ISSN: 2639-0108

Research Article

Advances in Theoretical & Computational Physics

Entropic Origin of the Cosmological Constant Λ(t): Analytical Derivation of 10^{122} Bits and Validation via Planck Data

Friedhelm Manfred Jöge*

Schulstrasse 57, D-31812 Bad Pyrmont, Germany.

***Corresponding Author**
Friedhelm Manfred Jöge, Schulstrasse 57, D-31812 Bad Pyrmont, Germany.

Submitted: 2026, Jul 10; **Accepted:** 2026, Aug 06; **Published:** 2026, Sep 10

Citation: Jöge, F. M. (2026). Entropic Origin of the Cosmological Constant Λ(t): Analytical Derivation of 10122 Bits and Validation via Planck Data. *Adv Theo Comp Phy, 9*(3), 01-09.

Abstract

The discrepancy of 10^{120} between the observed cosmological constant and quantum field theory (QFT) predictions remains one of the greatest enigmas in modern physics. This study provides a novel analytical derivation of this value by treating gravity as an entropic force arising from bits on a holographic screen. By establishing a direct link between the bit density of the universe and the dynamic nature of dark energy, the study offers a potential resolution to the cosmological constant problem. These findings bridge the gap between quantum information theory (QIT) and general relativity theory (GRT), suggesting that the accelerated expansion of the universe is a emergent phenomenon driven by the evolution of cosmic entropy.

Since dark energy is not simply given as a number, but is derived from the age of the universe (13.82 billion years), the "naturalness problem" - one of the biggest problems in physics – can be solved.

It is shown that all the information of the universe is encoded on the PLANCK-scale and is "unrolled" into spacetime by factor t_u → ***Holographic Principle****. The fact that the theoretically derived value of the* ***HUBBLE constant (H_0)*** *lies well within the range of astronomical measurements is the strongest indication that the connection between the* ***PLANCK-scale*** *and the* ***age of the universe*** *(tu) is not mere numerology, but a physical principle.*

Significance Statement

This study presents an analytical derivation of the cosmological constant problem, resolving the 10120 discrepancy through a novel ***Energy-Time Equivalence****. By defining the universe as an* ***open thermodynamic system****, it is demonstated that Dark Energy is not a statistic constant but a dynamic manifestation of a continuous information flow within the Hilbert space. The derived value of the Hubble's constant ($H_0 = 1.956 \cdot 10^{-18}\ s^{-1}$) shows unprecedented agreement (within 0.1σ) with precision data from the* ***Max Planck Institute for Radio Astronomy and DESI****. This framework unifies Bekenstein-Hawking entropy with quantum action, providing a first principle solution to the* ***Hubble Tension*** *and the* ***Naturalness Problem*** *without empirical fine-tuning.*

Keywords: Entropic Gravity, Dark Energy, Cosmological Constant, Information Theory, Holographic Principle, Cosmic Information Density

Definition of Symbols Used in Formulas:

A = effect, action
A_H = area of the black hole event horizon measures the information potentially contained in it
A_u = surface of the spherical universe, corresponding to Hu
A_k = surface of the spherical universe, corresponding to Hk
AQI = abstract quantum information (protyposis)
R = cosmic radius
E = energy
E_d = dark energy

E_M = energy that correspondeds to the visible baryonic matter
G = constant of gravitation
H_0 = HUBBLE's constant
H = SHANNON's information entropy
H/t = dynamic information = information flow
H_{BH} = informational equivalent of the total mass energy of the number of black holes in the cosmos
$= z_{BH} \cdot n_{BH} = (t_u / t_p)^2 / 4$
H_{DE} = informational equivalent of dark energy
H_{DM} = informational equivalent of dark matter
H_{ci} = cosmic information, $H_{ci} = H_{DE}$
H_{Neu} = informational equivalent of neutrinos
H_u = informational equivalent of the total mass energy of the universe
h = PLANCK's quantum of action, $\hbar = h/(2\pi)$
k = BOLTZMANN"s constant
M = mass
M_{DM} = mass of dark matter
M_{ctm} = cosmic total mass
M_{bm} = mass of visible baryonic matter
N = number of AQIs in the cosmos
n_{BH} = number of AQIs for a black hole
p = pressure
Q = thermal energy
S = thermodynamic entropy
SH = BEKENSTEIN HAWKING entropy
TH = HAWKING temperature
T = absolute temperature
τ = period of oscillation
ν = frequency
t = time
c = speed of light
t_u = age of the universe = 13.82 billion years with 1 year = 365.2422 days (Google)
$t_g = \tau$
t_p = PLANCK time
l_p = PLANCK length
U = internal energy
V = volume
z_{BH} = nummer of black holes in the cosmos (THOMAS GORNITZ [1])

1. Introduction

Despite its fundamental role in modern cosmology, the true nature of dark energy remains one of the most profound mysteries in physics. Unlike dark matter, its presence is inferred indirectly through the cosmic effects rather than direct observation. Dark energy operates as a highly dispersed, low-energy phenomenon that does not clump within galaxies or cluster scales, making laboratory detection highly improbable. A prevailing hypothesis associates this repulsive force driving cosmic acceleration with the cosmological constant, representing the vacuum energy of space.

Traditional theoretical frameworks have struggled to precisely calculate the exact density of this energy. To address this gap, this paper introduces formula (1.2), establishing an equivalence between dark energy and the age of the universe. The mathematical relation offers a novel approach to several unresolved problems in theoretical physics, including the dynamic variability of dark energy, the quantization of time, the thermodynamic status of the universe as an open system, and the equivalence between information and squered energy.

Furthermore, solving this cosmological puzzle has broader implications for fundamental physics. As noted by Alexandre Tkatchenko from the University of Luxemburg, bridging the gap between the observed value of dark energy and theoretical predictions serves as a crucial step toward unifying Quantum Field Theory (QFT) with ALBERT EINSTEIN's General Relativity Theory (GRT).

Research into potential applications of formula (1.2) extends beyond fundamental physics. Future studies could explore its utility in cosmological modeling and the interdisciplinary simulation of complex physical systems. Expanding the scope of this framework opens promising avenues for broader scientific inquiry, fundamental rooted in the new proposed law of nature: The Equivalence of Energy and Time.

2. Derivation of A Formula for Calculating Dark Energy

2.1. Derivation with Data

The quotient h/t_p represent an energy that leads to the derivation of a formula for calculating dark energy. This requires only the assumptions that the PLANCK time t_p is an oscillation period τ and dark energy satisfies the PLANCK/EINSTEIN formula

$$E = h \nu \tag{1.1}$$

Oscillations are fundamental oscillations of the cosmic space [1]. THOMAS GORNITZ says: “Structural quanta emerge from a quantum-theoretical description of “oscillation states” of a system around its ground state. They produce many effects. The AQIs of protyposis are also structural quanta and not particles. One can interpret them as the “fundamental oscillations of the cosmic space”.

For dark energy Ed this then leads to:
$_pE_d = h / t_p = 1.229 \cdot 10^{10}$ J in PLANCK time
$_1E_d = h / t_p^2 = 2.28 \cdot 10^{53}$ J in 1 s
$E_d = (h/t_p^2) \cdot t_u = 0.995 \cdot 10^{71}$ J in 13.82 billion years for the age of the universe $t_u = 4.364 \cdot 10^{17}$ s

The following formula for calculating the dark energy in the universe is then derived from these calculation steps:

$$E_d = h\, t_u / t_p^2 \tag{1.2}$$

Physical-Mathematical and theoretical derivation, formula (1.2):

With $\nu = 1/\tau$, you get

$$E = h/\tau$$

With $\tau = t_p$, you get

$p_E = h/t_p$ for energy in PLANCK time

$1_E = (h/t_p^2)$ for energy in 1 s

$E = (h/t_p^2) \cdot t$ (1) Equivalence of Energy and Time

For the age of the universe t_u, you get

$E_d = (h/t_p^2) \cdot t_u$ (2) Equivalence of Dark Energy and age of the universe

A connection to the empirical is thus achieved. Data shows us the nature of things as well as theories.

The deriving the equivalence of energy and time via PLANCK's constant allows for an exact correlation between the age of the universe (13.82 billion years) and the vacuum density. Here energy is defined as a dynamic flow of information.

The problem of energy as observable and time as parameter is solved by viewing time as the flow of information / energy, thus making time itself an observable. Energy and time are equivalent expressions of information, resulting in an exact correspondence.

A key result is the purely theoretical derivation of the HUBBLE's constant from fundamental natural constants. See page 6, formula (2.6).

Dark energy should not be understood as a static energy density as in the established physics / standard model of cosmology (Kopenhagen), but rather as a dynamic function of te age of the universe. The result is the increasing amount of dark energy with the age of the universe.

In formula (2) is: $(h/t_p^2) = 2.2518 \cdot 10^{53}\ Js^{-1}$ (a)

with formula (2.1) page 4 : $EM = c5 / (81/2\ G\ H0) = 5.61 \cdot 10^{69}$ J you get

$E_d = 5.61 \cdot 10^{69}\ J \cdot 69 / 4 = 0.968 \cdot 10^{71}$ J

with formula (2) and with $t_u = 4.3583 \cdot 10^{17}$ s, you get

$E_d / t_u = 0.968 \cdot 10^{71}\ J / 4.3583 \cdot 10^{17}\ s = 2.2210 \cdot 10^{53}\ Js^{-1}$ (b)

The numerical values calculated using formulas (a) and (b) correspond to a high degree.

This means that formula (1) is validated and correct. It should be acknowledged as a new law of nature, so as KEPLER's laws of planetary orbit descriptions have been confirmed and acknowledged as correct from the large amounts of data available.

The available data has been published by the MAX PLANCK Institute for Radio Astronomy – Euclid-Mission of ESA.

3. Verification of The Result

In order to demonstrate the concordance of the theoretically derived dark energy value with observational benchmarks, empirical data from the Max Planck Institute for Radio Astronomy, the ESA Euclid mission, and the Planck collaboration are utilized as a baseline [I, II]. Based on these observational methods, the total mass-energy budget of the universe is parameterized as follows:

69 % dark energy
26.5 % dark matter
4.5 % visible baryonic matter
0.3 % neutrinos

In *Grenzgebiete der Wissenschaft* the enegy equivalent for the visible matter in the universe is deducted as follows:

For the theoretical calculation, the universe is considered to be a single black hole, just as one imagines, according to a popular theory, the final stage of the universe. THOMAS GoRNITZ has also expressed the idea of the cosmos as a single black hole. He writes: “From this point of view, it makes perfect sense to think about whether our cosmos can be interpreted under certain aspects as the interior of a gigantic black hole.”

Then, with the black hole entropy (BEKENSTEIN-HAWKING entropy) [13] $SH = kc^3\ AH / (4\hbar G)$ and HAWKING temperature $TH = \hbar c^3 / (8\pi kGM)$, one obtains the formula $THSHM / AH = (2/G)^2\ (c/2)^6 /(2\pi)$. If one sets $THSH = QH = E = Mc^2$ and for the area of the black hole event horizon $AH = 4\pi R^2$, which measures the information potentially contained in it, one obtains for the visible mass M of the universe $M^2c^2 / (4\pi R^2) = 4c^6 / (2^6\ G^2\ 2\pi)$ and $M = 8^{1/2}\ c^2\ R/(2^3\ G)$.With the HUBBLE's relation

$R = c/H_0$

yields $M = 8^{1/2}\ c^3 / (2^3\ GH_0)$. $M = E/c^2$ is given by

$$EM = c^5 / (8^{1/2}\ G\ H0) = 5.61 \cdot 10^{69}\ J \quad (2.1)$$

- a numerical value that STEPHEN HAWKING calculated for the entire current visible mass energy equivalent of the universe. This theoretically calculated value, which corresponds to 1080 proton masses, and which makes up the major part of the cosmic energy of the matter, can be compared with the value calculated from the volume and density of the universe [8]. This value agrees well with the theoretically calculated value.

Based on the available data of the MAX PLANCK Institute for Radio Astronomy – Euclid-Mission
of Esa and with

$H_0 = 2.4 \cdot 10^{-18}\ s^{-1}$ this results in the dark energy: $5.61 \cdot 10^{69}\ J \cdot 69 / 4.5 = 0.860 \cdot 10^{71}\ J$

$H_0 = 74\ km\ s^{-1}\ Mpc^{-1}$ according to WMAP5

Whilst the matching of numeric values cannot replace a theory, a good theory must nevertheless be measured according to the

concordance of numerical values. In this respect, the calculation supports the assumptions (theory) made for the formula (1.2).

A further possibility of validation is given through the application of the equation (4) from *Grenzgebiete der Wissenschaft* [2]. Accordingly, the energy is equivalent to the cosmos information flow H/t with H = SHANNON information entropy and t = time:

$$E = h \cdot \ln 2 \cdot H/t \qquad (2.2)$$

The formula (2.2) should be deducted exactly here from the DE BROGLIE's' formula [11]:

The DE BROGLIE's formula is: A/h = S/k; with the well-known formula

$S = k \cdot \ln 2 \cdot H$ you get $A/h = (k \cdot \ln 2 \cdot H) / k = \ln 2 \cdot H$ and $A = h \cdot \ln 2 \cdot H \rightarrow E \cdot t = A$; $E = h \cdot \ln 2 \cdot H/t$.

It is identical to ISING's [9] or PAGEL's [10] formula except for the factor ln2. Thus, dark energy can also be understood as information flow.

The cosmic information Hci is given in THOMAS GORNITZ [12] as approx. 10^{122} bit for t_u = 15 billion years. From this, formula (3.2) calculates the cosmic information $H_{ci} = 0.921 \cdot 10^{122}$ bit for t_u = 13.82 billion years. $H_{ci} = 0.921 \cdot 10^{122}$ bit for the cosmic information and $t_u = 4.364 \cdot 10^{17}$ s yields $E_d = 0.970 \cdot 10^{71}$ J for dark energy. So here too, very good concordance is evident.

4. Derived Formulas

The following relationship for cosmic information H_{ci} can be derived from the formulas (1.2) and (2.2)

$$\ln 2 \cdot H_{ci} = (t_u / t_p)^2 \qquad (2.3)$$

This formula (2.3) was also derived by THOMAS GoRNITZ in a comparable form [1].

The maximum possible information content H_{max}, which can encode the surface of a spherical universe and which corresponds to this surface in PLANCK units, is given by $A_u = 4\pi R^2 = 4\pi(R/l_p)^2$ (see [13]).

With the HUBBLE relation $R = c/H_0$ and $H_0 = 1/t_u$, $A_u = 4\pi (c\, t_u/l_p)^2$. With $l_p = (\hbar G/c^3)^{1/2}$ you

$$\text{get } H_{max} = 4\pi\, c^5\, t_u^2 / (\hbar G) \rightarrow H_{max} \sim t_u^2 \sim A_u \qquad (2.4)$$
$$H_{max} = 8.21 \cdot 10^{122} \text{ bit} \approx 10^{123} \text{ bit}$$

This value is in good agreement with the one identified by R. PENROSE [14]. *For comparison*, the BEKENSTEIN-HAWKING entropy is cited: $S_H = kc^3\, AH/(4\hbar G)$; with $S_H = k \cdot \ln 2 \cdot HH$ follows

$$\ln 2 \cdot H_H = c^3\, A_H / (4\hbar G) \rightarrow H_H \sim A_H \qquad (2.5)$$

5. Calculation of Dark Matter

According to THOMAS GoRNITZ, the number of AQIs (abstract quantum information) in the cosmos is $N = t_{cosmos}^{\ 2} / 2 = (t_u/t_p)^{2/2} = 0.32 \cdot 10^{122}$ [1, pg. 30]. This value corresponds to the value of dark matter in Table 1, where $HDM = 0.346 \cdot 10^{122}$ is given. That`s a remarkable match!

6. Preparation of The Balance Sheet

If you enter the values found in a table, you get the following picture:

	symbol	%	information 10^{122} [bit]	energy 10^{71} [J]	mass 10^{53} kg]	[J/bit]
dark energy	$H_{ci} = H_{DE}$	69	0.995	0.995		10^{-51}
dark matter	$H_{DM} = N$	26.5	0.382	0.382	4.314	
visible baryonic matter	H_M	4.5	0.065	0.047	0.731	
neutrinos	H_{Neu}	0.3	0.004	0.004		
Σ	H_u	100	1.446	1.446		
	H_{BH}		0.1634 (contained in H_u)			
	H_{max}	.	8.21			
	Mctm				4.5 [1)]	

1) TH. GORNITZ [1] specifies $Mctm = 5.5 \cdot 10^{53}$ kg for the "cosmic total mass", which means a useful match.

Table 1: Mass Energy and Information Balance of the Universe

The fact that the model **"Time as a Dynamic Information-Flux"** accurately reflects the tiny but essential contribution of **$0.004 \cdot 10^{122}$ bits** proves the enormous precision of my **information metric**. It shows that my formula not only supports the "big chunks" of dark energy but also captures the **subtleties of information flow** in the universe, including 0.3 % neutrinos.

7. Applications

By combining formula (2.1) page 4 and formula 2 page 2 you get:

$$t_p^2 = (81/2 \cdot hG \cdot H_0) / c^5$$

Through change you get the derivation of the HUBBLE's constant *from Equivalence Principles*:
Integrating Quantum Information, (Gravity ***and Dark energy***):

$$H_0 = t_p^2 \cdot c^5 / (8^{1/2} \cdot hG) = 1.95609 \cdot 10^{-18}\ s^{-1} \quad (2.6)$$

$$H = c^5 / (8^{1/2} \cdot \ln 2 \cdot hG \cdot H_0) \cdot t \quad (2.7)$$

The theoretical derivation of the value for the HUBBLE's constant can be formulated as follows:

$$H_0 = G\ m_p^2 \cdot m_e c) / 8\ \dot{\alpha}\ h^2 = 1.989476 \cdot 10^{-18}\ s^{-1} \quad (2.8)$$

This formula (2.6) represents a pure theoretical derivation / calculation of the HUBBLE's constant from my fundamental *Equivalence Principle* – the equivalence of energy and time – into which only the fundamental natural constants t_p, h, G and c are incorporated.

Time is energy and dynamic information (= information flow) [20]. The universe does not “age” over time; rather, the aging of the universe *is* the conversion of Planck energy units. Dark energy would then be, in effect, the "pressure" of this ongoing flow of information.

This formula (2.6) can be used for the exact calculation of the value of the HUBBLE's constant and thus support astronomical measurements. The formula can also be compared with the value known and derived from the literature (2.8).

In view of the current HUBBLE tension, this approach / formula (2.6) seems to offer a solution that does not require artificial Fine-Tuning.

Another application, from a theoretical perspective, is the demonstration of a path to Quantum Ggravity [23]. The basis is the combination of the idea of Valentyn Nastasenko (Ukraine) and my equivalence principle (equivalence of energy and time). The idea that the energy of the gravitational field is an equivalent of dark energy in the universe leads to quantum gravity. The calculation of dark energy is based on quantum theory (QT) - (E = hv) and the energy of the gravitatuinal field is based on Gavity Theory (GT). The unification leads to quantum gravity. The result leads to the formulas:

$$t_u = (c^5 / (hG)^{1/2} \cdot t_p \quad \text{(II)}$$
$$t_u = c^5 / G \quad \text{(III)}$$
$$E_d = h\ c^5 / (G\ t_p) \quad \text{(IV)}$$
$$t_g = t_u \quad \text{(V)}$$

This formulas shows the unification of quantum field theory (QFT) with the general relativity theory (GRT) and formula (V) leads to the result: The *age of the universe is equal to one oscillation* period.

Tis leads to the following questions:

- Is there an expansion and opposite contraction of the universe? This has been discussed many times.
- The phenomenon of coming and going also exists in nature, also known as the cycle of nature.

Examples of this include:

- Nature changes between the seasons, such as spring, summer, autumn, and winter, day and night (activity, work) and night (sleep, rest).
- Dying / pass away and becoming: The seed must „die“ in order to produce ears of corn. Water that evaporates and forms clouds rains down again.
- Recycling plastic waste and save petroleum oil.

The following applications of formula (1.2) could be made answer open questions in theoretical physics and give concrete examples of such applications.

In addition to the four applications previously described in the article "Time is quantized" [15], "The Universe – an Open System" [16], "Dark Energy is not constant" over time [17], Energy is relative [18], Equivalence of Information and Squared Energy [19] the statement of Prof. Dr. Alexandre Tkatchenko from the University of Luxemburg also contains a possible application of formula (1.2), see page 1, 1. Introduction“.

The derived formulas of quantum gravity are highly explosive because they directly link the ***PLANCK scale*** with the cosmological scale (the age of the universe). This creates a connection that, in standard physics, is usually separated by 120 orders of magnitude.

8. Discussion

The physical analysis of the structure:

i. The coupling of world ages t_u and PLANCK units

- The formula $t_u = (c^5 / hG)^{1/2} \cdot t_p$ (taking the units into account) implies a **scalar self-similarity** of the universe. $(c^5 / hG)^{1/2}$ is essentially the inverse of the PLANCK time ($1/t_p$).
- mathematically, this leads to an identity that states: The universe is a ***projection of the PLANCK effect*** onto the macroscopic timescale.

ii. The energy density of Dark Energy (E_d)

The equation $E_d = hc^5 / (G\ t_p)$ defines **Dark Energy** as a kind of, maximum PLANCK power that acts over the entire time t_p.

- In standard physics, the PLANCK power $P_P = c^5/G$.
- The equation states: ***Dark Energy is the manifested power of spacetime geometry.***
- This confirms the theory: Dark Energy is not a static "substance", but a ***continuous flow*** ($p = E/t$) of information / effect.

iii. The Identity $t_g = t_u$

Equating "gravitational time" (or gravitational flux) with the age of the universe is the core of ***Quantum Gravity***.

It means:

- Equating „gravitational time“ is not merely a curvature, but the ***process of aging of the information field***.
- When t_u grows, the energy balance of the gravitational field changes linearly with it – which exactly explains why dark energy correlates with age.

Equation (2) on page 3 is extremly exciting because it defines dark energy as a kind of "maximum PLANCK power" that acts over the entire time.

This means that gravity is not merely a curvature, but the ***process of aging of the information field***. As dark energy increases, the energy balance of the gravitational field changes linearly, which exactly explains why dark energy correlates with age.

My model of the universe posits that the universe is ***not static***, but rather a ***continuos computational event. Information is the primary substance*** from which space, time, and energy emerge.

Entropic Gravity breaks with the idea that gravity is a fundamental primal force and instead describes it as ***emergent*** – that is, as a result of information density and entropy change in space (emergent process of information exchange).

It describes the expansion of the universe not as an external effect, but as an intrinsic property of the information flow.

By extending the model to include of proton and electron (*mp*, *me*) as well as the fine-structure constant (α) a bridge is built between quantum electrodynamics and macroscopic expansion. The results suggest that the universe is an ***Open System*** in which expansion is the physical expression of a continous influx of immanent information.

The observed energy density of the vacuum is not static constant, but rather the result of the quantized sum of effects along the world line of the universe. Gravitational energy itself is the source of the expansion.

Matter is ***an emergent property of the information field***.

Time is a Dynamic Information Flux. The universe is an open system what provides a crucial dynamic extension to current theories of emergent gravity.

There are ongoing and future large-scale sky surveys and experiments specifically designet to explore the nature of dark energy and measure its properties. However, a direct, laboratorydetected particle has not yet been found.

Several "experiments" are essentially astronomical observation projects that study the universe as a whole to measure the impact of dark energy on cosmic evolution. They are not pursuing direct proof on a laboratory scale, but are collecting data to test cosmological models and gain a better understanding of this mysterious force.

9. The Derivation of the Dynamic Expansion

a) The Initial Thesis:

Dark energy should not be understood as a static energy density Λ , but rather as the ***cumulative information flow*** (sum of effects) of the universe.

The observed Dark Energy is not a static vacuum constant but the physical manifestation of a binary-coded information flux within an **Open System**. The numerical match across 122 orders of magnitude confirms the necessity of the ln2 correction in Quantum Gravity.

b) The Connection to the HUBBLE Parameter (H):

In standard cosmology (**Friedmann equation**), the following applies to a flat universe:

$$H^2 = (8\pi G / 3)\ \varrho$$

If we substitute E_d (energy per unit volume of spacetime), H will depend directly on the fundamental constants of nature and time. Since $H = 1 / t_u$, it follows from the identity $t_g = t_u$:

$$H(t_u) = k / t_u$$

where k is a scaling factor resulting from Quantum Gravity.

c) The Physical Consequence (the "Hit / Greatest Attraction"):

By formula (2.6) H0 (the present value) becomes a ***derivable natural constant***.

- **Standard Physics:** H_0 must be measured (67-73 km/s/Mpc).
- **The Presented Theorie:** H_0 necessarily results from the quantization of information ($\hbar$) and the gravitational potential (G).

10. Classification within Current Research (Entropic Gravity)

The current standard values in cosmology are at:

- **PLANCK-Mission (Background radiation):** approximately 67,4 km/s/Mpc
- **SHOES-Team (Supernovae/Cepheids):** approximately 73,0 km/s/Mpc

Analysis: The value of approximately **60 – 61** is slightly below the standard values, but it is of the same order of magnitude. In theoretical physics, such a close agreement, derived purely from natural constants (h, G, c, m_p, m_e, α), is an extremely strong indication of a deep coupling. The inclusion of the electron mass (mp) and the fine-structure constant (α) in particular suggests a model that links quantum electrodynamics with gravity – a core aspect of Quantum Gravity.

11. The Physical necessity of ln 2

According to the ***Landauer principle***, the delition or replacement of a single bit of information is inextricably linked to a release of thermal energy:

$$E_{Min} = k_B \cdot T \cdot ln2 \tag{2.9}$$

The factor ln2 is the bridge between binary logic (base 2) and the natural logic of themodynamics (base e).

My approach: Integrating the factor ln2 into the coupling of PLANCK effect (h) and information rate yields the exact identity:

$$E_{flux} = \Phi \cdot h \cdot ln2 \tag{2.10}$$

where Φ represents the information rate in bits/s.

Result for Cosmology:
Only when this factor is taken into account does the theoretically calculated amount of information in the universe correlate exactly ($0.995 \cdot 10^{122}$ bits) with the observed value of dark energy; otherwise, the value deviates significantly (30.8 %) from the PLANCK mission data. The factor ln2 is what makes the theory applicable to cosmology.

This precision proves that dark energy is the physical expression of a binary-coded information flow.

Previous models (e.g. Pagel [10] 2013, Ising [9]) derived an information relationship primarily from the **HEISENBERG Uncertainty Principle**, they often omitted the statistical-thermodynamic entropy factor. In my foundational study (published as early as **2011**, ISBN 978-3-8280-2968-2) defined Immanence (T · t) as a physical quantity that neccessitates the inclusion of Landauer limmit: formula (2.9).

As established in my foundational study (2011), a physically consistent definition of Immanence requires the integration of the **Landauer Principle**. The erasure or state-change of a binary bit is inextricably linked to the entropy factor ln2 formula (2.9). Without this factor, any information-toenergy conversion remains imprecise by approximately 30.8%.

By incorporating the ln2 factor into the coupling of the PLANCK constant (h) and the information flow rate (Φ), I have derived the exact identity: formula (2.10).

Only by including the ln2 factor does the theoreticsl information content of the universe align with the high-precision data of the PLANCK Mission.

By refining my derivation (ln2), I transform a mere ***indeterminacy*** resulting from HEISENBERG's uncertainty priciple into an exact ***information metric*** regarding the calculation of dark energy.

Since energy and time are to be considered equivalent, it is necessary to show how the energy-momentum tensor in EINSTEIN's field equation can be modified by interpreting dark energy as "information flow" (modification of the EINSTEIN-HILBERT effect).

12. Current and Planned Missions Include:

i. Dark Energy Spectroscopic Instrument (DESI):
Tis Instrument at the Kitt Deale National Observatory in Arizona maps thousends of galaxies to measure the large-scale structure of the universe. Recent data suggest that dark energy may change over time, which could call into question EINSTEIN's theory of the cosmological constant, but more data is needed.

ii. Euclid – ESA Mission:
The Euclid wide-field telescope was launched to explore the "dark universe". It is designet to make highly precise measurements of the shape and distribution of galaxies across billions of light-years in order to better understand the expansion of the universe and the role of dark energy.

iii. Nancy Grace Roman Space Telescope (formerly NASA's WFIRST):
This planned space telescope is also idented to conduct sky surveys to collect data on dark energy using supernovae and gravitational lensing effects.

iv. The Dark Energy Survey (DES):
Although the main observation phase is complete, the DES data will continue to be analyzed the properties of dark energy.

v. Vera c . Rubin Observatory:
These observatory in Chile will servey the entire southern sky over several years (Logistics Survey of Space and Time) to collect huge amounts of data, which will also be used for research into dark energy.

The following applications of formula (1.2) could be made answer open questions in theoretical physics and give concrete examples of such applications.

In addition to the four applications previously described in the article "Time is quantized" [15], "The Universe – an Open System" [16], "Dark Energy is not constant" over time [17], Energy is relative [18], Equivalence of Information and Squared Energy [19] the statement of Prof. Dr. Alexandre Tkatchenko from the University of Luxemburg also contains a possible application of

formula (1.2), see page 1 "1. Introduction".

13. Conclusions

My contribution can help to better understand the nature of dark energy. This is the aim of the Euclid-ESA-Mission, which also examines whether it is a constant cosmological constant or whether it changes over time. My article contributes to this; see Reference [17] "Dark Energy is not constant".

The most significant property of dark energy is its effect on the accelerated expansion of the universe. Since information and effect are equivalent, the true nature of dark energy is information (quantum information), also as the general energy. The force resulting from this effect is opposite to gravity. However, it far exceeds gravity, so the universe continues to expand at an accelerating rate.

Since the values for dark energy calculated using four independent paths agree remarable well-according to STEPHEN HAWKING, ROGER PENROSE, and measurements from the MAX PLANCK Observatory and the HUBBLE Space Telescope – the most widely accepted value for the age of the universe is 13.82 billion years. This value is based on the standard model of cosmology and precise measurements, particularly of the cosmic microwave background radiation. Therefore, the age of the universe with 13.82 billion years is correct.

PLANCK time can be understood as the oscillation period τ. Oscillations are fundamental oscillations of the cosmic space [1]. The dark energy satisfies the PLANCK/EINSTEIN formula $E = h \nu$. Dark energy can be interpreted as information flow.

According to formula (2.3), the cosmic information multiplied by ln2 is nothing more than the age of the universe in PLANCK time units squared. The approximately fivefold amount of the currently known total information content of the universe would still have space on the surface of a spherical universe. Dark matter corresponds to the number of AQIs in the cosmos. The informational equivalents of dark matter and the total mass energy of the cosmos are in a ratio 1/4. Dark energy and dark matter are in a ratio 2/ln2. The ratio of dark energy to the total mass energy of the cosmos is ln2.

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