A Cosmological Model without Singularity and Dark Matter

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Abstract

According to the cosmological model without singularity, there are s-matter and v-matter which are symmetric and have opposite gravitational masses. In V-breaking s-matter is similar to dark energy to cause expansion of the universe with an acceleration now, and v-matter is composed of v-F-matter and v-W-matter which are symmetric and have the same gravitational masses and forms the world. The ratio of s-matter to v-matter is changeable. Based on the cosmological model, we confirm that big bang nucleosynthesis is not spoiled by that the average energy density of W-matter (mirror matter) is equal to that of F-matter (ordinary matter). According to the present model, there are three sorts of dark matter which are v-W-baryon matter (4/27), unknown v-F-matter (9.5/27) and v-W-matter (9.5/27). Given v-F-baryon matter (4/27) and v-W-baryon matter can cluster and respectively form the visible galaxies and dark galaxies. Unknown v-F-matter and v-W-matter cannot cluster to form any celestial body, loosely distribute in space, are equivalent to cold dark matter, and their compositions are unknown. The number in a bracket is the ratio of the density of a sort of matter to total density of v-matter. The decisive predict is that there are dark celestial bodies and dark galaxies. The energy of F-matter can transform into the energy of W-matter by such a process in which the reaction energy is high enough.
I. INTRODUCTION

Mirror matter as dark matter has been presented\cite{1}. In order that the model is consistent with the standard cosmological framework, the model ascribes the macroscopic asymmetry of the universe to asymmetric initial conditions of matter and mirror matter\cite{2}. However, when temperature is high enough, the expectation values of all Higgs fields are zero so that the static masses of all particles are zero, and all particles can transform from one into other. Consequently the energy densities of two sorts of matter must be equal if both are symmetric so that their degrees of freedom are equal to each other. Thus the asymmetric initial conditions make one to be uncomfortable.

A quantum field theory without divergence has been constructed which can obtain all results of the given quantum field theory and in which there is no divergence of loop-corrections and the energy of the vacuum must be zero without normal product\cite{3}. There must be two sorts of matter in this quantum field theory. The two sorts of matter are called $F-\text{matter}$ and $W-\text{matter}$, respectively. $F-\text{matter}$ and $W-\text{matter}$ are symmetric, and there are only gravitation and very weak interaction by Higgs bosons in low energy between both. $F-\text{matter}$ forms the given world and $W-\text{matter}$ is dark matter for a $F-\text{observer}$\cite{4}. This model of dark matter is equivalent to the model of mirror matter as dark matter.

A cosmological model without singularity has been constructed\cite{5}. The model can well
explain evolution of the universe, formation of large scale structure and the features of huge voids, naturally determines the cosmological constant to be zero, has no singularity and gives some predictions. Based on the cosmological model, we will see in the present paper that the average density of $W$–matter may be equal to that of $F$–matter. The average density of dark matter is the $23/4$ times of that of visible matter, because dark matter is composed of $W$–matter and a part of $F$–matter.

Second 2 discusses that the average density of $W$-matter is equal to that of $F$-matter. Second 3 discusses the sorts and average density of dark matter. Second 4 the interaction of $F$-scalar fields and $W$-scalar fields. Section 5 is the conclusions.

II. THE AVERAGE DENSITY OF W-MATTER IS EQUAL TO THAT OF F-MATTER

According to the cosmological model without singularity, the space evolving equations are\cite{5}

\begin{equation}
\ddot{R}(t) + K = \eta [\rho_v + V_v(\omega_v) + V_0 - \rho_s - V_s(\omega_s)] R^2(t) = \eta (\rho_g + V_g) R^2(t),
\end{equation}

\begin{equation}
\dot{R}(t) = -\frac{1}{2} \eta [(\rho_v + 3p_v) - 2(V_v(\omega_v) + V_0) - (\rho_s + 3p_s) + 2V_s(\omega_s)] R(t)
\end{equation}

\begin{equation}
= -\frac{1}{2} \eta (\rho_g + 3p_g - 2V_g) R(t),
\end{equation}

where $\omega = \Omega, \Phi$, and $\chi, \eta \equiv 8\pi G/3$; $\rho_v$ and $\rho_s$ are the mass densities of $v$–matter and $s$–matter (here $c = 1$), respectively; $V_v$ and $V_s$ are the densities of $v$–Higgs potential energy and $v$–Higgs potential energy, respectively. The curvature factor $K$ is a function of the gravitational mass density, and

\begin{equation}
\rho_g \equiv \rho_v - \rho_s, \quad p_g = p_v - p_s, \quad V_g = V_v(\omega_v) + V_0 - V_s(\omega_s).
\end{equation}

\begin{equation}
1 \geq K > 0 \quad \text{for} \quad \rho_g > 0, \quad K = 0 \quad \text{for} \quad \rho_g = 0, \quad 0 > K \geq -1 \quad \text{for} \quad \rho_g < 0.
\end{equation}

In $V$–breaking in which the expectation values of $v$–Higgs fields $\langle \omega_v \rangle \equiv \omega_v = 0$, and the expectation values of $s$–Higgs fields $\langle \omega_s \rangle' \equiv \omega_s' \neq 0$, the gravitational mass of $v$–matter is positive and the gravitational mass of $s$–matter is negative.
When temperature rises to the critical temperature $T_{cr}$ because space contracts$^5$, $\varpi_v = \varpi_s = 0$, $\rho_v = \rho_s$, $V_v(\varpi_v) = V_s(\varpi_s) = 0$ so that

$$\ddot{R} (t) = -K + \eta V_0 R^2 (t), \quad \dot{R}(t) = -\eta V_0 R (t) < 0. \quad (5)$$

There is the highest temperature $T_{\text{max}}$ at which $\dot{R} = 0$, $R(t) = R_{\text{min}} \equiv \sqrt{K/\eta V_0}$ and space inflation must occur.

$V - \text{matter}$ is composed of $v - F - \text{matter}$ and $v - W - \text{matter}$, $s - \text{matter}$ is composed of $s - F - \text{matter}$ and $s - W - \text{matter}$. $F - \text{matter}$ and $W - \text{matter}$ are symmetric so that divergence of loop corrections is eliminated and the energy of the vacuum is determined to be zero. There is only the gravitation and the interaction by Higgs bosons between $F - \text{particles}$ and $W - \text{particles}$. The interaction by Higgs bosons can be ignored when temperature is low because the masses of the Higgs bosons are all very large. Consequently $W - \text{matter}$ is regarded dark matter relative to $F - \text{matter}$, and vice versa. These are the necessary inferences of the quantum field theory without divergence$^3$. $F - \text{matter}$ and $W - \text{matter}$ correspond to ordinary matter and mirror matter in Ref$^1$, respectively.

The state with $T \geq T_{cr}$ is such a state with the highest symmetry. $\rho_{sF} = \rho_{sW} = \rho_{vF} = \rho_{vW}$ and $T_{sF} = T_{sW} = T_{vF} = T_{vW} = T$ in this state because $F - \text{matter}$ and $W - \text{matter}$ are symmetric and can transform from one into another, $s - \text{matter}$ and $v - \text{matter}$ are symmetric and can transform from one into another, and the thermal equilibrium can realized due to $\dot{R} \sim 0$ when $T \geq T_{cr}$.

After space inflation, reheating process occurs. After reheating process, the potential energy density transforms into $\rho'_0 = x V_0$ and $\rho'_s = (1 - x) V_0$, $\rho'_v > \rho'_s$ because $\langle \omega_v \rangle = 0 \rightarrow \langle \omega_v \rangle_0 \neq 0$, $\langle \omega_s \rangle = 0 \rightarrow \langle \omega_s \rangle_0 = 0$, $V_v = 0 \rightarrow -V_0$ and $V_s = 0 \rightarrow 0^5$. Thus, after reheating process, the evolving equations become

$$\ddot{R} (t) + K = \eta [\rho_{vF} + \rho_{vW} - \rho_{sF} - \rho_{sW}] R^2 (t) = \eta [2 \rho_{vF} - 2 \rho_{sF}] R^2 (t), \quad (7)$$

$$\ddot{R}(t) = -\eta [(\rho_{vF} + 3 \rho_{vW}) - (\rho_{sF} + 3 \rho_{sW})] R (t), \quad (8)$$

Here we still denote $\rho'_v + \rho_v$ and $\rho'_s + \rho_s$ by $\rho_v$ and $\rho_s$, respectively, for convenience.

It is seen from (4) and (7) that in contrast with the conventional cosmological models, although $\rho_{vF} = \rho_{vW}$, the $\dot{R} (t) + K$ cannot doubled because of $\rho_s = \rho_{sF} + \rho_{sW}$. Consequently the big bang nucleosynthesis cannot be spoiled by $\rho_{vF} = \rho_{vW}$ provided $\rho_s$ is suitably chosen.
For example, if $\rho_s = \rho_{eW}$ in the stage of the big bang nucleosynthesis, the evolving equations (7) – (8) become
\[
\ddot{R}(t) + K = \eta \rho_{eF} R^2(t) \\
\dot{R}(t) = -\frac{1}{2} \eta (\rho_{eF} + 3 \rho_{eF}) R(t),
\]
This is consistent with the conventional theory.

III. THE SORTS AND AVERAGE DENSITY OF DARK MATTER

Recent astronomical observations show that the universe expanded with a deceleration early and is expanding with an acceleration now. This implies that there is dark energy[6]. $\rho_{de}/\rho_{tot} = 0.73$, $\rho_{M}/\rho_{tot} = 0.27$, $\rho_M = \rho_{VM} + \rho_{DM}$, $\rho_{VM} \sim \rho_B$, $\rho_{DM}/\rho_{tot} = 0.23$ and $\rho_B/\rho_{tot} = 0.04$, here $\rho_{de}$ is the density of dark energy, $\rho_{tot}$ is the density of the total energy of the universe ($c = 1$), $\rho_{VM}$ is the energy density of visible matter, $\rho_{DM}$ is the energy density of dark matter, and $\rho_B$ is the energy density of visible baryon matter. According to the cosmological model without singularity[5], in the $V$–breaking, the effects of $s$–matter are equivalent to that of the so-called dark energy, and $\rho_v = \rho_M$. According to this dark-matter model [3, 4], because of the symmetry of $F$–matter and $W$–matter, we have
\[
\rho_M = \rho_v = \rho_{eF} + \rho_{eW} = 2 \rho_{eF}, \quad \rho_B = \rho_{eFB}, \\
\rho_{eF} = \rho_{eFB} + \rho_{eFu}, \quad \rho_{eW} = \rho_{eWB} + \rho_{eWu}, \\
\rho_{eFB} = \rho_{eWB}, \quad \rho_{eFu} = \rho_{eWu}, \quad \rho_{eD} = \rho_{eFu} + \rho_{eW} = \rho_{DM},
\]
where $\rho_v$ is the total energy density of $v$–matter, $\rho_{eF}$ and $\rho_{eW}$ are respectively the energy density of $v$–$F$–matter and the energy density of $v$–$W$–matter, $\rho_{eFB}$ and $\rho_{eWB}$ are respectively the energy density of $v$–$F$–baryon matter ($v$–FBM) and the energy density of $v$–$W$–baryon matter ($v$–WBM), $\rho_{eFu}$ is the energy density of unknown $v$–$F$–matter ($v$–UFM), $\rho_{eWu}$ is the energy density of $v$–$W$–matter ($v$–UWM) corresponding to $v$–UFM, and $\rho_{eD}$ is the total energy density of invisible $v$–matter. Here $v$–FBM is the given and visible matter which contains given baryon matter, black holes and neutrinos etc., $F$–matter contains $v$–FBM and invisible and unknown $v$–UFM. Considering $\rho_{eF} = \rho_{eW}$ because $F$–matter and $W$–matter are symmetric and can transform from one into another when temperature is high enough, we can determine the ratios of a density to another.
\[
\begin{align*}
\frac{\rho_{vF}}{\rho_{vW}} &= \frac{0.27/2}{0.27/2} = 1 = \frac{\rho_{vFB}}{\rho_{vW}B} = \frac{\rho_{vFu}}{\rho_{vBu}}, \\
\frac{\rho_{vFB}}{\rho_v} &= \frac{\rho_{vWB}}{\rho_v} = \frac{0.04}{0.27} = \frac{4}{27}, \\
\frac{\rho_{vFu}}{\rho_v} &= \frac{\rho_{vWu}}{\rho_v} = \frac{0.27/2 - 0.04}{0.27} = \frac{9.5}{27}, \\
\frac{\rho_{vD}}{\rho_v} &= \frac{\rho_{vW} + \rho_{vFu}}{\rho_v} = \frac{23}{27}, \\
\frac{\rho_{vD}}{\rho_{vFB}} &= \frac{0.27/2 + 0.095}{0.04} = \frac{23}{4}.
\end{align*}
\]
where $\Phi_f$ and $\Phi_w$ are the $24$ representation of $SU(5)$ group. The breaking component is

$$\Phi_i = \text{Diagonal} \left(1,1,1,-\frac{3}{2},-\frac{3}{2}\right) (\sigma_i + \varphi_i),$$

(12)

where the subscript $i = f, w$. From (11) – (12) we obtain

$$V_{fw} = -A \left(2\sigma_f \sigma_w \varphi_f \varphi_w + \sigma_f \varphi_f \varphi_w^2 + \sigma_w \varphi_w \varphi_f^2 + \frac{1}{2} \varphi_f^2 \varphi_w^2\right).$$

(13)

$|\sigma_w| = |\sigma_f|$ because of the symmetry of $s–\text{matter}$ and $f–\text{matter}$. Both $\sigma_i$ and $m(\varphi_i)$ are functions of temperature $T$. When $T \geq T_{cr}$, $\sigma_i = m(\varphi_i) = 0$. Consequently $f–\text{particles}$ and $w–\text{particles}$ can easily transform from one to another so that $\rho_F = \rho_W$. When $T \sim 0$, both $|\sigma_i|$ and $m(\varphi_i)$ are large enough. Consequently interaction between $f–\text{particles}$ and $w–\text{particles}$ by the scalar bosons may be ignored. Thus there is only the gravitation between $f–\text{matter}$ and $w–\text{matter}$ when temperature is low.

There are the couplings of fermions (and gauge particles) and scalar bosons[7]. Hence there are the interactions of $f–\text{fermions}$ and $w–\text{fermions}$ shown in figures 1-3 and the interactions of $f–\text{gauge}$ bosons and $w–\text{gauge}$ bosons via the scalar bosons $\varphi_f$ and $\varphi_w$. In the figures the dotted lines with arrows denote $W–\text{fermion}$ field $\psi_w$, the dotted lines without arrow denote $W–\text{scalar}$ field $\varphi_w$, the lines with arrows denote $F–\text{fermion}$ field $\psi_f$, the lines without arrow denote $F–\text{scalar}$ field $\varphi_f$, $M^2 = -2A\sigma_f \sigma_w$, $R_f = -A\sigma_f$, $R_w = -A\sigma_w$ and $S = -A/2$.

It can be seen from figure 1 and (13) that when $-A\sigma_f \sigma_w > 0$ and $k^2 - m^2 < 0$ or $-A\sigma_f \sigma_w < 0$ and $k^2 - m^2 > 0$, $f–\text{fermions}$ and $w–\text{fermions}$ are repulsive each other; when $-A\sigma_f \sigma_w > 0$ and $k^2 - m^2 > 0$ or $-A\sigma_f \sigma_w < 0$ and $k^2 - m^2 < 0$, $f–\text{fermions}$ and $w–\text{fermions}$ are attractive each other.

V. FEATURES AND OBSERVATION OF DARK MATTER IN PRESENT MODEL

According to the present model[3,4], $v–U FM$ and $v–U WM$ cannot form cluster, loosely distribute in space and have positive gravitational masses, hence both should be identified as cold dark matter. From (10) we have

$$\frac{\rho_{vF u} + \rho_{vW u}}{\rho_v} = \frac{0.095 \times 2}{0.27} = \frac{19}{27},$$

$$\frac{\rho_{vF u} + \rho_{vW u}}{\rho_{vD}} = \frac{0.095 \times 2}{0.23} = \frac{19}{23}.$$
FIG. 1: $f + \bar{f} \rightarrow w + \bar{w}$ realized by the tree digram.

FIG. 2: $f + \bar{f} \rightarrow w + \bar{w}$ realized by the two one-loop digrams.
FIG. 3: $f + \overline{f} \rightarrow w + \overline{w}$ realized by the two-loop diagram.

It is seen that the present model cannot differ from the cold dark matter model by $v - UFM$ and $v - UWM$. $W - \text{baryon}$ matter $v - WBM$ can form clusters of dark matter and dark galaxies$^{[3,4]}$. There possibly are such celestial bodies which are composed of mixture of $F - \text{matter}$ and $W - \text{matter}$ because both have positive gravitational masses. This is a decisive predict of the present model and mirror dark matter model. Dark celestial bodies flying to the earth are possibly detected by probing gravity-meters of clustering dark matter$^{[4]}$.

It can be seen from (13) and figures 1 – 3 that the energy of $F - \text{matter}$ can transform into the energy of $W - \text{matter}$ by such a process in which the reaction energy is high enough.

VI. CONCLUSIONS

According to the cosmological model without singularity, there are $s - \text{matter}$ and $v - \text{matter}$ which are symmetric and have oppose gravitational masses. In $V - \text{breaking} s - \text{matter}$ is similar to dark energy to cause expansion of the universe with an acceleration now, and $v - \text{matter}$ is composed of $v - F - \text{matter}$ and $v - W - \text{matter}$ which are symmetric and have the same gravitational masses. The ratio of $s - \text{matter}$ to $v - \text{matter}$ is changeable.

Based on the cosmological model, we confirm that big bang nucleosynthesis is not spoiled
by that the average energy density of $W$–*matter* (mirror matter) is equal to that of $F$–*matter* (ordinary matter).

According to the present model, there are three sorts of dark matter which are $v–W$–*baryon* matter ($4/27$) and unknown $v–F$–*matter* ($9.5/27$) and $v–W$–*matter* ($9.5/27$). Given $v–F$–*baryon* matter ($4/27$) can cluster to form the visible galaxies. $V–W$–*baryon* matter can cluster to form dark celestial bodies and dark galaxies. Unknown $v–F$–*matter* and $v–W$–*matter* cannot cluster to form any celestial body, loosely distribute in space, are equivalent to cold matter, and their compositions are unknown. The number in a bracket is the ratio of the density of a sort of matter to total density of $v–$ *matter*.

The decisive predict is that there are dark celestial bodies and dark galaxies. The energy of $F$–*matter* can transform into the energy of $W$–*matter* by such a process in which the reaction energy is high enough.

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