

The basic blocks of the universe matter: Boltzmann fundamental particle and energy quanta of dark matter and dark energy

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ABSTRACT

Recent astronomical NASA observations indicates that visible matter contributes only to about 4% of the universe total energy density, meanwhile, dark matter and dark energy contributes to 26% and 70% of the universe total energy, respectively, with an average density close to 10^{-26} kg/m³. This paper proposes an equation of state of dark energy and dark matter as one unified entity. This equation is derived based on the ideal gas equation, Boltzmann constant, Einstein energy-mass principle and based on the assumption that dark energy and dark matter behave as a perfect fluid. This analysis presents what could be the most fundamental particle and quanta of dark matter and dark energy. Considering NASA's Cosmic Microwave Background Explorer (CMB) which estimated that the sky has an average temperature close to 2.7251 Kelvin, then the equivalent mass and energy of the proposed fundamental particle is determined. It is found that this candidate particle has an equivalent mass of 4.2141×10^{-40} Kg which is equivalent to 3.7674×10^{-23} J. Surprisingly, this value has the same order of Boltzmann constant $KB = 1.38 \times 10^{-23}$ J/K. This candidate particle could be the most fundamental and lightest particle in Nature and serves as the basic block of matter (quarks and gluons). Moreover, assuming a uniform space dark energy/dark matter density, then the critical temperature at which the dark matter has a unity entity per volume is determined as 34.983×10^{12} K. Analytically, it proposes that at this trillion temperature scale, the dark matter particles unified into a new quark-hydron particle. Finally,

tentative experimental verification can be conducted using the Relativistic Heavy Ion Collider (RHIC).

Keywords: Dark Energy; Dark Matter; Equation of State; Boltzmann Constant; Boltzmann Particles; Einstein's Cosmological Constant

1. INTRODUCTION

Recent astronomical observations by the Supernova Cosmology Project, the High-z Supernova Search Team and cosmic microwave background (CMB) have provided strong evidence that our universe is not only expanding, but also expanding at an accelerating rate [1-8]. It was only in 1998 when dark energy proposed for the first time, after two groups of astronomers made a survey of exploding stars, or supernovas Ia, in a number of distant galaxies [1,3]. These researchers found that the supernovas were dimmer than they should have been, and that meant they were farther away than they should have been. The only way for that to happen, the astronomers realized, was if the expansion of the universe had sped up at some time in the past, as well as accounting for a significant portion of a missing component in the universe [9,10]. The only explanation is that there is a kind of force that has a strong negative pressure and acting outward in opposition to gravitational force at large scales which was proposed for the first time by Einstein in his General Relativity and given the name the cosmological constant Lambda [2]. This force is given the name Dark Energy, since it is transparent and cannot be observed or detected directly. The fourth law of thermodynamics is proposed by the author to account for the dark energy [11].

These cosmological observations strongly suggest that the universe is dominated by a smoothly homogenous

distributed dark energy component [12-20]. The quantity and composition of matter and energy in the universe is a fundamental and important issue in cosmology and physics. Based on the Lambda-Cold Dark Matter Model (Lambda-CDM 2006), dark energy contributes about 70% of the critical density and has a negative pressure. The cold dark matter contributes 25%, Hydrogen, Helium and stars contributes 5% and, finally the radiation contributes 5×10^{-5} . The measurements of the Wilkinson Microwave Anisotropy Probe (WMAP) satellite indicate the universe geometry is very close to flat [21].

Using the Doppler Shift phenomena, scientists can learn much about the motions of galaxies. They know that galaxies rotate because, when viewed edge-on, the light from one side of the galaxy is blue shifted and the light from the other side is red shifted. One side is moving toward the Earth, the other is moving away. They can also determine the speed at which the galaxy is rotating from how far the light is shifted. Knowing how fast the galaxy is rotating, they can then figure out the mass of the galaxy mathematically. According to Newton's laws, the rotation speed satisfies $v = \sqrt{GM/r}$, where M is the mass within radius r , and G is the Universal Gravitation constant. But as scientists look closer at the speeds of galactic rotation, they find something strange. The individual stars in a galaxy should act like the planets in our solar system—the farther away from the center, the slower they should move. But the Doppler Shift reveals that the stars in many galaxies do not slow down at farther distances. On the contrary, the stars move at flat speeds (see **Figures 1** and **2**) that should rip the galaxy apart because there is not enough measured mass to supply the gravity needed to hold the galaxy together. These high rotational speeds suggest that the galaxy contains more mass than was calculated. Scientists theorize that, if the galaxy was surrounded by a halo of unseen matter, the galaxy could remain stable at such high rotational speeds.

Much of the evidence for dark matter comes from the study of the motions of galaxies. Many of these appear to be fairly uniform, by the virial theorem the total kinetic energy should be half the total gravitational binding energy of the galaxies. Experimentally, however, the total kinetic energy is found to be much greater: in particular, assuming the gravitational mass is due to only the visible matter of the galaxy, stars far from the center of galaxies have much higher velocities than predicted by the virial theorem.

Galactic rotation curves, which illustrate the velocity of rotation versus the distance from the galactic center, cannot be explained by only the visible matter. Assuming that the visible material makes up only a small part of the cluster is the most straightforward way of accounting for

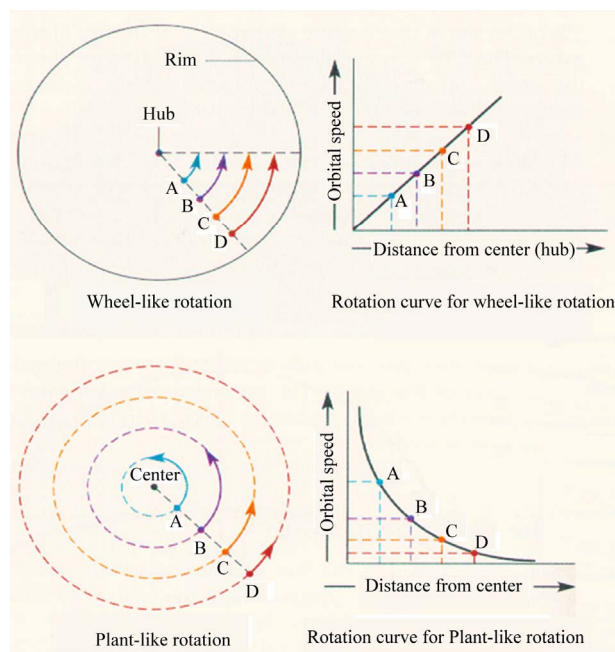


Figure 1. Rotation following Kepler's 3rd law is shown above as planet-like or differential rotation. Notice that the orbital speeds falls off as you go to greater radii within the Galaxy. This is called a Keplerian rotation curve.

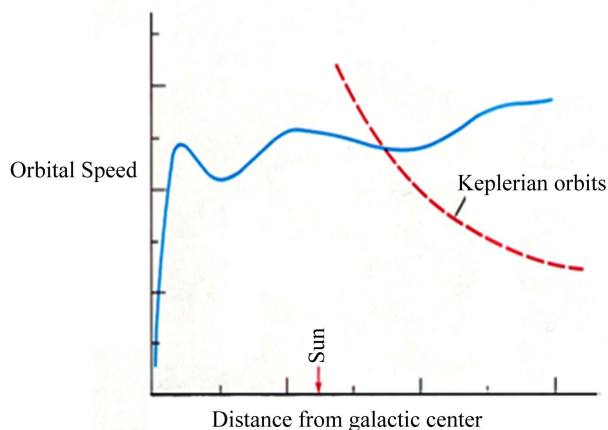


Figure 2. The observed rotation curve for the our galaxy Milky Way. To determine the rotation curve of the Galaxy, stars are not used due to interstellar extinction. Instead, 21-cm maps of neutral hydrogen are used. When this is done, one finds that the rotation curve of the Galaxy stays flat out to large distances, instead of falling off as in the figure above. This means that the mass of the Galaxy increases with increasing distance from the center.

this. Galaxies show signs of being composed largely of a roughly spherically symmetric, centrally concentrated halo of dark matter with the visible matter concentrated in a disc at the center.

Accordingly, dark matter can be defined as the matter of unknown composition that does not emit or reflect

enough electromagnetic radiation to be observed directly, but its presence can be inferred from gravitational effects on visible matter like galaxies and stars [22-25]. According to present observations of structures larger than galaxy-sized as well as Big Bang cosmology, dark matter accounts for the vast majority of mass in the observable universe (22%). The observed phenomena consistent with dark matter observations include the rotational speeds of galaxies, orbital velocities of galaxies in clusters, gravitational lensing of background objects by galaxy clusters, (**Figure 3**) and the temperature distribution of hot gas in galaxies and clusters of galaxies.

This paper introduces a proposed equation of state of dark energy and dark matter as one unified entity (Section 2). Such an equation is derived based on the assumption that dark energy and dark matter behave as a perfect fluid and using the ideal gas equation, Boltzmann constant and the energy-mass principle of Einstein. Moreover, this paper suggests what could be the most fundamental particle and quanta of dark matter and dark energy and its characteristics (Section 3). Moreover, based on NASA's Cosmic Microwave Background Explorer (CMB) which estimated that the sky has an average temperature close to 2.7251 Kelvin, then the equivalent mass and energy of fundamental particle of the dark matter/dark energy is determined with an equivalent mass of 4.2141×10^{-40} Kg which is equivalent to 3.7674×10^{-23} J. Since this value has the same order of Boltzmann constant $K_B = 1.38 \times 10^{-23}$ J/K.

Furthermore, dark matter particle could be the most fundamental and lightest particle in Nature and serves the basic block of matter (quarks and gluons). Moreover, assuming a uniform space dark energy/dark matter density, then the critical temperature at which the dark matter has a unity entity per volume is determined as 34.983×10^{12} K. At this temperature Boltzmann particles are melt (unified) to generate quarks which are considered the basic blocks of physical matter (Section 4). Finally, conclusions are discussed.

2. PRELIMINARY: THE EQUATION OF STATE OF DARK ENERGY AND DARK MATTER: THE UNIFIED ENTITY

This equation relates the pressure P , temperature T and the volume V of a substance behaves as an ideal gas [26], that is

$$PV = mRT \quad (1)$$

As it can be seen easily that **Eq.1** represents the energy associated with an ideal gas at given pressure P , temperature T and the volume V , that is

$$PV = mRT = E \quad (2)$$

Note that both sides of the equation has the units of



Figure 3. Gravitational lenses (Hubble Space Telescope, NASA).

energy (work done by pressure P). Assume now that dark energy behaves like an ideal gas with a negative pressure ($-P$) that causes the universe to expand with a total volume V , then by dividing both side of the equation of state (5) by V , then

$$P = \frac{m}{V} RT = \frac{E}{V} \quad (3)$$

Defining the mass density as $\rho_m = \frac{m}{V}$ and energy density as $\rho_E = \frac{E}{V}$, **Eq.3** yields to

$$P = \rho_m RT = \rho_E \quad (4)$$

Now by taking the ratio between the mass density and energy density then

$$\frac{\rho_E}{\rho_m} = RT \quad (5)$$

It can be concluded that the ratio between the mass density and energy density are proportional to the product of the temperature T and dark energy-dark matter constant R (known as Universal gas constant). It is worth to mention that NASA's Cosmic Microwave Background Explorer (CMB) in 1992 estimated that the sky has a temperature close to 2.7251 Kelvin. Moreover, the Wilkinson Microwave Anisotropy Probe (WMAP) in 2003 has made a map of the temperature fluctuations of the CMB with more accuracy [27-29].

The Boltzmann constant K_B is a physical constant that relates temperature to microscopic energy. $K_B = R/N_A$, where N_A is the Avogadro Number. $K_B = 1.38 \times 10^{-23}$ J/K. The numerical value of K_B measures the conversion factor for mapping from this microscopic energy E to the macroscopically-derived temperature scale.

The ideal gas law can now be expressed in terms of Boltzmann constant such that

$$PV = NK_B T \quad (6)$$

where N is the actual number of entities (particles). Now dividing both sides of (10) by volume to get the energy density then

$$P = \frac{N}{V} K_B T = \rho_N K_B T = \rho_E \quad (7)$$

This shows that the ratio between the energy density and the entities density is proportional to the absolute temperature times the Boltzmann constant.

The Boltzmann constant K_B is a physical constant that relates temperature to energy. $K_B = R/N_A$ where N_A is the Avogadro Number [27].

$K_B = 1.3806505 \times 10^{-23}$ J/K. The numerical value of K_B measures the conversion factor for mapping from this characteristic microscopic energy E to the macroscopically-derived temperature scale.

The ideal gas law can now be expressed in terms of Boltzmann constant such that

$$PV = NK_B T = E \quad (8)$$

where N is the actual number of molecules. Now dividing both sides of (8) by the volume to get the energy density then

$$P = \frac{N}{V} K_B T = \rho_N K_B T = \rho_E \quad (9)$$

By taking the ration between the energy density ρ_E and number of molecules density N/V , one gets

$$K_B T = \frac{\rho_E}{\rho_N} \quad (10)$$

or

$$\rho_N = \frac{\rho_E}{K_B T} \quad (11)$$

This shows that the ratio between the energy density and the molecular density is proportional to the absolute temperature times the Boltzmann constant. The simulation results demonstrate such a model.

3. PROPOSED DARK MATTER PARTICLE CANDIDATE

A quark-gluon plasma (QGP) or quark soup is a phase of quantum chromodynamics (QCD) which exists at extremely high temperature and/or density. This phase consists of (almost) free quarks and gluons, which are several of the basic building blocks of matter. Recent analyses from the Relativistic Heavy Ion Collider (RHIC), a 2.4-mile-circumference (atom smasher) at the US Department of Energy's (DOE) Brookhaven National Laboratory, establish that collisions of gold ions

traveling at nearly the speed of light have created matter at a temperature of about 4 trillion degrees Celsius—the hottest temperature ever reached in a laboratory, about 250,000 times hotter than the center of the Sun [30]. This temperature, based upon measurements by the PHENIX collaboration at RHIC, is higher than the temperature needed to melt protons and neutrons into a plasma of quarks and gluons. These new temperature measurements, combined with other observations analyzed over nine years of operations by RHIC's four experimental collaborations of BRAHMS, PHENIX, PHOBOS, and STAR indicate that RHIC's gold-gold collisions produce a freely flowing liquid composed of quarks and gluons. Such a substance, often referred to as quark-gluon plasma, or QGP, filled the universe a few microseconds after it came into existence 13.7 billion years ago. At RHIC, this liquid appears, and the quoted temperature is reached, in less time than it takes light to travel across a single proton. Search for the axions is investigated in work [30,31]. The axion is a proposed candidate particle for dark energy.

The Hadron Epoch covers the time from 10^{-6} seconds to 1 second after the Big Bang as shown in **Figure 4**. The temperature during this epoch is estimated to decrease from 10^{13} K to 10^{10} K. At 10^{-6} seconds Electrons and positrons annihilate each other during the hadron epoch. At 10^{-5} seconds, the temperature of the Universe is approximately 10^{13} K. Quarks combine to form protons and neutrons. The lowering temperature allows quark/anti-quark pairs to combine into mesons. After this period quarks and anti-quarks can no longer exist as free particles. At 10^{-4} seconds the temperature of the Universe is approximately 10^{10} (10 million) Kelvin. The existence of antimatter is cancelled out, as lepton/anti-lepton pairs are annihilated by existing photons. Neutrinos break free and exist on their own.

Now consider the estimations which show that values of universe dark energy density ($=1.2622 \times 10^{-26}$ kg/m³ = 6.8023 GeV), universe critical density ($=1.8069 \times 10^{-26}$ kg/m³ = 9.7378 GeV), universe matter density ($=0.54207 \times 10^{-26}$ kg/m³ = 2.9213 GeV), and universe radiation density ($=2.73 \times 10^{-31}$ kg/m³ = 1.4558 MeV).

In this proposed paper and based on astronomical observations that the average density of dark matter and dark energy is approximately 10^{-26} Kg/m³ and based on previous published work [12] that the density of dark matter is 0.54×10^{-26} Kg/m³ which is equivalent to 4.8277×10^{-10} J/m³. Now benefiting from (7) at CMB temperature $T = 2.73$ K, then

$$\rho_N = 12.81 \times 10^{12} \text{ entities/m}^3 \quad (12)$$

Since $\rho_N = 12.81 \times 10^{12}$ entities/m³ is corresponding to 0.54×10^{-26} Kg/m³, then each entity has a mass of

$0.54 \times 10^{-26} / 12.81 \times 10^{12} = 4.2141 \times 10^{-40}$ Kg . The equivalent energy of this particle is 3.7674×10^{-23} J . For the purpose of comparison, the mass of the most fundamental particles is listed in **Table 1**.

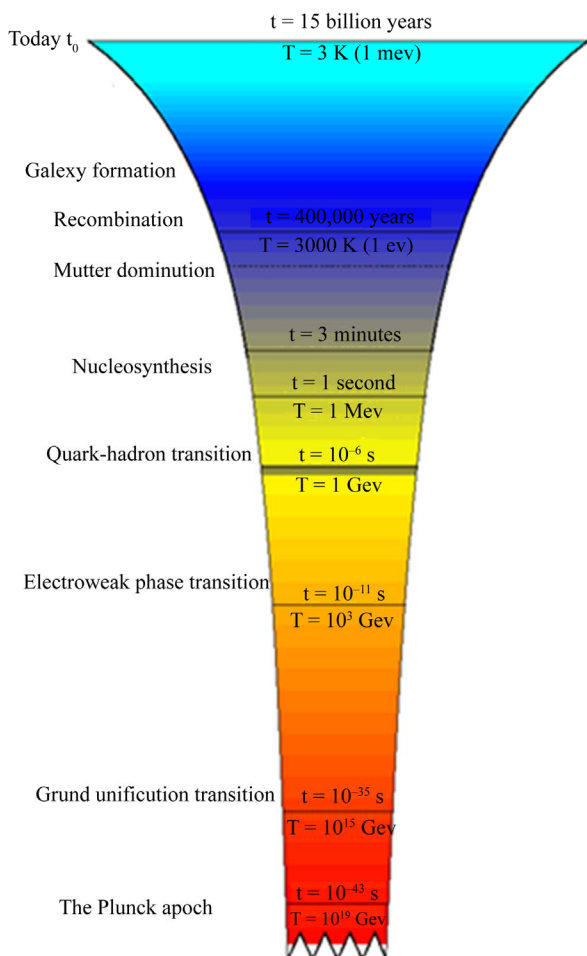


Figure 4. Quark-hadron transition and related temperature and time occurrence after big bang.

Table 1. Masses of different quarks and particles are known [32,33].

Symbol	Description	Value
m_e	Electron mass	511 keV
m_μ	Muon mass	105.7 MeV
m_τ	Tau mass	1.78 GeV
m_u	Up quark mass	1.9 MeV
m_d	Down quark mass	4.4 MeV
m_s	Strange quark mass	87 MeV
m_c	Charm quark mass	1.32 GeV
m_t	Top quark mass	172.7 GeV
m_b	Bottom quark mass	4.24 GeV

Furthermore, considering the lowest temperature in nature at Boomerang nebula which is 1 Kelvin, then the dark matter should be exactly equivalent to Boltzmann constant. As it can be seen, the mass of the electron is much heavier than this candidate particle by 2.159 Billion times. Furthermore, ρ_N is unity when the temperature T is equal to 34.983×10^{12} K . This temperature value is called the critical temperature.

As introduced before, it is estimated that at 100 microseconds after the Big Bang [34] the temperature was 10 TK. At 3 - 5 TK proton-antiproton reactions occur. If the density of dark matter/dark energy is uniform, homogeneous and constant through the universe, and since the density is at the same order of the proton-neutron, then it is very possible that dark energy/dark matter is converted into quarks at this critical temperature as followed.

Proposed dark matter candidate particle is characterized in the following table:

Boltzmann Particle, B	
m_B	4.2141×10^{-40} kg
	2.5386×10^{-13} u
$m_B c^2$	3.7674×10^{-23} J
	0.022695

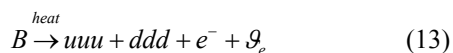
A comparison with the most known particles is shown below

Electron, e^-	
m_e	$9.10638215(45) \times 10^{-31}$ kg
	$5.4857990943(23) \times 10^{-4}$ u
$m_e c^2$	$8.18710438(41) \times 10^{-14}$ J
	0.510998910(13) Mev
Muon, μ^-	
m_μ	$1.88353130(11) \times 10^{-28}$ kg
	0.1134289256(29) u
$m_\mu c^2$	$1.692833510(95) \times 10^{-11}$ J
	105.6583668(38) Mev
Proton, p	
m_p	$1.672621637(83) \times 10^{-27}$ kg
	1.00727646677(10) u
$m_p c^2$	$1.503277359(75) \times 10^{-10}$ J
	938.272013(23) Mev
Neutron, n	
m_n	$1.674927211(84) \times 10^{-27}$ kg
	1.00866491597(43) u
$m_n c^2$	$1.505349505(75) \times 10^{-10}$ J
	939.565346(23) Mev
Deuteron, d	
m_d	$3.34358320(17) \times 10^{-27}$ kg
	2.013553212724(78) u
$m_d c^2$	$3.00506272(15) \times 10^{-10}$ J
	1875.612793(47) Mev

Triton, t	
m_t	$5.00735588(25) \times 10^{-27}$ kg 3.0155007134(25) u
$m_t c^2$	$4.50038703(22) \times 10^{-10}$ J 2808.920906(70) MeV
Helion, h	
m_h	$5.00641192(25) \times 10^{-27}$ kg 3.0149322473(26) u
$m_h c^2$	$4.49953864(22) \times 10^{-10}$ J 2808.391383(70) MeV
Alpha Particle, α	
m_α	$6.64465620(33) \times 10^{-27}$ kg
$m_\alpha c^2$	4.001506179127(62) u $5.97191917(30) \times 10^{-10}$ J 3727.379109(93) MeV

4. UTILIZATION OF DARK MATTER AND PROPOSED EXPERIMENT

There density are affected by the space temperature then utilization of its energy can be achieved at high temperatures such as Fermi melting point of quarks into quarkgluon plasma ($0.5 - 1.2 \times 10^{12}$ K) or higher. Hence ρ_N is unity when the temperature T is equal to 34.983×10^{12} K, then this temperature value is called the critical temperature. In other words at this temperature the $\rho_N = 12.81 \times 10^{12}$ entities/m³ of dark matter particles are unified (melted) to form quarks which work as the basic blocks of matter. Cooling quarks to 10^{13} K then quarks combine to form protons and neutrons.



B is after the dark matter candidate particle.

Similar to Relativistic Heavy Ion Collider (RHIC), here it is proposed to conduct an experiment at 4 Trillion Kelvin to generate quark-gluon plasma as explained in Section 3.

The following two tables, **Tables 2** and **3** show some a comparison with some physical phenomena temperatures so as to compare with the critical temperature at which dark matter particles unified into quarks.

5. CONCLUSIONS

A proposed equation of state of dark energy and dark matter as one unified entity is introduced such that dark energy and dark matter are not distinct. On the contrary, both dark energy and dark matter represent one unified entity. Such an equation is derived based on the assumption that dark energy and dark matter behave as a perfect fluid and using the ideal gas equation, Boltzmann constant and the energy-mass principle of Einstein. This principle agrees with the recent observations of NASA

Table 2. The temperature order between 1 and 10 K.

1 K	At the Boomerang nebula the coldest natural environment
1.5 K	Melting point of overbound helium
2.19 K	Lambda point of overbound superfluid helium
2.725 K	Cosmic microwave background
4.1 K	Superconductivity point of mercury
4.22 K	Boiling point of bound helium
5.19 K	Critical temperature of helium
7.2 K	Superconductivity point of lead
9.3 K	Superconductivity point of niobium

Table 3. The temperature order TK (10^{12} K).

0.5 - 1.2 TK	Fermi melting point of quarks into quark-gluon plasma
3 - 5 TK	In proton-antiproton reactions
Z ⁰	Electronuclear excitations
10 TK	100 microseconds after the Big Bang
300 - 900 TK	At proton-nickel conversions in the Tevatron's Main Injector

that dark energy and dark matter has close density values and in the range of 10^{-26} kg/m³.

Additionally, in this paper presents it is presented what could be the most fundamental particle and quanta of dark matter and dark energy and its characteristics. It is found that this candidate particle has an equivalent mass of 4.2141×10^{-40} Kg which is equivalent to 3.7674×10^{-23} J. This value has the same order of Boltzmann constant $K_B = 1.38 \times 10^{-23}$ J/K. Benefiting from CMB temperature $T = 2.73$ K, then each cubic meter of space contains 12.81×10^{12} entities/m³ of Boltzmann particles. As it can be seen, the mass of the electron is much heavier than this candidate particle by 2.159 Billion times. It could be the most fundamental and lightest particle in nature and serves as the basic blocks of matter (quarks and gluons).

Moreover, the critical temperature at which the dark matter has a unity entity per unit volume is determined as 34.983×10^{12} K. Considering the lowest temperature in nature at Boomerang nebula which is 1 Kelvin, then the dark matter should be exactly equivalent to Boltzmann constant. An experiment (similar to Relativistic Heavy Ion Collider (RHIC)) is proposed at the critical temperature to form quarks.

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