particle in $S$–breaking. We take the Newtonian approximation. Under the Newtonian limit, from (17) we have\[^{13}\]
\[
\Gamma^k_{00} \simeq \frac{1}{2} \frac{\partial g_{00}}{\partial x^k}, \quad (19)
\]
\[
\frac{\dot{x}^k}{x} \simeq -\Gamma^k_{00} \simeq -\frac{1}{2} \frac{\partial g_{00}}{\partial x^k}. \quad (20)
\]
From (18) we have
\[
R_{00} = 4\pi G (\rho_s - \rho_v). \quad (21)
\]
On the other hand, the approximate value of $R_{00}$ can be found from expression of the Ricci tensor, After neglecting the nonlinear terms and the terms that are time derivative, one finds
\[
R_{00} = \frac{\partial \Gamma^\alpha_{00}}{\partial x^\alpha} - \frac{\partial \Gamma^\alpha_{0k}}{\partial x^0} + \Gamma^\alpha_{00} \Gamma^\beta_{\alpha k} - \Gamma^\alpha_{0k} \Gamma^\beta_{0\alpha} \simeq \frac{1}{2} \nabla^2 g_{00}. \quad (22)
\]
From (21) and (22) we have
\[
\nabla^2 g_{00} = 8\pi G (\rho_s - \rho_v), \quad (23a)
\]
\[
\nabla^2 g_{00} = 8\pi G \rho_s, \quad \text{when } \rho_v = 0, \quad (23b)
\]
\[
\nabla^2 (-g_{00}) = 8\pi G \rho_v, \quad \text{when } \rho_s = 0. \quad (23c)
\]
Consequently, from (20) and (23) we have
\[
\frac{\dot{x}^k}{x} \simeq -\Gamma^k_{00} \simeq -\frac{1}{2} \frac{\partial g_{00}}{\partial x^k}, \quad \text{for } \rho_s, \quad (24a)
\]
\[
\frac{\dot{x}^k}{x} \simeq \Gamma^k_{00} \simeq \frac{1}{2} \frac{\partial g_{00}}{\partial x^k}, \quad \text{for } \rho_v.
\]

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

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

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

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

C. In fact, only the cosmological effects of \( v - \text{matter} \) are important and are consistent with the observed data up to now.

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

A. Spontaneous breaking of symmetry

Ignoring the couplings of \( \Phi_s \) and \( \chi_s \) and suitably choosing the parameters of the Higgs potential, analogously to Ref.\[11\]. we can prove from (8) – (10) that there are the following vacuum expectation values at the zero-temperature and the tree-level approximation,

\[
\langle 0 | \Omega_v | 0 \rangle = \Omega_{v0} = \langle 0 | \Phi_v | 0 \rangle = \Phi_{v0} = \langle 0 | \chi_v | 0 \rangle = \chi_{v0} = 0,
\]

\[
\langle 0 | \Omega_s | 0 \rangle = \Omega_{s0} \equiv v_{\Omega0},
\]

\[
\langle 0 | \Phi_s | 0 \rangle = \Phi_{s0} = \text{Diagonal} \left( 1, 1, 1, \frac{-3}{2}, \frac{-3}{2} \right) v_{\Phi0},
\]

In Eq. (24a) and (24b) is the same as (3.2.9) in Ref. [13], and the equation (24b) of motion of a \( s - \text{particle} \) is different from that of a \( v - \text{particle} \) in the same gravitational field.
\[ \langle 0 | \chi_s | 0 \rangle^+ = \overline{x}_0 = \frac{\nu \lambda}{\sqrt{2}} (0, 0, 0, 0, 1), \quad (28) \]

\[ v_{10}^2 = \frac{\mu^2}{f}, \quad f \equiv \lambda - \frac{15 w^2}{(15a + 7b)} - \frac{s^2}{\zeta}. \quad (29a) \]

Ignoring the contributions of \( \Phi_s \) and \( \chi_s \) to \( \Omega_{s0} \), at the zero-temperature we get

\[ v_{\Omega0}^2 = \frac{\mu^2}{\lambda}, \quad (29b) \]

\[ v_{\varphi0}^2 = \frac{2w}{(15a + 7b)} v_{\Omega0}^2, \quad (30) \]

\[ v_{\chi0}^2 = \frac{2\zeta}{\xi} v_{\Omega0}^2. \quad (31) \]

We take \( \Lambda > \lambda > 15w^2/(15a + 7b) + \zeta^2/\xi \). From (9)-(10) and (25)-(29a) it can be proved that all \( v-Higgs \) bosons can get their masses big enough. The masses of the Higgs particles exclusive of the \( \Phi_s-particles \) and the \( \chi_s-particles \) are respectively in the \( S-breaking \)

\[ m^2 (\Omega_s) = 2\mu^2, \quad (32) \]

\[ m^2 (\Omega_v) = \Lambda v_{\Omega0}^2 - \mu^2, \quad (33) \]

\[ m^2 (\Phi_v) = \frac{1}{2} \alpha v_{\Omega0}^2, \quad (34) \]

\[ m^2 (\chi_v) = \beta v_{\Omega0}^2. \quad (35) \]

We can choose such parameters so that

\[ m (\Omega_s) \simeq m (\Omega_v) \gg m (\varphi_v) \sim m (\varphi_s) \gg m (\chi_v) \sim m (\chi_s), \quad (36) \]

e.g., \( m (\Omega_s) \sim 10^{16} GeV \), \( m (\varphi_s) \sim 10^{14} GeV \) and \( m (\chi_s) \sim 10^{2} GeV \). It is easily seen from (32) – (35) that all real components of \( \Phi_v \) have the same mass \( m (\Phi_v) \), all real components of \( \chi_v \) have the same mass \( m (\chi_v) \) in the \( S-breaking \).

The \( S-breaking \) and the \( V-breaking \) are symmetric because \( s-matter \) and \( v-matter \) are symmetric. Hence when \( s \rightleftarrows v \) and \( S \rightleftarrows V \) in (25) – (35), the formulas are still kept.
B. The characters of the vacuum state

The characters of the vacuum state are as follows. Taking $V_0 = -V_{s_{\text{min}}}$ at the zero-temperature, considering (13d) and $V_{sv} = V_{svg} = 0$ in the $S$ – breaking and the symmetry between $s$ – matter and $v$– matter, in the vacuum state we have

$$V_{Sg_{\text{min}}} \equiv V_{s_{\text{min}}} (\omega_s) + V_0 - V_{v_{\text{min}}} (\omega_v) = 0,$$

$$V_{S_{\text{min}}} = (V_s + V_{sv})_{\text{min}} + V_0 = 0. \tag{37}$$

Applying the conventional quantum field theory to the present model, we have $\rho_0 = \rho_{s0} + \rho_{v0} \gg 0$. Because of the conjecture 1, $\rho_{s0} = \rho_{v0}$ and $\rho_{sg0} = -\rho_{vg0}$. Consequently, we have

$$\rho_{sg0} = -\rho_{vg0}, \quad \rho_{g0} = \rho_{sg0} + \rho_{vg0} = 0. \tag{39a}$$

here $\rho_0$ and $\rho_{g0}$ are the mass density and the gravitational mass density of the vacuum state, respectively.

According to the our quantum field theory$^{[6]}$,

$$\rho_{s0} = \rho_{v0} = \rho_0 = 0, \quad \rho_{g0} = 0. \tag{39b}$$

It is seen that in any case, $\rho_{g0} = 0$ is necessary provided the conjecture 1 is valid.

IV. 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

$$(ds)^2 = -(dt)^2 + R^2(t) \left\{ \frac{(dr)^2}{1-kr^2} + (r d\theta)^2 + (r \sin \theta d\phi)^2 \right\}, \tag{40}$$

where $k$ is the curvature factor. $k$ is regarded an arbitrary real constant in the Friedmann model. When $r \rightarrow \alpha r$, $R \rightarrow R/\alpha$ and $k \rightarrow k/\alpha^2$, (40) is unchanged. Thus, without losing generality, $k$ may be taken as 1, 0 or $-1$. Here $\alpha$ must be a positive number, hence $k$ cannot change from 1 into 0 or $-1$ by altering $\alpha$. 
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

\[ T_{sM\mu\nu} = (\rho_s + p_s) U_{s\mu} U_{s\nu} + p_s g_{\mu\nu}, \tag{41} \]

\[ T_{vM\mu\nu} = (\rho_v + p_v) U_{v\mu} U_{v\nu} + p_v g_{\mu\nu}, \tag{42} \]

where \( U_{a\mu} \) is a 4-velocity, \( a = s, v \). Considering the potential energy densities in (12), we can rewrite (41) – (42) and \((-g_{\mu\nu} V_0)\) as

\[ T_{s\mu\nu} = [\tilde{\rho}_s + \tilde{p}_s] U_{\mu} U_{\nu} + \tilde{p}_s g_{\mu\nu}, \tag{43} \]

\[ \tilde{\rho}_s = \rho_s + V_s (\omega_s), \quad \tilde{p}_s = p_s - V_s (\omega_s), \tag{44} \]

\[ T_{v\mu\nu} = [\tilde{\rho}_v + \tilde{p}_v] U_{\mu} U_{\nu} + \tilde{p}_v g_{\mu\nu}, \tag{45} \]

\[ \tilde{\rho}_v = \rho_v + V_v (\omega_v), \quad \tilde{p}_v = p_v - V_v (\omega_v), \tag{46} \]

\[ -g_{\mu\nu} V_0 = (\tilde{\rho} (V_0) + \tilde{p} (V_0)) U_{\mu} U_{\nu} + g_{\mu\nu} \tilde{p} (V_0), \quad \tilde{\rho} (V_0) = V_0, \quad \tilde{p} (V_0) = -V_0. \tag{47} \]

In fact, \( V_v = 0 \) due \( \langle \omega_v \rangle = 0 \) in the \( S \) – breaking, hence \( \tilde{\rho}_v = \rho_v, \quad \tilde{p}_v = p_v \).

Substituting (43) – (47) and the RW metric into (13) and considering (37) and \( U_\mu = (1, 0, 0, 0) \) which implies that a medium moves only as expanding of space, we get the Friedmann equations in the \( S \) – breaking

\[ \ddot{R} + k = \eta \left[ (\rho_s + V_s + V_0) - (\rho_v + V_v) \right] R^2 = \eta \left[ \rho_{SG} + V_{SG} \right] R^2 \equiv \eta \tilde{\rho}_{SG} R^2, \tag{48a} \]

\[ \rho_{SG} \equiv \rho_s - \rho_v, \quad V_{SG} \equiv V_s + V_0 - V_v, \quad \tilde{\rho}_{SG} = \rho_{SG} + V_{SG}, \quad \eta \equiv 8\pi G/3, \tag{48b} \]

\[ \ddot{R} = -\frac{1}{2} \eta \left[ (\rho_s + 3p_s) - 2 (V_s + V_0 - V_v) - (\rho_v + 3p_v) \right] R \equiv -\frac{1}{2} \eta \left( \tilde{\rho}_{SG} + 3 \tilde{p}_{SG} \right) R \]

\[ = -\frac{1}{2} \eta \left[ \rho_{SG} + 3p_{SG} - 2V_{SG} \right], \quad p_{SG} \equiv p_s - p_v, \quad \tilde{p}_{SG} = p_{SG} - V_{SG}. \tag{49} \]

Analogously, from (14), (44) and (46), we get

\[ \ddot{R} + k = \eta \left[ (\rho_v + V_v + V_0) - (\rho_s + V_s) \right] R^2 = \eta \tilde{\rho}_{VG} R^2, \tag{50} \]

\[ \ddot{R} = -\frac{1}{2} \eta \left[ (\rho_v + 3p_v) - 2 (V_v + V_0 - V_s) - (\rho_s + 3p_s) \right] R = -\frac{1}{2} \eta \left( \tilde{\rho}_{VG} + 3 \tilde{p}_{VG} \right) R, \tag{51} \]

in the \( V \) – breaking.
In the $S$–breaking, only (48)–(49) is applicable, and in the $V$–breaking, only (50)–(51) is applicable.

It is impossible when temperature is low that the $S$–breaking transforms into the $V$–breaking because of the coupling (10). But it is possible that $\langle \omega_s \rangle = \langle \omega_v \rangle = 0$ when temperature is high enough. Thus the transformation

\[
\langle \omega_s \rangle \neq 0 \text{ and } \langle \omega_v \rangle = 0 \rightarrow \langle \omega_s \rangle = \langle \omega_v \rangle = 0 \rightarrow \langle \omega_s \rangle = 0 \text{ and } \langle \omega_v \rangle \neq 0
\]  
(52)

is possible, i.e., the $S$–breaking can transform into the $V$–breaking via the highest temperature (see the following).

From (48) – (49) we obtain

\[
d \left[ (\rho_s - \rho_v) R^3 \right] /dt + R^3 (dV_{Sg}/dt) = -(p_s - p_v) dR^3 /dt + R (dk/\eta dt).
\]  
(53)

Let $\rho_m$ and $\rho_\gamma$ denote the mass density of particles whose static masses are not zero and the mass density of photon-like particles, respectively, we have $\rho = \rho_m + \rho_\gamma$ and $p = p_m + p_\gamma$. $p_\gamma = \rho_\gamma / 3$ and $p_m$ may be ignored when temperature is low. When $\rho_m$ is major and $(p_s - p_v)$, $dk/\eta dt$ (see the following section) and $(dV_{Sg}/dt)$ may be ignored, from (53) we have

\[
(\rho_{sm} - \rho_{vm}) R^3 = C_S,
\]  
(54a)

in the $S$–breaking, here $C_S$ is a constant. In contrast to the conventional theory, it is possible $C_S \geq 0$, $C_S = 0$ or $C_S < 0$. When $T_s \ll T_{cr} \equiv 2 \mu/\sqrt{\lambda}$, both $m(\Omega_s)$ and $m(\Omega_v)$ are all very big, hence $\rho_{sm}$ cannot transform into $\rho_{vm}$ by (10). Consequently one has

\[
\rho_{sm} R^3 = C_s, \quad \rho_{vm} R^3 = C_v, \quad C_S = C_s - C_v.
\]  
(54b)

Analogously, we have

\[
(\rho_{vm} - \rho_{sm}) R^3 = C_V
\]  
(55a)

\[
\rho_{vm} R^3 = C_v, \quad \rho_{sm} R^3 = C_s, \quad C_V = C_v - C_s,
\]  
(55b)

in the $V$–breaking.

When photon-like gases are major and $dk/\eta dt$ and $dV_{Sg}/dt$ may be ignored, after thermal equilibrium, $p_{a\gamma} \sim \rho_{a\gamma} / 3$, we have

\[
d \left[ (\rho_{s\gamma} - \rho_{v\gamma}) R^4 \right] dt = -\dot{V}_{Sg} R^4 \sim 0,
\]

\[
(\rho_{s\gamma} - \rho_{v\gamma}) R^4 = D_S,
\]  
(56a)
in the $S$–breaking. When the transformation $\rho_{s\gamma}$ into $\rho_{v\gamma}$ may be ignored, we have

$$\rho_{s\gamma} R^4 = D_s, \quad \rho_{v\gamma} R^4 = D_v, \quad D_S = D_s - D_v.$$  

(56b)

Similarly, one has

$$\left(\rho_{V v\gamma} - \rho_{V s\gamma}\right) R^4 = D_V = D_s - D_v,$$

(57a)

$$\rho_{v\gamma} R^4_v = D_v, \quad \rho_{s\gamma} R^4 = D_s, \quad D_V = D_v - D_s.$$  

(57b)

in the $V$–breaking.

**B. The evolving equations when $K = K(\rho_g(t, R(t)))$**

Provided the cosmological principle is valid, the metric tensor is the Robertson-Walker metric. $k$ in (40) is regarded an arbitrary real constant in the Friedmann model. When $r \to a r$, $R \to R/a$ and $k \to k/a^2$, (40) is unchanged. Thus, without losing generality, $k$ may be taken as 1, 0 or $-1$. Here $\alpha$ must be a positive number, hence $k$ cannot change from 1 into 0 or $-1$ by altering $a$. The R-W metric is undoubtedly right when all gravitation masses are positive, i.e. $m_g = m$. In contrast with the conventional theory, according to the present model, all $\rho_g > 0$, $= 0$ and $< 0$ are possible. Hence $k$ in (40) should be changeable from $k = 1$ to $-1$ corresponding to change of $\rho_g$ from $\rho_g > 0$ to $\rho_g < 0$. We consider $k$ to be a function of $\rho_g$, $\rho_g$ is the gravitational mass density in comoving coordinates. $\rho_g = \rho_{gm} + \rho_{g\gamma}$ can change as $\dot{R}$ because $\rho_{gm} = \rho_{m} - \rho_{sm} \propto R^{-3}$ and $\rho_{g\gamma} = \rho_{v\gamma} \propto R^{-4}$. On the other hand, although $\dot{R} = 0$, $\rho_g$ can also change (see section 8.7). This is because the repulsive potential energy is chiefly transformed into the kinetic energy of color single states. Hence we have

$$k \to K(t) = K(\rho_g(t, R(t))).$$

\[ \ddot{R} + 3K = 8\pi G \rho_g R^2 + \frac{2}{3} \frac{\dot{R}K}{K}, \]  

(58)

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

(59)

\[ \ddot{K} + \frac{3r^2K^2}{2 (1 - Kr^2)} + 3 \frac{\dot{R}K}{R} = 0. \]  

(60)

We discuss the evolving equations as follows\[9\].
1. When $\dot{K} \sim 0$, from (60) we have

$$\frac{\ddot{K}}{\dot{K}} = -3 \frac{\dot{R}}{R}. \quad (61)$$

Substituting (61) into (58) – (59), we get the Friedmann equations (48) – (49) or (50) – (51) anew. Hence the equations are self-consistent. Thus, when $\dot{K} \sim 0$, we can still determine $R(t)$ by (48) – (49) or (50) – (51).

$\dot{K} \sim 0$ is possible. Because $K\left(\rho_g\right)$ is a monotone and finite function of $\rho_g$, $dK/d\rho_g > 0$, it is necessary when $\rho_g \gg 0$ or $\rho_g \ll 0$, $K(t)$ slowly changes so that $\dot{K} \sim 0$. In fact, considering $\rho_g$ to be the gravitational mass density in the comoving coordinates, we have

$$R(t) = \left(\rho_{gm} + \rho_{g\gamma}\right) R^3 \left(\rho_{gm1} + \rho_{g\gamma1} \frac{R_1}{R}\right). \quad (62)$$

When $|\rho_{g\gamma1}/\rho_{gm1} R_1/R | \ll 1$, $\rho_g(t) \sim \rho_{gm}(t_1)$ so that $\dot{K} \sim 0$. From the conjecture 3, we can also determine only when $\rho_g \sim 0$ so that $K\left(\rho_g\right) \sim 0$, $\dot{K}$ is important. Because $K\left(\rho_g\right)$ is a monotone and finite function of $\rho_g$, $K\left(\rho_g\right) = 0$ and $dK/d\rho_g > 0$, it is necessary $K\left(\rho_g\right) > 0$ when $\rho_g > 0$ and $K\left(\rho_g\right) < 0$ when $\rho_g < 0$. When $\rho_g \gg 0$ or $\rho_g \ll 0$, we will regard $K\left(\rho_g\right)$ as a constant, e.g. $K = 1$ for $\rho_g \gg 0$ and $K = -1$ for $\rho_g \ll 0$.

2. When $R \rightarrow 0$, from (58) – (59) we have

$$\dot{R} = 0, \quad K = \eta \rho_g R^2, \quad (63a)$$

$$\ddot{R} = -\frac{\eta}{2} \left(\rho_g + 3p_g\right) R \approx -\frac{\eta}{2} \left(\rho_g + \rho_{g\gamma}\right) R = -\frac{\eta R_1^3}{2R^2} \left(\rho_{gm1} + 2\rho_{g\gamma1} \frac{R_1}{R}\right). \quad (63b)$$

This is similar to the conventional theory only when $\rho_g > 0$. According to present model, $\rho_g$ 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

$$\rho_g = \rho_{gm} + \rho_{g\gamma} = \frac{R_1^3}{R^3} \left(\rho_{gm1} + \rho_{g\gamma1} \frac{R_1}{R}\right) = \frac{R_1^3}{R^3} \rho_g = 0 \quad \text{so that} \quad K\left(\rho_g\right) = 0, \quad (64)$$

(58) – (59) becomes

$$\ddot{R} = 2 \frac{RR}{} K, \quad (65a)$$

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\[
\ddot{R} = -\frac{\eta}{2} \rho_{g\gamma} R - \frac{1}{3} \frac{\dot{R} \dot{K}}{K} = -\frac{\eta}{2} \rho_{g\gamma} R - \frac{1}{2} \frac{\dot{R}^2}{R} < 0. 
\]  
(65b)

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 \( R > 0 \) and \( \dot{R} < 0 \). 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 \( K \sim 0 \), \( \partial K/\partial t < 0 \) is marked and the universe is matter-dominated so that \( p_{s} - p_{v} \) may be ignored.

4. Although \( K \) is a function of \( r \) when \( K \sim 0 \), \( \rho_{g} \) and \( R \) are still independent of \( r \).[9]

5. In the \( S - breaking \), \( \rho_{s} \) can transform into \( \rho_{v} \) 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 from (53) we see

\[
\frac{d}{dt} \left[ (\rho_{s} - \rho_{v}) R^3 \right] = R \left( \frac{dK}{\eta dt} \right) < 0. 
\]  
(65c)

This implies \( \rho_{s} \) can transform into \( \rho_{v} \) 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 (65c) holds.

V. TEMPERATURE EFFECT

A. Two sorts of temperature

The thermal equilibrium between the \( v - particles \) and the \( s - particles \) can be realized by only (10). The Higgs bosons are hardly produced because the masses of the Higgs particles are all very big at low temperature. Consequently, the interaction between the \( v - particles \) and the \( s - particles \) may be ignored so that there is no thermal equilibrium between the \( v - particles \) and the \( s - particles \). Thus, when temperature is low, we should use two sorts of temperature \( T_{v} \) and \( T_{s} \) respectively to describe the thermal equilibrium of \( v - matter \) and the thermal equilibrium of \( s - matter \). Generally speaking, \( T_{v} \neq T_{s} \). When temperature \( T_{s} \) is so high that \( \langle \Omega_{s} \rangle \rightarrow 0 \) in \( S - breaking \), the masses of \( s - Higgs \) bosons will tend to zero (see below). On the other hand, because \( \langle \Omega_{v} \rangle = 0 \) in the \( S - breaking \), \( m(\Omega_{v}) \), \( m(\Phi_{v}) \) and \( m(\chi_{v}) \) will tend to zero as \( \langle \Omega_{s} \rangle \) tends to zero as well. Consequently \( \Omega_{s} \), \( \Phi_{s} \) and
\( \chi_s \) can be enormously produced and easily transformed into \( \Omega_v, \Phi_v \) and \( \chi_v \) by the couplings in (10). Other \( v - particles \) can be easily produced by the couplings of \( v - SU(5) \) as well. Consequently thermal equilibrium between the \( v - particles \) and the \( s - particles \) will appear provided \( T_s \) is high enough. In the case, contraction of space will stop and inflation must occur. Thus there must be the highest temperature \( T_{\text{max}} \).

B. The influences of finite temperature on the Higgs potential

1. Effective potentials

The influence of finite temperature on the Higgs potential in the present model are consistent with the conventional theory. For short, we consider only \( \Omega_a \) and \( \varphi_a, a = s, v \). When \( \chi_a \) is considered as well, the following inferences are still qualitatively valid. For

\[
V(\Omega_s) = -\frac{\mu^2}{2} \Omega^2_s + \frac{\lambda}{4} \Omega^4_s,
\]

to ignore the terms proportional \( \lambda^n, n > 1 \), the finite-temperature effective potential approximate to 1-loop in flat space is\textsuperscript{[14,15]}

\[
V_{\text{eff}}^{(1)T}(\Omega_s, T_s) = -\frac{1}{2} \left( \mu^2 - \frac{\lambda}{4} T^2_s \right) \Omega^2_s + \frac{\lambda}{4} \Omega^4_s - \frac{\pi^2}{90} T^4_s + \frac{\mu^2}{24} T^2_s. \tag{66a}
\]

Considering the influence of the expectation values \( v_{\Omega_v}(T_s, T_v) \), \( v_{\varphi_s}(T_s, T_v) \) and \( v_{\varphi_v}(T_s, T_v) \) and ignoring the terms irrelevant to \( \Omega_s \), we have

\[
V_{\text{eff}}^{(1)T}(\Omega_s, T_s, T_v) = -\frac{1}{2} \mu^2(T_s) \Omega^2_s + \frac{\lambda}{4} \Omega^4_s, \tag{66b}
\]

\[
\mu^2(T_s, T_v) \equiv \mu^2 - \frac{\lambda}{4} T^2_s - \Lambda v^2_{\Omega_v}(T_s, T_v) - \frac{15}{2} \left( \alpha v^2_{\varphi_v}(T_s, T_v) - w v^2_{\varphi_s}(T_s, T_v) \right). \tag{66c}
\]

In the \( S - breaking \), \( v_{\Omega_s}(T_s) \neq 0, v_{\varphi_s}(T_s, T_v) \neq 0 \), and \( v_{\Omega_v}(T_s, T_v) = v_{\varphi_v}(T_s, T_v) = 0 \). From (66b, c) we find

\[
v^2_{\Omega_s}(T_s, T_v) = \mu^2(T_s, T_v) / \lambda, \text{ when } \mu^2(T_s, T_v) > 0,
\]

\[
v_{\Omega_s}(T_s, T_v) = 0, \text{ when } \mu^2(T_s, T_v) \leq 0. \tag{66d}
\]

Similarly, for \( \Omega_v \) we have

\[
V_{\text{eff}}^{(1)T}(\Omega_v, T_s, T_v) = -\frac{1}{2} \mu^2(T_s, T_v) \Omega^2_v + \frac{\lambda}{4} \Omega^4_v, \tag{67a}
\]
\[
\mu_v^2(T_s, T_v) = \mu^2 - \Lambda v_{\Omega s}^2(T_s, T_v) - \frac{\lambda}{4} \pi_T^2 - \frac{15}{2} (\alpha v_{\varphi s}^2(T_s, T_v) - w v_{\varphi v}^2(T_s, T_v)). \tag{67b}
\]

\[
v_{\Omega s}^2(T_s, T_v) = \mu_v^2(T_s, T_v)/\lambda, \quad \text{when } \mu_v^2(T_s, T_v) > 0,
\]
\[
v_{\Omega s}(T_s, T_v) = 0, \quad \text{when } \mu_v^2(T_s, T_v) \leq 0. \tag{67c}
\]

In the \textit{S-breaking}, because of (10), it will be proved (see section 5.3)

\[
\mu_v^2(T_v) \leq 0, \quad \text{and } v_{\Omega v}(T_s, T_v) = 0. \tag{67d}
\]

For

\[
V(\Phi_s) = \left(\frac{1}{2} \alpha \Omega_v^2 - w \Omega_s^2\right) T r \Phi_s^2 + \frac{1}{4} a(T r \Phi_s^2)^2 + \frac{1}{2} b T r \Phi_1^4,
\]

ignoring the contributions of the Higgs fields and the fermion fields to one loop correction and only considering the contribution of the gauge fields to one-loop correction, when \(\varphi_s \ll kT\), \(k\) is the Boltzmann constant, the finite-temperature effective potential approximate to 1-loop in flat space is \cite{14}

\[
V_{eff}^{(1)}(\varphi_s, T_s) = V(\varphi_s) + B \varphi_s^4 \left(\ln \frac{\varphi_s^2}{\sigma^2} - \frac{25}{6}\right) + C T_s^2 \varphi_s^2 - \frac{\pi^2}{15} (kT_s)^4,
\]

where \(B = (5625/1024\pi^2) g^4\), \(\Phi_s = \text{Diagonal } (1, 1, 1, -\frac{3}{2}, -\frac{3}{2}) \varphi_s\). In general, \(w\) and \(\alpha < \lambda \sim g^4 < C = (75/16) (kg)^2\). We take \(w \simeq \alpha\) for simplicity. \(\sigma\) is a parameter at which the renormalized coupling-constant \(\lambda\) is defined,

\[
\left. \frac{d^4 V_{eff}^{(1)}(\varphi_s, T_s, T_v)}{d \varphi_s^4} \right|_{\varphi_s = \sigma} = \lambda.
\]

Only considering the contribution of the expectation values of \(\Omega_s\) and \(\varphi_v\) to \(V_{eff}^{(1)}(\varphi_s, T_s)\), taking \((15/16) (15a + 7b) = (11/3) B\), and ignoring the term \((kT_s)^4\) unconnected with \(\varphi_v\), from (8), (68) – (69) we have

\[
V_{eff}^{(1)}(\varphi_s, T_s, T_v) = A_s^2(\varphi_s, T_s, T_v) \varphi_s^2 + B \varphi_s^4 \left(\ln \frac{\varphi_s^2}{\sigma^2} - \frac{1}{2}\right), \tag{70a}
\]
\[
A_s^2(\varphi_s, T_s, T_v) \equiv \frac{15}{4} \alpha \left(v_{\Omega s}^2(T_s) - v_{\Omega v}^2(T_s)\right) + C T_s^2. \tag{70b}
\]

Similarly, we have

\[
V_{eff}^{(1)}(\varphi_v, T_v, T_v) = A_v^2(\varphi_v, T_v, T_v) \varphi_v^2 + B \varphi_v^4 \left(\ln \frac{\varphi_v^2}{\sigma^2} - \frac{1}{2}\right), \tag{71a}
\]
\[
A_v^2(\varphi_v, T_s, T_v) = \frac{15}{4} \alpha \left(v_{\Omega s}^2(T_s) - v_{\Omega v}^2(T_s)\right) + C T_v^2. \tag{71b}
\]
2. Critical temperatures and masses of the Higgs particles

The critical temperature $T_{s,\text{cr}}$ is such a temperature at which the minima are degenerate, i.e., $V_{\text{eff}}^{(1)T}(\varphi_s, T_{s,\text{cr}}) = V_{\text{eff}}^{(1)T}(0, T_{s,\text{cr}}) = 0$. In other words, $\langle \varphi_s \rangle = v_{\varphi_s} = 0$ when $T_s < T_{s,\text{cr}}$, and $v_{\varphi_s} = 0$ when $T_s \geq T_{s,\text{cr}}$. $T_{s,\text{cr}}$ and $A_{\varphi_s}^2(v_{\varphi_s}, T_s, T_v)$ can be determined from (70) by that when $\varphi_s = v_{\varphi_s}$

$$V_{\text{eff}}^{(1)T}(\varphi_s, T_{s,\text{cr}}) = 0, \quad \frac{\partial}{\partial \varphi_s} V_{\text{eff}}^{(1)T}(\varphi_s, T_{s,\text{cr}}) = 0. \quad (72)$$

$$v_{\varphi_s}^2 = \sigma^2 e^{-1/2}, \quad A_{\varphi_s}^2(v_{\varphi_s}, T_s, T_v) = B\sigma^2 e^{-1/2}, \quad (73a)$$

$$T_{s,\text{cr}}^2(T_s, T_v) = [B\sigma^2 e^{-1/2} + (15/4) (w_{\Omega_s}^2(T_s, T_v) - \alpha v_{\varphi_s}^2(T_s, T_v))] / C. \quad (73b)$$

In the $S$-breaking, $\varphi_s = 0 = 0$. Considering $v_{\varphi_s} = 0$ when $T_s = T_{s,\text{cr}}$ and $C > \lambda$, and taking $B\sigma^2 e^{-1/2} < \mu^2$, we find

$$T_{s,\text{cr}}^2(T_s, T_v) = \left[ B\sigma^2 e^{-1/2} + \frac{15}{4} \alpha \mu^2 \right] \left[ C + \frac{15}{4} \alpha \right] < \frac{\mu^2}{\lambda}. \quad (73c)$$

When $T_s \geq T_{s,\text{cr}}$,

$$v_{\varphi_s} = 0, \quad V_{\text{eff}}^{(1)T}(\varphi_s, T_s) = V_{\text{eff}}^{(1)T}(0, T_s) = 0,$$

$$m^2(\varphi_s, T_s) = 2 \left[ -\frac{15}{4} \alpha v_{\Omega_s}^2(T_s) + CT_s^2 \right], \quad (74a)$$

where $m(\varphi_s, T_s)$ is called the effective mass of $\varphi_s$ which implies that the temperature effect is considered. When $T_s < T_{s,\text{cr}}$

$$v_{\varphi_s}(T_s, T_v) \neq 0, \quad V_{\text{eff}}^{(1)T}(\varphi_s, T_s, T_v) = V_{\text{eff}}^{(1)T}(v_{\varphi_s}, T_s, T_v) < 0,$$

$$m^2(\varphi_s, T_s) = 15w_{\Omega_s}^2(T_s, T_v) - 4CT_s^2 + 8Bv_{\varphi_s}^2(T_s, T_v). \quad (74b)$$

Similarly, from (71) we have

$$v_{\varphi_v}^2 = \sigma^2 e^{-1/2}, \quad A_{\varphi_v}^2(\varphi_v, T_s, T_v) = B\sigma^2 e^{-1/2}, \quad (75a)$$

$$T_{v,\text{cr}}^2(T_s, T_v) = [B\sigma^2 e^{-1/2} + (15/4) \alpha (v_{\Omega_v}^2(T_s, T_v) - v_{\Omega_s}^2(T_s, T_v))] / C. \quad (75b)$$

In the $S$-breaking, $v_{\Omega_v}(T_s, T_v) = v_{\varphi_v}(T_s, T_v) = 0$. Considering $C > \lambda$, and taking $B\sigma^2 e^{-1/2} < \mu^2$, we find

$$T_{v,\text{cr}}^2(T_s, T_v) = \left[ B\sigma^2 e^{-1/2} - \frac{15}{4} \alpha \left( \mu^2 - \frac{\lambda}{4} T_s^2 + \frac{15}{2} \alpha v_{\varphi_s}^2(T_s, T_v) \right) \right] / C, \quad (75c)$$

$$T_{v,\text{cr}}^\text{max}(T_s, T_v) = B\sigma^2 e^{-1/2} / C < B\sigma^2 e^{-1/2} / \lambda < \frac{\mu^2}{\lambda}. \quad (75d)$$
$T_{v,\varphi_{cr}}^2 \leq 0$ implies $\varphi_{v}(T_s, T_v) = 0$. $T_{v,\varphi_{cr}}^2$ will increase from 0 to $B\sigma^2 e^{-1/2}$ as $\Omega_s (T_s)$ decreases from $\Omega_s (0)$ to 0 due to (75b). In the case, it seems $T_v^2 < B\sigma^2 e^{-1/2}$ so that $\varphi_{v}(T_s, T_v) \neq 0$ to be possible. In fact, this is impossible for the space-contraction process. In the case, it is necessary $T_s^2 \sim \mu^2/\lambda$ due to $\Omega_s (T_s) \sim 0$. Hence $\Omega_s$ and $\Omega_v$ or $\varphi_v$, and $\varphi_s$ and $\Omega_v$ can transform from one into another by (10) and $T_v / T_{v1} = R_1 / R = T_s / T_{s1}$. Consequently $\rho_s \sim \rho_v$ and $T_v \rightarrow T_s > T_{\varphi_{cr}}$ so that $\varphi_{v}(T_s, T_v) = 0$ (see below). Hence in the $S$--breaking, $\varphi_{v}(T_s, T_v) = 0$.

When $T_v \geq T_{v,\varphi_{cr}}$,

$$v_{\varphi_{v}} (T_s, T_v) = 0, \ V_{\text{eff min}}^{(1)}(\varphi_{v}, T_s, T_v) = V_{\text{eff}}^{(1)} (0, T_s, T_v) = 0, \quad (76a)$$

$$m^2(\varphi_{v}, T_v) = 2 \left[ \frac{15}{4} \alpha \nu_{\Omega s}^2 (T_s) + CT_v^2 \right]. \quad (76b)$$

In fact, only when $\Omega_s (T_s, T_v) \sim 0$, $\varphi_{v}(T_s, T_v) \neq 0$ due to (10). Hence when $T_v < T_{v,\varphi_{cr}}$,

$$m^2(\varphi_{v}, T_v) = -15\alpha \nu_{\Omega s}^2 (T_s) - 4CT_v^2 + 8B\sigma_v^2$$

$$= -4CT_v^2 + 8B\sigma_v^2. \quad (77)$$

In fact, in general, the case cannot emerge, because when $\Omega_s (T_s, T_v) \sim 0$, $T_s$ is very large. Hence $\rho_s$ and $\rho_v$ can transform from one into another so that $T_v \sim T_s$. Thus $T_v < T_{v,\varphi_{cr}}$ cannot emerge.

If $\Omega_s (T_s) = 0 = \Omega_v (T_v)$,

$$T_s^{2,\varphi_{cr}} = T_{v,\varphi_{cr}}^2 \equiv T_{\varphi_{cr}}^2 = B\sigma^2 e^{-1/2} / C. \quad (78a)$$

It is obvious

$$T_{s,\varphi_{cr}} > T_{\varphi_{cr}} > T_{v,\varphi_{cr}} \quad \text{when} \quad \Omega_s (T_s) \neq 0. \quad (78b)$$

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

$$T_{cr} = \frac{2\mu}{\sqrt{\lambda}} > T_{s,\varphi_{cr}}, \quad (79)$$

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

$$v_{\Omega s} (T_s) = 0, \ V_{\text{eff min}}^{(1)}(\Omega_s, T_s) = V_{\text{eff}}^{(1)} (0, T_s) = 0, \quad (80a)$$

$$m^2(\Omega_s, T_s) = \frac{1}{2} \lambda T_s^2 - 2\mu^2, \quad (80b)$$

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when \( T_s < T_{cr} \)

\[
v_{\Omega s}^2 (T_s, T_v) = \mu_s^2 (T_s, T_v) / \lambda > 0, \quad V_{\text{eff min}}^{(1)} (\Omega_s, T_s) = -\frac{\mu_s^4 (T_s, T_v)}{4\lambda} \quad (80c)
\]

\[
m^2 (\Omega_s) = 2\mu_s^2 (T_s, T_v). \quad (80d)
\]

When \( \mu_v^2 (T_s, T_v) \leq 0, \ v_{\Omega v} (T_s, T_v) = 0 \), and when \( \mu_v^2 (T_s, T_v) > 0, \ v_{\Omega v} (T_s, T_v) \neq 0 \).

Considering \( v_{\Omega s} (T_s) = 0 \) when \( T_s = T_{cr} \), from (67a,b) we find

\[
T_{vcr} = T_{cr}. \quad (81a)
\]

When \( T_v \gtrsim T_{cr} \),

\[
v_{\Omega v} (T_s) = 0, \quad V_{\text{eff min}}^{(1)T} (\Omega_v, T_v) = V_{\text{eff}}^{(1)} (0, T_v) = 0,
\]

\[
m^2 (\Omega_v, T_s) = \frac{1}{2} \lambda t_v^2 - 2\mu_v^2. \quad (81b)
\]

In the \( S - \) breaking, when \( v_{\Omega s} (T_s, T_v) \rightarrow 0 \), it is necessary \( T_s^2 \rightarrow 4\mu_s^2 / \lambda \). In the case, \( \rho_s \) and \( \rho_v \) can transform from one into another and

\[
T_v/T_{v1} = R_1/R = T_s/T_{s1},
\]

hence \( T_v^2 \rightarrow T_s^2 \sim 4\mu_s^2 / \lambda \). Consequently there still is \( \mu_v^2 (T_s, T_v) \leq 0 \). Hence in the \( S - \) breaking, when \( T_v < T_{cr} \), there still are

\[
v_{\Omega v} (T_s, T_v) = 0, \quad V_{\text{eff min}}^{(1)T} (\Omega_v, T_s, T_v) = V_{\text{eff}}^{(1)} (0, T_s, T_v) = 0,
\]

\[
m^2 (\Omega_v, T_s, T_v) = -2\mu_v^2 (T_s, T_v). \quad (81c)
\]

\textbf{C. \( \rho_s \) and \( \rho_v \) transform from one into another when \( T_s \rightarrow T_{cr} \) so that \( \rho_s - \rho_v \rightarrow 0 \)}

In the \( s - \) breaking, we consider the space contraction process. In low temperatures, \( V_{Sg} \sim 0, \ \rho_{sm} \gg \rho_{s\gamma} \), and the masses of all \( v - \) colour single states are not zero, i.e., \( \rho_{v\gamma} = 0 \). Thus \( \rho_{sm} \) and \( \rho_{vm} \) are major. \( \tilde{\rho}_{Sg} = \tilde{\rho}_s - \tilde{\rho}_v = \rho_s - \rho_{vm} > 0 \) so that space can contract. According to the conjecture 3 and the discussion about (61), \( K > 0 \) and \( \hat{K} \sim 0 \) when \( \tilde{\rho}_{Sg} = \tilde{\rho}_s - \tilde{\rho}_v \gg 0 \) so that (48)-(49) are still applicable.

When \( T_s \ll T_{cr} \), the transformation \( \rho_s \) into \( \rho_v \) may be ignored. From (54) one can rewrite (48)-(49) as

\[
\ddot{R} = -K + \frac{\eta C_S}{R},
\]

\[
\dddot{R} = -\frac{\eta C_S}{2 R^2}.
\]
where \( C_S = C_s - C_v > 0 \), \( C_a = \rho_a (T_a) R^3 (T_a) \), \( a = s, v \) and \( T_a \ll T_{cr} \). It is seen that space will monotonously contract faster and faster.

\( T_s \) must go up high as \( R \) decreases, because the non-zero momentum of a free particle \( p \propto 1/R(t) \), \( \triangle p \triangle x \gtrsim 1 \) and \( \rho_m \propto 1/R^3 (t) \).

When \( T_s \) and \( T_v \) are high enough so that masses of particles may be ignored, if the transformation \( \rho_s \) into \( \rho_a \) may still be ignored, from (56b) and (57b) we have

\[
\rho_a (T_a) R^4 (T_a) = D_a, \quad \rho_a (T_a) = \frac{\pi^2}{30} g_a^* T_a^4, \quad T_a R (T_a) = \left( 30 D_a/\pi^2 g_a^* \right)^{1/4}, \quad a = s, v, \tag{82}
\]

where \( g_a^* = g_{aB} + 7g_a^F/8, \ g_{aB} (g_{aF}) \) is the total number of the spin states of \( a - \text{bosons} \) \((a - \text{fermions})\). Considering \( s - \text{matter} \) and \( v - \text{matter} \) are symmetric, we have

\[
g_s^* = g_{sB} + 7g_s^F/8 = g_v^* = g_{vB} + 7g_v^F/8 \equiv g^*. \tag{83}
\]

It is seen that space contraction will cause \( T_s \) and \( T_v \) to rise. If \( T_s \) and \( T_v \) are high enough and the transformation \( \rho_s \) into \( \rho_v \) cannot be ignored, there will be \( \rho_s \sim \rho_v \) and \( T_s \sim T_v \). This is a expected result.

If there is only one sort of matter as the conventional theory or \( \rho_s \) and \( \rho_v \) cannot transform from one into other, space will continue to contract and \( T_s \) and \( T_v \) will continue to rise provided \( \tilde{\rho}_{Sg} R^2 - K > 0 \). In fact, in this case, space will contract to a singular point and \( T_s \) and \( T_v \) tend to infinite.

In contrast with the conventional theory, when \( T_s \) and \( T_v \) are high enough, \( \rho_s \) and \( \rho_v \) can transform from one into another by (10) i.e.,

\[
\Omega_s + \Omega_s \rightleftharpoons \Omega_v + \Omega_v, \quad \Omega_s + \Omega_s \rightleftharpoons \varphi_v + \varphi_v, \quad \varphi_s + \varphi_s \rightleftharpoons \Omega_v + \Omega_v,
\]

so that

\[
T_s = T_v = T, \quad \rho_s (T_s) = \rho_v (T_v) \equiv \rho (T) = \frac{\pi^2}{30} g^* T^4, \quad \tilde{\rho}_{Sg} = \rho_s (T_s) - \rho_v (T_v) + V_s + V_0 - V_v = V_0. \tag{84}
\]

The expectation values \( v_{s\Omega}, v_{v\Omega}, v_{s\varphi} \) and \( v_{\varphi v} \) will tend to zero when \( T_s \sim T_v \gtrsim T_{cr} \) because of (79), (73c), (75) and (78). Consequently, the masses of all particles which originating from the couplings with \( v_{s\Omega}, v_{v\Omega}, v_{s\varphi} \) and \( v_{\varphi v} \) are zero. Thus, the \( a - \text{Higgs} \) particles and the \( a - \text{fermions} \) or the \( a - \text{gauge} \) particles can transform from one into another by the \( a - SU(5) \) couplings so that the \( a - \text{Higgs} \) particles can enormously emerge \((a = s, v)\). The
s – Higgs particles and the v – Higgs particles can transform from one into another by the

coupling (10) so that the thermal equilibrium between s – matter and v – matter comes

into being. After thermal equilibrium, the number and the energy of every sort of particles

will satisfy statistical distribution determined by their spins. Thus we prove that (84) is

a necessary result of space contraction because of (83). It is seen that when \( T \geq T_{cr} \), i.e.,

\[ v_s \Omega = v_o \Omega = v_{\varphi s} = v_{\varphi v} = 0, \]

s – matter and v – matter are completely symmetric, and both \( s – SU(5) \) and \( v – SU(5) \) strictly hold water.

It is seen that end of space contraction is in the most symmetric state in which \( \langle \omega_v \rangle = \langle \omega_s \rangle = 0 \).

\( \langle \omega_v \rangle = \langle \omega_s \rangle = 0 \) is the sufficient but is not the necessary condition for (84). In fact,

provided the following conditions can be realized, (84) can come into being when \( T_s \) and \( T_v < T_{cr} \) as well.

A. \( m (\omega_a, T_v, T_s) \sim m (f_a, T_v, T_s) \) or \( m (g_a, T_v, T_s) \), or temperature is high enough so that \( \omega_a \) can enormously emerge. Here \( f_a \) and \( g_a \) denote fermions and gauge bosons, respectively.

\( m (f_a, T_v, T_s) \) and \( m (g_a, T_v, T_s) \) are small. Thus \( \Omega_a \) or \( \varphi_a \) and \( f_a \) or \( g_a \) can transform from

one into other by the \( SU(5) \) couplings.

B \( m (\omega_s, T_v, T_s) \sim m (\omega_v, T_v, T_s) \). Thus, \( \omega_s \) and \( \omega_v \) can transform from one into other by

(10)

The two conditions can be realized as well when \( T_s \sim T_v \lesssim T_{cr} \).

From (80d) and (81c), in the \( S – breaking \) we can rewritten \( m^2 (\Omega_v, T_v, T_s) \) as

\[
m^2 (\Omega_v, T_v, T_s) = -2 \mu_v^2 (T_v, T_s)
= \left( \frac{\Lambda}{\lambda} - 1 \right) m^2 (\Omega_s, T_s, T_v) - \frac{\lambda}{2} (T_s^2 - T_v^2) + 30 \alpha (v_{\varphi s}^2 - v_{\varphi v}^2). \tag{85a}
\]

When \( T_{s,cr} < T < T_{cr}, v_{\varphi s} = v_{\varphi v} = 0, m^2 (\Omega_s, T_v, T_s) \rightarrow 0 \) as \( T_s \rightarrow T_{cr} \), and

\[
m^2 (\Omega_v, T_v, T_s) = \left( \frac{\Lambda}{\lambda} - 1 \right) m^2 (\Omega_s, T_s, T_v) - \frac{\lambda}{2} (T_s^2 - T_v^2). \tag{85b}
\]

In the \( S – breaking \), \( m^2 (\Omega_s, T_s) \geq 0 \) and \( T_s \geq T_v \) when \( T_s \lesssim T_{cr} \) and space contracts. Hence

when \( m (\Omega_v, T_v, T_s) \sim 0 \), it is necessary \( m (\Omega_s) \gtrsim m (\Omega_v, T_v, T_s) \sim 0 \). In fact, if \( \lambda (T_s^2 - T_v^2)/2 \)
in (85b) is very large, \( \lambda T_s^2/2 \) is definitely very large, e.g. \( T_s^2 \lesssim 4 \mu^2/\lambda \). Consequently, because of (79c) and (66c), \( m (\Omega_s, T_s) \) is definitely very small and \( \Lambda/\lambda \gg 1 \). This case satisfies the
two conditions A and B above. If \( \lambda (T_s^2 - T_v^2)/2 \) is very small, \( m^2 (\Omega_s, T_s) \) must be less

than \( \lambda (T_s^2 - T_v^2)/2 \) provided \( \Lambda/\lambda - 1 > 1 \). When \( m^2 (\Omega_v, T_v, T_s) = 0, m^2 (\Omega_s, T_s) > 0 \)
because \( T_s^2 - T_v^2 > 0 \). Hence \( m (\Omega_s, T_s) \geq m (\Omega_v, T_v, T_s) \) when \( m (\Omega_v, T_v, T_s) \rightarrow 0 \). It is seen provided \( m^2 (\Omega_v, T_v, T_s) \sim 0, m (\Omega_s, T_s) \) is definitely very small and the conditions \( A \) and \( B \) above are definitely satisfied. Thus, \( \Omega_s \) and \( \varphi_s \) can transform into \( \Omega_v \) by (10) so that \( T_v \) and \( \rho_v \) increase. Hence (84) can come into being, and \( \mu^2_s (T_v, T_s) \leq 0 \) in the \( S - \text{breaking} \) when \( T_s \) and \( T_v \lesssim T_{cr} \) as well. Thus we prove (67d) to be valid. When \( v^2_{\Omega s} (T_s) \) continues to decrease to zero as \( T_s \) rises to \( T_{cr} \) due to space contraction, \( v_{\Omega s} (T_{cr}) = v_{\Omega v} (T_{cr}) = 0 \) and \( m (\Omega_v, T_v, T_s) = m (\Omega_s, T_s) = 0 \).

Even \( \chi_s \) and \( \chi_v \) are considered, the above conclusions still hold water qualitatively.

VI. SIMPLIFICATION OF THE HIGGS POTENTIAL

If we only discuss space inflation of the present model, the Higgs potentials (8) – (10) can be simplified as follows.

\[
V_s = -\frac{\mu^2}{15} (Tr \Phi_s^2) + \frac{1}{4} a (Tr \Phi_s^2)^2 + \frac{1}{2} b Tr (\Phi_s^4) - \frac{1}{2} \xi (Tr \Phi_s^2) \chi_s^+ \chi_s + \frac{1}{4} \xi (\chi_s^+ \chi_s)^2,
\]

\[
V_v = -\frac{\mu^2}{15} (Tr \Phi_v^2) + \frac{1}{4} a (Tr \Phi_v^2)^2 + \frac{1}{2} b Tr (\Phi_v^4) - \frac{1}{2} \xi (Tr \Phi_v^2) \chi_v^+ \chi_v + \frac{1}{4} \xi (\chi_v^+ \chi_v)^2,
\]

\[
V_{sv} = \frac{2}{23} \alpha (Tr \Phi_s^2) Tr \Phi_v^2 + \frac{1}{2} \beta (Tr \Phi_s^2) \chi_s^+ \chi_v + \frac{1}{2} \beta (Tr \Phi_v^2) \chi_v^+ \chi_s.
\]

Because of (86c), the breaking mode can only be the \( S-\text{breaking} \) \((\varpi_s = v_s (T_s, T_v), \varpi_v = 0)\) or the \( V-\text{breaking} \) \((\varpi_v = v_v (T_s, T_v), \varpi_s = 0)\). For simplicity, we only consider the \( V-\text{breaking} \) and ignore \( \chi_v \) and \( \chi_s \) for a time.

\[
V_{eff}^{(1)} (\varphi_v, T_s, T_v) = \frac{1}{2} (-\mu^2 + \alpha v_{\varphi v}^2 + 2CT_v^2) \varphi_v^2 + B \varphi_v^4 \left( \ln \frac{\varphi_v^2}{\sigma^2} - \frac{1}{2} \right),
\]

\[
V_{eff}^{(1)} (\varphi_s, T_s, T_v) = \frac{1}{2} (-\mu^2 + \alpha v_{\varphi v}^2 + 2CT_s^2) \varphi_s^2 + B \varphi_s^4 \left( \ln \frac{\varphi_s^2}{\sigma^2} - \frac{1}{2} \right),
\]

The critical temperatures and the effective masses are determined by

\[
T_{\varphi v cr}^2 = (B \sigma^2 e^{-1/2} + \mu^2 / 2 - \alpha v_{\varphi v}^2 / 2) / C,
\]

\[
T_{\varphi scr}^2 = (B \sigma^2 e^{-1/2} + \mu^2 / 2 - \alpha v_{\varphi v}^2 / 2) / C.
\]

\[
m^2 (\varphi_v, T_s, T_v) = 2 (\mu^2 - \alpha v_{\varphi v}^2 - 2CT_v^2) + 8B v_{\varphi v}^2, \text{ when } T_{\varphi v} < T_{\varphi v cr},
\]

\[
m^2 (\varphi_v, T_s, T_v) = (-\mu^2 + \alpha v_{\varphi v}^2 + 2CT_v^2), \text{ when } T_{\varphi v} \geq T_{\varphi v cr},
\]

\[
m^2 (\varphi_s, T_s, T_v) = 2 (\mu^2 - \alpha v_{\varphi v}^2 - 2CT_s^2) + 8B v_{\varphi s}^2, \text{ when } T_{\varphi s} < T_{\varphi scr},
\]

\[
m^2 (\varphi_s, T_s, T_v) = (-\mu^2 + \alpha v_{\varphi v}^2 + 2CT_s^2), \text{ when } T_{\varphi s} \geq T_{\varphi scr}.
\]
Substituting \((v_{\varphi v}(T_s, T_v) \neq 0, v_{\varphi s}(T_s, T_v) = 0)\) or \((v_{\varphi v}(T_s, T_v) = 0, v_{\varphi s}(T_s, T_v) \neq 0)\) into (88), we obtain the critical temperatures and the effective masses in the \(V - breaking\) or in the \(S - breaking\). There is no influence of \(\varphi_s\) to \(V(T_s, T_v)\) because \(\varpi_s = 0\) in the \(V - breaking\). Hence the potential (86), in fact, is equivalent to the \(SU(5)\) potential discussed by Ref. [14, 15].

When temperature descends due to space inflation so that \(T_v < T_{\varphi cr}\), \(V_{eff}(\varphi_v, T_s, T_v) = V_{eff}^{(1)}(v_v(T_s, T_v)) < 0, V_{eff min}(\varphi_s, T_s, T_v) = 0\). In the case, there is space inflation in the slow roll approximation. The duration \(\tau \sim 1/T_b\) \((T_b \sim 10^8 Gev)\) of inflation has been estimated by the Ref. [15].

The difference between (86) and (8) - (10) is the following.

The minimum \(V_{v,eff min}(\varphi_v)\) is the absolute minimum at the zero-temperature in the \(V - breaking\) according to (86). In contrast to (86), according to (8) - (10), \(V_{v,eff min}(\varphi_v)\) is not absolute minimum at the zero-temperature in the \(V - breaking\), but \(V_{s,eff min}(\varphi_v, \varphi_v) \ll V_{v,eff min}(\varphi_v)\) is the absolute minimum at the zero-temperature. We will see (8) - (10) has more important significance.

A. Change of \(w\) from \(> 0\) to \(< -1\) and \(q\)

In the inflation period (see Section 7.1, (103)), \(\rho_g = 0\) and \(V_g = V_0\). (51) can be rewritten as

\[
\frac{\ddot{R}}{R} = -\frac{\eta}{2}(V_0 - 3V_0). \tag{89}
\]

After reheating, \(V_g = 0\). In the \(V - breaking\),

\[
\frac{\ddot{R}}{R} = -\frac{\eta}{2} \left[ (\rho_{em} + \rho_{v\gamma} + 3p_{em} + 3p_{v\gamma}) - (\rho_{sm} + \rho_{s\gamma} + 3p_{sm} + 3p_{s\gamma}) \right]
= -\frac{\eta}{2} [\rho + 3p], \tag{90}
\]

where

\[
\rho \equiv \rho_{em} + \rho_{v\gamma},
\]

\[
p \equiv p_{em} + p_{v\gamma} - \rho_{sm}/3 - \rho_{s\gamma}/3 - p_{sm} - p_{s\gamma}, \tag{91}
\]

\(\rho\) is the conventional positive mass density, and \(p\) is the effective pressure density relative to \(\rho\). When the evolution equation is in the form (90), \(w\) is defined as
\[ w = p/\rho. \]  

(92)

Thus, in the inflation period, from (89) we find

\[ w = -1. \]  

(93)

For (90) we have

\[
\frac{w}{\rho_{\nu m} + \rho_{\nu \gamma}} = \frac{p_{\nu m} + p_{\nu \gamma} - \rho_{s m}/3 - \rho_{s \gamma}/3 - p_{s m} - p_{s \gamma}}{\rho_{\nu m} + \rho_{\nu \gamma}}.
\]  

(94)

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, \( p_{\nu m} \sim \rho_{\nu m}/3, p_{\nu \gamma} \sim \rho_{\nu \gamma}/3 \) and \( p_{s m} \sim \rho_{s m}/3 \). Consequently,

\[
w \sim \frac{\rho_{\nu m} + \rho_{\nu \gamma} - 2\rho_{s m}}{3(\rho_{\nu m} + \rho_{\nu \gamma})} > 0.
\]  

(95)

From (65c) and section 8.7, we know \( \rho_{s m}/\rho_{\nu m} \) is changeable. If after some a time,

\[
\rho_{s m} \sim 3\rho_{\nu m},
\]  

(96)

considering \( \rho_{\gamma} \propto R^{-4} \) and \( \rho_{\nu} \propto R^{-3} \), when \( R \) is large enough, \( \rho_{\nu \gamma} \sim 0 \) and temperature is low so that \( p_{\nu m} \sim 0 \) and \( p_{s m} \sim 0 \), from (94) and (96) we have

\[
w \sim \frac{-3\rho_{s m}}{3\rho_{\nu m}} \sim -1.
\]  

(97)

It is seen that \( w \) can change from \( w > 0 \) to \( w \sim -1 \) according to the present model.

According to the simplified Higgs potential (86), in the slow rolling approximation, we can get the results similar to (93) and (96) – (97).

In fact, space inflation or expansion with an acceleration is independent of the slow approximation, and \( w \) is not important for the present model. Although there is no slow approximation, space inflation can be explained because \( V_g = V_0 \) in the inflation process and the parameters \( \alpha \) and \( w \) in (8) – (10) are so chosen that \( \alpha > w \). Although \( V_g = 0 \) after reheating, space expansion with a deceleration or an acceleration can still be explained by the present model.

\( q \) is defined as

\[
q = \frac{\ddot{R}}{\dot{R}^2} = \frac{-K/R^2 + \eta (\rho_g + V_g)}{\eta (\rho_g/2 + 3p_g/2 - V_g)}.
\]  

(98)
When $\Omega_s = \Omega_v = 0$ (or $\varphi_s = \varphi_v = 0$ according to the simplified Higgs potential (86)), $\rho_v = \rho_s$, $p_v = p_s$, $V_s = V_v$, $K \sim 1$, $R \geq R_{\text{min}}$ to be finite and $V_g = V_0 \gg -K/R^2$. Consequently,

$$q = \frac{-K/R^2 + \eta V_g}{-\eta V_g} \leq -1.$$  \hspace{1cm} (99)

After the reheating, $V_v \sim -V_0$, $V_s = 0$, and $V_g = V_v + V_0 - V_s = 0$. When $\rho_g = \rho_v - \rho_s > 0$, $p_v > p_s$ and $-K/R^2 + \eta \rho_g > 0$,

$$q = \frac{-K/R^2 + \eta \rho_g}{\eta \rho_g/2 + 3p_g/2} > 0,$$  \hspace{1cm} (100)

where $K \sim 1$ due to $\rho_g > 0$.

When $\rho_g = 0$, $K = 0$, from (65) we have

$$q = -\frac{\dot{R}}{R^2} = \frac{3}{4} \frac{\eta \rho_g \dot{R} K}{\dot{K} R K} + \frac{1}{2}.$$  \hspace{1cm} (101)

When $\rho_g < 0$, $K \sim -1$. Considering $\rho_g = \rho_{mg} + \rho_{\gamma g}$, $\rho_{mg} \propto R^{-3}$, $\rho_{\gamma g} \propto R^{-4}$, $p_g$ may be neglected and $-K/R^2 + \eta \rho_g > 0$ when $R$ is large enough, we have

$$q = \frac{-K/R^2 + \eta \rho_g}{\eta \rho_g/2} < 0.$$  \hspace{1cm} (102)

In the case, space expands with an acceleration, although $V_g = 0$.

VII. 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, $\xi R \left(\Omega_s^2 - \Omega_v^2\right) = 0$ 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 is 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 \( \tilde{\rho}_{sg} = V_0 \)

   This has been proved in section 2.

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 \( \tilde{\rho}_{sg} = 0 \), it is necessary that there is no space-time singularity. Provided space contract because \( \tilde{\rho}_{sg} = 0 \), \( T_s \) 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 \( \varpi_s \) and \( \varpi_v \) are zero. Consequently \( \rho_s \) and \( \rho_v \) can transform from one into another. Thus \( \rho_s = \rho_v \), \( T_s = T_v \) and \( \tilde{\rho}_{sg} = V_0 \), 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 (61), we may take \( K = 1 \). Thus (48) – (49) is reduced to

\[
\begin{align*}
\dot{R}^2 &= -1 + \eta V_0 R^2, \quad (103a) \\
\ddot{R} &= \eta V_0 R. \quad (103b)
\end{align*}
\]

Consequently space inflation must occur and temperature will fast descend.

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

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

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

\[
\begin{align*}
R_{\text{min}} &= \sqrt{1/\eta V_0} \leq R_{cr}, \quad T_{cr} \equiv 2\mu/\sqrt{\lambda}, \quad (105a) \\
T_{\text{max}} &= T(R_{\text{min}}) = T_{cr} R_{cr}/R_{\text{min}} \geq T_{cr}, \quad (105b) \\
\rho_{\text{max}} &= \rho_{s\text{max}} + \rho_{v\text{max}} = 2\frac{\pi^2}{30}g^*T_{\text{max}}^4, \quad \text{and} \quad \tilde{\rho}_{\text{max}} = \rho_{\text{max}} + V_0. \quad (105c)
\end{align*}
\]

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

\[
\begin{align*}
R &= \sqrt{\frac{1}{H}} \cosh \sqrt{\eta V_0} \ (t - t_{FI}) = \sqrt{\frac{1}{H}} \cosh H \ (t - t_{FI}), \quad \sqrt{\eta V_0} \equiv H; \\
&= \sqrt{\frac{1}{H}} = R_{\text{min}}, \quad \text{when } t = t_{FI} \\
&\sim \frac{1}{2} \sqrt{\frac{1}{H}} \exp H \ (t - t_{FI}), \quad \text{when } H (t - t_{FI}) \gg 1,
\end{align*}
\]

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 \( S - \text{breaking} \) and the initial moment of the world in the \( V - \text{breaking} \). \( R_{\text{min}} \) and \( T_{cr} \) are two new important constants, and \( T_{\text{max}} \) and \( \rho_{\text{max}} \) are determined by \( R_{cr} \). It is seen that all \( R, T \) and \( \rho \) must be finite in the case. \((56b)\) is considered in \((105b)\). 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 \( R = R_{\text{min}} \), \( T = T_{\text{max}} \) or \( \rho = \rho_{\text{max}} \) and \( \dot{R} = 0 \).

We know that the duration of inflation \( \tau \) may be long enough for inflation (see below \((88)\)). After \( \tau \), \( R \) has a large enough increase.

\((104)\) 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 \( T \gtrsim T_{cr} \), considering \((56b)\), we have

\[
\rho_s R^4 = \rho_{scr} R^4 (T_{cr}) \equiv D_s = D_v = \rho_v R^4 = \rho_{ecr} R^4 (T_{cr}), \quad \rho_a = \frac{\pi^2}{30} g^* T^4_a,
\]

\[
\rho_{scr} = \rho_{ecr} = \rho_{cr} \equiv \frac{\pi^2}{30} g^* T^4_c = \frac{\pi^2}{30} g^* \frac{16 \mu^4}{\lambda^2}, \quad T^4_a R^4 = T^4_c R^4 (T_{cr}).
\]

Thus, when \( T \sim T_{cr} \), from \((118)\) we can rewrite the condition of inflation \((104)\) as

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

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., \( R_{\text{min}} > R(T_{cr}) \) and \( T(R_{\text{min}}) = T_{\text{max}} < T_{cr} \). 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 \( R_{\text{min}}, T_{\text{max}}, \rho_g, \rho_s \) and \( \rho_v \) must still be finite because of the cosmological principle, i.e. there is no space-time singularity. In the case, it is necessary

\[
\dot{R} = 0, \quad \ddot{R} > 0, \quad \text{when } R = R_{\text{min}},
\]

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because $R_{\min}$ is the end of contracting $R$. In the case, when $R \geq R_{\min}$, the evolving equations are still (48) – (49) 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 $T_{\text{max}}$. Because of the cosmological principle, all $\rho_s$, $\rho_v$, $\tilde{\rho}_S = \tilde{\rho}_s - \tilde{\rho}_v$ and $p \leq \rho/3$ are finite because of the cosmological principle. Hence $T_{S\mu\nu}$, $T_{S\nu\mu}$ and $T_{S\mu\nu} - T_{S\nu\mu}$ must be finite due to (43) – (47). Substituting the finite $T_{S\mu\nu} - T_{S\nu\mu}$ 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 $\tilde{\rho}_g = \tilde{\rho}_v - \tilde{\rho}_s = V_0$, (103) is consistent with the Lemaître model without singularity in which $\rho_g = 0$, $k = 1$ and the cosmological constant $\lambda_{\text{eff}} > 0^{[16]}$.

**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 $\rho_s$ and $\rho_v$ can transform from one to another when $T \geq T_{cr}$. It is seen that $\rho_g$ does not increase not only, but also decreases to zero when $T \geq T_{cr}$. 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 $T \geq T_{cr}$.

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 \( \mu \);
(c) there is an achronal set \( \Xi \) such that \( E^+(\Xi) \) or \( E^-(\Xi) \) 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 \((\mu, g)\) is not timelike and null geodesically complete if:

1. \( R_{ab}K_aK_b \geq 0 \) for every non-spacelike vector \( K \).
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 \( K \) is the tangent vector to the geodesic.
3. The chronology condition holds on \( \mu \) (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 \( \hat{\vartheta} \) 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 \( \mu \) 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,

$$R_{\mu\nu} = -8\pi G \left( T_{g\mu\nu} - \frac{1}{2} g_{\mu\nu} T_g \right)$$

$$= -8\pi G \left[ (T_{s\mu\nu} - T_{\nu\mu}) - \frac{1}{2} g_{\mu\nu} (T_s - T_v) \right].$$  \hspace{1cm} (109a)

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

$$\left[ (T^{ab} + T^{vb}) - \frac{1}{2} g^{ab} (T_s + T_v) \right] K_a K_b \geq 0,$$  \hspace{1cm} (109b)

the conditions of propositions 1 and 2 and condition (1) do no longer hold, because the gravitational mass density $\rho_g$ determines $R_{\mu\nu}$ and $\rho_g = \rho_v - \rho_s \neq \rho_v + \rho_s = \rho$. Hence (a) and (c) do not hold, but (b) still holds, and $\mu$ is timelike and null geodesically complete.

C. The process of space inflation

As mentioned before, the duration of space inflation is finite (see below (88)). Supposing $\lambda \sim g^4$, $g^2 \sim 4\pi/45$ for $SU(5)$, and considering $m(\Omega_s) = \sqrt{2}\mu$ (see (32)), from (66) we can estimate $T_{\text{max}}$,

$$T_{\text{max}} \gtrsim \frac{2\mu}{\sqrt{\lambda}} \sim \frac{2\mu}{g^2} \sim \frac{\sqrt{2}m(\Omega_s)}{4\pi/45} = 5m(\Omega_s).$$  \hspace{1cm} (110)

The temperature will strikingly decrease in the process of inflation, but the potential energy $V (\varpi_s \sim \varpi_v \sim 0) \sim V_0$ cannot decrease to $V_{\text{min}} (T_v)$ 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 (110) we have

$$H = aT_{\text{max}}^2, \quad a \equiv \sqrt{\eta\lambda/8} \sim g^2\sqrt{\eta}/8.$$  \hspace{1cm} (111)

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

Taking $T_{\text{max}} \sim 5m(\Omega_s) \sim 5 \times 10^{15}\text{Gev}$ 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 $10^{-33}s \sim (10^8\text{Gev})^{-1}$, $R_{\text{min}}$ will increase $\exp 100 \sim 10^{43}$ times. As mentioned before (see below (88)), the duration $\tau$ of inflation may be long enough, $\tau \sim 1/T_b^{[15]}$. Taking $T_{\text{max}} \sim 10^{15}\text{Gev}$ and $T_b \sim 10^8\text{Gev}$, we have $H^{-1} = 10^{-35}s$ and $\tau \sim 10^{-33}s$. The result is consistent with the Guth’s inflation model$^{[17]}$.}

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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.

The parameters in the Higgs potential can be so suitably chosen that $\tau$ is suitable. We discuss the problem in the following paper.

VIII. EXPANSION OF SPACE AFTER INFLATION

A. The reheating process

After inflation, the temperature must sharply descend. In the case, it is easily seen that the state with $\langle \omega_s \rangle = \langle \omega_v \rangle = 0$ is no longer stable and must decay into such a state with $V_{\text{min}}$. Either of the $S$-breaking and the $V$-breaking can come into being, because $s$-matter and $v$-matter are completely symmetric at $T_{\text{max}} \gtrsim T_{\text{cr}}$. Let the $V$-breaking comes into being, then $v - SU(5) \rightarrow v - SU(3) \times U(1)$ and $s - SU(5)$ symmetry is kept. In this case, $t_{FI}$ can be regarded as the initial moment for the world in the $V$-breaking. Thus we take $t_{FI} = 0$. Ignoring the effect of temperature ($T \sim 0$), from (8) – (10) we see the phase transition of the vacuum is as follows,

$$
\bar{\omega}_v(T_{\text{max}}) = 0 \rightarrow \bar{\omega}_v(T_v \sim 0) = \bar{\omega}_{v0},
$$

$$
\bar{\omega}_s(T_{\text{max}}) = 0 \rightarrow \bar{\omega}_s(T_s \sim 0) = \bar{\omega}_{s0} = 0,
$$

$$
V_v(\bar{\omega}_v, T_{\text{max}}) = 0 \rightarrow V_v(\bar{\omega}_{v0}, 0) = -V_0,
$$

$$
V_s(\bar{\omega}_s, T_{\text{max}}) = 0 \rightarrow V_s(\bar{\omega}_{s0}, 0) = 0, \quad V_{sv} = 0 \rightarrow 0,
$$

$$
V_{Vg} = V_v(T_{\text{max}}) + V_0 - V_s(T_{\text{max}})
$$

$$
= V_0 \rightarrow V_v(\bar{\omega}_{v0}, 0) + V_0 - V_s(\bar{\omega}_{s0}, 0) = 0. \quad (112)
$$

After transition, $V_v(T_{\text{max}}) - V_v(T_v \sim 0) = V_0$ must firstly transform into a lot of the $v$-Higgs particles. The $v$-Higgs particles can decay fast into the $v$-gauge bosons and the $v$-fermions by the $v$-SU(5) couplings. On the other hand, because of the coupling (10), the $v$-Higgs particles can transform into the $s$-Higgs particles as well. The $s$-Higgs particles $\Omega_s$, $\varphi_s$ and $\chi_s$ can fast decay into the $s$-gauge bosons and the $s$-fermions
by $s - SU(5)$ couplings. Let $\alpha V_0$ transform the $v - energy$, then $(1 - \alpha)V_0$ transforms the $s - energy$. 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

$$\rho_v = \rho'_v + \alpha V_0 > \rho_s = \rho'_s + (1 - \alpha)V_0.$$  \hspace{1cm} (113)

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.

In the $V - breaking$, the space evolving equations are (50) – (51). After the reheating process, $V \sim 0$. Thus, (50) – (51) reduce

$$\ddot{R} = -k + \eta (\rho_v - \rho_s) R^2 = -k + \eta \rho_{Vg} R^2.$$ \hspace{1cm} (114a)

$$\dot{R} = -\frac{\eta}{2} [(\rho_v - \rho_s) + 3 (p_v - p_s)] R = -\frac{\eta}{2} (\rho_{Vg} + 3p_{Vg}) R.$$ \hspace{1cm} (114b)

After $T_s$ and $T_v$ decline further, the $v$-particles exist in forms of nucleons, leptons and photons, and the $s$-particles will form $S - SU(5)$ color single states whose masses are non-zero.

**B. Change of gravitational mass density in comoving coordinates**

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

After reheating process, all Higgs particles have got their very big masses due to $T_v \sim T_s \sim 0$, hence $s$-matter and $v$-matter cannot transform into each other. $\rho_v = \rho_{vm} + \rho_{v\gamma}$ because $v - SU(5) \rightarrow v - SU(3) \times U(1)$. All $s$-particles must be the $s$-colour single states and there is no $s$-photonlike particle so that $\rho_{s\gamma} = 0$ so that $\rho_s = \rho_{sm}$, because $s - SU(5)$ is not broken in the $V - breaking$. Hence $\rho_v/\rho_s$ must decrease as $R$ increases because $\rho_m \propto R^{-3}$ and $\rho_\gamma \propto R^{-4}$. In the case, $V_{Vg} = 0$ and (114) reduces to

$$\ddot{R} + k = \eta (\rho_{vm} + \rho_{v\gamma} - \rho_{sm}) R^2 = \eta \rho_{Vg} R^2.$$ \hspace{1cm} (115)

$$\dot{R} = -\frac{\eta}{2} [(\rho_{vm} + \rho_{v\gamma} - \rho_{sm}) + 3 (p_{vm} + p_{v\gamma} - p_{sm})] R,$$ \hspace{1cm} (116a)

$$\simeq -\frac{\eta}{2} (\rho_{vm} + 2 \rho_{v\gamma} - \rho_{sm}) R = -\frac{\eta}{2} (\rho_{Vmg} + 2 \rho_{v\gamma g}) R.$$ \hspace{1cm} (116b)
where \( \rho_{\text{em}} \) and \( \rho_{\text{sm}} \) are neglected and \( \rho_{\text{v}\gamma} = \rho_{\text{v}\gamma}/3 \) is considered.

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

\[
\rho_v = \rho_{\text{v}\gamma} (t_3) + \rho_{\text{vm}} (t_3) > \rho_{\text{sm}} (t_3) > 3 \rho_{\text{vm}} (t_3),
\]

or \( y_3 + 1 > x > 3 \).

After the photons decoupled, the number \( n_{vN} \) of the \( v-\text{nucleons} \) and the number \( n_{v\gamma} \) of the \( v-\text{photons} \) are invariant and \( n_{vN0}/n_{v\gamma0} \sim 5 \times 10^{-10} \) when space expansion. The number \( n_s \) of the \( s-\text{colour} \) single states is invariant as well. Let \( \rho_{Vg} (t, R(t)) = \rho_{Vg} (R(t)) \), then \( \rho_{\text{sm}} \propto R^{-3}, \rho_{\text{vm}} \propto R^{-3} \) and \( \rho_{\text{v}\gamma} \propto R^{-4} \). Thus the gravitational mass density \( \rho_{Vg} (t) \) in comoving coordinates is changeable,

\[
\rho_{Vg} (t) = \rho_{\text{vm}} + \rho_{\text{v}\gamma} - \rho_{\text{sm}} = \rho_{\text{em}} (t_3) (1 - x + yR(t_3)/R(t))
\]

\[
= \rho_{\text{em}} (t_0) (1 - x) + \rho_{\text{v}\gamma0} R(t_0)/R(t)
\]

\[
= \rho_{\text{em}} (t_0) (1 - x + y_0 R(t_0)/R(t)),
\]

where \( y_0 = \rho_{\text{v}\gamma0}/\rho_{\text{em}0} \) and \( \rho_{\text{em}} (t_3) = \rho_{\text{em}} (t_0) \) is considered. Let \( \rho_{Vg} (t_2) = 0 \), then considering the conjecture 3, we have

\[
\rho_{Vg} (t_2) = K(t_2) = 0, \quad \frac{R(t_3)}{R(t_2)} = (x - 1)/y_3, \quad \text{or} \quad \frac{R(t_0)}{R(t_2)} = (x - 1)/y_0.
\]

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 \( y_0 = 1/6000 \).

\( \rho_{\text{em}} - \rho_{\text{sm}} \) will also change because of (65c) and the reason in section 8.7.

C. Space expands with a deceleration

From (118) – (119) we see when \( 0 < t < t_2, \rho_{Vg}(t) > 0 \) so that \( K (\rho_{Vg}) > 0 \). From (115), (116b) and (118) we have

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

\[
\ddot{R} = -\frac{\eta}{2} (\rho_{Vg} + \rho_{\text{v}\gamma})
\]

\[
= -\frac{\eta}{2} \frac{R^3 (t_3)}{R^2} \rho_{\text{vm}} (t_3) \left[ (1 - x) + \frac{2y_3 R(t_3)}{R} \right].
\]
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. We analyze the process in detail as follows.

1. It is possible that there is \(t_1\) to satisfy \(\ddot{R}(t_1) = 0\) because \(\dot{R} > 0\) and \(\ddot{R} < 0\) when \(t > t_3\).

   When \(\ddot{R}(t) = 0\), (58) – (59) reduces to (63) in which \(\rho_g = \rho_{Vg}\) and \(\rho_{g\gamma} = \rho_{vg\gamma}\) (because in the \(V\) - breaking now). There are two sorts of possibility when \(t > t_1\).

   A. \(\rho_{Vg}(t) > 0\) when \(t \leq t_1\) and \(\ddot{R}(t_1) = 0\), hence \(\dddot{R}(t_1) \leq 0\) \((\rho_{g\gamma} > 0\) as well). Thus \(R(t > t_1)\) will decrease as the conventional theory (space contracts).

   B. \(\rho_{Vg}\) decreases because space expands. It is possible that there is \(t_2 \leq t_1\) to satisfy \(\rho_{Vg}(t_2) = 0\) and \(\ddot{R}(t_2) \geq 0\). \(K(t_2) = 0\) because of the conjecture 3. In the case, \(\ddot{K}/K\) must be considered and (58) – (59) reduces to (65) in which \(\rho_{g\gamma} = \rho_{vg\gamma}\). From (65) we see that there are two sorts of possibility when \(t > t_2\).

   a. If \(\ddot{K}/K = 0\), \(\dot{R} = 0\) and \(\dddot{R} = -(\eta/2)\rho_{vg\gamma} < 0\). Hence space will contract with an acceleration. In the case, \(t_2 = t_1\).

   b. If \(\ddot{K}/K > 0\), \(\dot{R} > 0\) and \(\dddot{R} < 0\) so that space continues to expands with a deceleration.

   In the case, \(t_2 < t_1\), \(\ddot{R}(t_1) = 0\), \(\rho_{Vg}(t_1) < 0\) and \(K(t_1) < 0\) because of (118) – (119) and \(R(t_1) > R(t_2)\). There are the following three sorts of possibility, because of \(\rho_{Vg}(t_1) < 0\).

   (a). \(\rho_{Vg}(t_1) + \rho_{vg\gamma}(t_1) > 0\), so \(\ddot{R}(t_1) < 0\). Thus \(R(t > t_1)\) will decrease due to \(\ddot{R}(t_1) = 0\), i.e. space will contract with an acceleration.

   (b). \(\rho_{Vg}(t_1) + \rho_{vg\gamma}(t_1) < 0\), so \(\dddot{R}(t_1) > 0\). Thus \(R(t > t_1)\) will continue to increase due to \(\dot{R}(t_1) = 0\), i.e. space will expand with an acceleration.

   (c). \(\rho_{Vg}(t_1) + \rho_{vg\gamma}(t_1) = 0\), so \(\dddot{R}(t_1) = 0\). Thus \(R(t > t_1) = R(t_1)\), i.e., space will be static.

   In the case (c), in fact, \(\rho_{Vg} = \rho_{Vg}(t, R(t))\) which can still change although \(\dot{R} = 0\). This is because the major part of the repulsive potential energy between \(s - matter\) and \(v - matter\) will transform into \(s - energy\) when \(v - galaxies\) form (see below). Consequently, after long time, \(\rho_{Vg} = \rho_v - \rho_{sm}\) will strikingly decrease so that space will continue to expand with an acceleration.

   The cases are different from the conventional theory. According to the conventional theory, when \(\rho_{Vg}(t) = K(t) = 0\), there must be \(\dot{R} = \dddot{R} = 0\).
There is no the case $K/\dot{K} < 0$. This is because if $K/\dot{K} < 0$, there must be $\dot{R}(t) < 0$. This is contradictory to the premise $\dot{R}(t_2) < 0$.

2. The other possibility is when $\dot{R}(t) > 0$, $\ddot{R}$ have changed from $\dot{R} < 0$ in to $\dot{R} > 0$. In the case, space will continue to expand with an acceleration, and there is no stage in which $\dot{R}(t) = 0$.

To sum up, we see that after inflation, space first expands with a deceleration, then it is possible that space is static for a period and finally expands with an acceleration up to now.

D. Space expands with an acceleration

We consider the expanding process of space. After reheating, $V_{Vg} \sim 0$. Based on the discussion about (61) 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 (50) − (51) we have

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

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

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

$$\frac{\ddot{R}}{2} = \frac{H_0^2}{2} \left(\frac{\Omega_{gm0}}{a^2} - \frac{2 \Omega_{v\gamma0}}{a^3}\right),$$

where $\rho_g = \rho_{Vg}$ for simplicity, $C_0 = \rho_{m0} R_0^3$, $a = R/R_0$, $a_0 = H_0^2 = \eta \rho_c = \eta \rho_{gc}$, $\Omega_{gm0} = (\rho_{sm0} - \rho_{v\gamma0})/\rho_c = (x - 1) \rho_{vm0}/\rho_c$, $\Omega_{v\gamma0} = \rho_{v\gamma0}/\rho_c = y_0 \rho_{v\gamma0}/\rho_c$; $\Omega_{g0} = (\rho_{sm0} - \rho_{v\gamma0} - \rho_{v\gamma0})/\rho_c$, $H_0^2 R_0^2 = 1/(1 + \Omega_{g0})$. It is obvious that when $R_0/R < (x - 1)/2y_0$, $\dot{R} > 0$ and $\ddot{R} > 0$, i.e., space will expand with an acceleration.

E. To determine $a(t)$

It is difficult to uniformly describe the three evolving stages space since $K(t)$ 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 (121a) 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 (121a). As mentioned before, when \( t \leq t_1, \ddot{R}(t) < 0 \) so that space expands with a deceleration. From (121a) we have

\[
t = t_0 - \frac{1}{H_0\sqrt{1 + \Omega_{g0}}} \left\{ \sqrt{1 - M + \Gamma} - \sqrt{a^2 - Ma + \Gamma} \right\} + \frac{M}{2} \ln \frac{2 - M + 2\sqrt{1 - M + \Gamma}}{2a - M + 2\sqrt{a^2 - Ma + \Gamma}},
\]

(122)

where \( M = \Omega_{g0}/(1 + \Omega_{g0}), \Gamma = \Omega_{v0}/(1 + \Omega_{g0}) \).

Taking \( \Omega_{v0} = 0.001, \Omega_{g0} = 0.3\Omega_{v0} + 2\sqrt{\Omega_{v0}}, H_0^{-1} = 9.7776 \times 10^9 h^{-1} yr \) and \( h = 0.8 \), we get \( a(t) \). \( a(t) \) 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 \( \Omega_{v0} = 0.05, \Omega_{g0} = 2\sqrt{\Omega_{v0}}, \) we get the \( a(t) \) 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 \( \Omega_{g0} \leq 2\Omega_{v0} + 2\sqrt{\Omega_{v0}} \) (the condition \( a^2 > 0 \)), 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 \( \Omega_{v0}, \Omega_{g0} \rightarrow -\Omega_{g0} \) and taking \( a \sim 0 \), we can reduce (122) to the corresponding formula (3.44) in Ref. [8]

\[ F. \quad \text{The relation between redshift and luminosity distance} \]

Considering \( k = -1 \), from (40) and (120a) we have

\[
\int_{-\infty}^{1} \frac{c da}{a R \dot{a}} = - \int_{0}^{\infty} \frac{dr}{r \sqrt{1 + r^2}}.
\]

\( H_0 d_L = H_0 R_0 r (1 + z) = \frac{2c}{(\Omega_{g0} - 2\Omega_{v0})^2 - 4\Omega_{v0}} \cdot \left\{ 2 \left( 1 + \Omega_{g0} \right) - (1 + z) \Omega_{g0} \right\}

\[ + \left[ 2 \left( 1 + \Omega_{g0} \right) - \Omega_{g0} \right] \sqrt{1 - (\Omega_{g0} - 2\Omega_{v0}) z + \Omega_{v0}^2 z^2}, \]

(124)
where $z = (1/a) - 1$ is the redshift caused by $R$ increasing. Provided $\Omega_{gm0} \rightarrow -\Omega_{gm0}$, (124) is consistent with the corresponding formula (3.81) in Ref. [8]. Ignoring $\Omega_{v\gamma0}$, $\Omega_{gm0} \rightarrow -\Omega_{gm0}$ we reduce (124) to

$$H_0d_L = \frac{2c}{\Omega_{gm0}^2} \left\{ 2 + \Omega_{gm0} (1 - z) - [2 + \Omega_{gm0}] \sqrt{1 - \Omega_{gm0} z} \right\},$$

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

$$H_0d_L = z + \frac{1}{2} z^2 \left( 1 + \frac{1}{2} \Omega_{gm0} \right).$$

Taking $\Omega_{v\gamma0} = 0.001$, $\Omega_{gm0} = 0.3\Omega_{v\gamma0} + 2\sqrt{\Omega_{v\gamma0}}$ and $H_0^{-1} = 9.7776 \times 10^9 h^{-1} yr^{-1}$ and $h = 0.8$, from (124) 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.

G. Repulsive potential energy chiefly transforms into the kinetic energy of SU(5) color single states

The repulsion potential energy between $v - matter$ and $s - matter$ is determined by the distributing mode of $s - matter$ and $v - matter$. In $V - breaking v - particles$ with their masses can form $v - celestial$ bodies, but $s - matter$ which is $s - SU(5)$ color single states cannot form any dumpling and must loosely distribute in space. Consequently, the huge repulsion potential energy must chiefly transform into the kinetic energy of $s - SU(5)$ color single states when the $v - celestial$ bodies form or space expands. In fact, when flat space expands $N$ times, i.e., $R \rightarrow NR$, the repulsive-potential energy density $V_r$ becomes $V_r/N$ and

$$\triangle V_r = (1 - 1/N) V_r.$$  

(126)

Consider a system in flat space which is composed of a $v - body$ with its mass $M$ and a $s - colour$ single state with its mass $m$. It is easy to get the rate $\triangle E_m/\triangle E_M$ for static $M$ and $m$ at the initial moment.. 

$$\frac{\triangle E_m}{\triangle E_M} = \frac{2M + \triangle V_r}{2m + \triangle V_r}.$$ 

(127)

Because $M \gg m$, $\triangle E_m > \triangle E_M$.

Space expansion is not the necessary condition to transform repulsive potential energy into kinetic energy. Supposing $\dot{R} = 0$ and some $v - matter$ gather to a region and forms a
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.

galaxy, $s$ – matter which is initially in the region must be repulsed away from the region and increases its kinetic energy. The repulsive potential energy chiefly transforms into the kinetic energy of the $s$ – matter in this case as well.

IX. EXISTING AND DISTRIBUTIVE FORMS OF S-SU(5) COLOR SINGLE STATES IN THE V-BREAKING

When $T_s$ is low, the $s$ – $SU(5)$ color single states must loosely distribute in space or form $s$ – superclusterings, i.e., huge voids relative to $v$ – matter.
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 $\Omega_{m0} = 2 \sqrt{\Omega_{v\gamma 0}}$.

A. Sorts of s-SU(5) color single states in the V-breaking

$\varpi_s = 0$ and $\varpi_v \neq 0$ in the $V$–breaking. Thus the $s – SU(5)$ symmetry still holds water and $v – SU(5) \rightarrow v – SU(3) \times U(1)$. Hence all $s – gauge$ particles and $s – fermions$ are massless (if the masses originate from only the couplings of the $s – fermions$ with the $s – Higgs$ fields). When the temperature $T_s$ is high enough, all $s – gauge$ particles and $s – fermions$ must exist in plasma form. When $T_s$ is low, all $s – particles$ will exist in $s – SU(5)$ color-single state form (conjecture 4). Let $A$, $B$, $C$, $D$, $E$ denote the 5 sorts of colors. A component of 10 representation carries color $\alpha\beta$, $\alpha, \beta = A, B, C, D, E$, $\alpha \neq \beta$. A component of 5 representation carries color $\alpha$. A gauge boson carries colors $\alpha\beta^*$. There are the following sorts of the $s – SU(5)$ color-single states.

2-fermion states: $\bar{\alpha}\alpha^*$ or $(\alpha\beta)(\bar{\alpha}\beta)^*$, $\alpha \neq \beta$. When the spin of $\bar{\alpha}\alpha^*$ or $(\alpha\beta)(\bar{\alpha}\beta)^*$ is
zero, we denote $\alpha \alpha^* \text{ or } (\alpha \beta) (\alpha \beta)^*$ by $s - \pi$. When the spin of $\alpha \alpha^* \text{ or } (\alpha \beta) (\alpha \beta)^*$ is 1, we denote $\alpha \alpha^* \text{ or } (\alpha \beta) (\alpha \beta)^*$ by $s - \rho$. Analogously to QCD, we have $m (s - \pi) < m (s - \rho)$ (because of color-magnetic interaction) and can suppose $m (s - \pi) \sim m (\pi)$ to be minimum
in all $s - SU(5)$ color-single states. In contrast with a given $\pi - meson$, $s - \pi$ must be stable, because there is no the electroweak interaction in the case $\omega_s = 0$.

3-fermion states: $(AB) (CD) E \text{ or } (AB) A^* B^*$. When the spin of $3 - fermion$ states is $1/2$, we denote them by $s - N$. $s - N$ is stable, and we can suppose $m (s - N) \sim m (N)$. $N$ denotes a given nucleon.

4-fermion states: $(AB) CDE$.

5-fermion states: $ABCDE \text{ or } (AB) (BC) (CD) (DE) (EA)$.

Gauge boson single-states: $(\alpha \beta^*) (\alpha^* \beta)$ or $(\alpha \beta^*) (\beta \gamma^*) (\gamma \delta^*)$ etc., $\alpha \neq \beta \neq \gamma$.

Fermion-gauge boson single-states. $\alpha^* (\alpha \beta^*) \beta$, $\alpha^* (\alpha \gamma^*) (\gamma \delta^*) \beta$ etc.

Of course, there are the $s - antiparticles$ corresponding to the $s - colour$ single states above as well.

**B. The characters of the s-SU(5) color single states in V-breaking**

We can only qualitatively discuss the $SU(5)$-color single states by comparing the $SU(5)$-color single states with the $SU(3)$-color single states, because there is no mature theory of strict $SU(5)$ symmetry up till now. The following inferences are obtained on the basis of the sameness of the $SU(5)$ and $SU(3)$ groups, hence they are reliable.

The characters of the $s - SU(5)$ color single states in the $V - breaking$ are as follows.

1. If the masses of the $s - SU(5)$ fermions only originate from the coupling of the $s - SU(5)$ fermions with the $s - SU(5)$ Higgs fields, they all must be zero because $\langle \omega \rangle = 0$ in the $V - breaking$. If such mass terms $m \bar{\psi} \psi + M Tr \bar{\Psi} \Psi$ are added to $L$ ($L_V$ and $L_S$), the masses of the $s - SU(5)$ fermions are non-zero. Here $\psi$ and $\bar{\Psi}$ are respectively the representations $\underline{5}$ and $\underline{10}$. The masses of all $SU(3)$ color single states (include gluon balls) are non-zero. Consequently, we can determine that all $SU(5)$-color single states can get their suitable masses.

2. In contrast with $SU(3)$ color single states among which there are the electromagnetic and weak interactions due to the gauge group is $SU(3) \times U(1)$, there is no electroweak interaction among the $s - SU(5)$ color single states because $s - SU(5)$ is a simple group.
Hence the $s - SU(5)$ color single states with the minimum masses must be stable.

3. The interaction radius of the $s - SU(5)$ color single states must be finite and much smaller ($\sim 1 \times 10^{-15}m$) than the radius of hydrogen atoms ($\sim 1 \times 10^{-10}m$). This is because the interactions can come into being only by exchanging the $s - SU(5)$ color single states, and the masses of all $s - SU(5)$ color single states are non-zero.

Thus we can approximately regard the $s - SU(5)$ color single states as ideal gas without collision.

In a word, the $s - SU(5)$ color single states are analogous to $v - neutrinos$, but in contrast with the $v - neutrinos$, there is the repulsion between the $s - SU(5)$ color single states and $v - matter$.

From the characters of the $s - SU(5)$ color single states mentioned above, we will see that the $s - SU(5)$ color single states in the $V - breaking$ cannot form clusters and must loosely distribute in space, but it is possible they form $s - superclusterings$ as the neutrinos.

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

Generalizing equations governing nonrelativistic fluid motion$^8$ to present model, we have

$$\left( \frac{\partial}{\partial t} + \mathbf{v_v} \cdot \nabla \right) \mathbf{v_v} = -\frac{\nabla p_v}{\rho_v} - \nabla \Phi, \quad (128)$$

$$\frac{\partial}{\partial t} \rho_v + \nabla \cdot (\rho_v \mathbf{v_v}) = 0 \quad (129)$$

$$\nabla^2 \Phi = 4\pi G (\rho_v - \rho_s), \quad (130)$$

$$\left( \frac{\partial}{\partial t} + \mathbf{v_s} \cdot \nabla \right) \mathbf{v_s} = -\frac{\nabla p_s}{\rho_s} + \nabla \Phi, \quad (131)$$

$$\frac{\partial}{\partial t} \rho_s + \nabla \cdot (\rho_s \mathbf{v_s}) = 0, \quad (132)$$

in the $V - breaking$, where $\partial/\partial t + \mathbf{v_v} \cdot \nabla$ is call the convective derivative. We can produce the linearized equations of motion by collecting terms of first order in perturbations about
a homogeneous background $\rho_v = \rho_{v0} + \delta \rho_v$ etc. Let

$$v_v = v_{v0} + \delta v_v, \quad v_s = v_{s0} + \delta v'_s$$

(133a)

$$\rho_v = \rho_{v0} + \delta \rho_v, \quad \rho_s = \rho_{s0} + \delta \rho_s,$$

(133b)

$$\delta_v = \frac{\delta \rho_v}{\rho_{v0}}, \quad \delta_s = \frac{\delta \rho_s}{\rho_{s0}},$$

(133c)

considering $v_{v0} = H x = \left(\frac{\dot{a}}{a}\right) x$, we get

$$\left(\frac{\partial}{\partial t} + v_{v0} \cdot \nabla\right) \delta v_v = -\frac{\nabla \delta \rho_v}{\rho_{v0}} - \nabla \delta \Phi - (\delta v_v \cdot \nabla) v_{v0},$$

(134)

$$\nabla \delta v_v = -\nabla \delta v_v,$$

(135)

$$\nabla^2 \Phi = 4\pi G \left(\rho_{v0} \delta_v - \rho_{s0} \delta_s\right),$$

(136)

$$\left(\frac{\partial}{\partial t} + v_{s0} \cdot \nabla\right) \delta v_s = -\frac{\nabla \delta \rho_s}{\rho_{s0}} + \nabla \delta \Phi - (\delta v_s \cdot \nabla) v_{s0},$$

(137)

$$\left(\frac{\partial}{\partial t} + v_{s0} \cdot \nabla\right) \delta s = -\nabla \delta v_s,$$

(138)

Defining the comoving spatial coordinates

$$x(t) = a(t) r(t), \quad \delta v(t) = a(t) u(t),$$

(139)

we have $\nabla x = \nabla r/a$. Let

$$\delta_{vk} = \delta_{vk} (t) \exp (-i k_v \cdot r), \quad \delta_{sk} = \delta_{sk} (t) \exp (-i k_s \cdot r),$$

(140a)

$$c_v^2 = \frac{\partial p_v}{\partial \rho_v}, \quad c_s^2 = \frac{\partial p_s}{\partial \rho_s},$$

(140b)

from (134) – (140) can get

$$\left(\frac{\partial}{\partial t} + v_{v0} \cdot \nabla\right)^2 \delta_{vk} + \frac{\dot{a}}{a} \delta_{vk} = 4\pi G \left(\rho_{v0} \delta_v - \rho_{s0} \delta_s\right) - \frac{c_v^2 k_v^2}{a^2} \delta_{vk},$$

(141)

$$\left(\frac{\partial}{\partial t} + v_{s0} \cdot \nabla\right)^2 \delta_{sk} + \frac{\dot{a}}{a} \delta_{sk} = 4\pi G \left(\rho_{s0} \delta_s - \rho_{v0} \delta_v\right) - \frac{c_s^2 k_s^2}{a^2} \delta_{sk},$$

(142)

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

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

(143a)

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

(143b)
According to the present model, there must be \( \dot{a}/a = (-K/a^2 + \eta \rho_g)^{1/2} \sim 0 \), 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 \( \delta_{v\kappa} (t) > \delta_{s\kappa} (t) \) when \( \rho_v = \rho_s \), because \( s-SU(5) \) color single states in the \( V - \text{breaking} \) can be regarded as ideal gas without collision. The ideal gas has the effect of free flux damping for clustering. Ignoring \( \delta_{sk} \) in (141), for \( \dot{a}/a \sim 0 \) and \( (4\pi G \rho_{v0} - c_s^2 k_v^2) > 0 \), from (141) we get

\[
\ddot{\delta}_{v\kappa} (t) = (4\pi G \rho_{s0} - c_v^2 k_v^2) \delta_{v\kappa}, \quad \delta_{v\kappa} (t) = \exp (t/\tau), \quad (144)
\]

where \( k_v' = k_v/a, \tau = 1/\sqrt{4\pi G \rho_{s0} - c_v^2 k_v^2} \). We see that \( \delta_{v\kappa} (t) \) will exponentially grow for long-wavelength. We cannot get the result as (144) for \( \delta_{sk} \) from (142), 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 \( \Delta t \), the distance \( l \) to be damped out is \( l = v_{s0} \Delta t \). 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 \( \dot{a}/a \) 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 \( s - \text{superclustering} \), i.e., huge \( v - \text{voids} \), in which \( \rho_s \gg \rho_v \).

To sum up, because of the following two reasons, the perturbation \( \delta_{v\kappa} \) 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 \( s - \text{matter} \) and \( v - \text{matter} \) are opposite and \( K (\rho) \) is changeable. Consequently, from (141) and (144) we see that \( \delta_{v\kappa} (t) \) will exponentially grow for long-wavelength in the stage.

2. From (141), (143) and (144) we see that \( \delta_{v\kappa} (t) \) can grow faster than that determined by (144) because \( \rho_{v0} \delta_{v\kappa} + \rho_{s0} | \delta_{sk} | > \rho_{v0} \delta_{v\kappa} \). The origin is the repulsion between \( s - \text{matter} \) and \( v - \text{matter} \).
XI. SOME GUESSES, NEW PREDICTIONS AND AN INFERENCE

A. Some guesses

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

If the whole universe is the world in the $S$-breaking or the world the $V$-breaking, the analysis above is correct. But according to the present model, as mentioned before, there are the two sorts of symmetry breaking which are different in essence. Thus it is possible that there are different breaking forms in different regions of the universe.

As mentioned above, $v$-matter and $s$-matter are symmetric and mutually repulsive, $v$-matter in the $V$-breaking can form $v$-galaxies and $s$-matter in the $S$-breaking can form $s$-galaxies.

From this we present a new cosmic model as follows.

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

$$\langle \omega_v \rangle = 0 \quad \text{and} \quad \langle \omega_s \rangle = \langle \omega_s \rangle_0 \quad \text{in} \quad s\text{-cosmic islands,} \quad \text{and} \quad \langle \omega_s \rangle = 0 \quad \text{and} \quad \langle \omega_v \rangle = \langle \omega_v \rangle_0 \quad \text{in} \quad v\text{-cosmic islands.}$$

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

$$0 < |\langle \omega_s \rangle_T| < |\langle \omega_s \rangle_0|, \quad 0 < |\langle \omega_v \rangle_T| < |\langle \omega_v \rangle_0|.$$  \hspace{1cm} (145)

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. $(u\bar{u} \mp d\bar{d}) / \sqrt{2}$ 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 $(u\bar{u} \mp d\bar{d}) / \sqrt{2}$ 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

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

(146)

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 \( T - \text{region} \), from (145) we see that the mass \( m_T \) of an electron and the mass \( M_T \) of a proton inside the \( T - \text{region} \) must be

\[ m_T < m, \quad M_T < M. \]

Thus we have

\[ \mu_T < \mu, \quad \Delta \omega_{nk} = \omega_{nk} - \omega_{nkT} = -\frac{(\mu - \mu_T)e^4}{2\hbar^3}(\frac{1}{n^2} - \frac{1}{k^2}) < 0. \quad \text{(147)} \]

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 \( T - \text{region} \) 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 \( T - \text{region} \) of our cosmos island and they have the mass redshifts. The fine-structure constant is considered to change based on the redshifts of some quasars according to the conventional theory. In contrast with the conventional, we consider that the mass of electrons possibly changes, but is not the fine-structure constant to change.

An ordinary \( s - \text{galaxy} \) and a \( s - \text{quasar} \) can be neighboring, because a \( T - \text{region} \) must be neighboring to an ordinary region.

### B. New predictions

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

Hot dark matter, e.g. the neutrinos, can form huge voids, but cannot explain evolution of structure with middle and small scales. Cold dark matter can explain evolution of structure with the middle and the small scales, but cannot explain the huge voids. The problem of huge voids remains unsettled.

According the present model, huge \( v - \text{voids} \) in the \( V - \text{breaking} \) are, in fact, superclusterings of \( s - \text{particles} \). The huge \( v - \text{voids} \) not empty, and in which there is \( s - \text{matter} \) with a bigger density, \( \rho'_s \gg \rho'_v, \rho'_s > \rho_s \) and \( \rho'_v < \rho_v \), here \( \rho'_s \) and \( \rho'_v \) denote the densities in
the huge $v$-voids. Because there is the repulsion between $s$-matter and $v$-matter and there is the gravity among $s$-particles, a huge $v$-void can form. The forming process is analogous to that of the neutrino-superclusterings. The characters of such a huge $v$-void are as follows.

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 $\rho'_s$ and are scattered by $\rho'_s$ 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 $\rho_s$ must be small when $\rho_v$ 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 $\varphi_v = \varphi_{v0}$
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 hole. 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.

4. 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 always expand with an 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.

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

The effective cosmological constant $\lambda_{\text{eff}} = \lambda + \rho_0$. The conventional theory can explain evolution with a small $\lambda_{\text{eff}}$. Such a small $\lambda_{\text{eff}}$ cannot be derived from a elementary theory. According to the conventional quantum field theory, $\lambda_{\text{eff}} = \lambda + \rho_0$, $\rho_0 \gg \lambda_{\text{eff}}$. In fact, $\rho_0$ 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, $\lambda_{\text{eff}} = \lambda = 0$, although $\rho_0$ is still very big according to the conventional quantum field theory.

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

Applying the conventional quantum field theory to the present model, we have $\rho_0 = \rho_{s0} + \rho_{v0}$. Both $\rho_{s0}$ and $\rho_{v0}$ 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

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

(148a)

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

(148b)

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

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

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

(149)

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

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

(150)

This is a reasonable result.

XII. 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 $\rho_t$ and the ratio of the
density of dark energy $\rho_{de}$ to $\rho_t$ 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 ratio of the density $\rho_{vFB}$ to $\rho_t$ 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 $\rho_{vWu} = 0.095\rho_t$. $\rho_{vWB}$ can form dark galaxies and can be observed, $\rho_{vWu}$ and $\rho_{vFu}$ cannot form any dumpling.

The $vFu$– particles is possibly observed in future. $\rho_{vF}$ and $\rho_{vW}$ 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 $\rho_{sl}$) are possibly less than 1Mev so that they may be ignored when temperature $T \gtrsim 1Mev$, and the others (their density are denoted by $\rho_{sm}$) are larger than 1Mev. $\rho_{sm}$ and $\rho_{sl}$ 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 $n_n/n_p$,

$$Y_4 = 2/[1 + (n_n/n_p)^{-1}],$$

(151a)

$$n_n/n_p = \exp(-\Delta m/kT_1), \quad \Delta m = m_n - m_p,$$

(151b)

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 $\Gamma$ is the interaction rate experienced by a particle.

As mentioned above,

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

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 $m_{sm} \gtrsim 1 Mev$ and the others with their masses $m_{sl}$ and $1 Mev > m_{sl} > 1 eV$. Thus, when $T_s \gtrsim 1 Mev$, $m_{sl}$ may be ignored so that $\rho_{sl} \propto T_s^4$, and when $T_s \lesssim 1 eV$, $\rho_s = \rho'_sm + \rho_{sl} \propto T_s^3$.

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

$$H_1^2 = \frac{R^2 (T_1)}{R^2 (T_1)} = \eta \rho_g (T_1) = \eta [\rho_v (T_{v1}) - \rho_s (T_{s1})]$$

$$\quad = \eta [\rho_{vFm} + \rho_{vWm} + \rho_{vF\gamma} + \rho_{vW\gamma} (T_{v1}) - (\rho_{sm} + \rho_{sl} (T_{s1}))]$$

$$\quad \simeq \eta [\rho_{vF\gamma} + (\rho_{vW\gamma} (T_{v1}) - \rho_{sl} (T_{s1}))]$$

$$\quad = \eta \left[ \frac{\pi^2}{30} g^* T_{v1}^4 + \left( \frac{\pi^2}{30} g^* T_{v1}^4 - \rho_{sl} (T_{s1}) \right) \right].\quad (152)$$

$$\rho_{sl} (T_s)/\rho_{sl} (T_{s1}) \propto T_s^4/T_{s1}^4 = (R_1/R)^4 = T_{v1}^4/T_{v1}^4, \quad \text{when} T_v \gg T_{vdec}, \quad (153)$$

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

$$\frac{\pi^2}{30} g^* T_{v1}^4 - \rho_{sl} (T_{s1}) \sim 0, \quad (154a)$$

$$H_1^2 \sim \eta \frac{\pi^2}{30} g^* T_{v1}^4. \quad (154b)$$

For the freeze-out temperature $T_{v1}$ is determined by $\Gamma_1$ and $H_1$. $\Gamma_1$ in the present model is the same as that in the conventional theory. $(154b)$ 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 $(154b)$, we get the equation to determine $T_{v1}$

$$\Gamma_1 (T_{v1}) \sim G_F T_{v1}^3 = H_1 = [\eta (\rho_v (T_{v1}) - \rho_s (T_{s1}))]^{1/2} \sim \left( \eta \frac{\pi^2}{30} g^* T_{v1}^4 \right)^{1/2}. \quad (155)$$
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 obtain 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.

**XIII. 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 \( T_{rec} \),

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

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

\[
T_{rec} = 3423.5K = 0.295 ev. \quad (156a)
\]

\[
(1 + z_{rec}) = T_{rec}/Tv0 = 1255. \quad (156b)
\]

**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\(^{[18]}\)

\[ \rho_{vF\gamma} = \rho_{vW\gamma} = \frac{\pi^2}{30} g_\gamma^* \left( \frac{kT_v}{hc} \right)^4. \quad (157a) \]

\[ g_\gamma^* = 2 + \frac{7}{8} \times 6 \times \left( \frac{4}{11} \right)^{4/3} = 3.36. \quad (157b) \]

Thus, considering \( T_{i0} = T_0 = 2.728K = 2.35 \times 10^{-4} ev \), we get

\[ \rho_{\nu r0} = 2\rho_{vF\gamma 0} = 2 \times \left[ \frac{3.36}{2} \times \frac{\pi^2}{30} \times 2 \times (2.35 \times 10^{-13} Gev)^4 \right] \]

\[ = 6.7425 \times 10^{-51} Gev^4. \quad (158) \]

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

\[ \rho_{i0} = 2\rho_{vFm0} + 2\rho_{vF\gamma 0} \simeq \rho_{vm0} = \Omega_0 \rho_c \]

\[ = 1.8789 \times 10^{-26} h^2 \Omega_0 \cdot kg \cdot m^{-3} = 9.238 \times 10^{-48} Gev^4, \quad \text{when } h = 0.65. \quad (159) \]

where \( h = 0.5 - 0.8, \rho_{vm0} = \rho_{vFm0} + \rho_{vWm0}, \) and \( \rho_{\nu r0} = \rho_{vF\gamma 0} + \rho_{vW\gamma 0} = 2\rho_{vF\gamma 0} = 2\rho_{\nu r0}. \)

From (158) – (159) \( T_{\text{veq}} \) can be determined as follows

\[ \rho_{\text{veq}} (T_{\text{veq}}) = \rho_{vm0} \left[ R_0 / R_{\text{eq}} (T_{\text{veq}}) \right]^3 = \rho_{\nu r0} \left[ R_0 / R_{\text{eq}} (T_{\text{veq}}) \right]^4 = \rho_{v\gamma\text{eq}} (T_{\text{veq}}), \quad (160a) \]

\[ \frac{R_0}{R_{\text{eq}}} = \frac{T_{\text{veq}}}{T_{i0}} = \frac{\rho_{vm0}}{\rho_{\nu r0}} = \frac{\Omega_0 \rho_c}{2\rho_{vF\gamma 0}} = (1 + z_{\text{eq}}) = 1370, \quad (160b) \]

\[ T_{\text{veq}} = 0.32 ev, \quad \text{when } h = 0.65, \]

\[ \frac{R_0}{R_{\text{eq}}} = \frac{T_{\text{veq}}}{T_{i0}} = \frac{\rho_{vm0}}{\rho_{\nu r0}} = 1272, \quad (160c) \]

\[ T_{\text{veq}} = 0.295 ev = T_{\text{rec}}, \quad \text{when } h = 0.624. \]

According to the present model, (160) is a crude approximation, \( \rho_v - \rho_s \) is changeable not only because of \( \rho_{vm} \propto R^{-3}, \rho_{v\gamma} \propto R^{-4} \) and \( \rho_{s\gamma} \propto R^{-3}, \) but also because of (65c).

According to the conventional theory, \( \rho_{\gamma 0} = \rho_{\nu r0}/2, \rho_0 = \rho_{\nu r0}, \) hence if \( h = 0.65 \) and \( \Omega_0 = 0.27, \)

\[ T_{eq}' = T_0 R_0 / R_{eq}' = (1 + z_{eq}) T_0 = (\rho_{m0}/\rho_0) T_0 = 2 (\rho_{m0}/\rho_{\nu r0}) T_0 = 0.64 ev = 2 T_{\text{veq}}. \quad (161) \]
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 $T_v = T_{veq}, T_s = T_{sq}, \rho_{sm}(T_s) = t_{mq}\rho_{vm}(T_{veq})$ and the masses of all s-color single states cannot be ignored, i.e. $\rho_{sm}(T_{sq}) = \rho_s(T_{sq})$. Considering

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

ignoring the transformation $\rho_v$ into $\rho_s$, we can rewrite $\rho_v$, $\rho_{v\gamma}$ and $\rho_{sm}$ as follows.

$$\rho_v = \frac{\rho_{vm}}{\rho_{vm0}_{\rho_c}} \rho_c = \frac{R_0^2}{R^3} \Omega_{m0} \rho_c = A^3 \Omega_{m0} \rho_c, A \equiv \frac{T_v}{T_{v0}} = 1 + z,$$  \hspace{1cm} (163a)

$$\rho_{v\gamma} = \frac{\rho_{v\gamma e}}{\rho_{v\gamma eq} \rho_{vmeq} \rho_{vm0} \rho_c} \rho_c = \left( \frac{T_{v0}}{T_{veq}} \right) A^4 \Omega_{m0} \rho_c,$$ \hspace{1cm} (163b)

$$\rho_{sm} = \frac{\rho_{smq}}{\rho_{smq} \rho_{vmeq} \rho_{vm0} \rho_c} \rho_c = t_{mq} A^3 \Omega_{m0} \rho_c,$$ \hspace{1cm} (163c)

Ignoring $K$, considering $H_0 = \sqrt{\eta \rho_c} = 65 km \cdot (s \cdot Mpc)^{-1} = 1.4 \times 10^{-42} Gev$, $\Omega_{m0} = 0.27$, and $T_{v0}/T_{veq} = (2.35 \times 10^{-4}) / 0.32 = 0.734 \times 10^{-3}$, we get

$$H^2 = \eta \rho_g = \eta \left( \rho_{vm} + \rho_{v\gamma} - \rho_{sm} \right)$$

$$= 0.27 \times 1.4^2 \times 10^{-82} A^3 \left( 1 - t_{mq} + 0.734 \times 10^{-3} A \right) Gev.$$ \hspace{1cm} (164)

This is the only deference between the present model and the conventional theory in order to determine the decoupling temperature.

We have the same interaction rate experienced by one photon and Saha equation as the conventional theory\cite{19}

$$\Gamma = n_{vF} c \sigma_{th} = \chi \xi n_{vF} c \sigma_{th} = \frac{2.4}{\pi^2} \xi T_{v0}^3 \sigma_{th} \chi A^3 = 5.4 \times 10^{-36} \xi \chi A^3 Gev,$$  \hspace{1cm} (165)

$$\frac{1 - \chi}{\chi^2} = 1.1 \times 10^{-8} \xi T_{v0}^{3/2} \exp \frac{13.6}{T_v} = 3.96 \times 10^{-14} \xi A^{3/2} \exp \frac{57872}{A},$$ \hspace{1cm} (166)

where $T_v = T_{v0} (T_v/T_{v0}) = 2.35 \times 10^{-4} A$ is considered. Only for comparison of the present model with the conventional theory, we use the same equation (166) and the same crude approximation $\Gamma = H$ to evaluate the decoupling temperature. Taking $\Gamma = H$, and $t_{mq} =$
from (164) − (165) we have
\[ \chi A^{3/2} = \xi^{-1}1.347 \times 10^{-7} \left( 1 - t_{mq} + 0.734 \times 10^{-3}A \right)^{1/2} \]
\[ = 269 \left( -0.5 + 0.734 \times 10^{-3}A \right)^{1/2} , \quad \text{when } \xi = 5 \times 10^{-10}, \quad (167) \]
Substituting (167) into (166), we get
\[ A^{3/2} = \xi^{-1}1.347 \times 10^{-7} \left( 1 - t_{mq} + 0.734 \times 10^{-3}A \right)^{1/2} \]
\[ + \xi^{-1}7.185 \times 10^{-28} \times \left( 1 - t_{mq} + 0.734 \times 10^{-3}A \right) \times \exp \frac{57872}{A} \quad (168) \]
Taking \( t_{mq} = 1.5 \) and \( \xi = 5 \times 10^{-10} \), we get
\[ A = 1 + z_{dec} = 1097, \quad T_{vdec} = 0.258\text{eV}, \quad \chi = 0.004. \quad (169) \]
Taking \( t_{mq} = 1.5 \) and \( \xi = 3 \times 10^{-10} \), we get
\[ A = 1 + z_{dec} = 1108, \quad T_{vdec} = 0.260\text{eV}, \quad \chi = 0.0068, \quad (170) \]
Taking place of (164) by the equation in the conventional theory
\[ H^2 = \eta \rho_g = \eta \rho_{vm} = 0.27 \times 1.4^2 \times 10^{-82}A^3\text{GeV}, \quad (171) \]
we have
\[ A = 1 + z_{dec} = 1121, \quad T_{vdec} = 0.263\text{eV}, \quad \chi = 0.007, \]
when \( t_{mq} = 1.5, \quad \xi = 5 \times 10^{-10}, \quad (172) \]
\[ A = 1 + z_{dec} = 1132, \quad T_{vdec} = 0.266\text{eV}, \quad \chi = 0.012, \]
when \( t_{mq} = 1.5, \quad \xi = 3 \times 10^{-10}. \quad (173) \]
\( z_{dec} \) is not susceptible for change of \( t_{mq} \) in the scope 1.1 − 1.7.
Considering
\[ \frac{\rho_{\text{vmdec}}}{\rho_{\text{vmeq}}} = \left( \frac{T_{\text{vdec}}}{T_{\text{veq}}} \right)^3, \quad \frac{\rho_{\text{vγdec}}}{\rho_{\text{vγeq}}} = \left( \frac{T_{\text{vdec}}}{T_{\text{veq}}} \right)^4, \quad \rho_{\text{vmeq}} = \rho_{\text{vγeq}}, \quad (174) \]
we have
\[ \frac{\rho_{\text{vγdec}}}{\rho_{\text{vmdec}}} = \frac{T_{\text{vdec}}}{T_{\text{veq}}} = \frac{0.258}{0.32} = 0.81. \quad (175) \]
It is seen from (175) that in the decoupling stage, \( \rho_{\text{vmdec}} \sim \rho_{\text{vγdec}} \) 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 $3.8 \times 10^5$ 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 $\Delta t'_{hc}$ according to the present model and that according to the conventional theory is $\Delta t''_{hc} = 3.8 \times 10^5 a$, there must be

$$\Delta t_{hc} > \Delta t'_{hc}.$$ \hfill (176)

The reasons are as follows.

That (152) holds implies

$$\rho_g (T_{v1}) = \rho_{vFm} (T_{v1}) + \rho_{vWm} (T_{v1}) + \rho_{vFr} (T_{v1}) - \rho_{sm} (T_{s1}) + (\rho_{vWr} (T_{v1}) - \rho_{sl} (T_{s1}))$$

$$\sim \rho_{vFm} (T_{v1}) + \rho_{vWm} (T_{v1}) + \rho_{vFr} (T_{v1}) - \rho_{sm} (T_{s1}) \sim \rho_{vF\gamma} (T_1)$$

$$\sim \rho_m (T_1) + \rho_{\gamma} (T_1) \sim \rho_{\gamma} (T_1) = \rho_g (T_1), \hfill (177)$$

where $\rho_m (T)$ and $\rho_{\gamma} (T)$ are the mass density in the conventional theory ($T = T_v$), and $\rho_m (T_1) \ll \rho_{\gamma} (T_1)$ etc are considered. It is necessary that when $T_v \geq T_{v1}$, (152) or (177) 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 $\rho_{v\gamma} (T_v) \gg \rho_{sm} (T_v)$ 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 $1 Mev > m_{sl} \geq 1 ev$) when $T_v < T_{v1}$. Hence when $T_v < T_{v1}$,

$$H^2 (T_v) = \eta \rho_g (T_v) < \eta (\rho_m (T) + \rho_{\gamma} (T)) = \eta \rho_g' (T) = H'^2 (T). \hfill (178)$$

This implies (176) to hold. On the other hand, the sound speed $c_{vs} = \partial p_v / \partial \rho_v$ is determined by only $p_v$ and $\rho_v$ or $T_v$ and $m_p$, and is independent of $\rho_s$. 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 elementary sound wave must be longer according to the present model than that according to the conventional theory.

Based on $\Delta t''_{hc} = 3.8 \times 10^5 a$, space-time is flat or $K = 0$ as the conventional theory, but based on $\Delta t_{hc} > \Delta t'_{hc}$ and $c_s = c'_s = \partial p / \partial \rho$, space-time is open or $K < 0$ as 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.

XIV. CONCLUSIONS

The new conjectures are proposed that there are \( s - \text{matter} \) and \( v - \text{matter} \) which are symmetric, whose gravitational mass densities are opposite to each other and whose energies are all positive. Both can transform from one to another when temperature \( T \gtrsim T_{cr} \). Consequently there is no singularity in the model and the cosmological constant \( \lambda = \lambda_{\text{eff}} = 0 \) is determined although the energy density of the vacuum state is still large and there is no the fine tuning problem, even if \( \lambda_{\text{eff}} \neq 0 \).

There are two sorts of breaking modes, i.e. the \( S - \text{breaking} \) and the \( V - \text{breaking} \). In the \( V - \text{breaking} \) \( v - SU(5) \) symmetry is broken into \( v - SU(3) \times U(1) \) for \( v - \text{particles} \) and \( s - SU(5) \) symmetry is still strictly kept for \( s - \text{particles} \). Consequently \( v - \text{particles} \) get their masses determined by the \( SU(5) \) GUT and form the \( v - \text{galaxies} \) etc., while \( s - \text{particles} \) are massless and form \( s - SU(5) \) color-single states which loosely distribute in space and can cause space to expand with an acceleration. In contrast with the dark energy, the gravitational masses of \( s - \text{matter} \) is negative in the \( V - \text{breaking} \).

The conjectures are not in contradiction with all given experiments and astronomical observations up to now, although the conjecture 1 violates the equivalence principle.

The curvature factor \( K \) in the RW metric is regarded as a function of the gravitational mass density in the comoving coordinates.

Based on the present model, the space evolving process is as follows. Firstly, in the \( S - \text{breaking} \), \( \rho_{Sg} = \rho_s - \rho_v > 0 \) and \( K > 0 \), hence space contracts and \( T_s \) rises. When \( T_v \sim T_s = T_{cr} \), \( \langle \omega_s \rangle = \langle \omega_v \rangle = 0 \), both \( v - SU(5) \) and \( s - SU(5) \) symmetries is strictly kept (this state have the highest symmetry), and the masses of all particles originating from the couplings with the Higgs fields are zero so that \( \rho_s \) and \( \rho_v \) can transform from one into another. As a consequence \( \rho_s = \rho_v \), \( T_v = T_s \) and \( \tilde{\rho}_{Sg} = \rho_s - \rho_v + V_0 = V_0 \) so that inflation must occur. After the inflation, the phase transition of the vacuum, i.e. the reheating process, occurs. After the reheating process, this state with the highest symmetry transits to the state with the \( V - \text{breaking} \). Space in the \( V - \text{breaking} \) have three evolving stages. Space firstly expands with a deceleration because \( \rho_{Vg} = \rho_v - \rho_s > 0 \) and \( K > 0 \); then comes
to static because $\rho_{\nu g} = 0$ and $K = 0$; and finally expands with an acceleration up to now because $\rho_{\nu g} < 0$ and $K < 0$. The results above is still valid when $V \cong S$ and $v \cong s$. It is seen that the world in the $S - breaking$ and the world in the $V - breaking$ can transform from one into another. The evolving process of the cosmos is different from that determined by the conventional theory. $w = p/\rho$ changes from $w > 0$ into $w < -1$ is obtained.

There are the critical temperature $T_{cr}$, the highest temperature $T_{\text{max}}$, the least scale $R_{\text{min}}$ and the largest energy density $\rho_{\text{max}}$ in the universe. $R_{\text{min}}$ and $T_{cr}$ are two new important constants, $T_{\text{max}}$ and $\rho_{\text{max}}$ are determined by $R(T_{cr})$.

A formula is derived which well describes the relation between a luminosity distance and its redshift.

Generalizing equations governing nonrelativistic fluid motion to the present model, the equations of $v - structure$ formation have been derived. According to the equations, galaxies formed earlier and more easily than the conventional theory.

Two guesses have been presented. The universe is composed of infinite $s - cosmic$ islands and $v - cosmic$ islands. Some huge redshifts (e.g. the big redshifts of quasi-stellar objects) are explained as the mass redshifts which is caused by $m_{eT} < m_e$, here $m_{eT}$ is the mass of an electron in a transiting region and $m_e$ is the given mass of an electron in the normal region.

Three new predicts have been given. Huge $v - voids$ in the $V - breaking$ are not empty, but are superclusterings of $s - particles$, there must be $s - matter$ with its density $\rho_s \gg \rho_v$ in the $v - voids$. 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 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.

The primordial nucleosynthesis and $CMBR$ are explained based on the $F - W$ dark matter model (or the mirror dark matter model) and this cosmological model.

The first peak of the $CMBR$ power spectra is the evidence of existence of the elementary wave. The elementary wave began at reheating and ended at recombination after $\Delta t'_{hc} \equiv 3.8 \times 10^5$ years according to the conventional theory. But according to the present model, it is necessary that $\Delta t_{hc} > \Delta t'_{hc}$, because the sound speed $c_s \sim c'_s$ and $H = \eta \rho_g < H' = \eta \rho'_g = \eta \rho'$. Consequently, space-time is open or $K < 0$ according to the present model.
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[1] S. W. Hawking and G.F.R. Ellis, The Large Scale Structure of Space-Time, Cambridge University Press, (1999) p7, p98, p101, p137, p256-298.

[2] R.R., Caldwell, Phys. World 17, (2004) 37; T, Padmanabhan, Phys. Rep. 380 (2003) 325; P.J.E Peebles and B. Ratra, Rev. Mod. Phys. 75 (2003) 559.

[3] S. Weinberg, Phys. Rev. Lett. 59 (1987) 2607; H. Martel, P.R. Shapiro and S. Weinberg, Astrophys.J 492 (1998) 29.

[4] P.J.E. Peebles and B. Ratra, Astrophys. J.325 (1988) L17; B Ratra and P.J.E. Peebles, Phys. Rev. D 37 (1988) 3406; P.J.E., Peebles and B. Ratra, Rev. Mod. Phys. 75 (2003) 559.

[5] L.J, Hall, Y. Nomura, and S.J. Oliver, Phys. Rev. Lett. 95 (2005) 141302.

[6] S-H, Chen, ‘Quantum Field Theory Without Divergence A’, (2002a) hep-th/0203220; S-H, Chen, ‘Significance of Negative Energy State in Quantum Field Theory A’ (2002b) hep-th/0203230; S-H, Chen, ‘Quantum Field Theory :New Research’, O. Kovras Editor, Nova Science Publishers, Inc. (2005a) p103-170.

[7] S-H, Chen, ‘A Possible Candidate for Dark Matter’, (2001) hep-th/0103234; S-H, Chen, ‘Progress in Dark Matter Research’ Editor: J. Val Blain, (2005b) pp.65-72. Nova Science Publishers, Inc. arXiv: 1001.4221.

[8] J. A, Peacock, Cosmological Physics, Cambridge University Press, (1999) p579, p458, (3.44) in p78, (3.81) in p90, (3.78) in p89, p460-464, p664, 296 (9.81).

[9] S-H Chen, ‘Discussion of a Possible Universal Model without Singularity’, (2009) arXiv: 0908.1495; S-H, Chen, ‘A Possible Universal Model without Singularity and its Explanation for Evolution of the Universe’, (2006) hep-th/0611283.

[10] G. W. Gibbons, and S. W. Hawking, Phys. Rev D, 15, (1977) 2752.

[11] M Chaichian and N.F.Nelipa, ‘Introduction to Gauge Field Theories' Springer-Verlag Berlin Heidelberg, (1984) p269; G. G. Ross, ‘Grand Unified Theories', The Benjamin/Cummings Publishing Company, INC, (1984) p177-183.

[12] S. Weinberg, Gravitation and Cosmology, New York, Wiley (1972) Chanter 12 section 3.
[13] M. Carmeli, ‘Classical Fields: General Relativity and Gauge Theory’, World Scientific Publishing, (1982) p89-92, (3.2.1), (3.2.7), (3.2.8), (3.2.9), (3.2.1), (3.2.15), (3.2.16)-(3.2.18).

[14] S. Coleman and E.J. Weiberg Phys. Rev. D7. (1973) 1888; R.H. Brandenberg, Rev. of Mod. Phys. 57. (1985) 1.

[15] Liu Liao, Jiang Yuanfang and Qian Zhenhua, Progress in Physics, V.9, No. 2, (1989) p159.

[16] H.C. Ohanian, and R. Ruffini, Gravitation and Spacetime (2nd ed.), W.W. Norton and Company, Inc. (1994) Section 9.9.

[17] A. H. Guth, Phys. Rev. D 23, (1981) 347.

[18] A.R. Liddle and D.H. Lyth, Cosmological Inflation and Large-Scale Structure, Cambridge University Press 2000, p20 (2.27).

[19] Yu Yunqiang, Lectures in Cosmological Physics, Peking University Press, 2002, p151, (6.21), p170-172.
