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[Stéphane Wojnow](#) \*

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Article

# Adaptation of the Entropic Gravity Formula for a Generalization to Cosmology $R_h=ct$ in Accordance with the Law of Conservation of Energy

Stéphane Wojnow  
Independent Researcher, Limoges, France; wojnow.stephane@gmail.com

Abstract

We found, then we demonstrated an exact heuristic adaptation of the entropic gravity formula with a simple factor for adaptation to the quantum linear thermodynamic cosmology of type  $R_h=ct=c/H$ , which is in the field of classical mechanics, at the apparent horizon universe. This factor, which is a simple change of bits numbers, is imposed by the law of conservation of energy, when is applied to the Hubble volume, as was recently demonstrated. This formula could shed new light on gravitational entropy, refine the standard cosmological model, and bring us closer to a theory of everything that unifies the fields of relativity and quantum mechanics. Next, we propose a precise definition of quantum gravity that complies with the laws of thermodynamics.

**Keywords:** thermodynamics; entropic gravity; cosmology; temperature of CMB; law of conservation of energy; quantum gravity

## 1. Introduction

Einstein said about thermodynamics: "A theory is the more impressive the greater the simplicity of its premises is, the more different kinds of things it relates, and the more extended is its area of applicability. Therefore, the deep impression which classical thermodynamics made upon me. It is the only physical theory of universal content concerning which I am convinced that within the framework of the applicability of its basic concepts, it will never be overthrown." [1]

Entropy is a measure of the disorder or randomness of a system. According to the second law of thermodynamics, the entropy of an isolated system increases over time, or at best remains constant. This law gives time a fundamental direction, often referred to as the 'arrow of time'.

Contemporary cosmology and modern physics take different approaches to entropy. We find that, when adapted to the quantum thermodynamic cosmology of type  $R_h=ct=c/H$  in a heuristic way, Erick Verlinde's entropic gravity [2] is consistent with the law of energy conservation for the Hubble volume. This study complements the work of Fu-Wen Shu and Yungui Gong. [3]

## 2. Background

In 2010, Erick Verlinde proposed his vision of gravity entropic [2]. His gravity entropic formulas derived from the holographic principle are extremely easy and are as follows:

$$N = \frac{A}{l_{Pl}^2} \tag{1}$$

where  $N$  is the number of bits encoded on a surface,  $A$  is the area,  $l_{Pl} = \sqrt{\frac{\hbar G}{c^3}}$  is the Planck length,  $G$  is the gravitational constant and  $c$  the speed light in vacuum.

$$N_{GH} = \frac{A c^3}{\hbar G} \tag{2}$$

Gravity Holographic energy,  $E_{GH}$ , is expressed as follows:

$$E_{GH} = \frac{1}{2} N k_B T \quad (3)$$

In 2015, Tatum et al. [4] proposed an equation for the CMB temperature, noted  $T_{cmb}$ , that has since been formally derived from the Stefan-Boltzmann law by Haug and Wojnow [5,6]

$$T_{cmb} = T_{Rh} = \frac{\hbar c}{4\pi k_b \sqrt{R_h} 2 l_{Pl}} K \quad (4)$$

where  $T_{Rh} = T_{cmb}$  is the temperature of Hubble sphere.

This can be derived as follows:

$$Rh = \frac{\hbar^2 c^2}{16\pi^2 k_b^2 T_{cmb}^2 2 l_{Pl}} m \quad (5)$$

This can also be derived as follows:

$$l_{Pl} = \frac{\hbar^2 c^2}{16\pi^2 k_b^2 T_{cmb}^2 2 Rh} m \quad (6)$$

where  $k_b$  is Boltzmann's constant, the Hubble radius is defined by  $R_h = \frac{c}{H} = c t_{Rh}$ , where  $H$  is the Hubble parameter and  $t_{Rh}$  the Hubble time,

These interdependent values with the Planck temperature,  $T_{Pl} = \frac{1}{k_B} \sqrt{\frac{\hbar c^5}{G}}$  are necessary and sufficient to lead us to the formulation of quantic gravity, compatible with the energy contained in the Hubble sphere, i.e. at the apparent horizon, in accordance with the law of conservation of energy.

In 2025, Wojnow demonstrated the law of conservation of energy applied to the Hubble volume in the field of the quantum linear thermodynamic cosmology [9].

### 3. Heuristic Formulation and Demonstration of the Gravity Holographic of Our Apparent Universe

Firstly, we are in the field of classical mechanic quantum thermodynamic cosmological models  $Rh = c t_{Rh} = \frac{c}{H}$  model. Where  $E_{Rh} = \frac{c^4 Rh}{2G}$  is all energy contained in Hubble volume. So, it is necessary that the geometric mean be applied to the area sphere in the following manner:

$$A_{Rh} = 4\pi Rh l_{Pl} \frac{T_{Pl}}{8\pi T_{Rh}} \quad (7)$$

Indeed, geometric means are commonly used in our particular approach to quantum thermodynamic cosmological models  $Rh=ct$  between unitary quantum values and  $Rh=ct$  model values, see [4,7]. The utilization of the factor  $\frac{T_{Pl}}{8\pi T_{Rh}}$ , is also a component of our methodology.  $\frac{T_{Pl}}{8\pi T_{Rh}}$ , and count the inverse of number Planck temperature over the cosmic time  $t_{Rh}$ . See for example when we count the number  $\frac{t_{Rh}}{2 t_{Pl}}$  of Planck time in quantum thermodynamic cosmological models [8].

From Eq.2 and Eq.7, we derived when we assume double universe theory or mirror universe theory to have  $N_{Rh} = 2 N_{GH}$ , as follows:

$$N_{Rh} = 2 * 4\pi Rh c t_{Pl} \frac{T_{Pl}}{8\pi T_{Rh}} \frac{c^3}{\hbar G} \quad (8)$$

$$E_{Rh} = \frac{1}{2} N_{Rh} \frac{c^3}{\hbar G} k_B \quad (9)$$

$$E_{Rh} = \frac{1}{2} 2 * 4\pi R h l_{Pl} \frac{T_{Pl}}{8\pi T_{Rh}} \frac{c^3}{\hbar G} k_B T_{cmb} \quad (10)$$

With  $l_{Pl} = c t_{Pl}$ , where  $t_{Pl}$  is the Planck time, we derived Eq.10 as follows:

$$E_{Rh} = \frac{1}{2} c t_{Pl} \frac{T_{Pl}}{T_{Rh}} \frac{c^3 R h}{\hbar G} k_B T_{cmb} \quad (11)$$

Since we have  $T_{cmb} = T_{Rh}$  we derive Eq.11 as follows:

$$E_{Rh} = \frac{1}{2} t_{Pl} \frac{c^4 R h}{\hbar G} k_B T_{Pl} \quad (12)$$

With  $t_{Pl} = \sqrt{\frac{\hbar G}{c^5}}$  and  $T_{Pl} = \frac{1}{k_B} \sqrt{\frac{\hbar c^5}{G}}$ , we derive Eq.12 as follows:

$$E_{GH} = E_{Rh} = \frac{1}{2} \frac{c^4 R h}{G} = \frac{c^4 R h}{2 G} \quad (13)$$

We have proven that this consistent adaptation and double universe theory which is necessary for  $N_{Rh} = 2 N_{GH}$  (see for example [8]), the holographic energy coming from the gravity holographic is equal to all energy contents in Hubble volume,  $\frac{c^4 R h}{2 G}$ , i.e., at the apparent horizon.

It is important to emphasize and remember that, in this approach  $T_{Rh}$  and  $t_{Rh}$  are interdependent:

$$T_{cmb} = T_{Rh} = \frac{\hbar}{k_b 4\pi \sqrt{t_{Rh} 2t_{Pl}}} K \quad (14)$$

and

$$t_{Rh} = \frac{\hbar^2}{T_{cmb}^2 k_b^2 16\pi^2 2t_{Pl}} s \quad (15)$$

#### 4. About the Quantum Gravity

Using Eq. 12, we can derive an exact, deterministic formula for quantum gravity  $G_{Pl}$  in an isolated, sphere system that complies with the laws of thermodynamics as follows:

$$G_{Pl} = \frac{1}{2} \frac{c^4 t_{Pl} c t_{Rh}}{\hbar E_{Rh}} k_B T_{Pl} \quad (16)$$

$$G_{Pl} = \frac{1}{2} \frac{c^5 t_{Pl} t_{Rh}}{\hbar E_{Rh}} k_B T_{Pl} \quad (17)$$

$$G_{Pl} = G \quad (18)$$

#### 5. Conclusion

The contribution of the gravity universe entropy formula  $Rh=ct$  to this emerging quantum thermodynamic cosmological model is an important advance. It provides a reliable formula in this field of research, paving the way for new developments in the string theory. In another hand, its provided perspectives on the issues faced by the contemporary standard cosmological model.

Indeed, there is a potential link between the  $Rh = ct = \frac{c}{H}$  models and the cosmological standard model with the formula of observable radius:  $R_{obs} = \frac{c}{H_0} \int_{a=0}^{a=1} \frac{da}{a^2 \sqrt{\Omega_r a^{-4} + \Omega_m a^{-3} + \Omega_k a^{-2} + \Omega_\Lambda}}$ . This could

precision and refine the standard cosmological model. We live inside a black hole which can be considered as an isolated system [9]. This contribution is based on Lavoisier's law of conservation of mass written in energy terms as  $E = mc^2$ . "Nothing is lost, nothing is created, everything is transformed." In other words, our origin comes from nothingness, or from a simple quantum fluctuation in a flat, infinite universe with no beginning and no end of time.

Note: Since Haug proved the link between H and Tcmb [5,6], all of Tatum et al.'s subsequent publications on FSC [4] could be considered accurate after careful verification. See for example <https://doi.org/10.4236/jmp.2018.98091> on the same subject.

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