Journal of Modern Physics, 2025, 16(3), 347-361
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

Beyond ΛCDM: The Dark-Energy-Matter Coupled Model

Ti-Pei Li[1,2,3]

[1]Department of Astronomy, Tsinghua University, Beijing, China
[2]Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China
[3]School of Physics and Astronomy, Yunnan University, Kunming, China
Email: litp@mail.tsinghua.edu.cn

How to cite this paper: Li, T.-P. (2025) Beyond ΛCDM: The Dark-Energy-Matter Coupled Model. *Journal of Modern Physics*, **16**, 347-361.
https://doi.org/10.4236/jmp.2025.163019

Received: December 26, 2024
Accepted: March 14, 2025
Published: March 17, 2025

Abstract

In the dark-energy-matter coupled neutral universe model (DEMC), the universe was generated by inflation of a limited region in an infinite gravitationally neutral static vacuum ocean. The inflation was driven by a phase transition in a limited vacuum region which made the repulsive field in this region dominant, and the net repulsive interaction drove the vacuum to be inflation. At the end of the inflation, the universe returned to the state of attraction-repulsion equilibrium, and began to be uniform, isotropic and inertial expansion. The age of the expanding universe is ~28 billion years. The observed anisotropies in cosmic microwave background (CMB) mostly come from a phase transition of the expanding cosmic vacuum at ~14 billion years earlier while the cosmic redshift $z\sim 1$. Observations of CMB and early celestial objects show that about 25 billion years ago at $z\sim 10$ another cosmic phase transition occurred. Quite a lot of difficult problems which challenge the standard model of cosmology (ΛCDM), such as mature galaxies and black holes in early universe, Hubble tension, cosmological constant problem, large-scale anomaly etc. can be explained in DEMC.

Keywords

Cosmic Vacuum, Expanding Universe, Age of the Universe, Hubble Tension

1. Gravitationally Neutral Universe

The surprising finds of the James Webb Space Telescope (JWST) about the early universe—weird size, brightness, mass and shape of galaxies, weird giant black holes, weird efficiency of star formation, weird correlation between brightness, power and mass of an object, weird presence of litter red dots and chaos of elongated galaxies—seriously challenge the standard model of cosmology ΛCDM [1]. The challenge is so severe that it requires a careful and fundamental examination of models of cosmology.

1.1. Cosmic Homogeneity, Isotropy and Flatness

The basic framework of ΛCDM is the curved spacetime of general relativity. However, precise cosmological observations show that the universe is indeed a flat space with a zero curvature, and high degree of homogeneity and isotropy. The flatness of the cosmic vacuum indicates that the ubiquity of attractive gravity is only a hypothesis derived from infinite extrapolation of local physical phenomena. On a cosmological scale, space might be gravitationally neutral. Measurements of the expansion of the universe indicate that there exist undeniable repulsive material components in the universe, such as dark energy. The gravitationally neutral universe composed of attractive dark matter (and a small amount of baryonic matter) coupled with repulsive dark energy is the true object of cosmic expansion dynamics. In addition, time in cosmic dynamics must be the absolute time that describes the overall expansion of the universe; Even the Friedman equations of standard cosmology require the use of the Robertson-Wolker metric to derive from the gravitational field equation of general relativity, and the time in the Robertson-Wolker metric is the absolute time of the universe that is independent of spatial position. Therefore, cosmic dynamics should be constructed in a flat spacetime composed of uniform fload time and three-dimensional space. The author [2] has constructed a gravitationally neutral universe model in flat spacetime, the Dark-Energy-Matter Coupled model (DEMC). The standard model ΛCDM with curved spacetime and the gravitationally neutral model DEMC with flat spacetime have proposed completely different theoretical predictions for the expansion rate, thermal process, and age of the universe, which can be clearly tested by observations.

1.2. Cosmic Dynamics

Cosmic dynamics is the dynamics of cosmic vacuum. The cosmic vacuum is not a system of particle dynamics, but a thermodynamic system, its dynamics is neither classical mechanics nor relativistic mechanics. The basic physical quantities of cosmic dynamics are energy density and temperature, and the basic processes are density fluctuations, collective oscillations (thermal phonons) and critical phase transitions between attractive and repulsive fields. The expanding universe originates from the phase transition in a limited region in the primitive static vacuum of the attraction-repulsion equilibrium, the inflation caused by the transformation of the attraction field to the repulsive field, the inflation process produces material particles with inertial mass, the local interactions, and the high temperature neutral vacuum of uniform isotropic expansion. The time sequence of the whole process of the universe can only be characterized by the thermodynamic variables of vacuum-temperature or energy density. The uniform and isotropic space-time of the universe is composed of cosmic time τ and three dimensional Euclidean space. The expansion of the cosmic radius $R(\tau)$ is not any mechanical movement of material particles. Only the process of phase transition of the background vacuum (interconversion between dark energy and matter) itself can affect the uniform expansion of the universe as a whole.

For the expending universe, let M_m and M_λ be the inertial mass of gravitational matter and that of repulsive matter (dark energy) respectively, E_{rad} be the radiation energy, then the total inertial mass $M_\mathrm{I} = M_m + M_\lambda + E_{rad}$, total gravitational mass $M_g = M_m - M_\lambda$. Relative to the primitive static vacuum, the cosmic kinetic energy $E_k = M_\mathrm{I}\dot{R}^2/2$, and gravitational potential energy $E_p = -GM_\mathrm{I}M_gR^{-1}$. The uniform and isotropic expanding vacuum has no relativistic effect of translational motion and no transfer of mechanical energy-radiation energy (therefore, the comoving system of the expanding vacuum can be regarded as a static inertial frame); From the conservation of mechanical energy

$$E_{mech} = E_k + E_p = \text{const}$$

the energy equation of the expanding universe can be derived as

$$\dot{a}^2 = \frac{8\pi G}{3}\rho_g a^2 + \epsilon \tag{1}$$

where the scale factor of the universe $a = R/R_0$, the current radius of the universe R_0, the gravitational mass density ρ_g, and the constant $\epsilon = 2E_{mech}/R_0^2 M_\mathrm{I}$. The equation of motion of the expanding universe is the Lagrangian equation

$$\frac{\partial L}{\partial R} - \frac{\mathrm{d}}{\mathrm{d}\tau}\left(\frac{\partial L}{\partial \dot{R}}\right) = 0 \tag{2}$$

where the Lagrangian of the universe

$$L = M_\mathrm{I}\dot{R}^2/2 + GM_\mathrm{I}M_gR^{-1} \tag{3}$$

The laws of conservation, including the gauge invariance, require that the cosmic vacuum be a gravitationally neutral vacuum, $\rho_g = 0$. According to the cosmic energy Equation (1), the normal state of the expanding universe is uniform expansion at the speed

$$\dot{a} = \sqrt{\epsilon} \tag{4}$$

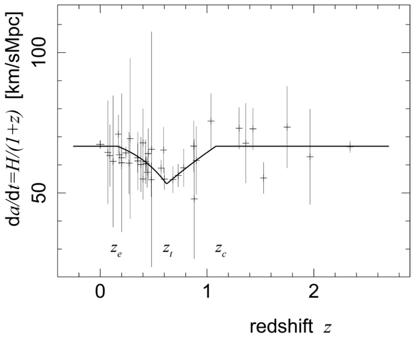

Figure 1. Cosmic expansion rate verses redshift. The line is the fitted result based on the DEMC model.

The data points in **Figure 1** are measurement results of the cosmic expansion velocity $\dot{a}$ at different cosmological redshifts z, from which we can see that the two most accurate observational results, the expansion velocity of the early ($z=2.3$) and the current ($z=0$), have the largest time interval but their values are very close; Starting from $z=z_c\sim 1$, the recent universe is likely to have a phase transition process during which attractive matter M_m and repulsive matter M_λ convert each other and the universe firstly deviate from and then recovery again to the inertial expansion. For the phase transition starting from the critical redshift z_c with critical temperature T_c and critical radius R_c, taking the gravitational mass M_g as the thermodynamic potential of the universe, and adopting the methodology of Landau mean-field theory for continuous phase transition [3], we expand M_g in power series of $\left(R-R_c\right)/R_c$ about the transition point R_c as

$$M_g=b_0+b_1\left(R-R_c\right)/R_c+\cdots \tag{5}$$

with $b_0=M_g\left(R=R_c\right)=0$. For the decelerating phase of $z\le z_c$, only the first two terms in the power series are used

$$M_g=-b\left(R-R_c\right) \tag{6}$$

where $b>0$. Substituting (6) into Equation (2) we get the equation of motion for the decelerating phase

$$\ddot{R}=-G\left(M_gR^{-2}+bR^{-1}\right) \tag{7}$$

Combining Equation (1) of energy and Equation (7) of motion, we get the evolution equation for the decelerating phase

$$\ddot{a}=-\frac{1}{2}\left(\dot{a}^2-\alpha\epsilon\right)a^{-1} \tag{8}$$

with the constant $\alpha=1-2Gb/R_0^2$. The solution of Equation (8) is

$$\dot{a}=\sqrt{\xi\left(1+z\right)-\alpha\epsilon}\quad\left(z_t\le z<z_c\right) \tag{9}$$

where z_t is the end redshift of the decelerating phase, the positive integral constant $\xi=\epsilon\left(1+\alpha\right)/\left(1+z_c\right)$.

During the deceleration phase, part of dark matter in the universe is converted into dark energy. After the decelerating phase, the universe at $z<z_t$ relaxed to an equilibrium state again through a part of dark energy converting back into dark matter. For a continuous phase transition at z_t, the acceleration $\ddot{a}\left(z=z_t\right)=0$, from Equation (8) the expansion rate is

$$\dot{a}\left(z=z_t\right)=\sqrt{\alpha\epsilon} \tag{10}$$

Substituting Equation (10) into Equation (9) we get

$$z_t=\frac{2\alpha}{1+\alpha}\left(1+z_c\right)-1 \tag{11}$$

From $0<z_t<z_c$ we find

$$\frac{1}{2z_c+1}<\alpha<1 \tag{12}$$

Define a dimensionless relative density of gravitational mass

$$\eta = \frac{\rho_g}{\rho_c} = \frac{\dot{a}^2}{\epsilon} - 1 \tag{13}$$

where the critical density

$$\rho_c = \frac{3}{8\pi G}\epsilon\left(1+z\right)^3$$

By Onsager's principle of the symmetry of the kinetic coefficients ([3] §120), η should be symmetric around $z = z_t$, *i.e.* η at $z_e \le z < z_t$ is the same with that at $z' = 2z_t - z$, where z_e is the red shift at the end of the phase transition

$$z_e = 2z_t - z_c. \tag{14}$$

Then from Equation (9) we can get the evolution equation of the accelerated expansion phase

$$\dot{a} = \sqrt{\eta\left(1+2z_t - z\right) - \alpha\epsilon} \quad \left(z_e \le z < z_t\right) \tag{15}$$

Using Equations (11) and (14), the number of undetermined parameters in three evolution Equations (4), (9) and (15) can be reduced to three. The values of the undetermined parameters estimated by fitting the data shown in **Figure 2** with Equation (4), (9) and (15) are as follows: $\sqrt{\epsilon} = 66.7 \pm 0.9$ km·s^{-1}·Mpc^{-1}, $\alpha = 0.64 \pm 0.04$ and $z_c = 1.08 \pm 0.15$. From Equations (11) and (14) we have $z_t = 0.62$ and $z_e = 0.16$. The solid line in **Figure 2** is the evolution curve obtained by fitting the model of uniform expansion + phase transition to date: from $z_c = 1.08$ the universe of uniform expansion began to decelerate, the relaxation process of phase transition started from $z_t = 0.62$, and from $z_e = 0.16$ the universe has recovered to an uniform expansion.

The Friedmann equation of the standard universe model ΛCDM is a general relativistic equation of an ideal fluid, a particle system. The Friedmann equation predicts that under the action of gravity, velocity of particles that make up the cosmic fluid monotonously drop until to the critical point of z_t, and then infinitely rise accelerated by the cosmological constant. For the future of $z < 0$, it is impossible to confirm whether the universe is an inertial expansion with occasional phase transition or an infinite acceleration to tearing; However, for the early universe of $z \ge 4$, the expansion speed of the universe expected by the standard model is far greater than the current speed, so it will be possible to make a clear choice between the two models of universe.

In the gravitationally neutral universe, there is no Big Bang singularity that puzzles physics: the universe was generated by an inflation of a limited region in an infinite vacuum ocean (see **Figure 2**). The vacuum before inflation is a gravitationally neutral vacuum in which the attractive and repulsive fields were balanced to each other and no mechanical motion and thermal motion existed, it is an absolutely rest frame of reference (cosmic rest system) for motions of cosmic and local systems. The inflation was driven by the phase transition in the limited vacuum region: part of the attractive field was transformed into the repulsive field, which made the repulsive field in this region dominant, and the net repulsive field drove the vacuum to be uniform and isotropic inflation.

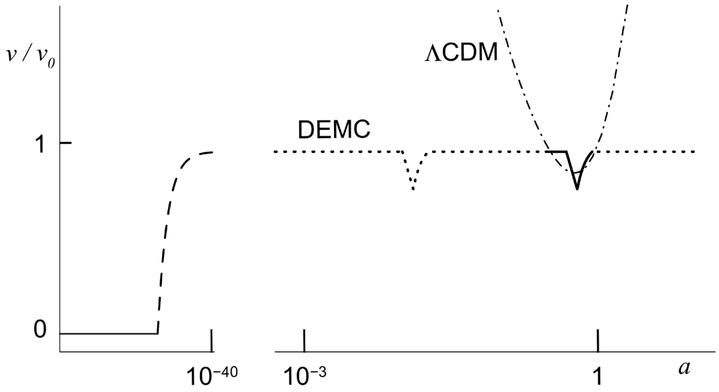

Figure 2. Evolutionary history of the DEMC universe. The horizontal axis is the scale factor $a = R/R_0 = 1/(1+z)$ with R being the radius of the universe, R_0 the current radius, and z the red shift. The vertical axis is the relative expansion speed v/v_0, where $v = \dot{a}R_0$, v_0 is the current speed. So far, only in the $0.25 < a \le 1$ (or $0 \le z < 3$) interval, there are measured results of v/v_0. The dotted line is the result obtained by fitting the existing observational data with ΛCDM model. The rest of the curve represent the DEMC model: the thick and solid line segments are obtained by fitting the measured data; the dotted line is for the expectations for the early and future universe (assuming that there is also a phase transition in the early universe); the dashes and fine solid lines of the earlier period with $a \le 10^{-40}$ represent the universe during inflation and before inflation, respectively.

2. Early Universe

2.1. Cosmic Thermodynamics

If gravity is only a manifestation of the curved spacetime, it cannot be thermalized, as a result the standard model ΛCDM cannot describe the thermal process of the universe. So far, standard cosmology has been based on interactions between photons, electrons, and baryonic matter to explain the thermal history of the universe, and mistakenly portrayed the early universe as "is flooded with light", becoming a universe dominated by luminous matter. In the cosmological equation of general relativity, the cosmic medium is taken as an ideal gas, but the ideal gas cannot radiate as a blackbody. In order to explain the Planck blackbody radiation spectra of cosmic microwave background (CMB) measured by the *COBE* satellite [4], textbooks of cosmology interpret CMB as photons at early universe in thermal equilibrium with the hot dense matter, they then began a free expansion with temperature inversely proportional to the scale a of the universe: *i.e.* although the cosmic energy density $\rho \propto (1+z)^{-3}$, but strangely its temperature $T \propto (1+z)$ in ΛCDM [5]. This kind of model using only a small amount of electromagnetic radiation decoupled from the hot dense matter to represent the thermal history of the universe, does not explain why dense matter has a single temperature, and completely disregards the energy density or temperature of the expanding universe should be inversely proportional to the cubic of cosmic scale a, or proportional to the cubic of $\left(1+z\right)$.

The temperature of a gravitationally neutral universe is not one of local temperatures of dense matter, the global temperature of the universe should be the thermal equilibrium temperature of the cosmic continuum consisting of coupled attractive and repulsive gravity. Thermal processes in electrically neutral condensed matter can be described by optical phonons generated by electromagnetic vibration and acoustic phonons generated by elastic vibration. In DEMC, the gravitationally neutral vacuum with balanced attraction and repulsion is composed of thermal gravitational phonons and a small number of optical phonons; The temperature of the universe is the thermal equilibrium temperature of thermal photons and thermal gravitational phonons in the cosmic vacuum, which is inversely proportional to the cubic of cosmic scale or $T\propto\left(1+z\right)^{3}$.

2.2. Age of the Universe

The standard cosmology ΛCDM believes that the relativistic dynamic process after the Big Bang formed the observed whole sky temperature map of CMB; But in the gravitationally neutral universe model DEMC, phase transitions can occur more than once, and the observed CMB angular power spectrum mainly determined by the latest phase transition. On the observed CMB whole sky temperature map, tens of thousands of cold and hot spots with an angular diameter of $\theta\sim1^{\circ}$ are products of the cosmic phase transition began from $z\sim1$; Every cold or hot spot is a sub region (sub universe) of the expanding universe. The Milky Way is just one of many galaxies in a certain sub universe, and the variation of expansion rate between redshift z_c and z_e in **Figure 1** came from mutual transformation of material components in this sub universe during the phase transition period.

In DEMC model, the normal state of the universe is the uniform expansion at a constant velocity v_u, and deceleration or acceleration of expansion is only a transient phenomenon in a phase transition period of the universe. In the stationary expanding DEMC universe, the difference between the present age τ_o and the age τ_z at redshift z

$$\Delta\tau_z\equiv\tau_o-\tau_z=\int_{R_z}^{R_o}\frac{\mathrm{d}R}{v\left(R\right)}\simeq\frac{R_o-R_z}{v_u}=\frac{2z}{1+z}\Delta\tau_1 \tag{16}$$

where $v\left(R\right)$ is the expanding velocity of the universe with radius R, and R_z and R_o are radius of the universe at redshift z and at present respectively with $R_z=R_o/\left(1+z\right)$. If the Milky Way was formatted during the phase transition process shown in **Figure 1**, based on the age of the Milky Way it can be estimated that the time interval between the age τ_0 at present and that at $z=1$ as

$$\Delta\tau_1\equiv\tau_0-\tau_{z=1}\sim14\text{ billion years} \tag{17}$$

With Equation (17) and letting $z\to\infty$ in Equation (16) the current age of the universe can be estimated as

$$\tau_o=2\Delta\tau_1\sim28\text{ billion years} \tag{18}$$

Therefore, in DEMC, the so called "Big Bang" is just a cosmic phase transition occurred at $z \sim 1$ with the age of the universe ~14 billion years. Before the so called "Big Bang", the universe had already lasted long time evolution of another ~14 billion years, there existed enough time to produce early transformation. From Equation (16), the early universe at $z \sim 5$ was born ~23 billion years ago or aged ~5 billion years.

2.3. Early Black Holes and Galaxies

The standard model ΛCDM gives a cosmic age of about 14 billion years, which is very close to the age of the Milky Way estimated by isotope dating, some stars even exceeding it. The *JWST* discovered the existence of a large number of supermassive black holes in the early universe with redshift z from 4 to 6, their ages approximately from 1 billion to 1.5 billion years in ΛCDM [6]. Carbon dusts that could only exist in ancient galaxies, such as the Milky Way, have also been discovered by *JWST* in early galaxies [7]. Recently, *JWST* has reported the secure observation of galaxy JADES-GS-z14-0 at $z = 14.1793 \pm 0.0007$ with robustly detecting (6.6σ) of a bright oxygen line [OIII] 88 μm [8]. In ΛCDM, the metal-enriched galaxy JADES-GS-z14-0 was already formed just a mere 3 billion years after the Big Bang! Therefore, the standard model that the universe expands faster in early periods is likely to greatly underestimate ages of early universe.

2.4. Litter Red Dots and Elongated Galaxies

JWST has unveiled numerous faint, broad-line new type objects at $z > 5$ known as the little red dots (LRDs) [9]-[12]. The LRDs seem to be small, red-tinted galaxies; they are actually red, not just redshifted, but no trace of them has ever been found in today's universe. In ΛCDM, LRDs should ignite about only 6 billion years after the Big Bang and blazed for a billion years. In addition to LRDs, *JWST* also discovered other strange objects. For example, small early galaxies have oddly elongated shape. This new class of galaxies in the early universe has also no counterpart in the universe today and inconsistent with ΛCDM [13] [14]. In DEMC, both LRD and elongated galaxy could be explained as early galaxies, with the former being X-rays from a supermassive black hole at the center of a galaxy which travel through over a distance greater than ~23 billion light-years and reddened by the interaction between photons and interstellar/intergalactic plasma, and the latter being galaxy radiation observed along the direction close to the galactic disk.

3. Cosmic Landscape

On the map of CMB temperature anisotropies shown in **Figure 3**, there exist a few tens of thousands of hot and cold spots with typical angular scale $\theta \sim 1^\circ$, each one will form a sub expending universe. Therefore, the expending universe consists of a few tens of thousands of parallel sub expending universes. Our Milky Way belongs to a parent sub universe which comes from a certain 1°-diameter spot, say a parent cold spot.

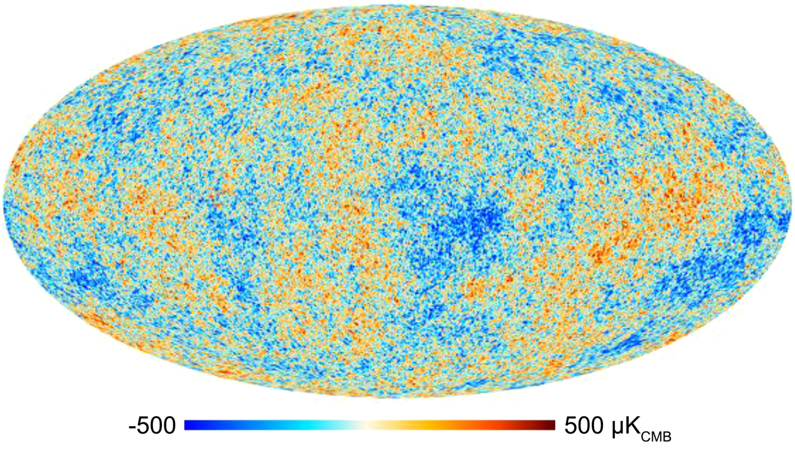

Figure 3. The anisotropy of the cosmic microwave background radiation.

In ΛCDM, all spots on CMB anisotropy maps are the product of the Big Bang. However, there is a most prominent 10˚-diameter cold spot located at $(b,l)=(-55.8^\circ, 209.4^\circ)$ on CMB maps made by *WMAP* and *Planck* satellites, which should be a topological defect in the very early universe, but the energy scale required to produce it is too high [15], leading Gurzadyan and Penrose [16] to argue that it was a supermassive black hole before the Big Bang.

In DEMC, spots of 1˚-diameter on CMB maps come from a phase transition of the cosmic medium at $z \sim 1$, when the age of the universe was about 14 billion years. The 10˚-diameter spot can be naturally interpreted as a product of an earlier cosmic phase transition at $z \sim 10$, which was about 12 billion years earlier than the last phase transition at $z \sim 1$.

It is worth noting that the high red shift galaxies and black holes found by *JWST* that challenge the standard model are all within the scope of this big cold spot. Furthermore, Liu and Li [17] pointed out that the temperature map of this cold spot has a characteristic structure: a circular ring about 4˚ from the center has the largest temperature fluctuation (see the upper left panel of **Figure 4**); and that quite a few other 10˚-diameter cold or hot spots with similar characteristic temperature structure have also found in *WMAP* maps (as shown in the remaining panels in **Figure 4**) and in *Plank* maps as well.

As previously mentioned, for the gravitationally neutral universe DEMC, cold/hot spots of ~1˚ on all-sky CMB maps are sub universes formed during the phase transition at redshift of $z \sim 1$ about 14 billion years ago, while these cold/hot spots of ~10˚ should be sub universes formed during a phase transition at redshift of $z \sim 10$ about 25 billion years ago. The average temperature difference distribution obtained by superimposing 1˚ cold or hot CMB spots after aligning with their extreme temperature points [18] presents a feature of standing wave effect of disturbance propagation within ~1˚ horizon when $z \sim 1$; For the characteristic feature of cold/hot spots shown in **Figure 4**—largest temperature fluctuations at ~4˚ rings—should be attributed to standing wave effects of disturbance propagation within ~10˚ horizon when $z \sim 10$.

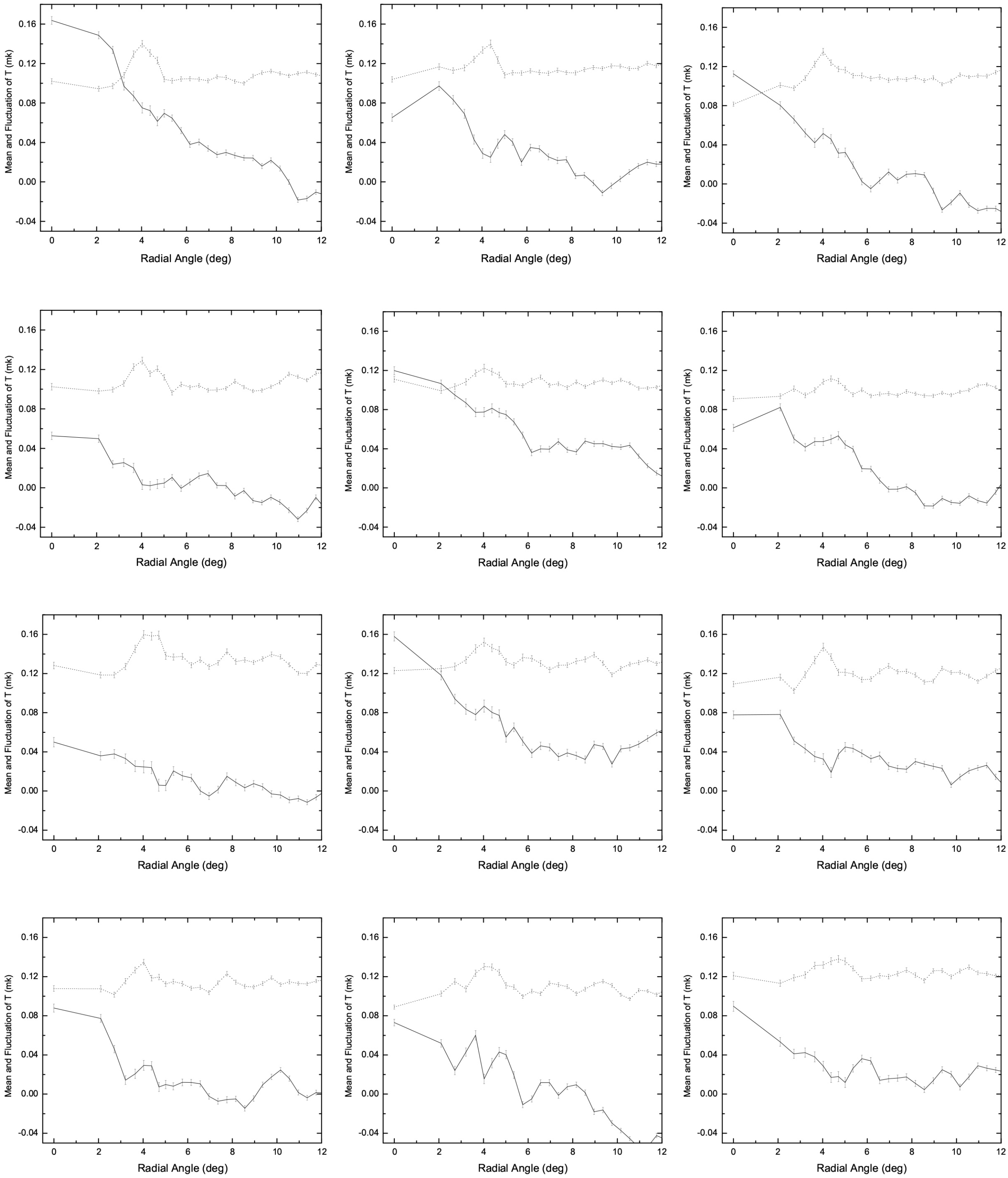

Figure 4. Temperature distributions of CMB cold/hot spots with angular diameter of ~10˚ in the *WMAP* temperature map. The abscissa θ is the angle towards the spot center, and the ordinate is the absolute value $\left|\langle T\rangle\right|$ of the average temperature on the circular ring with angle θ (solid line), and their root mean square fluctuation $\sqrt{\left\langle \left(T-\langle T\rangle\right)^2\right\rangle}$ (dotted line). Starting from the top row and each row counts from left to right, the 1st, 4th, 6th, 8th, and 12th are cold spots, while the remaining are hot spots; and their positions (b,l) are (−55.8, 209.4), (−85.1, 113.4), (−31.1, 318.1), (58.3, 55.5), (76.9, 155.8), (28.7, 83.1), (27.2, 224.0), (−27.7, 159.2), (−44.4, 20.2), (−65.7, 225.9), (−32.2, 325.3) and (−38.1, 132.6), respectively.

On the CMB angular power spectrum shown in **Figure 5**, the acoustic peak at multipole moment index $l \sim 200$ (angular scale $\theta \sim 1^\circ$) and overtones are the results of local acoustic oscillations within horizons in the beginning of the cosmic phase transition at $z \sim 1$; In the large-scale spectrum of **Figure 5**, there is also an obvious concave structure at $l \sim 20$ ($\theta \sim 10^\circ$), supporting that the earlier phase transition of the expanding universe at $z \sim 10$ really occurred.

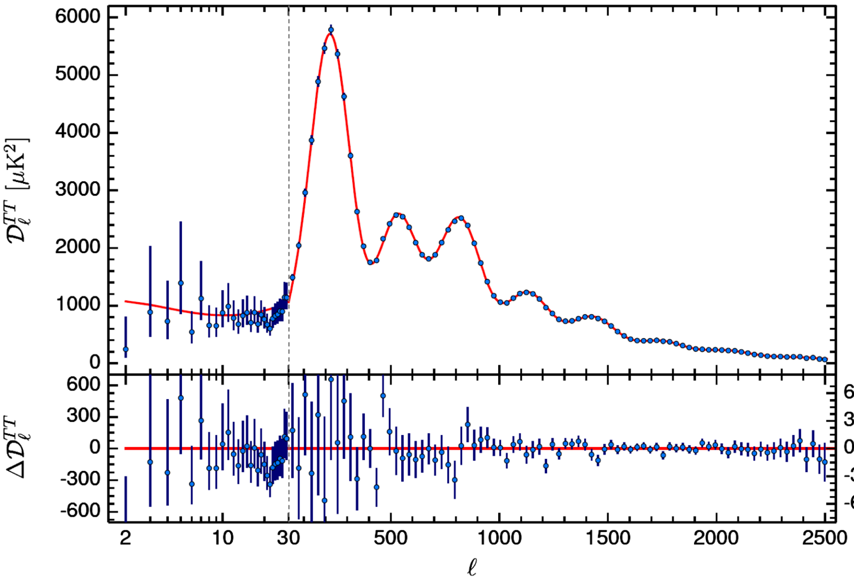

Figure 5. Angular power spectrum of cosmic microwave background radiation measured by *Planck* satellite (from [19]). The curve is the theoretical spectrum of ΛCDM model.

Thus, much richer than expected by the Big Bang model, the observed expending universe has undergone at least two phase transitions, each produced a large number of sub universes expanding in parallel: ~10^4 sub universes from the last phase transition at $z \sim 1$ and ~10^2 ones from the previous phase transition at $z \sim 10$. Parallelly expending universes form the observable universe. Each sub universe is composed of clusters of galaxies and voids. Most of observed objects and voids almost uniform distributed in the sky belong to the parent sub universe where the Milky Way galaxy is located, and a small number of celestial bodies belonging to other sub universes may also be observed in their corresponding ~1° or ~10° sky range, respectively. It can be expected that with the development of optical and radio telescopes and through in-depth observations to the universe, human understanding of the temporal and spatial scales of the universe and physical processes in the universe could be essentially expanded.

4. Discussion

4.1. Hubble Tension

The precondition for the Hubble parameter H_0 to be constant in cosmology is that all the observed objects are in the same uniform expansion system, as required by the Big Bang model. However, the observed universe does not meet the above condition. As mentioned in the previous section, although most of the observed objects belong to the same sub universe, there are still a few belong to different parallel sub universes generated by phase transitions at different epochs. Furthermore, to keep the universe remain gravitational neutrality and expansion homogeneity during phase transitions, the variation of expansion rate of a hot spot during the phase transition could be opposite to **Figure 1**, then during the last phase transition with $z < 1$ the expansion rate of a galaxy which come from a hot spot will be greater than that from a cold spot.

4.2. Where Are We From

Which cold spot with diameter of $\sim 1^\circ$ in **Figure 3** our galaxy come from? The intensity of the big cold spot located at $(b,l) = (-55.8^\circ, 209.4^\circ)$ is much higher than other visible big spots, suggesting that the parent spot of our galaxy is much closer to this big cold spot in the southern sky. This conjecture is also helpful to explain quite a few north-south asymmetries observed in CMB anisotropies and other astronomical phenomena, and will be tested by further observations.

4.3. Neutrality of Cosmic Vacuum

The neutrality of the vacuum medium of the universe is necessary not only for a self-consistent cosmological model, but also for mechanical dynamics, electromagnetism, and microscopic physics as well.

For example, there exists a serious trouble in relativistic electrodynamics: For a uniformly moving electron of $\gamma = 1/\sqrt{1 - v^2/c^2}$ the electromagnetic mass deduced from Maxwell's equations through forces between the charge and electromagnetic field should be [20]

$$m = \frac{4}{3}\gamma m_0 \tag{19}$$

with m_0 being the rest mass of electron, which significantly contradicts the special theory of relativity. Feynman regarded this trouble as letting the theory of electromagnetism "ultimately falls on its face" [21]. The same problem also exists in particle dynamics. The long standing "4/3 problem" comes from that the mass increase of moving charges is not caused by any forces. For a gauge charge of long-range force (electric charge or gravitational charge), when it is rest its field energy (inertial mass) m_0 exists in the inverse-square field (Coulomb field) surrounding the charge, and when it is moving at a constant velocity its field energy m exists in the virtual massless particles of the velocity field which is moving along with the charge [22], where $m = \gamma m_0$. As $m > m_0$, some of the virtual massless particles constituting the velocity field must come from the vacuum, which must be electrically neutral and/or gravitationally neutral to meet the requirement of charge conservation. In mechanical dynamics, movement of objects and change of mechanical energy (kinetic energy and potential energy) are caused by forces. Different from processes in mechanical dynamics, the conversion process from a static vacuum medium to a velocity field composed of virtual massless particles does not involve any forces, nor does it cause changes in mechanical energy. Therefore, the moving mass $m = \gamma m_0$ is the total inertia of the moving object or velocity field (in three physical dimensions), where the redundant $\gamma m_0/3$ in Equation (19) is the kinetic energy of the object (in one physical dimension — the direction of out force) that doesn't present in a process without force.

4.4. Two Vacuums

The density ρ_v of zero point energy of vacuum is an important parameter in quantum field theory, which is contributed by known quantum fields, but much larger than the current energy density ρ_0 of cosmic vacuum:

$$\rho_v \simeq 10^{120} \rho_0 \tag{20}$$

This is a major difficulty in physics, the cosmological constant problem [23].

The cosmological constant problem may indicate that special relativity and quantum field theory need different background vacuum-expansion vacuum and absolute rest vacuum, and these two vacuums coexist at the same time. If the current universe with energy density ρ_0 and scale R_0 is originated from an area with scale R_v and density ρ_v in the infinite rest vacuum, and the energy density of expanding vacuum decreases with the increase of cosmic scale, then it can be derived from Equation (20) that

$$R_0/R_v \simeq 10^{40} \tag{21}$$

A number of dimensionless ratios composed of microphysical and cosmological parameters are close to a "cosmic big number" 10^{40} [24]. The formula (21) shows that, since the birth of the universe the expansion multiple of the scale is also close to the "cosmic big number". The difference of energy density between the two vacuums can be explained by the expansion of the universe: the static cosmic vacuum has a constant energy density ρ_v, but after the scale of expanding vacuum increased about 10^{40} times, the current density of the expending vacuum should decrease by about 10^{120} times.

The law of conservation of energy, momentum, angular momentum, and the gauge invariance of long-range force fields, require the background space to be not only uniform, isotropic and charge neutral, but also in rest, that is, the background space is a force-free vacuum. The finite expanding vacuum expands in the infinite absolute static vacuum. The two vacuums both are force-free space with zero intensity of force field, can coexist without interfering with each other. The expansion of the universe is uniform and isotropic without center (or any position can be a center), and the frame moving together with expansion can be used as a static inertial frame. Therefore, the background vacuum of peculiar motions and that of virtual processes of quantum field theory can coexist.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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