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Aspects on the thermodynamics of early universe

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Abstract. Based on a new physical-geometrical model for a possible evolution of early universe, the resulting thermodynamic aspects and consequences are studied. By considering an initial singularity, similar to BIG BANG, containing the total energy of the universe, the apparition of this energy from chaos is justified by using the uncertainty relation of Heisenberg. In this way, the violation of the energy conservation law - therefore of the first law of Thermodynamics - is justified. Then, by applying the second and the third laws, one shows that Big Bang (more correct name would be Big Flash) is entropy increasing as any natural process. The emerging energy expands as a spherical wave at the speed of light generating space and time. A structuring model of the primary wave is adopted by reason of geometrical simplicity and satisfying the conservation laws. From thermodynamic point of view, an adiabatic transformation leads to an exponent close to the evolution of a mono-atomic gas. The entropy variation confirms by comparison the ordering character of universe structuring.

Keywords: singularity, primordial void, physical void, photon gas, structured evolution.

1. Introduction

The birth and evolution of the universe has always been an object of interest for physicists, philosophers and theologians. Today, the theory accepted by most scientists shows that the universe appeared 13,7 billion years ago from an explosion followed by a continuous expansion that can be observed even today.

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The initial explosion marking the beginning of the universe was called "***Big-Bang***" (though in the vacuum, the sound cannot propagate, so it should be called "***Big-Flash***" more correctly). The Big Bang theory has been embraced by most cosmologists, considering several observations and measurements that support it. One of these observations refers to the continuous expansion of the universe, which is taking place at the speed. Of
The first researcher who made public the discovery of the expanding universe was Hubble in 1929 [3]. This discovery is crucial in modern physics, as according to Newton and later Einstein's theory, a static universe would undergo a continuous contraction due to gravity (which, physically, was not observed). An expanding universe opposes gravitational contraction and, depending on the rate of expansion, the process will either be slowed down to stopping and reversing (i.e. starting of contraction) or will continue indefinitely.
Other remarkable results can be found in the papers of Russian physicist Alexander Friedmann, who had predicted Hubble's discovery of the expanding universe since 1922 [3]. According to his hypotheses, the universe can have 3 possible evolutions (expansion followed by contraction, limited expansion and unlimited expansion). However, Friedmann supported the first kind of evolution, based on the idea of a space bent into itself, similar to the surface of the Earth.
There exist several ways in which the appearance and evolution of the universe can be imagined. One of them considers a beginning of a cycle in a pulsating universe. This avoids the answer to the question: How did the universe arise? It also avoids the problem of space and time appearance. In fact, the problem resumes in the form: how did the first cycle begin, or how did the first Big-Bang take place?
The idea of the pulsating universe was suggested by Einstein in 1930, but it could not be assessed by experimental evidence at the time. However, with the discovery of dark matter and energy in the 21st century, the model of the pulsating universe came back into attention at the present. In a paper written by one of the authors, a possibility for a pulsating universe is proposed within the Newton formula by using a hydro-dynamical model of gravity [1].
In the following, some aspects that appear in the search for models describing the evolution of the early universe will be discussed, based on some new hypotheses stated by the first of the authors.

2. Statements related to the universe formation. Uncertainty relation

As it has been argued previously, even in the sense of a pulsating universe, the arising problem is "how did ***the first Big Bang (Big-Flash)*** take place" and "where the released energy came from". To answer these questions, two points of view will be considered:

a) Theological statement: The world was created from nothing (chaos), the so-called "***creatio ex nihilo***". In this sense, *at the command of God*: "*Let there be light!*", the light appeared as a radiant energy; from that moment on, time began to flow, and space emerged as the light propagated.

b) Physical statement: The Big-Bang took place by the explosion of a "black hole," which contained a huge build-up energy in an extremely small space. One cannot tell where this "black hole" came from. (An alternative hypothesis may, however, considers a process with an infinite number of cycles, in which case it can be argued that it is no longer necessary to speak about a first Big-Bang).

It is noted that there are several aspects on which theological and physical statements are not contradictory:

1) Time and space began with Big-Bang (Big-Flash);
2) The original energy is radiant (in the form of light);
3) The amount of energy that comes into play is enormous but finite;
4) The beginning was a singularity.

Of course, to describe the Big Bang, one uses the concepts we have reached today. The impossibility of appearing any amount of energy "out of nothing", expressed in a general way in the form of the ***law of conservation and transformation of energy***, is an experimentally proven reality. On the other hand, with the advent of *Quantum Physics*, deviations from the law of energy conservation began to be accepted for very short time intervals with subsequent recoveries. An example of this is the description of interactions between elemental particles [8]. The basis for these acceptances is Heisenberg's uncertainty principle which has the expression [8]:

$$\Delta E \cdot \Delta t \geq \frac{\mathrm{h}_P}{4\pi} \tag{1}$$

where $\Delta E, \Delta t$ represent the uncertainties referring to energy and time, and h_P is the Planck's constant (h_P = 6,626·10^{-34} J.s). If one takes into consideration the minimum value, corresponding to "equal" sign, a deviation from law of energy conservation is found, i.e. an amount of ΔE on a maximum time interval Δt.

If we apply this interpretation to Big-Flash, by taking ΔE to be the energy of the universe E_U, we get that Big-Flash is possible if it occurs in a time frame $(\Delta t)_{BF}$ not larger than:

$$(\Delta t)_{BF} = \frac{\mathrm{h}_P}{4\pi E_U} \tag{2}$$

For $E_U = 3{,}468 \cdot 10^{70}$ J, which is an acceptable value according to present information, one finds $(\Delta t)_{BF} = 1{,}525 \cdot 10^{-105}$ s, that is an extremely small time, but not impossible in the creationist vision. In any case, we believe to have yet another argument that *Physics* is not totally contradictory to *Theology*, nor to *creatio ex nihilo*.

On the other hand, creation of energy E_U during the time $(\Delta t)_{BF}$ requires the action of an average power P_{BF} which is given by formula:

$$P_{BF} = \frac{E_U}{(\Delta t)_{BF}} = \frac{4\pi E_U^2}{h_P} \tag{3}$$

By doing the calculations using the above data, one derives for the power of universe creation: $P_{BF} = 2{,}266 \cdot 10^{175}\ \mathrm{W}$.

3. Primordial and physical void; 2nd and 3rd laws of *thermodynamics*

It is hard to give a definition of the void as the absence of something that exists. Theologically, "chaos" (meaning void) signifies that, until the creation of the world, there was nothing but God, specifying that God was not created "of Himself": God is ***uncreated*** while the universe is ***created***. The distinction between "uncreated" and "created" is a fundamental thesis in *Theology*.

From a physical point of view, after Dirac [8], the void represents a zero energy space, yet it can still extract energy, leaving negative energy gaps. Such a void (which we will call ***physical***) emerged ***after*** Big-Flash, that is to say, with respect to a reality, which is the universe. In our considerations, however, we need a void (called ***primordial***), existing "before" Big-Flash.

A ***primordial*** void, in our opinion, could be represented after Big-Flash, by what remains if we ignore everything that occurs at singularity, including space and time. We will assign it zero energy: $E_{Void} = 0$, but without allocating space and time. If, hypothetically, we associate it with a ***space*** of the universe, as well as a ***time*** equal to the age of the universe, then it becomes a ***physical void***, denoted hereinafter simply ***void***.

We will synthesize our conclusions in the form of the following axioms:

Axiom A1:

A1.1. - The total energy of the universe E_U, time and space have a common origin; this is a singularity, which we will call Big-Flash (Big-Bang).

A1.2. - The total energy of the universe E_U is of radiant form and it has formed within a time frame $(\Delta t)_{BF}$ given by the uncertainty relation (2), that is

$$(\Delta t)_{BF} = \frac{h_P}{4\pi E_U} \tag{4}$$

Thus, a deviation from the current law on energy conservation was allowed over the time interval $(\Delta t)_{BF}$, based on the uncertainty relation; this is physically the "source" of the energy of the universe. Therefore, it can be stated that uncertainty is also freedom! We note, however, that during the time frame $(\Delta t)_{BF}$, an average power like that one given by the relation (3) acted:

$$P_{BF} = \frac{4\pi E_U^2}{h_P} \tag{5}$$

A1.3. - The space generated over the time $(\Delta t)_{BF}$ is a sphere of a radius given by the relation:

$$R_{BF} = c \cdot (\Delta t)_{BF} \tag{6}$$

where c is a limiting speed in the universe and represents the speed of expansion with which the boundary of the universe moves. If one takes for c the current speed of light in vacuum ($c \cong 3 \cdot 10^8$ m/s, respectively), then the generated space will have the radius:

$$R_{BF} = 3 \cdot 10^8 \times 1{,}525 \cdot 10^{-105} = 4{,}575 \cdot 10^{-97} \text{ m} \tag{7}$$

A1.4. - It is considered as ***center of universe*** $C(\vec{r}_U)$, any point on the sphere of the universe having the radius $|\vec{r}_U| = R_{BF}$, that is

$$|\vec{r}_U| = c \cdot (\Delta t)_{BF} \tag{8}$$

Axiom A2: The ***primordial void*** is defined ***after*** Big-Flash, by what remains if we ignore everything that occurs at singularity, including space and time. It is assigned zero energy: but it is assigned no time and no space. If, hypothetically, we associate with a space equal to the universe space, as well as a time equal to the age of the universe, we will simply speak about ***void***.

Axiom A3:

A3.1. - At the time t_{BF}, one associates to the universe an absolute temperature T_{BF} equal to the "particle" temperature of the universe:

$$T_{BF} = \frac{E_U}{k_B} \tag{9}$$

where k_B is the Boltzmann's constant, $k_B = 1{,}38046 \cdot 10^{-23}$ J/K.

The value of this temperature obtained by direct calculation will be:

$$T_{BF} = \frac{3{,}468 \cdot 10^{70}}{1{,}38 \cdot 10^{-23}} = 2{,}513 \cdot 10^{93} \text{ K} \tag{10}$$

A3.2. - Throughout the evolution of the universe, until the occurrence of matter from the radiant energy, "particle temperatures" are associated, based on the structuring model described below.

A3.3. - One associates to the void a null temperature $T_{Void} = 0$, as well as a null entropy; according to the third law of *Thermodynamics* one has:

$$S_{Void} = \lim_{T_{Void} \to 0} \frac{E_{Void}}{T_{Void}} = 0 \tag{11}$$

As a result, the entropy variation at Big-Flash is:

$$S_{BF} - S_{Void} = \frac{E_U}{T_{BF}} - 0 = \mathrm{k}_B \tag{12}$$

The entropy rise derived from equation (12) is very small, but it has to be mentioned that it occurred in a very small time interval, that is $(\Delta t)_{BF}$.

Remark: The last equation shows that the formation of the universe is a ***natural*** process whose evolution starts from a certain level of order and, along with the Big-Flash, it reaches in a very short time a lower level of order, showing an entropy rise, according to the 2nd law of *Thermodynamics*. The huge degree of thermodynamic non-equilibrium makes possible to develop some ordered structures during the evolution of the universe. The remaining problem in discussion is to determine how the primordial level of order was achieved, generating the consequent evolution of the universe according to the current laws of *Physics*.

4. Adopted model of early universe

We will define as "early universe" the universe lying in the time interval from Big-Flash up to the appearance of the neutron-based radiant matter, according to a model proposed by the first author [2] and presented below.

Table 1 gives the values for the radius of universe r_o, the associated "particle" temperature and the corresponding time elapsed since the Big-Flash instant, taking into account possible ratios between the total energy of the universe E_U and the energy corresponding to a rest mass of neutrons E_{ne}^0. It can be seen that the temperatures are much higher than the Planck temperature (10^{32} K) while the time scale is much shorter than the Planck time (10^{-43} s). The radius of the universe was calculated on the assumption that its expansion velocity is constant and equal to the speed of light in vacuum, $c = 3 \cdot 10^8$ m/s.

The existence of a constant limit speed of expansion could be linked to the balance of the high pressure forces at those moments and the forces of gravity, which are also very large at the small distances that exist immediately after Big-Flash.

The radius of the universe (that is of the primary sphere) increases in time with the speed of light *c*. According to one of the basic hypotheses of the proposed model, a physical-geometric scheme of the future evolution has to be established. It is assumed that at a certain stage *S* defined by the radius of the primary sphere (denoted by R_S), this one splits into smaller spheres of radii r_S according to the scheme:

$$R_S = n_A K_A^S r_0 \ , \ r_S = K_A r_{S-1}, \ S = 1, 2, 3, \ldots \tag{13}$$

where n_A şi K_A are whole numbers. There will be later established as convenient values $n_A = 3$ and $K_A = 11$. The K_A spheres are identical and have the centers in two orthogonal planes passing through *Oz* axis. One of the two orthogonal planes is represented in Fig. 1 for $K_A = 11$; a free space ratio of 16/27 is found. However, there is not enough room for another identical sphere.

Although other configurations of identical spheres are possible as well, we choose the one of above to analyze the proposed model.

Table 1 – **Radius, temperature and elapsed time of universe since Big-Flash instant**

E_U / E_{ne}^0	10^{76}	10^{78}	10^{80}	10^{82}	10^{85}
r_o [m]	$1,31866 \cdot 10^{-91}$	$1,31866 \cdot 10^{-93}$	$1,31866 \cdot 10^{-95}$	$1,31866 \cdot 10^{-97}$	$1,31866 \cdot 10^{-100}$
T_o [K]	$7,27977 \cdot 10^{88}$	$7,27977 \cdot 10^{90}$	$7,27977 \cdot 10^{92}$	$7,27977 \cdot 10^{94}$	$7,27977 \cdot 10^{97}$
t_o [s]	$4,39553 \cdot 10^{-100}$	$4,39553 \cdot 10^{-102}$	$4,39553 \cdot 10^{-104}$	$4,39553 \cdot 10^{-106}$	$4,39553 \cdot 10^{-109}$

We will associate to the universe the physical-geometric scheme described below:

● During the first phase (*S*=1), the radius of the universe's sphere increases to the value $R_1 = n_A K_A r_0$. Then, while in the center we have a sphere of radius $r_1 = K_A r_0$, the energy of the universe splits into K_A equal parts, to which the temperatures $T_1 = T_0 / K_A$ will be associated. By conveniently selecting $n_A = 3$, the K_A parts can be considered as identical spheres of radius $r_1 = K_A r_0$, like the central sphere. In this way, the configuration of Fig. 1 is obtained. The sphere of radius R_1 keeps expanding with the speed of light *c*.

● In the next phase (*S*=2), the sphere of radius $R_1 = n_A K_A r_0$ where $n_A = 3$ already divided according to the model of the previous phase, keeps expanding until its radius gets the value $R_2 = n_A K_A R_1 = (n_A K_A)^2 r_0$. The schematized process of phase 1 is repeated, and a sphere of radius $r_2 = K_A r_1 = K_A{}^2 r_0$ is formed at the center of each previous sphere; a further uniform distribution of the energies upon K_A parts occurs, obtaining equal energy values $E_U / K_A{}^2$ and associated temperatures $T_2 = T_0 / K_A{}^2$.

● The structuring of the universe continues similarly up to a final phase corresponding to neutrons formation [2].

The diagram in Fig.1 showing an initial sphere of a radius increasing with the speed of light which splits, is called the ***associated Physical-Geometric Scheme*** **(SFGA)**, and it describes a possible evolution of the early universe.
Although the inner regions may not all be of spherical shape (as seen in the fixed coordinate system), this model presents some essential elements, consistent with a physical evolution:

a) Extending of the front with the limit speed *c* ;

b) The same energies and radii corresponding to spherical regions that develop;

c) Conservation of energy, momentum and spin can be satisfied by choosing suitable values for the whole number K_A.

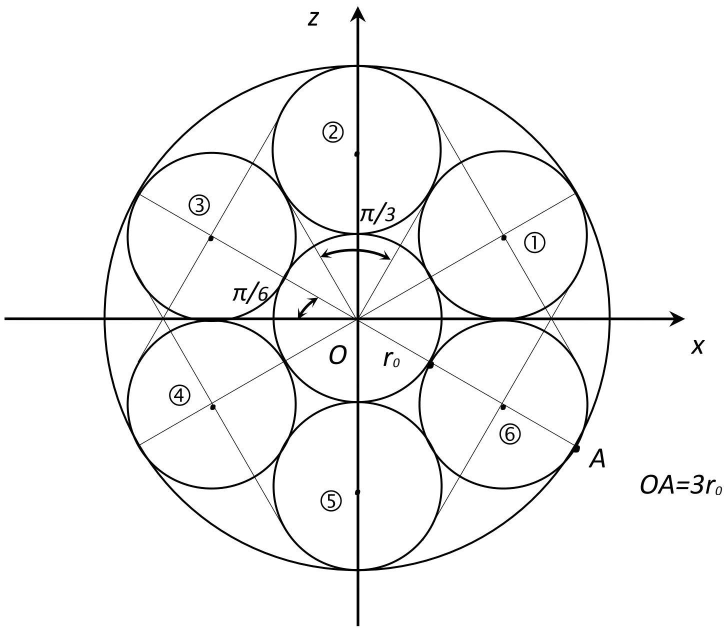

Fig. 1. Physical-geometric scheme for the structuring of early universe.

5. Thermodynamics of evolution of early universe after big-flash

Due to the expansion of the universe, its average temperature will decrease over time. It will be considered that the evolution of the universe takes place according to the ***associated Physical-Geometric Scheme*** **(SFGA)** presented above. Therefore, we will watch the instants when structuring occurs, and the associated inner spheres will be assigned with particle temperatures corresponding to their energies. In this way, the ***temperature associated to the universe is imposed by the structuring process***.

We will look in the next for a possible link to the known thermodynamic processes, taking into account the expansion of the universe. By considering the following acceptable values today:

- the total energy of the universe $E_U = 3{,}468 \cdot 10^{70}$ J,
- the neutron rest mass: $m_{ne}^0 = 1{,}6747 \cdot 10^{-27}$ kg corresponding to a rest energy

$$E_{ne}^0 = m_{ne}^0 \cdot c^2 = 1{,}507 \cdot 10^{-10} \text{ J},$$

a number of S = 77 structuring stages of early universe is found [2]. The occurrence of the matter is considered as the effect of a "resonance", i.e. ***it occurs when the neutron radius becomes very close to the wavelength of the attached photon***. At the same time, the particle temperature of the neutron: $T_{ne}^0 = 1{,}092 \cdot 10^{13}$ K is reached.

We will notice that through the boundary of the universe does not come in and does not come out any form of energy, the frontier moving in vacuum at the limit speed, so that the total energy of the universe remains constant. Consequently, the transformation of "***photon gas***" which fills the sphere of the universe will be considered ***adiabatic***. Considering the collisions of the photons making up the gas to be elastic and with no friction, it follows that there are sources of entropy related only to the heat transfer between the temperatures before and after restructuring (see relation (17) below). We remark also that the main force existing in early universe - gravity, cannot be considered as generating entropy, being an ordering force; among other things, gravity is responsible for the restructuring process itself.

The decreasing temperature in the universe will be considered as the result of a process of rearrangement of the photon gas at restructuring, in which the number of photons in the gas gets higher, while the energy of each photon gets lower as its wavelength increases, along with the expanding volume of the universe.

In this sense, ***in the structuring evolution***, if (1) it is an initial state and (2) the state in which the radius of the universe has increased three times, and the temperature according to SFGA is $T_2 = T_1 / K_A$, the following relations can be written:

$$E_{U2} = E_{U1} = E_U,\ R_2 = 3R_1,\ T_2 = T_1 / K_A \tag{14}$$

By cconsidering an adiabatic transformation of exponent α and observing that the volumes are proportional to the cube of the radii, we can write the in the case of the restructuring as follows [2]:

$$T_2 (3R_1)^{3(\alpha-1)} = T_1 {R_1}^{3(\alpha-1)},\ T_2 = T_1 / K_A,\ \alpha = 1 + \frac{\ln K_A}{3 \ln 3} \tag{15}$$

For K_A = 11, one yields α = 1,7276. Comparing to an ideal gas, it is observed that the photon gas, which evolves according to the structuring model already presented, behaves very closely to a mono-atomic gas whose adiabatic exponent is k = 5/3 = 1,6667.

Remark: Of course, the exponent α depends on the variation of specific entropy [4]; although the correction with the specific entropy variation is very small due to the very high temperatures, we considered for simplicity a constant value, which is an average value over the temperature range before and after the transformations.
Regarding the ***entropy*** of the early universe as a whole S_E, ***unstructured***, one considers the universe to evolve as in the case of the adiabatic expansion of a photon gas (as there is no heat exchange through the boundary which extends with the speed of light). As such, between temperatures and volumes there will be a relation of form (15), that is:

$$TR^{3(\alpha-1)} = \text{const.} \tag{16}$$

We have considered the exponent to be the same as in the case of structuring, so that the variation of entropy between two successive states (1) and (2) will be of form:

$$S_{E1} - S_{E2} \sim E_U \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \sim E_U \left[R_2^{3(\alpha-1)} - R_1^{3(\alpha-1)} \right] \tag{17}$$

By expressing the entropy variation with respect to the increase of the radius of the universe in the two cases (universe structured according to SFGA and unstructured universe), it follows that:

$$(S_{E2})_{str} - S_{E1} \sim E_U R_1^{3(\alpha-1)} \left[K_A^{3(\alpha-1)} - 1 \right] > 0 \qquad \text{(structured universe)} \tag{18}$$

$$(S_{E2})_{nestr} - S_{E1} \sim E_U R_1^{3(\alpha-1)} \left[(3K_A)^{3(\alpha-1)} - 1 \right] > 0 \qquad \text{(unstructured universe)} \tag{19}$$

It can be seen from the above equations that in the case of the structured universe, the entropy rise is lower than in the unstructured case, which is in agreement with the fact that structuring is equivalent to a negative source of entropy.

6. Conclusions

The proposed model of universe evolution allows to obtain today acceptable values of physical quantities such as the background temperature of the universe (microwave radiation) and the radius of the universe. Also, the recently published values of Hubble's constant (which characterize the speed of universe expansion) are consistent with the notion of "center of universe" and the linear distribution of departure velocity of cosmic systems from each other, covering the range (0; *c*). Considering adiabatic transformation in agreement with the conditions at the universe frontier, one obtains an exponent close to the evolution of a mono-atomic gas. On the other hand the entropy variation confirms that the structuring is ordering.

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