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Article

Informational Nature of Dark Matter and Dark Energy and the Cosmological Constant

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Abstract – In this article, realistic quantitative estimation of dark matter and dark energy considered as informational phenomena have been computed, thereby explaining certain anomalies and effects within the universe. Moreover, by the same conceptual approach, the cosmological constant problem has been reduced by almost 120 orders of magnitude in the prediction of the vacuum energy from a quantum point of view. We argue that dark matter is an informational field with finite and quantifiable negative mass, distinct from the conventional fields of matter of quantum field theory and associated with the number of bits of information in the observable universe, while dark energy is negative energy, calculated as the energy associated with dark matter. Since dark energy is vacuum energy, it emerges from dark matter as a collective potential of all particles with their individual zero-point energy via Landauer's principle.

Keywords – Dark matter; Dark energy; Cosmological constant; Vacuum energy; Landauer's principle; Information.

1. Introduction

The universe is filled with mysteries, and some of the darkest areas of it pertain to concepts like dark matter and dark energy. These dark phenomena are some of the deepest cosmic mysteries. Nevertheless, some informational perspectives shed light on dark matter, and dark energy, lifting the veil on the informational nature of these phenomena.

Starting from the point, that, information entropy is equivalent to thermodynamic entropy when the same degrees of freedom are considered [1], the information entropy of the physical world is thus the number of bits needed to account for all possible microscopic states [1]. According to these perspectives and based on the mass-energy-information equivalence principle proposed by Vopson [2], a principle testable via a given experimental protocol [3], the entropic information theory approach [4] is a method that regards the mass of an information bit as definite and measurable, and which considers dark matter as being the number of bits of the observable universe computed by taking in consideration the mass of bit of information. This approach also computes dark energy, as the energy associated to dark matter via the Landauer's principle [5].

In this article, we argue that dark matter is an informational field distinct from the conventional fields of the quantum field theory, having a finite and quantifiable negative mass, while dark energy, i.e., vacuum energy, is a collective potential of all particles with their individual zero-point energy, a negative energy, emerging from dark matter via the Landauer's principle.

After having estimate the dark matter as the number of bits, corresponding to the number of bits of information content of the whole observable universe, using the entropic information theory approach, an estimation of the dark energy has been computed, using the Landauer energy equivalent of the total information [6].

The dark energy can be associated to the cosmological constant and the cosmological constant can be formulated to be equivalent to the zero-point radiation of space, i.e. the vacuum energy [7]. The dark energy, i.e. vacuum energy is associated to the cosmological constant being expressed into the Landauer energy equivalent, the Landauer energy equivalent of an elemental bit of information is defined in form and value identical to the characteristic energy of the cosmological constant [8].

By taking in consideration the mass of bit of information instead of Planck mass in the prediction of the vacuum energy from a quantum point of view, this approach when applicated to the cosmological constant problem can reduce the discrepancy of the results by 120 orders of magnitude.

2. Dark Matter as Information

Dark matter is an elusive and as-yet-unidentified form of matter that cannot be directly observed or detected through electromagnetic radiation such as light or radio waves. The existence of dark matter was first proposed in the 1930s by Swiss astronomer Fritz Zwicky, who observed that the visible matter in galaxy clusters was not sufficient to explain the observed gravitational effects on the motions of galaxies within the clusters. Since then, numerous lines of evidence from astronomical observations have supported the presence of dark matter, including the way galaxies rotate, the gravitational lensing effects of galaxy clusters, and the large-scale structure of the universe.

Vopson says that since for more than 60 years we have been trying unsuccessfully to understand what dark matter is, it could very well be information. "If the principle of mass-energy-information equivalence [2] is correct and information does have mass, a digital informational universe would contain a lot of it, and perhaps the missing dark matter could be just information," Vopson said [9].

So, within this framework arises a fundamental question:

“How many bits of information are contained in the observable universe?”

Going back as far as the late 1970s, this question has been addressed in several studies and several answers have been given. For example, using the Bekenstein–Hawking formula for the black-hole entropy [10, 11] the information content of the universe has been calculated by Davies [12].

$$I \approx \frac{2\pi G M_u^2}{hc} = 10^{120}\ bits \tag{1}$$

Where:
c is the speed of light.
G is the gravitational constant.
h is Planck’s constant.
M_u is the mass of the universe enclosed within its horizon.

Wheeler’s approach which estimated the number of bits in the present universe at temperature T = 2.735 K from entropy considerations, resulting in 8×10^{88} bits content [13].

Lloyd which took a similar approach and estimated the total information capacity of the universe as [14].

$$I = \frac{S}{k\ ln(2)} \approx (\rho c^5 t^4)^{3/4} \approx 10^{90}\ bits \tag{2}$$

Where:
S is the total entropy of the matter dominated universe.
c is the speed of light.
k is the Boltzmann constant.
ρ is the matter density of the universe.
t is the age of the universe at present.

Now, we examine the same issue via the entropic information approach [4]. This approach is founded on considering the information such as the number of bits within a system necessary to specify the actual microscopic configuration among the total number of microstates allowed and thus characterize the macroscopic states of the system under consideration.

The entropic information approach is based on the mass of information bit formula from mass-energy-information equivalence principle [2]. We start this entropic information approach by introducing the mass of information into the hidden thermodynamics of Louis De Broglie [15].
Entropy becomes a sort of opposite to action with an equation that relates the only two universal dimensions of the form:

$$\frac{action}{h} = -\frac{entropy}{k} \tag{3}$$

Where:
h: Planck constant.
k: Boltzmann constant.
With $action = Energy * Time$.
and $Energy = mc^2$.

with mass of information bit:

$$mass_{bit} = \frac{k\,T\,ln(2)}{c^2} \tag{4}$$

Where:
c: speed of light.
k: Boltzmann's constant.
T: the temperature at which the bit of information is stored.

$$\frac{action}{h} = \frac{mc^2t}{h} = -\frac{entropy}{k} = -\frac{k\,ln(w)}{k} \tag{5}$$

$$\frac{action}{h} = \frac{mc^2t}{h} = \frac{\frac{k\,T\,ln(2)}{c^2}c^2t}{h} = -\frac{entropy}{k} = -\frac{k\,ln(w)}{k} \tag{6}$$

$$\frac{action}{h} = \frac{mc^2t}{h} = \frac{k\,T\,ln(2)t}{h} = -\frac{entropy}{k} = -\,ln(W) \tag{7}$$

$$ln(W) = -\frac{kT\,ln(2)t}{h} \tag{8}$$

Moreover, as since entropy is:

$$S = k\,ln(W) \tag{9}$$

We obtain a new value for the entropy S, expressed as the number of bits of information, with formula based on the hidden thermodynamics of Louis de Broglie [15] wherein the introduction of the mass of the bit of information gives:

$$k\,ln(W) = -k\frac{k\,T\,ln(2)\,t}{h} \tag{10}$$

$$S = -\,k^2\frac{\mathrm{T}\ln(2)t}{h} \tag{11}$$

Where:
k: Boltzmann's constant.
h: Planck constant.
T: the temperature at which the bit of information is stored.
t: time required to change the physical state of the information bit.

Traditionally in thermodynamic terms, entropy is a measure of disorder or randomness in a system, negative entropy, i.e., the negentropy, is uncommon, it implies a system becoming more ordered or less random, and typically it refers to systems that are gaining order.

Something worth mentioning: in the influential 1944 book "What is Life?", Erwin Schrödinger, a Nobel Prize-winning physicist, proposed the concept that life sustains itself through negentropy [16].

In quantum information theory, we interpret negative entropy as "negative" information", suggesting a process where quantum states are becoming less entangled or more distinct, leading to a decrease in the overall quantum information content. In terms of bits, this implies that fewer bits are needed to describe the system's state, indicating a movement toward a simpler or more predictable state, or indicating that the system is losing complexity. The entropic information theory approach [4] can formulate a set of five equivalent equations expressing entropy: Boltzmann, Einstein, Planck, Avogadro, and fine structure formulation as seen in Figure 1.

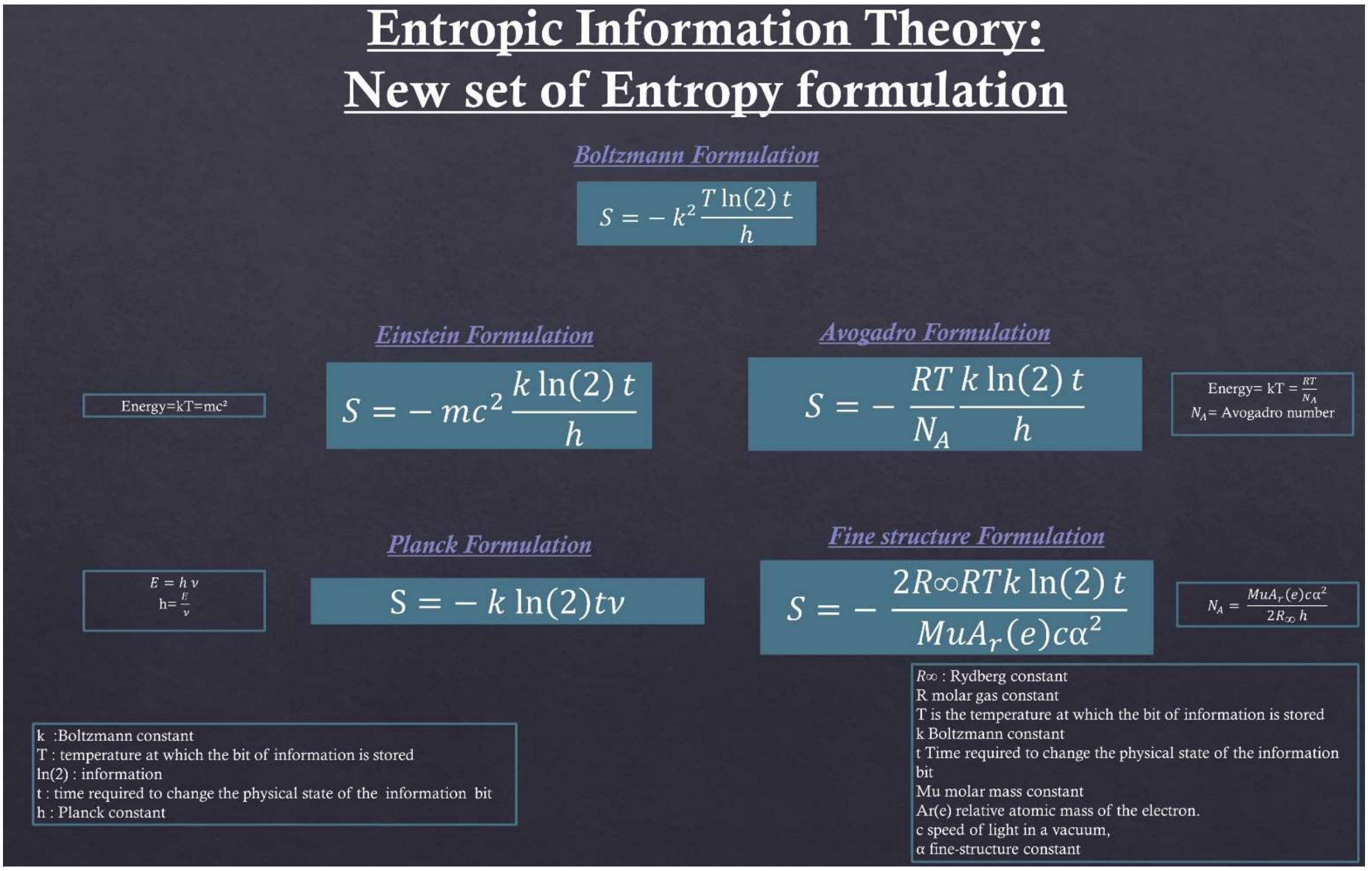

Figure 1. New set of entropy formulation from Entropic Information Theory.

The entropic information approach [4] can calculate an estimation of the bits of information contained in the observable universe from a new formulation of entropy, entropy based on the mass of the information bit:

$$S = -mc^2 \frac{k\, ln(2)\, t}{h} \qquad (12)$$

We use the mass of the universe and the age of the universe for the calculations. It is well-accepted that the matter distribution in the Universe is 5% ordinary baryonic matter, 27% dark matter and 68%, dark energy [17]. For the observable universe, we estimate its mass of "ordinary" matter at 1.25×10^{53} kg, knowing that it is estimated that the universe is made up of only 5% ordinary matter, the total mass of the universe would therefore be 20 times greater. This gives us a total mass (dark energy and dark matter included) of 2.78×10^{54} kg.

$$mass_{univ} = 2.78 \times 10^{54}\, kg$$

For the age of the universe, we use 13.8 billion of years, which expressed in seconds is:

$t_{univ} = 4.35486 \times 10^{17}$seconds

$$-\frac{2.78\ 10^{54}\times\ 299792458^2\times 1.380649\ 10^{-23}\times \ln(2)\times 4.35486\times 10^{17}}{6.6267015\times 10^{-34}} = -1.57056\times 10^{99} \text{ bits} \quad (13)$$

The estimation of the number of bits of information in the observable universe based on new entropy formula from entropic information theory approach [4], with $mass_{univ}$ = 2.78 × 10^{54} kg and t_{univ} = 4.35486 × 10^{17} $seconds$, the result is "$-$ 1.57056 × 10^{99} bits".

$$S = -mc^2\frac{k\,ln(2)\,t}{h} \quad (14)$$

N.B: The relationship between thermodynamic entropy S and Shannon entropy H given by S =k H ln(2) is not used to convert the result into informational terms because the result of the entropic information theory [4] approach to entropy is expressed in informational terms, indeed it is the mass of the bit of information that has been implemented into the initial equation considered, the hidden thermodynamics of louis de Broglie [15], so the results of the entropy are expressed in the number of bits as the theory of entropic information is based on the number of bits of the system, the number of bits necessary to specify the real microscopic configuration among the total number of microstates allowed and thus characterize the macroscopic states of the system considered.

The absolute value of the number of "$-$ 1.57056 × 10^{99} bits" is the estimated number of bit content of the observable universe computed by the entropic information theory [4] approach, being remarkably close to an estimate of the information bit content of the universe with 5.2 × 10^{94} bits that would be sufficient to account for all the dark matter missing in the visible universe following Vopson using the reasoning developed in [18, 19]. The negative sign of this number indicates a movement towards a simpler or more predictable state, indicating that the system is losing its complexity.

Vopson estimated that around 5.2 × 10^{94} bits would be enough to account for all the missing dark matter in the observable universe [17, 18]. The estimated bit content of the observable universe from the entropic information theory approach is the absolute value of the number "$-$ 1.57056 × 10^{99} bits", while the negative sign indicates a movement towards a simpler or more predictable state, implying that the system is losing its complexity.

3. Dark Matter as Negative Mass

We can note about the dark matter estimation by the number of bits of information in the observable universe based on the "Einstein entropy formulation" from the entropic information approach, the presence of a negative sign, relative to dark matter with negative mass.

$$S = -mc^2\frac{k\,ln(2)\,t}{h} \quad (15)$$

The presence of this negative sign come from the use of the formula of Louis de Broglie, about the hidden thermodynamics [15] into which was injected the mass of the information bit [2]. About this "Einstein entropy formulation" obtained by the entropic information approach, the negative sign refers to a state in which the disorder or randomness of a system decreases, or the uncertainty or information content decreases, implicating a movement towards a more organized, structured, or predictable state. The $\ln(2)$ factor comes from defining the information as the logarithm to the base 2 of the number of quantum states [20].

In theoretical physics, negative mass is a hypothetical type of exotic matter whose mass is opposite sign to the mass of normal matter. In 1928, Paul Dirac's theory of elementary particles, now part of the Standard Model, already included negative solutions [21]. The Standard Model is a generalization of quantum electrodynamics (QED) and negative mass is already built into the theory.

The idea of negative mass arises from certain solutions to the equations of general relativity, the theory of gravity formulated by Albert Einstein.

The idea of connecting negative mass to dark matter comes from attempts to explain some of the observed behaviors of dark matter in the universe. One of the significant challenges in understanding dark matter is that it appears to exert gravitational forces on visible matter, such as galaxies, causing them to move differently than what would be expected based solely on the visible mass distribution. This discrepancy is known as the "missing mass problem" or the "galaxy rotation problem."

The observed discrepancies in galactic rotation curves can be explained by the negative mass which interacts with ordinary matter, and potentially generates gravitational repulsion between negative and positive masses, this repulsion can then counterbalance the gravitational attraction of visible matter.

4. Dark Energy as Vacuum Energy

Information entropy is equivalent to thermodynamic entropy when the same degrees of freedom are considered [1]. Indeed, Boltzmann's entropy formula can be derived from the Shannon entropy formula when all states are equally probable. If you have W microstates equiprobable with probability $p_i = 1/_W$, then:

$$S = -k \sum p_i \ ln(p_i) = \mathrm{k} \sum \frac{(ln(W))}{W} = k \ ln(W) \tag{16}$$

If we consider the simplest case where there are 2 equally likely microstates, the entropy is:

$$S = k \ ln(2) \tag{17}$$

This corresponds to 1 bit of information because there are 2 possible states (0 or 1). The information entropy of the physical world is thus the number of bits needed to account for all possible microscopic states [1].

We have already computed the number of bits of information in the observable universe based on the "Einstein entropy formulation" from the entropic information approach, as being dark matter, now, we focus to the notion of energy related to this number of bits as the Landauer's principle identifying temperature as the only parameter connecting information to energy.

The Landauer's principle states that any irreversible computation or erasure of information in a physical system must dissipate a minimum amount of energy, which is given by:

$$\Delta E = k \, T \ \ln(2) \tag{18}$$

Where:
ΔE is the minimum energy dissipation.
k is Boltzmann's constant.
T is the temperature of the system in Kelvin.
$\ln(2)$ is the natural logarithm of 2 (approximately 0.6931).

The $\ln(2)$ factor comes from defining the information as the logarithm to the base 2 of the number of quantum states [19].

Landauer's principle applies to all systems in nature so that any system, temperature T, in which information is 'erased' by some physical process will output $\mathrm{k\,T} \ln(2)$ of heat energy per bit 'erased' with a corresponding increase in the information of the environment surrounding that system [5]. Landauer's principle can be derived from microscopic considerations [22] as well as derived from the well-established properties of the Shannon-Gibbs-Boltzmann entropy [23]. Landauer's principle has now been experimentally verified for classical bits and quantum qubits [23, 24]. The Landauer Principle reveals the fundamental connection between information theory and the laws of thermodynamics. This important physical prediction that links information theory and thermodynamics was experimentally verified for the first time in 2012 [25].

Information is therefore directly bound up with the fundamental physics of nature.

We obtain the equivalent Landauer energy of a fundamental bit of information in a universe at temperature, T_{univ}, ρ_{tot} is the total density of matter in the universe (baryon + dark).

$$k\,T_{univ}\ \ ln(2) = \sqrt[4]{\frac{15\,\rho_{tot}\hbar^3 c^5}{\pi^2}}\ln(2) \qquad (19)$$

This Landauer energy of a fundamental bit is defined identically to the characteristic energy of the cosmological constant, which is closely associated with the concept of dark energy [8].

The right-hand side of this equation is identical to equation 17 of [26] for the characteristic energy of the cosmological constant - with the sole addition of $\ln(2)$ to convert between entropy units - between natural information units, nats, and bits [8].

The formula of total information equivalent energy, is given by Landauer's principle [8]:

$$N_{Bits}\ k\ T_{univ}\ \ ln(2) \qquad (20)$$

$T_{univ} = 2.725\ K$

$N_{Bits} = -1.57056 \times 10^{99}$, the value obtained for the estimation of the number of bits corresponding to all the content of the whole observable universe, considered as Dark matter.
We obtain,

$$-1.57056 \times 10^{99} \times 1.380649 \times 10^{-23} \times\ 2.725 \times ln(2) = -4.09569 \times 10^{76} \text{ Joules} \qquad (21)$$

The estimation of the energy associated with the number of bits of information of the observable universe based on the entropic information theory and the Landauer's principle $N_{Bits}\ k\ T_{univ}\ \ ln(2)$ with temperature of universe, $T_{univ} = 2.725\ K$ is -4.09569×10^{76} Joules.

The dark energy density in the universe is about 7×10^{-30}g/cm3 on average. This is uniform throughout the Hubble volume of the entire universe i.e. the volume of the universe with which we are in causal contact. The Hubble volume is $10^{31}\ ly^3$ i.e., cubic light years. This gives $8.46732\times10^{84}\ cm^3$ as the volume of the universe. Using the mass-energy equivalence, you find that the total dark energy content in the entire universe is around 10^{69}Joules.

The entropic information theory can provide a quantitative account for dark energy, accounting for the present dark energy value, $\sim10^{69}$ Joules. The entropic information theory provides an estimation of -4×10^{76} Joules, close to this estimation.

The dark energy is the estimation of the Landauer energy equivalent of the total information of the observable universe, the estimation of the energy associated to dark matter by the Landauer principle, thus, dark energy is the estimation of the energy associated with the number of bits of information in the observable universe based on the "Einstein entropy formulation" from the entropic information approach.

See Table 1 About value over time and temperature of dark energy, the Landauer energy equivalent of the total information of the observable universe, the estimation of the energy associated to dark matter by the Landauer principle, according to the formula of dark energy based on Landauer's principle from the entropic information theory with this formula: $-\ \mathrm{mc}^2\,\frac{\mathrm{k\ln(2)t}}{\mathrm{h}}\ \mathrm{k\,T\ln(2)}$.

Table 1. Value over time and temperature of the dark energy, Landauer energy equivalent of the total information of the observable universe, from the entropic information theory: $-\ mc^2\,\frac{k\,ln(2)t}{h}\ k\,T\ln(2)$.

Time t(sec)	13,8 billion years 4.35486 E+17	380000 years 1,1991642 E+13	3 minutes 180
Temperature (T)	2.725	3000	1,00 E+9
Mass (m)	2.78E+54	2.78E+54	2.78 E+54
Speed of light ² (c²)	8.98755E+16	8.98755E+16	8.98755 E+16
Boltzmann constant (k)	1.38 E-23	1.38 E-23	1.38 E-23
ln(2)	0.69347	0.69347	0.69347
Planck constant (h)	6,63 E-34	6,63 E-34	6,63 E-34
Dark energy $-\mathrm{mc}^2\,\frac{\mathrm{k\ln(2)\,t}}{\mathrm{h}}\ k\,T\ln(2)$	-4.09569 E+76	-1.2416 E+75	-6.2124 E+69

The dark energy can be associated to the cosmological constant and the cosmological constant can be formulated to be equivalent to the zero-point radiation of space, i.e., the vacuum energy [7].

5. Dark Energy as Negative Energy

The dark energy being the energy associated to dark matter, we can note about the dark energy estimation, estimation of the energy associated to dark matter by the Landauer principle based on the “Einstein entropy formulation” from the entropic information approach, the presence of a negative sign concerning dark energy, relative to negative energy.

Concerning negative energy, currently, the closest known real representative of such exotic matter is a region of negative pressure density produced by the Casimir effect. It's important to note that while the Casimir effect is a result of negative energy considerations, it is a real and experimentally confirmed phenomenon. Indeed, in line with Casini and Bousso's works [27-35] on the positivity of quantum relative entropy, which establishes the validity of the Bekenstein bound, the employed framework enables an understanding of the Casimir effect, wherein the localized energy density falls below that of the vacuum, indicating a negative localized energy.

In physics, the negative energy is a concept used to explain the nature of certain fields, including the gravitational field and various quantum field effects. Negative energies and negative energy density are consistent with quantum field theory [36].

6. Vacuum Energy, Cosmological Constant, and information

The cosmological constant (CC) term in Einstein’s equations, Λ, was first associated to the idea of vacuum energy density. The zero-point-energy is usually supposed to contribute to the cosmological constant. The mismatch between the small cosmological constant compared with the huge zero-point-energy is considered as one of the most serious problems in physics. Essentially, a non-zero vacuum energy is expected to contribute to the cosmological constant, which affects the expansion of the universe. Using quantum field theory, one can calculate the quantum mechanical vacuum energy (or zero-point energy) for any quantum field. The result of this calculation can be as high as 120 orders of magnitude larger than the upper limits obtained via cosmological observations.
In quantum mechanics, the vacuum energy is not zero due to quantum fluctuations. The ground state energy of the harmonic oscillator is $\frac{\hbar\omega}{2}$ in contrast to the classical harmonic oscillator whose ground state energy is zero. The formalism of quantum field theory makes it clear that the vacuum expectation value summations are in a certain sense summation over so-called "virtual particles". Quantum fields can be described as an infinite collection of harmonic oscillators, so naively the vacuum energy, which would be a sum over all the harmonic oscillator ground state energies, should be infinite. But, in practice, we would expect the sum to be cut off at some energy scale above which the true fundamental theory must be invoked.
The cosmological constant Λ was introduced by Albert Einstein into general relativity in 1917. Including the cosmological constant, Einstein’s field equations are:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda G_{\mu\nu} = -\frac{8\pi G}{c^4} T_{\mu\nu} \tag{22}$$

The cosmological constant can be interpreted as the energy density of the vacuum. Specifically, if we introduce

$$T_{\mu\nu}^{vacuum} = \frac{c^4 \Lambda}{8\pi G} g_{\mu\nu} \tag{23}$$

Then (22) can be rewritten as

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda G_{\mu\nu} = -\frac{8\pi G}{c^4} \left(T_{\mu\nu} + T_{\mu\nu}^{vacuum}\right) \tag{24}$$

if we compare (23) with the energy-momentum tensor of a perfect fluid,

$$T_{\mu\nu} = \left(\rho + \frac{p}{c^2}\right) u_\mu u_\nu - p g_\mu \tag{25}$$

then we would conclude that the energy density of the vacuum is:

$$c^2\rho_{vac} = \frac{c^4\Lambda}{8\pi G} \tag{26}$$

and the equation of state of the vacuum is $p = \rho c^2$.

The current astrophysical data can be interpreted as being consistent with a nonzero value of the cosmological constant. The latest data can be found in the table of Astrophysical constants and parameters in [37]. This table includes the following two entries,

$$\frac{c^2}{3H_0^2} = 6.3 \ \pm 0.2 \ \ 10^{51}\, m^2 \tag{27}$$

$$\Omega_\Lambda = 0.685^{+0.017}_{-0.016} \tag{28}$$

where $\Omega_\Lambda \equiv \frac{\rho_{vac}}{\rho_{c,0}} = \frac{\Lambda c^2}{3H_0^2}$ and H_0 is the present-day Hubble parameter.

The vacuum energy density is given by (26) and the critical density today is given by $\rho_{c,0}\,\frac{3H_0^2}{8\pi}$

Hence

$$\Omega_\Lambda = \frac{\rho_{vac}}{\rho_{c,0}} = \frac{\Lambda c^2}{3H_0^2} \tag{29}$$

Employing the numbers given in eq. (27) and (28), it follows that:

$$\Lambda = \frac{3H_0^2}{c^2}\,\Omega_\Lambda = (1.09 \pm 0.04)\ 10^{-52}\ m^{-2} \tag{30}$$

Using (30), we obtain,

$$\rho_{vac} = \frac{\Lambda c^2}{8\pi G} = \frac{(1.1 \ \ 10^{-52}\ m^2)\ (3 \ \ 10^8\ ms^{-1})^2}{8\pi(6.673\ 10^{-11}\ m^3kg^{-1}s^{-2})} = 5.9 \ \ 10^{-27}\ kg\ m^{-3} \tag{31}$$

Thus, the numerical value of the vacuum energy is:

$$\rho_{vac}c^2 = 5.31 \ \ 10^{-10}\, J = 3.32\ GeV\ m^{-3} \tag{32}$$

after using the conversion 1 $Ev = 1.6 \text{ x } 10^{-19}\, J$ and 1 $Gev = 10^9\ eV$.

In order to see whether this vacuum energy is large or small, we need to invoke quantum mechanics. In quantum mechanics, there is a natural association between length scales and energy scales. The key conversion factor is:

$$\hbar c = 197\ MeV\ fm = 1.97 \ \ 10^{-7}\ eVm \tag{33}$$

where $1\ fm = \ 10^{-15}\ m$.

Thus:

$$1\ m = \ \hbar c(5.08 \ \ 10^{-6}\ eV^{-1}) \tag{34}$$

Using this conversion factor, we can write,

(35)

$$\rho_{vac}c^2 = \frac{3.32\ 10^9\, eV}{(\hbar c)^3\ (5.08\ 10^{-6})^3} = \frac{(2.24\ 10^{-3}\ eV\ )^4}{(\hbar c)^3}$$

Given our lack of knowledge of the fundamental theory above the Planck energy scale, a reasonable first guess would be to cut off the vacuum energy sum at the Planck scale. Thus, the "prediction" of quantum mechanics is that the energy density of the vacuum due to vacuum fluctuations should be roughly given by:

$$\rho_{vac}^{QM}\, c^2 \sim \frac{M_{PL}c^2}{L_{PL}^3} = \left(\frac{\hbar c^5}{G}\right)^{\frac{1}{2}} \left(\frac{c^3}{\hbar G}\right) c^2 = \left(\frac{\hbar c^5}{G}\right)^2 \frac{1}{(\hbar c)^3} = \frac{(M_{PL}c^2)^4}{(\hbar c)^3} \tag{36}$$

Putting in the numbers,

$$\rho_{vac}^{QM}\, c^2 \sim \frac{(1.22\ 10^{19}\, GeV\ )^4}{(\hbar c)^3} = \frac{(1.22\ 10^{28}\, eV\ )^4}{(\hbar c)^3} \tag{37}$$

Thus, the quantum mechanical prediction for the vacuum energy is given by (37). How good is this prediction? Let us compare this to the observed vacuum energy given in (35):

$$\frac{\rho_{vac}c^2}{\rho_{vac}^{QM}c^2} = \left(\frac{2.24\ 10^{-3}}{1.22\ 10^{28}}\right)^4 = 1.13\ 10^{-123} \tag{38}$$

The observed vacuum energy density is a factor of 10^{123} smaller than its predicted value!
This is by far the worst prediction in the history of physics!! So, how do we fix this?

It is believed that there exists some mechanism that makes Λ small but non-zero.

The order of the obtained result is dictated by the utilization of the Planck mass in the calculation, indeed, with the $M_{PL} = 2.177\text{x}\, 10^{-8}\ kg$ which multiply the value of conversion between kilograms and electron volt:

$1\, kg = 5.60958616721986\ \text{x}\, 10^{35}\, eV$, we obtain:

$$M_{PL} = 5.60958616721986\ \ 10^{35} \times 2.177\ \ 10^{-8} = 1.221297 \times 10^{-28}\ \ eV \tag{39}$$

But if we do the calculation with the replacement of M_{PL} by $M_{bit} = 2.91 \times 10^{-40}\, kg\ at\ T = 2.73\ K$ [2] multiply by the value of conversion, kg to eV:

1kg=5.60958616721986 10^{35} eV, we obtain

$$2.91 \times 10^{-40} \times 5.60958616721986 \times 10^{35} = 0.00016323895\, eV \tag{40}$$

$$\frac{\rho_{vac}c^2}{\rho_{vac}^{QM}c^2} = \left(\frac{2.24 \times 10^{-3}}{1.6323895 \times 10^{-4}}\right)^4 = (13.7222151944)^4 = 3.54565848944 \times 10^4 \tag{41}$$

The cosmological constant requires that empty space takes the role of gravitating negative masses which are distributed all over the interstellar space as first stated by Einstein [38, 39].

By taking account of the mass of the bit of information instead of the Planck mass in the cosmological constant calculation we have reduced the discrepancy of 120 orders of magnitude in the prediction of the vacuum energy from a quantum perspective.

7. Conclusions

In this article, we have computed realistic quantitative estimations of dark matter and dark energy, as informational phenomena, where dark matter is the number of bits of information content of the whole observable universe, associated with a quantifiable and definite negative mass, and, where dark energy is the energy associated to it, by the Landauer's principle, dark energy being computed as negative energy associated to the vacuum energy, moreover, with the same informational approach, we have reduced by almost 120 orders of magnitude the vacuum energy prediction from a quantum point of view.

We argue that dark matter is calculated as informational field, an informational zero-point field, distinct from the conventional fields of matter of quantum field theory, associated with the dark matter as having a finite and quantifiable negative mass associated with the number of bits of the observable universe, from which, according to the Landauer's principle, emerges dark energy. This dark energy computed as the zero-point energy of the vacuum, is explained as a collective potential of all particles with their individual zero-point energy, negative energy, emerging from dark matter.

The negative mass and negative energy associated respectively to dark matter and dark energy comes from the use of the entropic information approach [4], a method that regards the mass of an information bit as definite and measurable [2, 3].

The entropy formula considered to compute the dark matter and dark energy as respectively negative mass and negative energy, can quantify, by the absolute value of its result, the number of bits of information content of the whole observable universe, and express the concept of negative entropy, i.e., negentropy interpreted as "negative" information, a process where quantum states are becoming less entangled or more distinct, leading to a decrease in the overall quantum information content. In terms of bits, this implies that fewer bits are needed to describe the system's state, indicating a movement toward a simpler or more predictable state, or indicating that the system is losing complexity. Negative entropy, i.e., negentropy, interpreted as "negative information", implies that dark matter and dark energy as informational phenomena are less complex or chaotic than previously thought.

The Standard Model already includes negative mass, already builds into the theory, moreover, negative energies and negative energy density are consistent with quantum field theory [37].

The negative mass of the dark matter component interacts with ordinary matter, generating gravitational repulsion between negative and positive masses, this repulsion can then counterbalance the gravitational attraction of visible matter, leading to the observed discrepancies in galactic rotation curves.

While the negative energy, associated here, to the dark energy component, is a concept used to explain the nature of certain fields, including the gravitational field and various quantum field effects, currently, the closest known real representative of such exotic matter is a region of negative pressure density produced by the Casimir effect with a negative localized energy.

One way to envisage the dark energy is that it is linked to the vacuum of space. The larger the volume of space, the more vacuum energy (dark energy) is present and the greater its effects, dark matter (negative mass) calculated as informational field and dark energy (negative energy) computed as vacuum energy increase in function.

Dark Energy is proportional to both the total number of bits and the temperature, and therefore proportional to the volume of the universe as in the volume model, and proportional to the surface of the universe in the holographic model.

The dark energy can be associated to the cosmological constant and the cosmological constant can be formulated to be equivalent to the zero-point radiation of space, i.e., the vacuum energy [7]. The dark energy is associated to the cosmological constant being expressed into the Landauer energy equivalent, which can be defined in a form and value identical to the characteristic energy of the cosmological constant.

The cosmological constant wherein the mass of bit of information has been taken in consideration instead of Planck mass, reducing the discrepancy by almost 120 orders of magnitude in the prediction of the vacuum energy from a quantum point of view, has been computed.

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