



## The Fundamental Particle and Energy Quanta of Dark Matter and Dark Energy: Boltzmann Particles and Utilization its Energy

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**Abstract.** This paper presents what could be the most fundamental particle and quanta of dark matter and dark energy and its characteristics. Recent observations have shown 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. This paper is a continuation of previous published work at ICREPQ'08 and ICREPQ'07 which was based on the assumption that dark energy and dark matter are identical and behave as an ideal gas. Furthermore, based on Boltzmann constant and NASA's Cosmic Microwave Background Explorer (CMB) which estimated that the sky has a temperature close to 2.7251 Kelvin, then the equivalent mass and energy of fundamental particle of the dark matter/dark energy is determined. It is found that this candidate particle has an equivalent mass of  $4.2141 \times 10^{-40}$  Kg which is equivalent to  $3.7674 \times 10^{-23}$  J. Since this value has the same order of Boltzmann constant  $K_B = 1.38 \times 10^{-23}$  J / K, then this particle is called Boltzmann particle. 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. Boltzmann particle could be the most fundamental and lightest particle in Nature. 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  $34.983 \times 10^{12}$  K. This analysis shows that the dark matter is a preferably a cold matter since its volumetric density is inversely proportional to the absolute temperature of the space.

Keywords- Dark Energy, Dark Matter, Equation of State, Boltzmann Constant, Einstein's Cosmological Constant

### 1. INTRODUCTION

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. And on top of that, the stars move at flat speeds (see Fig. 1 and 2) that should rip the galaxy apart; 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.

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. 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. 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, and the temperature distribution of hot gas in galaxies and clusters of galaxies [3][7-8].

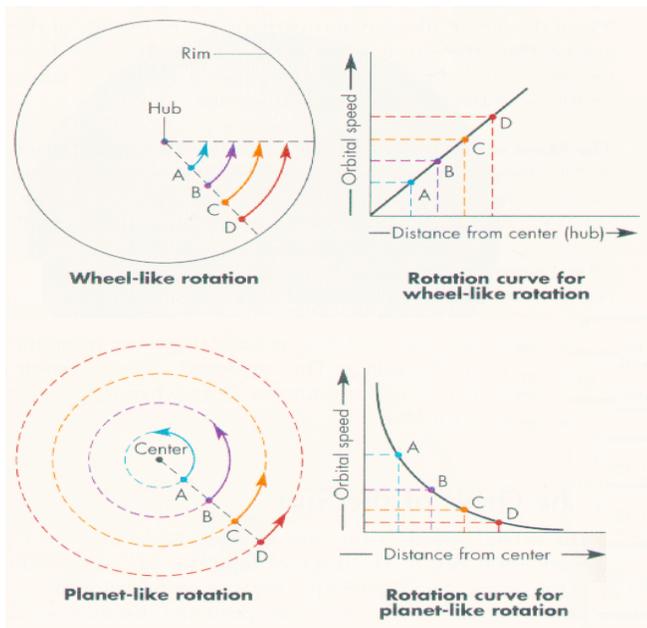


Figure 1: Rotation following Kepler's 3rd law is shown above as planet-like or differential rotation. Notice that the orbital speeds falls off as you go to greater radii within the Galaxy. This is called a Keplerian rotation curve

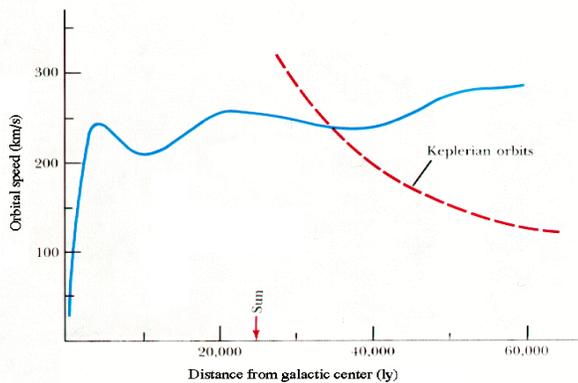


Figure 2: The observed rotation curve for the our galaxy Milky Way. To determine the rotation curve of the Galaxy, stars are not used due to interstellar extinction. Instead, 21-cm maps of neutral hydrogen are used. When this is done, one finds that the rotation curve of the Galaxy stays flat out to 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.

The dark matter component has vastly more mass than the visible component of the universe. At present, the density of ordinary baryons and radiation in the universe is estimated to be equivalent to about one hydrogen atom per cubic meter of space. Only about 4% of the total energy density in the universe as inferred from gravitational effects can be seen directly. About 22% is thought to be composed of dark matter.

The remaining 74% is thought to consist of dark energy, an even stranger component, distributed diffusely in space.

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 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.

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 [3-10]. 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 [3] [7-8].

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. 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 [3]. This force is given the name Dark Energy, since it cannot be observed or detected directly. These cosmological observations strongly suggest that the universe is dominated by a smoothly homogenous distributed dark energy component.

This paper presents what could be the most fundamental particle and quanta of dark matter and dark energy and its characteristics. Recent observations have shown 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. This is a continuation of previous published work at ICREPQ08 and ICREPQ07 which based on the assumption that dark energy and dark matter are identical and behave as an ideal gas. Furthermore, based on Boltzmann constant and NASA's Cosmic Microwave Background

Explorer (CMB) which estimated that the sky has a temperature close to 2.7251 Kelvin, then the equivalent mass and energy of the dark matter/dark energy fundamental particle is determined. It is found that this candidate particle has an equivalent mass of  $4.2141 \times 10^{-40}$  Kg which is equivalent to  $3.7674 \times 10^{-23} J$ . Since this value is a multiple of Boltzmann constant  $K_B = 1.38 \times 10^{-23} J$ , then this particle is called Boltzmann particle. Boltzmann particle could be the most fundamental particle in Nature. Moreover, the critical temperature at which the dark matter has a unity entity per volume is determined as  $34.983 \times 10^{12} K$ . This analysis shows that the dark matter is a preferably a cold matter since its volumetric density is inversely proportional to the absolute temperature of the space.

## 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 [2], that is

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

As it can be seen easily that equation (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 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

$$\rho_E = \frac{E}{V}, \text{ equation (3) yields to}$$

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

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 [11].

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.

## 3. BOLTZMANN PARTICLES

Based on astronomical observations that the average density of dark matter and dark energy is approximately  $10^{-26} Kg / m^3$  and based on previous published work [12] that the density of dark matter is  $0.54 \times 10^{-26} Kg / m^3$  which is equivalent to  $4.8277 \times 10^{-10} J / m^3$ . Now benefiting from (7) at CMB temperature  $T=2.73 K$ , then

$$\rho_N = 12.81 \times 10^{12} \text{ entities} / m^3 \quad (8)$$

Since  $\rho_N = 12.81 \times 10^{12} \text{ entities} / m^3$  is corresponding to  $0.54 \times 10^{-26} Kg / m^3$ , 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  $3.7674 \times 10^{-23} J$ . 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. Since the particle equivalent energy has the same order of Boltzmann constant, then it is called Boltzmann particle. As it can be seen, the mass of the electron is much heavier than this Boltzmann particle by 2.159 Billion times. Furthermore,  $\rho_N$  is unity when the temperature  $T$  is equal to  $34.983 \times 10^{12} K$ . This temperature value is called the critical temperature. It is estimated that at 100 microseconds after the Big Bang 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.

**Proposed Boltzmann Particle,  $B$**

$m_B$	$4.2141 \times 10^{-40}$	kg
	$2.5386 \times 10^{-13}$	u
$m_B c^2$	$3.7674 \times 10^{-23}$	J
	0.022695	$\mu eV$

A comparison with the most known particles is shown below

Electron,  $e^-$

$m_e$	$9.109\ 382\ 15(45) \times 10^{-31}$	kg
	$5.485\ 799\ 0943(23) \times 10^{-4}$	u
$m_e c^2$	$8.187\ 104\ 38(41) \times 10^{-14}$	J
	0.510 998 910(13)	MeV

Muon,  $\mu^-$

$m_\mu$	$1.883\ 531\ 30(11) \times 10^{-28}$	kg
	0.113 428 9256(29)	u
$m_\mu c^2$	$1.692\ 833\ 510(95) \times 10^{-11}$	J
	105.658 3668(38)	MeV

Proton, p

$m_p$	$1.672\ 621\ 637(83) \times 10^{-27}$	kg
	1.007 276 466 77(10)	u
$m_p c^2$	$1.503\ 277\ 359(75) \times 10^{-10}$	J
	938.272 013(23)	MeV

Neutron, n

$m_n$	$1.674\ 927\ 211(84) \times 10^{-27}$	kg
	1.008 664 915 97(43)	u
$m_n c^2$	$1.505\ 349\ 505(75) \times 10^{-10}$	J
	939.565 346(23)	MeV

Deuteron, d

$m_d$	$3.343\ 583\ 20(17) \times 10^{-27}$	kg
	2.013 553 212 724(78)	u
$m_d c^2$	$3.005\ 062\ 72(15) \times 10^{-10}$	J
	1875.612 793(47)	MeV

Triton, t

$m_t$	$5.007\ 355\ 88(25) \times 10^{-27}$	kg
	3.015 500 7134(25)	u
$m_t c^2$	$4.500\ 387\ 03(22) \times 10^{-10}$	J
	2808.920 906(70)	MeV

Helion, h

$m_h$	$5.006\ 411\ 92(25) \times 10^{-27}$	kg
	3.014 932 2473(26)	u
$m_h c^2$	$4.499\ 538\ 64(22) \times 10^{-10}$	J
	2808.391 383(70)	MeV

Alpha particle,  $\alpha$

$m_\alpha$	$6.644\ 656\ 20(33) \times 10^{-27}$	kg
	4.001 506 179 127(62)	u
$m_\alpha c^2$	$5.971\ 919\ 17(30) \times 10^{-10}$	J
	3727.379 109(93)	MeV

The following two tables show some a comparison with some physical phenomena temperatures.

Table I: 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 II: 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

#### 4. UTILIZATION OF DARK MATTER/DRAK ENERGY

Since dark matter/dark energy behaves like an ideal fluid and 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 quark-gluon plasma ( $0.5\text{--}1.2 \times 10^{12} K$ ) or nuclear fusion ( $1\text{--}100 \times 10^9 K$ ).

Furthermore,  $\rho_N$  is unity when the temperature T is equal to  $34.983 \times 10^{12} K$ . This temperature value is called the critical temperature. It is estimated that at 100 microseconds after the Big Bang 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-nitron, then it is very possible that dark enrgy/dark matter is converted into quarks at this critical tmaprature.

#### 5. CONCLUISON

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