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Initial Conditions of the Big Bang Process

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ABSTRACT

Conceptions of the Big Bang and their foundation in theories connect the origin of the universe to the decay of a 'false' vacuum along with the emergence of space and time. They are based on the assumption of initial conditions that lack physical justification, in particular, the assumption that space and time emerged from nothing, with the simultaneous birth of matter and energy intertwined with the expansion of space over time.

The presented work derives a thermodynamic equation for a non-singular origin of expansion, the solution of which points to the possibility of regular physical conditions existing prior to the so-called 'Big Bang'. This relies on the premise of a defined numerical density of primary particles in relation to the volume determined by the particle's wavelength relative to the volume defined by the Planck length, a dimension given solely by a combination of fundamental constants. This can be characterized as a description of false vacuum decay. The equation also specifies the conditions for the existence of a true vacuum, primarily a zero ambient temperature of this vacuum, as well as the 'freezing' temperature of its particles.

The solution to the equation determines the mass of the resulting universe and the initial ambient temperature of the false vacuum from the known mass of the Higgs boson. The possibility of the evolution of the false vacuum state prior to the Big Bang is also discussed on the basis of particles other than the Higgs boson.

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Definition of Physical Spaces

Current concepts of the macro-world, whose state is described by gravitational theories according to I. Newton and more generally formulated by A. Einstein's General Theory of Relativity, can be explained as two faces of reality. The first face, the gravitational one, is fundamentally based on the scale of the gravitational radius

$$R_g = \frac{Gm_0}{c^2} \qquad (1)$$

determined by the gravitational constant G, the rest mass m_0 of a physical object, and the speed of light c. The second face of reality is determined by the Compton wavelength λ_c and pertains to the world of quantum mechanics. Here we use the notation

$$R_q = \frac{h}{m_0 c} \qquad (2)$$

where h is the Planck constant. While the first face of reality does not include the Planck constant in its definition, the second face does not contain the gravitational constant.

Dimensional analysis allows us to arrive at an expression for a third face of physical reality, which we shall designate as superquantum, using the formula

$$R_{sq} = \frac{h^2}{Gm_0^3} \qquad (3)$$

It is evident that the third face of reality is expressed without the presence of the speed of light c. The universal constant common to both the gravitational macro-world and the quantum micro-world is evidently the Planck length [1].

$$l_P = \sqrt{\frac{Gh}{c^3}} \qquad (4)$$

Multiplicative relationships between these quantities are also represented in physical reality. The product

$$R_g R_q = \frac{Gh}{c^3} = l_P^2 \qquad (5)$$

defines the Planck area, whereas the product

$$R_g R_{sq} = \frac{h^2}{m_0^2 c^2} = R_q^2 \qquad (6)$$

defines the Compton area. For further consideration, it will be suitable to use the product

$$R_g R_q R_{sq} = \frac{h^3}{m_0^3 c^3} \qquad (7)$$

the obvious nature of which is the Compton volume. All these quantities represent certain invariants in the real world, i.e., quantities whose values do not depend on a change in the object's position. For the sake of completeness in describing the faces of physical space, it is necessary to include the product

$$R_q R_{sq} = \frac{h^3}{G m_0^4 c} \qquad (8)$$

in which all fundamental constants appear, and which can be termed the superquantum area.

De Broglie Wavelength
The quantities determined by equations (1) through (8) are constants for a given particle rest mass *m*_0. For a particle moving at a velocity v, it is characterized by the de Broglie wavelength [2].

$$\lambda_B = \frac{h}{mv}$$

when $v \ll c$. For velocities comparable to the speed of light, the exact expression must be applied

$$\lambda_B = \frac{h}{mv} = \frac{h}{\frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}v}$$

valid in the range $0<v<c$. Then $\infty>\lambda_B>0$.

Definition of Maximum Particle Number Density
If we know the numerical density of particles in a bounded space, the total mass of the universe can be determined

$$m_U = N_B m_{0H}$$

where $N_B = \frac{\lambda_B^3}{l_P^3}$ and m_{0H} is the mass of, for example, the Higgs boson. The maximum particle number density is expressed by the number of cells of Planck volume contained within a volume determined by the de Broglie wavelength of these particles.

Derivation of the Thermodynamic Equation for the Origin of the Big Bang
From the temperature equation with three degrees of freedom

$$T = \frac{2m_0}{3k}\left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}-1\right)c^2, \text{ we obtain } \sqrt{1-\frac{v^2}{c^2}} = \frac{\frac{2m_0c^2}{3k}}{T+\frac{2m_0c^2}{3k}},$$

where k is the Boltzmann constant. Substituting into

$\lambda_B^3 = \frac{h^3}{m_0^3 v^3}\left(1-\frac{v^2}{c^2}\right)\sqrt{1-\frac{v^2}{c^2}}$ and with a defined number of particles

$$N_B = \frac{\lambda_B^3}{l_P^3}, \text{ we obtain } \frac{h^3}{m^2v^3 l_P^3}\cdot\frac{\frac{2mc^2}{3k}}{T+\frac{2mc^2}{3k}}\cdot\left(\frac{\frac{2mc^2}{3k}}{T+\frac{2mc^2}{3k}}\right)^2 = m_U$$

Note: For the sake of simplifying the notation, the rest mass designation m_0 of the particle is replaced by m.

After simple algebraic manipulations, we obtain

$$T^3 + \frac{2}{k}mc^2T^2 + \frac{4}{3}\frac{1}{k^2}m^2c^4T + \frac{8}{27}\frac{1}{k^3}m^3c^6\left(1 - m^2v^3\frac{l_P^3}{h^3}m_U\right) = 0 \qquad (9)$$

the thermodynamic equation for the origin of the Big Bang. The equation determines the temperature of a system of particles of mass m at their mean velocity v, which together constitute the total mass of the system.

Solution of the Equation for the True Vakuum
If we set $v=0$ in equation (9), the constant term of the equation will contain a combination of fundamental constants with the particle mass as in the other terms of the equation, taking the form

$$T^3 + \frac{2}{k}mc^2T^2 + \frac{4}{3}\frac{1}{k^2}m^2c^4T + \frac{8}{27}\frac{1}{k^3}m^3c^6 = 0 \qquad (12)$$

By substitution $A = \frac{mc^2}{k}$, we transform the equation into the form

$$T^3 + 2AT^2 + \frac{4}{3}A^2T + \frac{8}{27}A^3 = 0 \qquad (13)$$

The solution of equation (13) for the reduced form yields a triple root $T_{R1,2,3}=0$, whereas the solution of the original unreduced equation has a triple root [3].

$$T_{1,2,3} = T_{R1,2,3} - \frac{2}{3}A, \text{ hence } T_{1,2,3} = -\frac{2mc^2}{3k} \qquad (14)$$

Substituting specific values into equality (14), for the mass of the Higgs boson, the 'freezing' temperature is $-9.678878 \cdot 10^{14}$ K.

This result can be interpreted as the existence of a zero absolute temperature of the true vacuum, within which frozen arbitrary particles are available whose negative temperature is given by the specified expression.

Solution of the Equation for the False Vakuum
The solution for the false vacuum consists in satisfying the condition that the constant term in equation (9) be equal to zero, that is

$$1 - m^2v^3\frac{l_P^3}{h^3}m_U = 0 \qquad (10)$$

Then the temperature-dependent part of the equation with T can be rewritten as

$$T\left(T^2 + T_0T + \frac{1}{3}T_0^2\right) = 0 \qquad (11)$$

where $T_0 = \frac{2}{k}mc^2$.

Equation (11) has three roots: one real root $T_1=0$ and two complex, complex-conjugate roots $T_2=T_0\left(-1+\frac{1}{\sqrt{3}}i\right)$ and $T_3=T_0\left(-1-\frac{1}{\sqrt{3}}i\right)$.

The temperature $T_1=0$ is characteristic of a true vacuum. For this temperature, the temperature component of equation (9) is zero. For the constant term of the same equation to be zero, it is necessary to determine the particle mass m, its mean velocity v in a medium of free particles, and the resulting total mass of the medium, or the mass of the future universe m_U. Such an environment characterizes a false vacuum represented by free excited particles moving at a mean velocity v.

Let us define $m=m_H$ and velocity v=1" $m \cdot s^{-1}$. For this velocity and the mass of the Higgs boson, equation (10) yields

$$m_U = \frac{h^3}{l_P^3}\cdot\frac{1}{m_H^2v^3} = 8{,}8028462 \cdot 10^{52} \text{ kg.}$$

This mass corresponds to a Schwarzschild radius

$R_S = \frac{2Gm_U}{c^2} = 1{,}307296 \cdot 10^{26}$ m, i.e., $13{,}828474 \cdot 10^9$ light-years.

For the given Higgs boson mass and mean velocity, the temperature of this 'Higgs gas' is $5.3 \cdot 10^{-3}$ K.
Similarly, both values determine the volume bounded by the de Broglie wavelength

$$\lambda_{BH}{}^3 = \left(\frac{h}{m_Hv}\right)^3 = 2.97223587 \cdot 10^{-9} \text{ m}^3.$$

Then the density of this 'Higgs gas' is given by the ratio $8.8028462 \cdot 10^{52}/2.97223587 \cdot 10^{-9} = 2.961691564 \cdot 10^{61}$ $kg \cdot m^{-3}$.

From equation (10), for velocity v=c, the equivalent mass of a quantum of electromagnetic radiation, a photon, can be determined as the second limiting case for the same mass of the universe, m=m_{ph}. Thus

$$m_{ph} = \sqrt{\frac{h^3}{l_P^3} \cdot \frac{1}{m_U c^3}} = 4{,}2947876 \cdot 10^{-38} \text{ kg}.$$

Order of magnitude-wise, this mass value corresponds to the energy of photons with a characteristic temperature of approximately 280 K.

Various scenarios for the origin of the Big Bang follow from the above. These scenarios do not require infinite temperature and infinite density. The first scenario assumes the decay of a cold 'Higgs gas' with a decay time into particles of baryonic matter, dark matter particles, and dark energy particles on the time scale of the boson half-life of 10^{-21}s , simultaneously with the expansion of space. The second scenario assumes the existence of a dense photon gas, which itself lacks the prerequisites for the decay into the aforementioned trio of particles. In the third scenario, both previous scenarios are combined, which, through the combination of spin-0 Higgs bosons and spin-1 photons, provides a better explanation for the later stages of evolution following the Big Bang.

In paper an equation is presented according to which the sum of masses in the three-particle creation of dark energy, dark matter, and baryonic matter equals zero [4]. For this to hold, under the assumption that the dark energy particle with a negative value (antigravitational effect) remains at the center of mass of the creation, the dark matter and baryonic matter particles must acquire kinetic energies equivalent to the mass difference between dark energy and the sum of the masses of dark matter and baryonic matter particles.

The calculation performed in the paper determines the ratios v_{DM}/c=0.798403 for m_{DM} and v_{BM}/c=0.980535 for m_{BM}. These masses and velocities can determine local density and temperature conditions of the components of the universe on a local scale.

From equation (10), we determine

$m_{LBM} = \frac{h^3}{l_P^3} \frac{1}{m_{BM}^2 v_{BM}^3} = 1{,}028023 \cdot 10^{32}$ kg for a locally small bang

accompanied by the creation of baryonic matter, dark matter, and dark energy particles. The assumed creation of these particles proceeds with an equal representation of the number of particles of each kind. Here, for a particle mass $m_{BM} = 1.67492750056 \cdot 10^{-27}$ kg represented by the neutron mass, the above mass contains a total baryon number of

$\frac{1{,}028023 \cdot 10^{32}}{1{,}67492750056 \cdot 10^{-27}}$=6,139382152$\cdot 10^{58}$. With the same number of dark matter particles, the total mass of dark matter will be 6,139382152$\cdot 10^{58} \cdot$1,03763661$\cdot 10^{-26}$ = 6,370447684$\cdot 10^{32}$ kg. The total positive mass of the local small bang object is therefore the sum of the aforementioned masses, namely 7,398749684$\cdot 10^{32}$ kg.

The total negative mass of dark energy associated with the creation, determined by the previous procedure at a value of −13297.5 MeV per particle, has a magnitude of -1,45533495$\cdot 10^{33}$ kg. This negative mass with an antigravitational effect manifests as an inflationary effect of spatial expansion within the local small bang. However, taken together, these local events lead to the effect of a global Big Bang and global inflation. At the same time, the sum of the masses of dark energy particles, dark matter particles, and baryon matter particles in the black hole of their kinetic energies is equal to zero.

Conclusion

Current concepts associate the initial phase of the origin and evolution of the universe, as defined by the initial conditions of the Big Bang, with a transition from infinite density and unbounded temperature during the process of inflation to the emergence of an expanding space filled with baryonic matter, dark matter, and dark energy. The considerations presented here, supported by fundamental relations from gravitational physics and quantum mechanics, allow us to specify initial conditions that are constrained to a temperature near absolute zero and an ambient density several orders of magnitude lower than the limiting Planck density, or rather an infinite density.

The subsequent decay of this medium, composed of a mixture of scalar Higgs field particles and electromagnetic field quanta, into the three aforementioned components of the currently observed universe is already accompanied by a high temperature determined by the motion of dark matter particles and baryons. In the following phase, baryons form objects orders of magnitude hundreds of times more massive than the Sun through the combined action of the strong interaction, electromagnetic interaction, and gravitational interaction. In this stage of evolution, the dark matter particles, which have a high temperature and are subject solely to the gravitational interaction, leave their place of origin and, aided by the antigravitational effect of dark energy particles, establish an initially uniformly dense environment containing localized high-density regions formed by baryons, the seeds of the first very massive stars.

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