

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

Advances in Exploration of the Dark Universe
(Dark Energy & Dark Matter)

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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 $t_u \rightarrow$ **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* (t_u) is not mere numerology, but a physical principle.

Keywords

Entropic Gravity, Dark energy, Cosmological Constant, Information Theory, Holographic Principle, Cosmic Information Density

Statements

Data Availability

The astronomical datasets analyzed during the current study are public available from the Max Planck Institute for Radio Astronomy. All other data generated and analyzed, including the mathematical derivations, are fully included within this published article.

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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 squared 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

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, pg.15]. THOMAS GÖRNITZ 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 E_d this then leads to:

$${}_pE_d = h / t_p = 1.229 \cdot 10^{10} \text{ J in PLANCK time}$$

$${}_1E_d = h / t_p^2 = 2.28 \cdot 10^{53} \text{ J in 1 s}$$

$$E_d = (h/t_p^2) \cdot t_u = 0.995 \cdot 10^{71} \text{ J in 13.82 billion years for the age of the universe } t_u = 4.364 \cdot 10^{17} \text{ s}$$

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 of formula (1.2):

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

$$E = h/\tau$$

With $\tau = t_p$, you get

$${}_pE = h/t_p \quad \text{for energy in PLANCK time}$$

$${}_1E = (h/t_p^2) \quad \text{for energy in 1 s}$$

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

For the age of the universe t_u , you get

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

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 the age of the universe. The result is the increasing amount of dark energy with the age of the universe.

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

with formula (2.1) page 4 : $E_M = c^5 / (8^{1/2} G H_0) = 5.61 \cdot 10^{69} \text{ J}$
you get

$$E_d = 5.61 \cdot 10^{69} \text{ J} \cdot 69 / 4.5 = 0.860 \cdot 10^{71} \text{ J}$$

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

$$E_d / t_u = 0.9814 \cdot 10^{71} \text{ J} / 4.3583 \cdot 10^{17} \text{ s} = .22520 \cdot 10^{53} \text{ Js}^{-1} \quad (b)$$

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* [2, pg. 218] the energy 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 GÖRNITZ has also expressed the idea of the cosmos as a single black hole [1, pg.30 at the end of 7.2]. 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] $S_H = kc^3 A_H / (4\hbar G)$ and HAWKING temperature $T_H = \hbar c^3 / (8\pi kGM)$, one obtains the formula $T_H S_H M / A_H = (2/G)^2 (c/2)^6 / (2\pi)$. If one sets

$T_H S_H = Q_H = E = Mc^2$ and for the area of the black hole event horizon $A_H = 4\pi R^2$, which measures the information potentially contained in it, one obtains for the visible mass M of the universe $M^2 c^2 / (4\pi R^2) = 4c^6 / (2^6 G^2 2\pi)$ 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

$$E_M = c^5 / (8^{1/2} G H_0) = 5.61 \cdot 10^{69} \text{ J} \quad (2.1)$$

- a numerical value that STEPHEN HAWKING calculated for the entire current visible mass energy equivalent of the universe [7, pg.1355]. This theoretically calculated value, which corresponds to 10^{80} 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

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

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

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, pg. 226]. Accordingly, the energy is equivalent to the

information flow H/t with $H = S_{\text{SHANNON}}$ information entropy and $t = \text{time}$:

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

The formula (2.2) should be deduced 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 $\ln 2$. Thus, dark energy can also be understood as information flow.

The cosmic information H_{ci} is given in THOMAS GÖRNITZ [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 $t_u = 4.3583 \cdot 10^{17}$ s yields $E_d = 0.928 \cdot 10^{71}$ 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)

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

This formula (2.3) was also derived by THOMAS GÖRNITZ in a comparable form [1, pg. 30].

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

$$\text{get } H_{\text{max}} = 4\pi c^5 t_u^2 / (hG) \rightarrow H_{\text{max}} \sim t_u^2 \sim A_u \quad (2.4)$$

$$H_{\text{max}} = 8.21 \cdot 10^{122} \text{ bit} \approx 10^{123} \text{ bit}$$

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

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

5. Calculation of dark matter

According to THOMAS GÖRNITZ, the number of AQIs (abstract quantum information) in the cosmos is $N = t_{\text{cosmos}}^2 / 2 = (t_u/t_p)^2 / 2 = 0.32 \cdot 10^{122}$ [1, pg. 30]. This value corresponds to the value of dark matter in Table 1, where $H_{DM} = 0.382 \cdot 10^{122}$ 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:

Table 1: Mass energy and information balance of the universe

	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			
	M _{ctm}				4.5 ¹⁾	

1) TH. GÖRNITZ [1, pg.31] specifies M_{ctm} = 5.5 · 10⁵³ kg for the “cosmic total mass”, which means a useful match.

The fact that the model „**Time as a Dynamic Information-Flux**“ accurately reflects the tiny but essential contribution of **0.004 · 10¹²² 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:

$$t_p^2 = (8^{1/2} \cdot hG \cdot H_0) / c^5$$

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

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

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

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

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

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 Gravity [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) - ($E = h\nu$) and the energy of the gravitational field is based on Gravity 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.*

This 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:

1. 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.

2. 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.

3. 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 extremely exciting because it defines dark energy as a kind of „maximum PLANCK power“ that acts over the entire time.

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 **continuous 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 (m_p , m_e) 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 continuous 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 designed to explore the nature of dark energy and measure its properties. However, a direct, laboratory-detected 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.

4. 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 $\ln 2$ correction in Quantum Gravity.

a) The connection to the HUBBLE parameter (H):

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

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

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.

b) The physical consequence (the „hit / greatest attraction“):

By formula (2.6) H_0 (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 (h) and the gravitational potential (G).

5. 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 ($h, G, c, m_p, m_e, \alpha$), is an extremely strong indication of a deep coupling. The inclusion of the electron mass (m_p) and the fine-structure constant (α) in particular suggests a model that links quantum electrodynamics with gravity – a core aspect of Quantum Gravity.

6. The Physical necessity of $\ln 2$

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

$$E_{min} = k_B \cdot T \cdot \ln 2 \quad (2.9)$$

The factor $\ln 2$ is the bridge between binary logic (base 2) and the natural logic of thermodynamics (base e).

My approach: Integrating the factor $\ln 2$ into the coupling of PLANCK effect (h) and information rate yields the exact identity:

$$E_{flux} = \Phi \cdot h \cdot \ln 2 \quad (2.10)$$

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 $\ln 2$ 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 ($T \cdot t$) as a physical quantity that necessitates the inclusion of Landauer limit: 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 $\ln 2$ formula (2.9). Without this factor, any information-to-energy conversion remains imprecise by approximately 30.8%.

By incorporating the $\ln 2$ 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 $\ln 2$ factor does the theoretical 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 principle 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).

Current and planned missions include:

Dark Energy Spectroscopic Instrument (DESI):

This Instrument at the Kitt Peak National Observatory in Arizona maps thousands 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.

Euclid – ESA Mission:

The Euclid wide-field telescope was launched to explore the „dark universe“. It is designed 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.

Nancy Grace Roman Space Telescope (formerly NASA's WFIRST):

This planned space telescope is also intended to conduct sky surveys to collect data on dark energy using supernovae and gravitational lensing effects.

The Dark Energy Survey (DES):

Although the main observation phase is complete, the DES data will continue to be analyzed for the properties of dark energy.

Vera c. Rubin Observatory:

This observatory in Chile will survey the entire southern sky over several years (Legacy 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 to answer open questions in theoretical physics and give concrete examples of such applications.

In addition to the five 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“.

8. 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 remarkably 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, pg. 15]. 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 $\ln 2$ 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 $2/\ln 2$. The ratio of dark energy to the total mass energy of the cosmos is $\ln 2$.

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 H_u

A_k = surface of the spherical universe, corresponding to H_k

AQI = abstract quantum information (prototyposis)

R = cosmic radius

E = energy

E_d = dark energy

E_M = energy that corresponds 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
 S_H = BEKENSTEIN HAWKING entropy
 T_H = 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 GÖRNITZ [1])

References

- [1] GÖRNITZ, TH.: Quantum cosmology <https://vixra.org/pdf/1701.0544v1.pdf>
- [2] JÖGE, F.: Information und Wirkung. Zur Einführung des Immanenzbegriffs als physikalische Größe. *Grenzgebiete der Wissenschaft (GW)* 64 (2015) 3, 215-228.
- [3] Jöge, F.M.: Information und Wirkung Beitrag zur Einführung des Immanenzbegriffs als physikalische Größe. Eine naturwissenschaftlich-philosophische und erkenntnistheoretische Betrachtung. © Frieling-Verlag Berlin, 1. Auflage 2011, ISBN 978-3-8280-2968-2
- [4] Jöge, F.M.: Information and Effect: An Introduction to the Concept of Immanence as a Physical Quantity. *Scientific God Journal*, Volume 9, Issue 8, pp.598-613
- [5] Jöge, F.M.: Equivalence of Information and Immanence. *International Journal of Physics and Astronomy*, December 2020, Volume 8, No. 2, pp.1-2
- [6] Jöge, F.M.: Equivalence of Information and Effect. *European Journal of Applied Sciences*, 25-February 2024, Volume 12, No. 1, pp.234-243
- [7] EIGEN, M.: Von der Entropie zur Information-die physikalische Chemie der belebten Materie. Bunsentagung Berlin. *Ber. Bunsenges. Phys. Chem.* (1994) 11, 1351-1364.
- [8] TIPLER, P.A. / LLEWELLYN, R.A.: *Moderne Physik*. München / Wien: Oldenbourg Wissenschaftsverlag, 2003.
- [9] ISING, H.: Information and energy <https://dx.doi.org/10.6084/m9.figshare.2115400.v1>
- [10] PAGEL, L.: Information ist Energie. Definition eines physikalisch begründeten Informationsbegriffs. Wiesbaden: Springer Vieweg/ Springer Fachmedien, 2013, pg.27.
- [11] DE BROGLIE, L.: La Thermodynamique de la particule isolée (ou Thermodynamique cachée des particules). Paris: Gauthier-Villars, 1964, p.88/89; ders.: The Reinterpretation of wave mechanics. *Foundations of Physics* 1 (1970) 1, 5-15, pg.10.
- [12] GÖRNITZ, TH.: *Der kreative Kosmos: Geist und Materie aus Information*. Heidelberg/ Berlin: Spektrum, Akademie Verlag, 2002, pg. 388. Wiesbaden: Springer Vieweg/ Springer Fachmedien, 2013, pg.27.
- [13] BEKENSTEIN, J.: Information in the holographic universe. *Sci. Am.* 289 (2) (2003), 58-65.
- [14] PENROSE, R.: *The Emperor's New Mind*. Oxford University Press, 1989, pp. 480.
- [15] JÖGE, F.M.: Time is quantized. *International Journal of Physics and Astronomy*, December 2023, Volume 11, pg. 2
- [16] JÖGE, F.M.: The Universe – an Open System. *International Journal of Physics and Astronomy*, December 2023, Volume 11, pg. 1
- [17] JÖGE, F. M.: Dark Energy is not constant. *Applied Sciences Research Periodicals (ASRP)*, June 2024, Vol. 2, No. 6, pp. 1-2
- [18] JÖGE, F. M.: Energy is relative. *Advances in Theoretical & Computational Physics*, 09-Dec-2024, Volume 7, Issue 4, pg.1
- [19] JÖGE, F. M.: Equivalence of Information and Squared Energy. *Advances in Theoretical & Computational Physics*, 09-Dec-2024, Volume 7, Issue 4, pg. 1
- [20] Jöge, F.M.: Time is Energy and Dynamic Information. *Advances in theoretical & Computational Physics*, Volume 7, Issue 3, pp. 1-2
- [21] Jöge, F.M.: About the Information Contained in Constants. *Advances in Theoretical & Computational Physics*, 27-Mar-2025, Volume 8, Issue 1, pp. 1-2
- [22] Jöge, F.M.: About the Percentage Composition of the Energies of the Universe, Provided by the MAX PLANCK Institute for Radio Astronomy – Exact Calculation of the Value of the HUBBLE's Constant. *Advances in Theoretical & Computational Physics*, 24-Mar-2025, Volume 8, Issue 1, pp. 1-2
- [23] Jöge, F.M.: Quantum Gravity – To Unification of Quantum Field Theory (QFT) and General Relativity Theory (GRT). *Open Access Journal of Physics*, Volume 7, Issue 3, pp. 29-32
- [24] TRIBUS, M.; MC IRVINE, E.C.: Energy and Information. *Sci. Am.* 225 (3) (1971) 179-188.
- [25] SEDLACEK, KL.-D.: *Aquivalenz von Information und Energie*. Norderstedt: Books on Demand GmbH Verlag, 2nd ed. 2010, pg. 40.

I. Planck Collaboration. *Planck 2018 results. VI Cosmological parameters*. Astronomy & Astrophysics 641, A6 (2020).

II. Euclid Collaboration: *Euclid preparation*. [Euclid-ESA-Mission]