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Non-singular model of universe

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Abstract
Einstein equations give minimum and maximum limits of cosmic scale factor by considering pressure. In our suggested model the contraction before expansion of cosmos is like the birth of a star. As in nuclear fusion stage, the temperature and pressure of the star depends on its mass, in the order of magnitude of universe mass fusion after gravitational contraction brings about explosion. This does not require to accept the big bang singularity. Explosions have thrown external layers and formed parts of the expanding cosmos in several stages. We dealt with the problem of horizon by considering the idea of step- by step explosions. In observable part of the universe high percentage of dark energy and dark matter confirms that these are the remains of other parts of the cosmos. Neutrinos being highly energetic and without any interaction are the most suitable candidates for dark energy and massive black holes being found at the central part of galaxies and in stellar clusters are the most suitable candidates for dark matter.

Keywords
Cosmology; Big bang; Scale factor; Dark energy; Dark matter; Horizon problem

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1. Introduction

Bouncy models of cosmos are two groups. In first group, the start point is density and temperature singularities (big bang) that in short time have led to inflated expansion and after inflation, usual expansion has continued. The problems of flatness and horizon are tackled by inflation pattern. In big bang model, zero limit for scale factor is resulted from Einstein equations for which a cosmic dust system with $T_1^1 = P = 0$ is proposed. Nevertheless, inflationary big bang theory has faced challenges [1, 2].
In order to avoid singularity, the second group of bouncy models of cosmos has been introduced. These models consist of initial contraction phases and following expansion with one bounce without singularity between them where contraction converts to expansion. In [3] a model has been introduced representing that the universe starts to contraction by overcoming vacuum energy in $t = -\infty$ until it reaches to the stage of bounce without singularity. In [4] it has been shown that considering a term which is dependent on momentum in Hamiltonian, Einstein equation leads to the universe non-singular expansion. Another model of general relativity bouncing cosmology with a parameter of state equation has been suggested so that big bang singularity is replaced by a length scale of the space-time defect [5]. Other theories also have been introduced more completely such as periodic universe [6, 7] and cosmic string [8].
At a glance, there is an interest in the start of cosmos evolution. The hypothesis about dust (zero pressure) in high density specially in zero scale factor ($S \to 0$) is unacceptable and instead, by considering adiabatic changes, nonzero pressure has to be replaced in Einstein equations that leads to $S_{min} \neq 0$ (section 2). Let us ask: Would it be feasible to get ideas of astrophysics in the stars formation and use them as a mechanism of the universe formation? Could we replace a big bang pattern, by a known effect which leads to an expansive universe? The contraction before expansion is like the birth of a star.
Supernova data confirm that cosmic expansion is accelerating, which is the reason for the constant term Λ in Einstein equation. Cosmological constant does not vary with cosmic expansion [9]. It is a constant energy called dark energy forming %75 of energy-matter of universe which its origin and its nature have not yet been determined. There has been found a difference of the 60 order of magnitude in quantum vacuum zero-point energy, suggested in standard theory as the cosmological constant and that of experimental results [10]. In our suggested model, Einstein equations [8, 10] and gravity [11–13] do not require to be modified for explanation of accelerating cosmos expansion, cosmological constant and dark energy.
Planck 2018 data challenge the flatness of the universe. In angular power spectra of microwave, the angular scale of distribution is focused on closed model with curvature density corresponding Ω_k=-0.04 [14]. Therefore, new evidences show that the flatness problem does not need to be solved by inflationary theories. Moreover in new model the problem of horizon is solved without inflation assumption.
Our suggested model has an idea for the origin of the dark matter. The exploration into finding heavy particles having no interactions as the candidates for dark matter has been inconclusive [15–17], because the ratio of mass to light (M/L) for galaxies is 50 times of that of sun and this ratio for galactic

clusters is 300-500 times larger than that of sun. That is, with the increase in scale, there is more increase in the ratio of mass to light. Other candidates are black holes [15] and dense masses [18] that have to form a large percentage of the matter of the universe. This model has an idea to answer to this question: What is the origin of massive black holes which are in the core of galaxies and stellar clusters? [19, 20]

2. Adiabatic contraction and expansion

General relativity and Einstein equations in cosmology are the strongest theoretical foundation of a cosmological paradigm. Additionally, phase transitions, pressure components and the probable existence of matter and energy out of observable system also need to be considered. Moreover, there is no reason that cosmos evolutions lack first stage of shrinkage before its expansion and also there is no motive for universe expansion to originate from a singularity of temperature and pressure. However, these two differences do not lead to the difference in the stages of cosmos evolution after nuclear synthesis.
By considering homogeneity and isotropy symmetries, Einstein equations give

$$2\frac{\ddot{S}}{S}+\frac{\dot{S}^2+kC^2}{S^2}=\frac{8\pi G}{C^2}T_1^1 \tag{1}$$

$$T_1^1=T_2^2=T_3^3$$

$$\frac{\dot{S}^2+kC^2}{S^2}=\frac{8\pi G}{3C^2}T_0^0 \tag{2}$$

where, C is speed of the light in vacuum, k is a constant value which is dependent on mass-energy of the system and indicates the curvature of the universe. For a flat universe $k=0$. The evolution of universe is presented with scale factor $S(t)$ defined by relation

$$\mathbf{r}=S(t)\mathbf{r}_0 \tag{3}$$

The Hubble constant of expansion is defined by

$$H=\frac{\dot{S}}{S} \tag{4}$$

$$\mathbf{V}=H\mathbf{r} \tag{5}$$

Firstly, we consider the conditions of the dust, in which the pressure P is ignorable:

$$T_1^1=P=0 \tag{6}$$

$$T_0^0=\frac{\rho_0 C^2 S_0^3}{S^3}=\rho C^2 \tag{7}$$

Consequently, equations 1 and 2 simplify to

$$2\frac{\ddot{S}}{S}+\frac{\dot{S}^2+kC^2}{S^2}=0 \tag{8}$$

$$\frac{\dot{S}^2+kC^2}{S^2}=\frac{8\pi G\rho_0}{3}\frac{S_0^3}{S^3} \tag{9}$$

The parameter of $q(t)$ as an index of acceleratio $\ddot{S}$ is defined by equation

$$\frac{\ddot{S}}{S}=-q(t)H^2 \tag{10}$$

We assume that in equations 8 and 9, two limits $S\to 0$ and $S\to\infty$ are not acceptable ($k=1$), and from equations 8, 9, 10 we get

$$\dot{S}^2=C^2\left(\frac{a}{S}-1\right), \qquad S\neq 0 \tag{11}$$

Where, with regard to current conditions (q_0,H_0), α is given by [21]:

$$\alpha=\frac{2q_0}{(2q_0-1)^{\frac{3}{2}}}\frac{C}{H_0}=S_{1max} \tag{12}$$

We have to accommodate the pressure in the hydrogen perfect gas conditions. In a contraction process, like what happens in the star formation, the energy resulting from gravitational condensation leads to increase in temperature and achievement of atomic hydrogen with the order of 1000 K. Here, we show that for atomic hydrogen adiabatic evolution, Einstein equations have a response with two limitations of S_{min} and S_{max}. Then, for the stage of plasma of hydrogen, we discuss about the effect of radiation pressure and electrons pressure. In high density, the approximation of P equals to zero, that is, the conditions of dust are not reliable. For small S, the evolution is adiabatic and in high temperatures, hydrogen is monatomic, so we have

$$T_1^1=P \tag{13}$$

$$P(S^3)^\gamma=\alpha_1 \qquad \textit{and} \qquad \gamma=\frac{5}{3} \tag{14}$$

$$P=\alpha_1 S^{-5} \tag{15}$$

Taking the cosmological constant λ into account, the equations of the evolution of the universe can be derived from equations 1, 15, 2 and 7 as follow:

$$2\frac{\ddot{S}}{S}+\frac{\dot{S}^2+kC^2}{S^2}-\lambda C^2=\frac{8\pi G}{C^2}\alpha_1 S^{-5} \tag{16}$$

$$\frac{\dot{S}^2+kC^2}{S^2}-\frac{1}{3}\lambda C^2=\frac{8\pi G\rho_0}{3}\frac{S_0^3}{S^3} \tag{17}$$

By subtracting two sides of eq. 17 from eq. 16, it is concluded that

$$2\frac{\ddot{S}}{S}-\frac{2}{3}\lambda C^2+\frac{8\pi G\rho_0 S_0^3}{3}\frac{1}{S^3}=\frac{8\pi G\alpha_1}{C^2}\frac{1}{S^5} \tag{18}$$

Inserting equations 10 and 4 in eq. 18 gives

$$-2q\frac{\dot{S}^2}{S^2}-\frac{2}{3}\lambda C^2+\frac{\alpha_2}{S^3}-\frac{\alpha_3}{S^5}=0 \tag{19}$$

Both α_2 and α_3 constants depend on mass and the current conditions of universe, S is not equal to zero, and with opting for $\lambda > 0$ and considering pressure $P \neq 0$ in adiabatic evolution, the eq. 19 gives

$$-2q\dot{S}^2-\frac{2}{3}\lambda C^2 S^2+\frac{\alpha_2}{S}-\frac{\alpha_3}{S^3}=0 \tag{20}$$

Putting $\dot{S}$=0, equation 20 has two solutions, that are obtained from intersections of two curves: $y=\frac{2}{3}\lambda C^2 S^2$ and $y=\frac{\alpha_2}{S}-\frac{\alpha_3}{S^3}$ (see Fig. 1). Therefore, S gets its value in the following range

$$S_{min} < S < S_{max} \tag{21}$$

So, S does not reach to zero point, and there is no singularity. S has also an upper limit, that is, universe is closed, which is consistent with Planck 2018 results [14]. This S_{max} indicates that the universe is finite and cosmological constant, λ, is an indicator for extra constant energy of observable system. Taking pressure and adiabatic evolution into account, it is the same as the model of the star formation [22]. Up to this step, it can be concluded that, the universe reaches S_{min}, and then, the expansion period starts and it approaches to the current conditions where the acceleration of expansion is positive (see Fig. 2). Considering asymmetry of matter-antimatter in our observable universe, the assumption is that the universe has formed just of hydrogen at the beginning and its evolution, through gravity, has initiated from a S_{max}.
Other experimental evidence such as cosmic microwave, formation of structures and diversity of elements in addition to physical considerations are indicators of the occurrence of other processes before the S_{min} limit, including hydrogen ionization and nuclear fusion. These give rise to an enhancement in S_{min} which need to be remarked. After the stage of minimum value of S, the cosmological constant of observable universe is positive. We will explain these considerations in following section.

3. Cosmic explosions

Above discussion is reliable before reaching the S_{min}, that is, up to pressure and temperature at which hydrogen has not been ionized and up to the temperatures at which radiation energy can be excluded. Otherwise, the contributions of the electrons pressure and that of radiation pressure in hydrogen plasma should also be taken into account [23].

$$P_e=\frac{hc}{8m}\left(\frac{3}{\pi m}\right)^{\frac{1}{3}}\rho^{\frac{4}{3}} \tag{22}$$

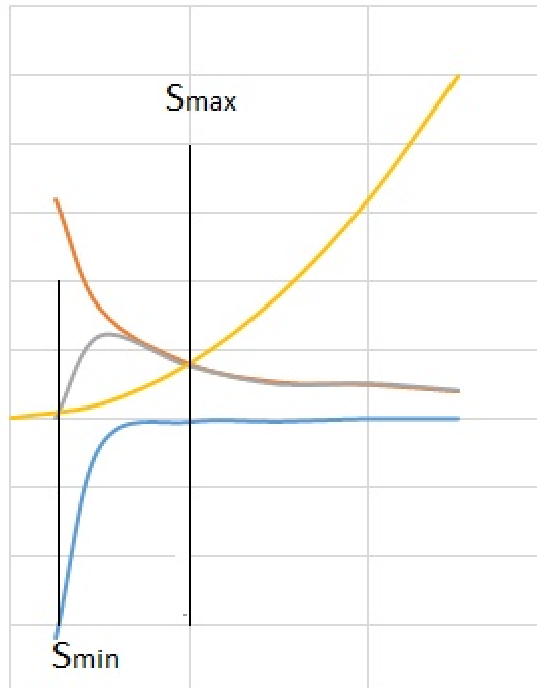

Figure 1. S_{min} and S_{max} limits of evolutions of cosmos are determined from equation 20 (without considering numerical scale).

$$P_{rad}=\frac{\sigma}{3}T^4 \tag{23}$$

Where, m is hydrogen mass (proton), ρ is density of electrons and σ is Stefan-Boltzmann constant. Therefore, the total pressure would be:

$$P_{tot}=P_i+P_e+P_{rad} \tag{24}$$

In which P_i, P_e and P_{rad} are the pressures of hydrogen ions, electron gas and radiation respectively. In contraction step, the addition of P_e and P_{rad} to the pressure of the system, leads to an increase in the value of S_{min}, and since these pressures are imposed opposite to the direction of the gravity, therefore there is no singularity.
Additionally, we consider the similarity to a star in hydrogen plasma. Energy is released by hydrogen fusion, before reaching the mentioned limit. Firstly, heat transfers through the convection mechanism and at high temperatures, the radiation mechanism is dominant, however, the condensations which results from cosmic enormous mass, decreases the exhaust of radiation energy [22]. Radiation pressure increases with T^4 and causes to explosions, firstly because the ratio of the temperature of a star to that of the sun, in terms of the ratio of their masses is equal to [22]:

$$\frac{T_*}{T_\odot}=\left(\frac{M_*}{M_\odot}\right)^{\frac{1}{3}}=\left(\frac{P_*}{P_\odot}\right)^{\frac{1}{4}} \tag{25}$$

And secondly, the ratio of the longevity of a star to that of the sun is equal to [22,24]:

$$\frac{t_*}{t_\odot} = (\frac{M_*}{M_\odot})^{-2.3} \tag{26}$$

In the star-like model of cosmos, if cosmic mass is assumed to be about 10^{20} times of the mass of the sun, $M_\odot$, by using extrapolation of equation 25, the pressure would be 10^{27} times of the pressure of the sun and by using the extrapolation of equation 26, the ratio of the duration of cosmic explosion to the longevity of the sun becomes about 10^{-46}. If the sun has the longevity of the order of 10^{16} seconds, the duration of cosmic explosion would be of the order of 10^{-30} seconds.
Hydrogen masses of external layers are projected and form an expanding system, whose parts have different speeds which leads the parts to diverge. This projection of external layers is the same as the explosion of a supernova [24]. Another similarity between cosmic system and quasars is explainable. High redshift in quasars indicates that they are distant more than a billion of light year [25]. For diverging velocity of 0.16C, we achieve to a radiation power of about 40 times of the most brilliant galaxies [24]. Now the question is that what is the energy source of the quasar? Quasars are the core of the active galaxies that affect the light of their stars [21]. According to this, the existence of massive black holes with the mass of the order of 10^7 times of that of the sun at the center of such galaxies is the reason for their strong gravity. This leads to the materials which are affected by this gravity releasing energy. By this energy, ionized gases are repelled out of quasar before reaching to Schwarzschild radius. Regarding cosmos, before explosion, two sources of energy are gravitational contraction and hydrogen fusion increasing radiation temperature and pressure up to the limit of cosmic explosion in the condition of the lack of energy transmission.
In cosmic scales, after an explosion, the pressure decreases and a huge nucleus, still of the order of cosmic mass, remains. Therefore, condensation and fusion are repeated and other explosions will occur. Each of these explosions becomes the origin of the formation of a "sky" that expands and gradually cools down.
Each of these skies, in its expansive evolution, follows Einstein equation. Our observable universe is the last sky and the cosmological constant of this system shows the presence of the energy of the other skies which are formed before (dark energy). The number of explosions or the number of skies is less than the ratio of the total matter (including dark matter) to the observable one.
According to Einstein equation, the evolution of the whole universe with $\lambda = 0$ starts from the upper limit (eq. 12). After adiabatic process, the system reaches hydrogen fusion and explosions. After the last explosion, the observable universe, now has accelerating expansion, and the Einstein equations with $\lambda > 0$ are applied to it. Data of expansion of the cosmos are the results of its observable part. Consequently, taking the effect of dark energy which results from other skies into account, considering the cosmological constant λ in the equation of the expansion of the last sky would be necessary.
Neutrinos increase the Hubble parameter [26]. The best candidate for dark energy is electron neutrinos because:
a) The energy of these relativistic particles is 0.42MeV and the product of their mass times the square of light speed is just 60eV [27] and some neutrinos were found in 2013 [28,29] whose energies were 14 orders of magnitude larger than the reported ones.
b) Such particles, in other skies (out of the observable system), are also formed through hydrogen fusion and highly energetic neutrinos are an indicator for the explosive nature of cosmic fusion.
c) Neutrinos are stable and without interaction, so they can form a constant energy, and high percentage of the amount of dark energy may results from several cosmic explosions.
The best candidates for dark matter are initial black holes that about 80 percent of them are the residuals of other skies. Following properties seem to be adequate for accepting this issue:
a) Only, their gravitational effects are identifiable.
b) These black holes exist at the center of galaxies [30] and in galactic clusters and increase the ratio of mass to light in large scales.
c) The black holes provide the gravity which is necessary for formation of a galaxy. As a result, they need to exist before the formation of galaxies.
Thus far, without being obliged to accept the singularity and ambiguity in $S \to 0$ for $t = 0$, we have achieved ideas for the cause and the origin of cosmological constant and dark energy and have justified the accelerating expansion of the universe. Moreover, we have suggested the origin of dark matter. Our basic issues are contraction before explosion, the lack of singularity and the formation of several skies. We have also indicated their impacts. In following section, we discuss the evolutions of the universe with a general point of view by applying the results of sections 2 and 3.

4. Description of evolutions

Now, that we have to accept the asymmetry of particles-antiparticles as an experimental fact, let us consider an isotropic mass distribution of hydrogen in saturation conditions as the initial conditions of the system. Sprays of liquid hydrogen were formed and gradually converted to large masses of liquid hydrogen, and space was created around hydrogen areas.
Liquid hydrogen masses become close to each other through gravity from a S_{max}, and stick together. This step, as a "dust" system $(T_1^1 = P = 0)$ in cosmic scales, is described by equations 8 and 9. In central parts, gravitational force was greater and the speed of gravitational collapse was high. This led to more energy release, increase of temperature and pressure generation.
After that, the evolution, in the form of adiabatic extraction of the perfect gas, was described by equation 20. The pressure and temperature, in central parts sharply increased, and

this pressure prevented the surrounding areas from collapsing. Accordingly, surrounding areas were separated from central parts. In this step of the evolution of cosmos, the central parts included hot plasma which is surrounded by hydrogen gas, and ultimately, there was liquid hydrogen, in cold external shell. The pressure and temperature increased gradually from outside to inside layers. Nuclear fusion of hydrogen ions started before reaching the S_{min}.
This fusion happened in core where the temperature was at its maximum level and there was heat transfer by convection. The increase in density which results from cosmic mass of the system was obstacle to the exhaust of radiation energy and consequently pressure and temperature increased rapidly. Equations 25 and 26 show that there were huge explosions after radiation pressure which is provided from cosmic mass. In shell projection, this was similar to the explosion of a supernova. Enormous bubbles, including the hydrogen, ejected away. Nevertheless, the scale of remaining core was yet of cosmic scale. With renewed gravitational condensation and hydrogen fusion, similar explosions were repeated.
Several consecutive enormous explosions cause expanding systems to form by following equation 20 and figures 1 and 2. Dense clouds, which consist of hydrogen bubbles H^1 and H^2 that were projected in each stage through an explosion, diverged because of having different speeds, and formed an extensive system that was expanding. Each of such system is called a sky. The extent of each sky depends on its start time. Skies have some overlaps and next skies are smaller. In the last stage, our observable sky has formed through the last explosion which is expanding. This is the smallest sky amongst the previous ones and all of skies have expanded in their volumes.
What exists and can be discovered from pervious skies are as follows:
a) Dark matter: black holes around which present galaxies and galactic clusters have been formed and the Nobel Prize in physics 2020 awarded for the discovery of one of them.
b) Dark energy: It is neutrinos which result from nuclear reactions in other skies. These relativistic particles which result from hydrogen fusion have remained because of the absence of interaction, and have formed an external constant energy for the observable expanding universe.
c) Cosmic microwave background: It is the cold radiation resulting from several and consecutive cosmic explosions. This is similar to periodic universe model which introduce the microwave background as the result of the evolutions of universe in previous periods. The problem of horizon is addressed by the presence of the radiation resulting from the previous explosions.
The ejected masses approach black holes through the gravity and the effect of angular momentum, which leads to form galaxies that rotate around their own center. Gigantic black holes exist in galaxies such as that of Milky Way galaxy. Therefore, the causes of the formation of galactic structures are gravitational instability, which results from the black holes of preceding skies. Stars form after local gravitational condensation and the fragmentation of galaxy system [22, 31], and rotate around black holes.

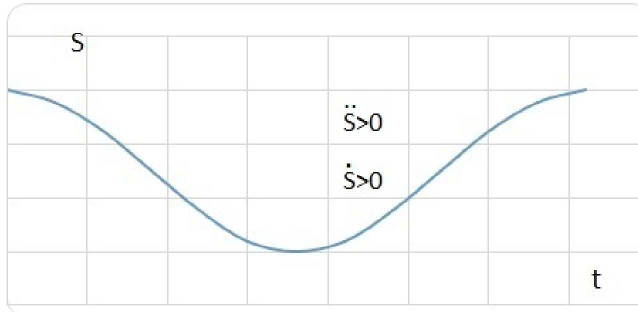

Figure 2. Schematic of time variations and the evolution of cosmos (without considering numerical scale). The expansion and positive acceleration are shown for current condition.

5. Results and summary

Eq. 20 with $\lambda \neq 0$ showed that $S \to 0$ limit was unacceptable and as the answers of Einstein equation two S_{min} and S_{max} limits were predictable. By considering the pressures of electrons and radiation, the minimum of scale factor increased. Therefore, system did not confront with singularity at $S = 0$. The limit of S_{max}, the sign for positive curvature, has been confirmed with Planck 2018 results [14].
As observational asymmetry of particles-antiparticles, an acceptable assumption was to choose isotropic distribution of saturated hydrogen as starting point of the evolutions of the universe. Gravitational contraction starts based on Einstein equation with $\lambda = 0$ and $T_1^1 = P = 0$, then tends to adiabatic evolution with $P \neq 0$. This contraction and increase in temperature continued up to nuclear fusion of hydrogen. After that, due to radiation pressure resulting from cosmic mass, several and consecutive explosions occurred and universe was divided into expansive several parts.
Accelerating expansion of each of these new systems follows Einstein equation with $\lambda > 0$, so that, for observable universe, the effect of the presence of the energy of other systems is considered as constant λ. This can suggest a solution for the problem of cosmological constant. The origin of dark energy and cosmological constant [9] may not be the vacuum energy [10], but it can be the constant energy remained from other skies. As the most suitable candidate for dark energy consists of neutrinos, relativistic particles justify positive acceleration of universe explosion. According to reports, this forms about %75 of universe energy and, especially, extremely energetic neutrinos result from several fusion explosions, so in the observable universe their sources have not yet been identified [32].
In nonsingular model of cosmos, problem of flatness does not exist. Moreover, cosmic microwave does not encounter to problem of horizon because the whole explosions have not

Table 1. Answer to the cosmological questions in the nonsingular model of cosmos.

Row	Issue	Non-singular model of universe
1	The nature of dark matter	Black holes and dense masses of skies
2	The origin of dark matter	Previous explosions
3	The nature of dark energy	Scattered neutrinos in universe
4	Cosmological constant	The energy out of observable system
5	The origin of cosmic microwave	Cooled radiation of explosions
6	Universe curvature	Positive curvature
7	Solving of horizon problem	The presence of radiation before the last explosion
8	The origin of structures formation	Gravitational concentration around previous black holes
9	The cause for the abundance of light elements	Initial hydrogen
10	Evolution in t=0	The explosion resulting from cosmological hydrogen fusion
11	The cause for expansion of the observable universe	The radiation pressure in cosmic fusion explosion
12	The cause for positive acceleration of the expansion	The energy of cosmic explosions neutrinos

happened at the same time. In fact, the radiation has kept the temperature balance in the observable universe which has been created in previous explosions and has had adequate time for connection in the horizon of observable universe. Therefore, nonsingular model of cosmos does not require inflation assumption.

Observable matter is a small percentage of the existent matter in cosmos. The rest is the dark matter identified by its gravitational effects in galactic clusters [33] and galaxies rotation curve [34]. Initial black holes and residual ones of other skies make dark matter and because of this, they are many times bigger than observable matter in our sky. the presence of black holes in the center of galaxies indicates that gravitational instability around them together with angular momentum of masses resulting from the latest cosmic explosion are the origin of these structures. Hereupon, such black holes should exist before the formation of galaxies and birth of stars, which in turn can be the evidence for the presence of other skies. Skies with their dense masses (dark matter), neutrinos (dark energy), and cold homogeneous radiation (cosmic microwave background) have remained.

Table 1 shows the cosmological results of new suggested model. In present work, our concentration was on the initial extraction, lack of singularity, diversity of explosions, and horizon problem elimination. In future works the calculation of amounts of dark energy and dark matter and the formation of structures considering their suggested origin are going to be done.

6. Conclusion

a) The assumption of cosmic singularity in density and temperature can be avoided and it does not need to assume that at the origin of time, the whole material with the mass of larger than $10^{20}M_{\odot}$ had been centralized in dimensions with the Planck length:

$$L_p = \sqrt{\frac{\hbar G}{C^3}} = 1.6\times 10^{-35}\mathrm{m}$$

b) The nature of the initial explosion is not ambiguous and unknown. The expanding universe is the result of nuclear explosions.

c) Phasic cosmic explosions lead cosmic background microwave not to encounter with horizon problem.

d) The dark matter (lost mass) of the cosmos, which includes %90 of its mass, are the dense masses and remained black holes from different parts of the cosmos that have been formed before its visible part.

e) The best candidates for dark energy are neutrinos.

f) The whole changes of the universe include six periods:

Hydrogen condensation and its cohesion

Gravitational contraction and as a result heating and the formation of plasma

Nuclear fusion of Hydrogen and explosions

Cooling during expansion of the cosmos

The formation of galaxies and stars

The stability and equilibrium of stars and formation of planets

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Conflict of interest statement:
The authors declare that they have no conflict of interest.

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