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A Square-Root Approach for Cosmic Temperature Evolution in the Early Formation of Stars in the Young Universe

Johann Michael Köhler[1*]

[1] Techn. Univ. Ilmenau, Institute for Micro- Und Nanotechnologies/Institute for Chemistry and Microreaction Technology, Dept. Phys. Chem. and Microreaction Technology, Ilmenau, Germany

Email Address

michael.koehler@tu-ilmenau.de (J. Michael Köhler)
*Correspondence: michael.koehler@tu-ilmenau.de

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Abstract:

In this paper, a simple approach for general temperature decay function in the early phase of cosmic evolution is studied. New findings on the age of early developed galaxies demand for a re-thinking of the fate of young universe. The square-root scenario is compatible with an early aggregation of masses and an early beginning of the formation of galaxies and stars.

Keywords:

Early Developed Galaxies, Young Universe, Linearly Increasing Energy, Square-Root Scenario, Formation of Galaxies and Stars

1. Introduction

The investigation of early cooling of gas clouds, mass aggregation [1, 2], exotic masses and energy [3, 4], galaxies [5, 6] and star formation [7-12] is a key issue for understanding the spatial self-organization in the universe [13]. Investigation of galaxy groups and colliding galaxies with very high red shift speak for the fact that the evolution of early stars and galaxies proceeded, obviously, faster than expected [14]. The reported data are originating from a region which is in an age of only 2% of the recent age of universe. This age corresponds to a mean energy (or mass) density which is 125 000 times higher than the recent mean mass density in the universe as it is defined by the cosmological standard model.

One reason for the unexpected low age of these galaxies could concern deviations in the estimated temperature development. An early formation of stars and galaxies demands for a comparatively fast decay of cosmic temperature in the earlier phases of cosmic evolution. Therefore, the general temperature decay function of the universe is important for mass aggregation and for the early development of large compact objects.

In the following, a simple approach for general temperature decay function will be discussed. This approach means a faster decay in the early phase of cosmic evolution and slower temperature decay in the later phase. The back-extrapolation of such a slower temperature decrease leads to lower temperatures in the young universe, to an earlier date for the phase of arising cosmic transparency and early beginning of the formation of stars and galaxies.

2. Conventional Points of View for The Estimation of Cosmic Temperature Evolution

The large spectrum of temperatures in the different cosmic objects demands for a reference for any general temperature. For this purpose, the equivalent temperature of cosmic microwave background (CMB) can be used. Its photon energy gives a universal value for the lower limit of cosmic temperature spectrum on large scale distances. Its comparatively high homogeneity and isotropy observed from earth is a strong argument for using this radiation as a reference for cosmic temperature.

A rough function for the recent assumption of temperature development is given by the data of arising transparency in the universe (t_1) which is assumed to be developed about 380 000 years after big bang [15], the related temperature at this time T_1 (about 3000 K) and the recent (t_2) temperature T_2 related to the CMB of 2.7 K. These data result in an approximation for the cosmic temperature evolution by a $t^{(-2/3)}$ – function:

$$T_1 / T_2 = (t_1 / t_2)^u \quad \rightarrow \quad u = \ln \{ (T_1 / T_2) / (t_1 / t_2) \} \qquad (1)$$

$$u \approx \ln (3000/2.7) / \ln (380\,000/13\,700\,000\,000) \approx -0.67 \qquad (2)$$

A simple back-extrapolation of this temperature function results into a temperature of about 16 million Kelvin for one year after big bang, of $1.6 * 10^{12}$ K for one second after big bang and $1.2 * 10^{41}$K for the first Planck time interval (about $5*10^{-44}$s). The last mentioned temperature would be much higher than the Planck temperature of $1.417*10^{32}$ K [16].

An alternative approach comes from the assumption of a constant number of CMB photons in the universe and a decrease in the photon energy by the expansion-induced cosmological redshift. According to this point of view, the wave length of this photons λ_{CMB} is enhanced approximately linearly with the increasing size of the universe [17]. Therefore, a simple linear relationship is given for the temporal function:

$$\lambda_{CMB,1} / \lambda_{CMB,2} = t_1 / t_2 \qquad (3)$$

The equivalent energy E_{CMB} for the CMB photons is given by a linear equation, too:

$$E_{CMB} = h*c / \lambda_{CMB} \qquad (4)$$

From this, a linear relation for the temperature is obtained, if this energy is expressed as thermal energy Eth by application of Boltzmann constant k_B and the Wien law [8]:

$$E_{th} = k_B * T = E_{CMB} \quad à \quad E_{th} = h*c / \lambda_{CMB} \qquad (5)$$

$$T = h*c / (\lambda CMB * kB * X);\ X = 4.96511 \qquad (6)$$

The character of this radiation can be interpreted by looking to development of the total energy of radiation during cosmological expansion: The total CMB energy E_{tot} can be estimated by the product of the photon energy E_{CMB} and the total number of CMB photons N_{CMB} :

$$E_{tot} = N_{CMB} * h*c / \lambda_{CMB} \qquad (7)$$

or

$$E_{tot,1} / E_{tot,2} = \lambda_{CMB,2} / \lambda_{CMB,1} \quad (8)$$

Under the postulate of a nearly homogeneous distribution of the CMB photons in the universe, their total number can be expressed by their density ρ_{CMB} and the volume of the universe V_k:

$$N_{CMB} = \rho_{CMB} * V_k \quad (9)$$

The volume development can be approximated by a cubic function of time:

$$V_{k,1} / V_{k,2} = (t_1 / t_2)^3 \quad (10)$$

The photon density is an inverse function of the cube of time:

$$\rho_{CMB,1} / \rho_{CMB,2} \sim (t_2 / t_1)^3 \quad (11)$$

And the energy density E_{tot}/V_k is decreasing with the exponent -4:

$$E_{tot}/V_k = N_{CMB} * h*c / (\lambda_{CMB} * t^3) \quad \text{à } E_{tot} / V_k \sim t^{-4} \quad (12)$$

This function is in good agreement with the character of the evolution of a black body radiation of linear decreasing temperature.

Both approaches have to postulate sophisticate temperature functions [18-22] including a slower temperature decrease in the first phase, if the Planck temperature is assumed to be the highest possible temperature. One consequence of these approaches is a comparatively late mass aggregation and a late formation of stars and galaxies. This situation seems not to fit perfectly with the observed situation in the young universe and, in particular, with the early formation of galaxies and stars.

3. Postulates for a Uniform Temperature Decay in the Universe

In contrast to the both above mentioned temperature evolution function, slower temperature decay will discussed in the following. For the estimation of temperature evolution, two unconventional postulates are made. The first concerns the constancy of mass (resp. energy) of the universe. In contrast to the recently favoured cosmological models, a universe of linearly increasing mass is postulated [23]. The power of energy increase P_k is assumed to be given by Planck constant h and Planck time t_p:

$$P_K = h * t_p^{-2} \quad (13)$$

It is necessary to remark that this simple postulate is not identical with the old idea of a steady state universe [24, 25] as discussed by Fred Hoyle and coworkers. It assumes to describe the universe as a system with a t^{-2} – function for the evolution of mass/energy density. The product of the assumed mass/energy generation power and the cosmic age t_k (about $4.3*10^{17}$s) leads to an approximated final energy E_k or equivalent mass m_k in a reasonable order of magnitude:

$$E_k = P_k * t_k = 1.06 * 10^{71} \text{ J} = 1.2 * 10^{54} \text{ kg} * c^2 \quad (14)$$

The second postulate concerns the behaviour of photons at high time scales. It is assumed that the whole space is completely filled by a three-dimensional wave mosaic. This “Puzzle-like” structure is formed by a balancing of energy of photons due to energy exchange. The result is a broad band of electromagnetic frequencies. This band is observed, now, in form of the recent CMB. The postulation of a certain energy equilibration at large time scales is not necessarily related to a specific assumption on the origin of the CMB.

The mean wave length of this radiation λ_{CMB} is roughly approximated by the volume of universe V_k and the number of photons N_{CMB} without reconsidering a special cosmic geometry (conventionally approximated by a cube with a side length and by a geometry factor g, Planck length l_p and the number of elementary time steps $z = t_k/t_p$, roughly = $8*10^{60}$):

$$V_k = N_{CMB} * \lambda_{CMB}^3 \quad = g^3 * (z * l_p)^3 \tag{15}$$

$$\lambda_{CMB} = g * (z * l_p) * N_{CMB}^{-1/3} \tag{16}$$

There is a very large spectrum of temperatures in the recent universe. It reaches from the equivalent temperature of the CMB (2.7 K) to billions of Kelvin in the centre of collapsing stars. The equivalent temperature of CMB marks the lower end of this spectrum. But, this temperature is not connected to a single or a group of localized objects, but is present in all parts of the giant space between stars and galaxies. Thus, it can be regarded as a general background temperature.

It can be estimated by the balance between thermal energy and photon energy:

$$T = h * c * k_B^{-1} * \lambda_{CMB}^{-1} * X \tag{17}$$

The CMB wave length can be substituted following eq. (16):

$$T = h * c * k_B^{-1} * X^{-1} * g^{-1} * z^{-1} * l_p^{-1} * N_{CMB}^{1/3} \tag{18}$$

For the initial phase of cosmic evolution (z=1, N_{CMB} = 1, and g= 1) T_1 is obtained:

$$T_1 = h * c * k_B^{-1} / l_p = 1.46 * 10^{32}\ K \tag{19}$$

This value corresponds to the above mentioned Planck temperature.

The expected recent maximal number of CMB photons N_{CMB} (for g=1 and z = $8*10^{60}$) can be estimated by rearranging eq. (16) and inserting a mean wave length of about 1.4 mm (corresponding roughly to the maximum wave length of 1.1 mm of the recent CMB, corresponding to a temperature of 2.7 K):

$$N_{CMB} = [(z * l_p) / \lambda_{CMB}]^3 \approx 1.5 * 10^{87} \tag{20}$$

This would result in to a recent CMB photon density ρ_{CMB} (for g=1) of

$$\rho_{CMB} = N_{CMB} / (z * l_p)^3 \approx 3.7 * 10^8\ m^{-3} \tag{21}$$

The photon energy density E_d can be approximated by the maximum wave length and the photon density of:

$$E_d \approx \rho_{CMB} * h * c / \lambda_{CMB} \approx 6.7 * 10^{-14}\ Jm^{-3} \tag{22}$$

This value is in rough agreement with the estimation of the photon energy density E_{dSB} by the application of the Stefan-Boltzmann law on CMB-related power P:

$$E_{dSB} = 6 * \sigma * T^4 / c \approx 6.25 * 10^{-14}\ Jm^{-3} \tag{23}$$

with

$$\sigma = 2\pi^5 * k_B^4 / (15\ h^3 c^2) \tag{24}$$

This energy density can be compared with the expected energy density $E_{d,\ tot}$ obtained from the total energy which was developed during the cosmic evolution (eq.

(14)). It can be estimated by reconsidering cosmic volume. For a geometry factor g=1 it is obtained

$$E_{d,\,tot} = E_k / V_k = (h * z / t_p) / (z * l_p)^3 = h / (z^2 * l_p^3 * t_p) \approx 2.6 * 10^{-8}\,Jm^{-3} \quad (25)$$

This means that only a small part of the total cosmic energy (about $2.5*10^{-6}\,E_k$) is stored in form of the CMB.

4. Approach for Evolution of CMB-Related Temperature

The number N_{CMB} is increasing during the evolution of universe if the above formulated postulates are valid. This increase is due to the above postulated closed "wave mosaic" on the one hand and the decreasing mean frequency in cause of the cosmic space expansion (cosmological redshift) on the other hand. For simplification, it is assumed that there is an approximately constant proportional loss of CBM photon density by a factor y. This leads to following change of N_{CMB}:

$$dN_{CMB} / dz \approx y * P_k * t_p * z * l_p * h^{-1} * c^{-1} * N_{CMB}^{-1/3} \quad (26)$$

$$\int N_{CMB}^{1/3} dN_{CMB} \approx \int (y * P_k * t_p * z * l_p * h^{-1} * c^{-1}) dz \quad (27)$$

$$3/4 * N_{CMB}^{4/3} \approx 0.5 * y * P_k * t_p * z^2 * l_p * h^{-1} * c^{-1} \quad (28)$$

$$N_{CMB} \approx (2/3 * y * P_k * t_p * z^2 * l_p * h^{-1} * c^{-1})^{3/4} \quad (29)$$

$$N_{CMB}^{1/3} \approx (2/3 * y * P_k * t_p * z^2 * l_p * h^{-1} * c^{-1})^{1/4} \quad (30)$$

The evolution of CMB-related temperature can be estimated by substitution of wave length (eq. (16), for g=1) in Wien law [26]:

$$T = h * c * k_B^{-1} * X^{-1} / (z * l_p * N_{CMB}^{-1/3}) \quad (31)$$

$$T = h * k_B^{-1} * X^{-1} * N_{CMB}^{1/3} / (z * t_p) \quad (32)$$

Substitution with eq. (30) leads to:

$$T \approx h * k_B^{-1} * X^{-1} * (2/3 * y * P_k * t_p * z^2 * l_p * h^{-1} * c^{-1})^{1/4} / (z * t_p) \quad (33)$$

$$T \approx h * k_B^{-1} * X^{-1} * (2/3 * y * P_k * z^2 * h^{-1})^{1/4} / (z * t_p^{1/2}) \quad (34)$$

Or condensed by

$$Y \approx h * k_B^{-1} * X^{-1} * (2/3 * y * P_k * h^{-1})^{1/4} * t_p^{-1/2} \quad (35)$$

to

$$T = Y * z^{(-1/2)} \quad (36)$$

Thus the evolution of temperature is obtained as a square root function of z, what means that it is a square root function of time, too. The factor Y can be empirically determined by the recent equivalent temperature T_{rec} of CMB:

$$Y = T_{rec} * z^{1/2} = 7.6 * 10^{30}\,K \quad (37)$$

and

$$y^{(1/4)} / X = Y / [\, h * k_B^{-1} * (2/3 * P_k * h^{-1})^{1/4} * t_p^{-1/2}] = Y/8.4*10^{32} = 8.8*10^{-3} \quad (38)$$

The CMB-related temperature evolution (with increasing z) can be adapted by following simple approximation:

$$T \approx T_p * z^{(-1/2)} \quad * (1{,}0209)^{-\ln(z)} \quad (39)$$

Recently ($z \approx 8 * 10^{60}$), the CMB equivalent temperature is approximated by this equation as following:

$$T_{rec} \approx 1.4 * 10^{32}\ K / [\sqrt{(8*10^{60})} * 1{,}0209^{140{,}23}] = 2.7\ K \qquad (40)$$

Following this square root function of T with z (scenario 3, -1/2-decay), the temperature of the universe was significant smaller during the most part of the universe history (Figure 1a) than predicted by the scenarios 1 (-2/3-decay) and 2 (linear decay). The scenario 3 would speak for an earlier beginning of star formation, as reported recently [14]. The lower temperature of scenario 3 is related to a slower decay of the temperature. The 3000 K level, which is assumed to be achieved about 380 000 years after big bang following scenario 1, would be achieved already after about 100 000 years in case of scenario 3 (Figure 1b). The back-extrapolation in direction of higher temperature leads to significant differences for the early temperature development. The 10 million Kelvin level would be achieved in scenario1 after about one year. The linear decay would demand for 10 000 years. In scenario 3, this temperature would be achieved after one day, already (Figure 2). Scenario 3 allows an extrapolation back to the very beginning of cosmic evolution. In contrast, the scenarios 1 and 2 require complex mechanism with considerable slower temperature decay in the very early phases of cosmic expansion.

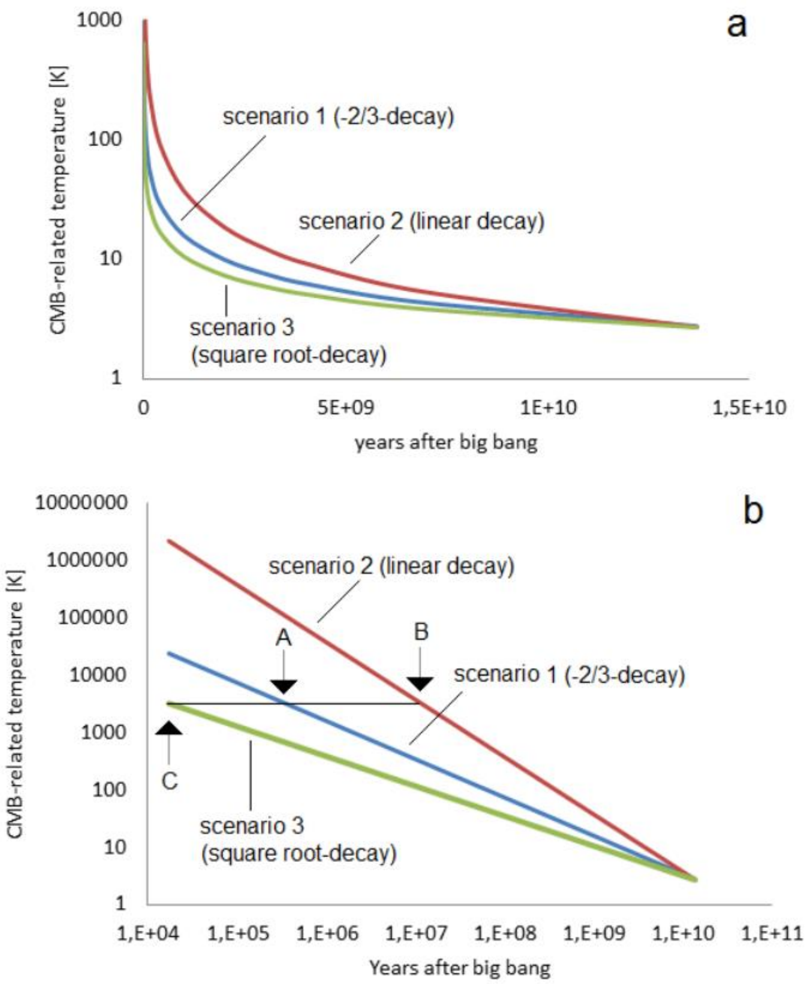

Figure 1. *CMB-related temperature decay in the universe development following three different scenarios: a) semi-logarithmic plot for 13.7 Ga universe history, b) double-logarithmic plot illustrating the different time spans between big bang and achieving the 300-K-level.*

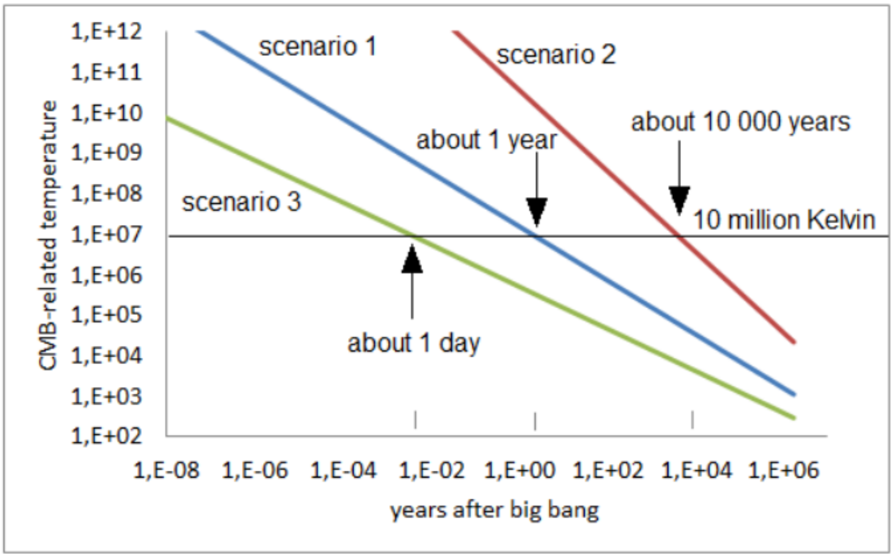

Figure 2. *CMB-related temperature decay in the early phase of cosmic evolution (double logarithmic plot) illustrating the different time spans between big bang and achieving the 10 million-K-level.*

5. Conclusions

The appearance of galaxies and stars in a very early phase of cosmic evolution demands for a re-thinking about the temperature development in the universe. Lower temperatures in the young universe could be caused by the assumption of approximately a square root function in the temperature decay. Such a function can be deviated from the postulation of a universe of linearly increasing energy (resp. equivalent mass), for example.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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