

Entropic Information & Black Hole: Black Hole Information Entropy *The Missing Link*

Abstract

Understanding the 'Area Law,' in regards to the black hole entropy, based on an underlying fundamental theory has been one of the goals pursued by all models of quantum gravity. In black hole thermodynamics, black hole entropy is a measure of uncertainty or lack of information about the actual internal configuration of the system. The Bekenstein bound corresponds to the interpretation in terms of bits of information of a given physical system down to the quantum level. However, at present, it is not known which microstates are counted by the entropy of black holes. Here, i show that the new formulation of entropic information approach, based on the bit of information gives an explanation of information processes involved in calculating entropy on missing information from black holes as well as down to the quantum level. Moreover, this formulation of entropic information constitutes a new coherent global mathematical framework candidate to be the Grand Unification Theory; with information as the ultimate building block of universe.

KEYWORDS: information, entropy, entropic information, Black hole, Quantum Gravity, Bekenstein bound, bits, Grand Unification theory

1. Introduction

Black holes are one of the most interesting classes of objects in the entire universe; indeed, they explain how the Universe works at the largest and smallest scales (understand, general relativity and quantum physics). Black holes are the places where you get extremely strong gravity on small scales of length, ideal places, where gravity and quantum mechanics interact. Incidentally, our inability to express gravity in terms of quantum mechanics is the biggest obstacle to the realization of a Theory of Everything. Moreover, in regards to black holes, until now, we don't know what is the black hole entropy and what physical quantity does it describe? But here I am able, with the help of entropic information theory, to provide a deeper and structurally different underlying theory that can explain what is the quantity describe by the entropy of black hole and which lead to quantum gravity and to a new definition of the entropy concept.

2 Methodology

2.1 Black Hole Thermodynamics

The history goes back in the mid-1970s with the researches on black hole thermodynamics by Bekenstein and Hawking.

In 1973, Bekenstein the first to suggest that black holes could have entropy as well as temperature. Doubting the concept of temperature, Stephen Hawking worked to demonstrate that it was a mistake, but discovers by his own calculations that Bekenstein's theory is correct.

In 1974, Hawking calculated the gravitational collapse of a star and how the formation of the black hole affects the quantum fields. Hawking's calculations and the research that followed help bridge the gap between gravitation and quantum physics opening the first path towards an unification of the two realms. Indeed, for the first time a formula that of the temperature of the black hole involved all the constant in modern physics bringing together: relativity, gravitation, quantum physics and thermodynamics

The diagram shows the Hawking temperature formula $T = \frac{\hbar c^3}{8\pi G k_B M}$ on a black background. The constants are color-coded and connected to their respective physical domains by lines:

- \hbar (pink) is connected to "quantum" (pink).
- c^3 (red) is connected to "relativity" (red).
- G (green) is connected to "gravitation" (green).
- k_B (blue) is connected to "thermodynamics" (blue).

Fig 1 Hawking temperature formula:
with for the first time all the constant in modern physics bringing together: relativity, gravitation, quantum physics and thermodynamics

2.2 Bekenstein Bound

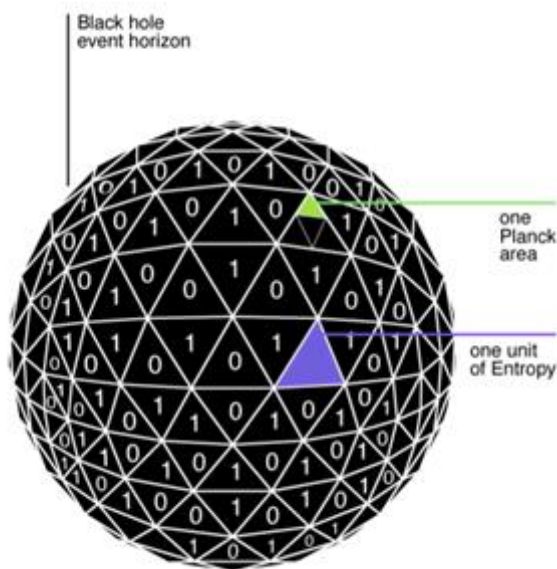
In physics, an upper limit on the thermodynamic entropy S , or Shannon entropy H , that can be contained within a given finite region of space which has a finite amount of energy is the Bekenstein bound (named after Jacob Bekenstein)—or conversely, the maximal amount of information required to perfectly describe a given physical system down to the quantum level.[1]

Furthermore, generally, the entropy is proportional to the number of bits necessary to describe the state of the system considered. This result, which was demonstrated by Jacob Bekenstein corresponds to the interpretation in terms of bits of information

$$S_{\text{BH}} = \frac{k_B}{4} \left(\frac{c^3}{\hbar G} \right) A = k_B \frac{A}{4\ell_P^2} = S = k_B \ln \Omega$$

Fig 2. Bekenstein interpretation of Black hole entropy in terms of bits of information

Fig 3. Bekenstein bound, the entropy of a black hole is proportional to the number of Planck areas that it would take to cover the black hole's event horizon



According to the Bekenstein bound, the entropy of a black hole is proportional to the number of Planck areas that it would take to cover the black hole's event horizon.

Since Casini's work in 2008 [2][3][4][5][6][7][8][9][10][11][12] [13] the precise formulation of the bound is no more a matter of debate.

In physics, the Planck surface is a surface unit that is part of the system of natural units called Planck units.

In the thermodynamics of black holes, Planck's surface, determined only in terms of the fundamental constants of relativity, gravitation and quantum mechanics corresponds to a quantity of information.

The Planck surface is defined as the squared Planck length:
with:

$$s_P = \frac{\hbar G}{c^3}$$

\hbar is the reduced Planck constant
G is the gravitational constant
c is the speed of light in vacuum.

The Planck surface intervenes in particular in the thermodynamics of black holes, where it corresponds to a quantity of information.

The Planck surface is a specific expression for black-hole entropy in terms of black-hole area.

The Planck surface is the quarter of the area by which the horizon of a spherical black hole increases when it absorbs a bit of information.

Once the body has fallen in a black hole, the information about the internal configuration of the body becomes truly inaccessible. We thus expect the black-hole entropy, as the measure of inaccessible information, to increase by an amount S.[14]

In fact, one can say that the black-hole state is the maximum entropy state of a given amount of matter.

It should be clear that the black-hole entropy we are speaking of is not the thermal entropy inside the black hole.

We take the area of a black hole as a measure of its entropy – entropy in the sense of inaccessibility of information about its internal configuration.[14]

2.3 Entropy and Information

The connection between entropy and information is well known.

The entropy of a system measures one's uncertainty or lack of information about the actual internal configuration of the system. Suppose that all that is known about the internal configuration of a system is that it may be found in any of a number of states with probability p_n for the n th state. Then the entropy associated with the system is given by Shannon's formula

$$S = -\sum_n p_n \ln p_n$$

As a bit is also numerically equal to the maximum entropy that can be associated with a yes-or-no question, i.e., the entropy when no information whatsoever is available about the answer.

One easily finds that the entropy function is maximized when $P_{yes}=P_{no}=1/2$.

Thus, in our units, one bit is equal to $\ln 2$ of information

If the base of the logarithm is b, we denote the entropy as Hb(X).
 If the base of the logarithm is e, the entropy is measured in nats.

Unless otherwise specified, we will take all logarithms to base 2, and hence all the entropies will be measured in bits.

2.4 Black Hole: Storage of mass bit information at Hawking Temperature

About The mass bit of information and the Second equivalence from Entropic Information Theory [15]

$$\ln(W) = \frac{\text{action}}{h} = t\nu = \frac{mct^2}{h} = \frac{k_B T \ln(2)t}{h}$$

we have

$$\frac{k_B T \ln(2) t}{h}$$

T is temperature at which the bit of information is stored
 t : time required to change the physical state of the information bit
 where $k_B = 1.38064 \times 10^{-23}$ J/K is the Boltzmann constant
 where c is the speed of light in vacuum 299792458 m·s⁻¹ ((exact by definition))

With the Hawking Temperature:

$$T_H = \frac{1}{k_B} \frac{\hbar c^3}{8\pi GM} = \frac{1}{k_B} \frac{hc^3}{16\pi^2 GM}$$

with T_H in $\ln(W) = \frac{k_B T \ln(2)t}{h}$

$$\ln(W) = \frac{k_B \frac{1}{k_B} \frac{hc^3}{16\pi^2 GM} \ln(2)t}{h}$$

$$\ln(W) = \frac{c^3 \ln(2)t}{16\pi^2 GM}$$

2.5 Black Hole & Entropic Information Theory: Different forms

2.5.1 Black Hole Entropic Information and classical Entropy form

In ordinary statistical mechanics, the entropy S is a measure of the multiplicity of microstates that hide behind one particular macro-state. A special case of this is Boltzmann's famous formula $S = k_B \ln W$ where W stands for the number of equally probable microstates of a particular macro-state.

Since black hole entropy plays a role quite analogous to that of ordinary entropy, e.g. it participates in the second law, many have wondered what the microstates that are counted by black hole entropy are?

As a side note, it can also be shown that the Boltzmann entropy is an upper bound to the entropy that a system can have for a fixed number of microstates meaning: [15]

$$S \leq k \ln W$$

Boltzmann 'entropy formula can be derived from Shannon entropy formulae when all states are equally probable

$$S = -k \sum p_i \ln(p(i)) = k \sum \frac{\ln(W)}{W} = k \ln(W)$$

with: $\ln(W) = \frac{c^3 \ln(2)t}{16\pi^2 GM}$

in regard to $S = k \ln(W)$

$$S_{BH} = k \frac{c^3 t}{16\pi^2 GM} \ln(2)$$

The $\ln 2$ factor comes from defining the information as the logarithm to the base 2 of the number of quantum states.[16]

2.5.2 Black Hole Entropic Information and Information Theory form

The thermodynamics of black holes suggests certain relationships between the entropy of black holes and their geometry.

The universal form of the bound was originally found by Jacob Bekenstein in 1981 as the inequality[1][2][3]

$$S \leq \frac{2\pi kRE}{\hbar c}$$

where S is the entropy, k is Boltzmann's constant, R is the radius of a sphere that can enclose the given system, E is the total mass–energy including any rest masses, \hbar is the reduced Planck constant, and c is the speed of light. Note that while gravity plays a significant role in its enforcement, the expression for the bound does not contain the gravitational constant G .

In informational terms, the relation between thermodynamic entropy S and Shannon entropy H is given by

$$S = kH \ln 2$$

whence

$$H \leq \frac{2\pi RE}{\hbar c \ln 2}$$

where H is the Shannon entropy expressed in number of bits contained in the quantum states in the sphere.

The $\ln 2$ factor comes from defining the information as the logarithm to the base 2 of the number of quantum states.[16]

The choice of logarithms – statistical functions almost always use logarithms to scale down ratios and large numbers towards a common range representable between 0 and 1.

It is then natural to introduce the concept of black-hole entropy as the measure of the inaccessibility of information (to an exterior observer) as to which particular internal configuration of the black hole

$$\frac{c^3 t}{16\pi^2 GM} = \frac{2\pi CRM}{\hbar \ln(2)}$$

$t = \frac{32\pi^3 GRM^2}{\hbar \ln(2)c^2}$
$R = \frac{\hbar t \ln(2)c^2}{32\pi^3 GM^2}$
$M = \sqrt{\frac{\hbar t \ln(2)c^2}{32\pi^3 GR}}$

2.5.2.1 Schwarzschild Metric case:

$$\frac{c^3 t}{16\pi^2 GM}$$

$$\frac{1}{4} \frac{c^3}{4\pi^2 GM} t$$

$$\frac{1}{4} \frac{c^2}{2GM} c \frac{t}{2\pi^2}$$

With $\frac{c^2}{2GM} = \frac{1}{R}$

$$\frac{ct}{8\pi^2 R} = \frac{2\pi CRM}{\hbar \ln(2)}$$

$t = \frac{16\pi^3 R^2 M}{\hbar \ln(2)}$
$R = \sqrt{\frac{\hbar t \ln(2)}{16\pi^3 M}}$
$M = \frac{\hbar t \ln(2)}{16\pi^3 R^2}$

2.5.2.2-Dimensional Analysis Proof :

$$\frac{32\pi^3 GRM^2}{\hbar \ln(2) c^2}$$

With

$$M=M$$

$$R=L$$

$$c=L \cdot T^{-1}$$

$$\hbar = M \cdot L^2 \cdot T^{-1}$$

$$G = M^{-1} \cdot L^3 \cdot T^{-2}$$

$$\frac{M^{-1} \cdot L^3 \cdot T^{-2} \cdot M^2 \cdot L}{M \cdot L^2 \cdot T^{-1} \cdot L^2 \cdot T^{-2}}$$

$$\frac{1}{T^{-1}}$$

$$T$$

2.5.3 Black Hole Entropic Information and Planck Area relation form

Thus, knowing the value of temperature, Hawking was able to propose that black holes possessed entropy, speaking in terms

$$S_{BH} = \frac{1}{4} k_B \frac{c^3}{\hbar G} A$$

where k_B is Boltzmann's constant and \hbar is the reduced Planck constant.

This result corresponded exactly to the interpretation in terms of bits of information found by Bekenstein shortly before.

Indeed, the number of bits of information absorbed by the black hole is, according to this formula equal to a quarter of the ratio of the surface of the black hole to the Planck surface $\hbar G / c^3$



With
$S_{BH} = k \frac{c^3 t}{16\pi^2 GM} \ln(2) = \frac{1}{4} k \frac{c^3}{\hbar G} A$

With

$$A = 16\pi(GM/c^2)^2$$

$$k \frac{c^3 t}{16\pi^2 GM} \ln(2) = \frac{1}{4} k \frac{16\pi G^2 M^2 c^3}{\hbar c^4 G}$$

$t = \frac{64\pi^3 M^3 G^2}{\hbar \ln(2) c^4}$
$M = \sqrt[3]{\frac{\hbar t \ln(2) c^4}{64\pi^3 G^2}}$

2.5.3.1 Schwarzschild Metric case:

$$\frac{c^3 t}{16\pi^2 GM}$$

$$\frac{1}{4} \frac{c^3}{4\pi^2 GM} t$$

$$\frac{1}{4} \frac{c^2}{2 GM} c \frac{t}{2\pi^2}$$

With $\frac{c^2}{2 GM} = \frac{1}{R}$

$$k \frac{ct \ln(2)}{8\pi^2 R} = \frac{1}{4} k \frac{16\pi G^2 M^2 c^3}{\hbar c^4 G}$$

$t = \frac{32 \pi^3 R G M^3}{\hbar c^2 \ln(2)}$
$R = \frac{\hbar t c^2 \ln(2)}{32 \pi^3 G M^3}$
$M = \sqrt{\frac{\hbar t c^2 \ln(2)}{32 R \pi^3 G}}$

2.5.3.2-Dimensional Analysis Proof:

$$\frac{256 \pi^3 G^2 M^3}{4 \hbar \ln(2) c^4}$$

With :

M=M

R=L

c=L·T⁻¹

t=T

ħ =M·L²·T⁻¹

G=M⁻¹·L³·T⁻²

$$\frac{M^{-2} \cdot L^6 \cdot T^{-4} \cdot M^3}{M \cdot L^2 \cdot T^{-1} \cdot L^4 \cdot T^{-4}}$$

$$\frac{1}{T^{-1}}$$

$$T$$

2.6 Entropy & Degree of Freedom

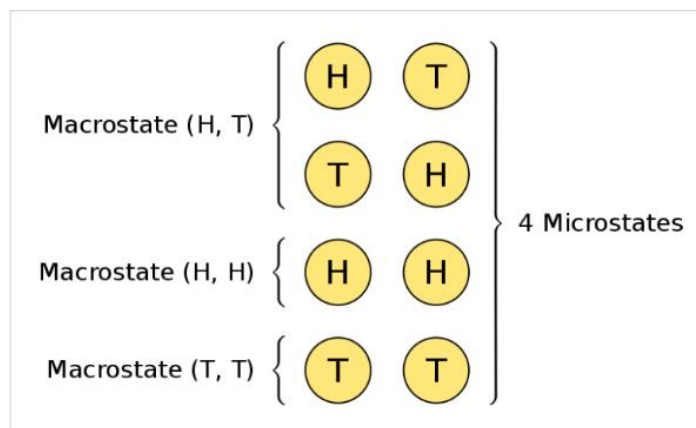


Fig 4 microstates and macrostate of flipping a coin twice: all microstate are equally probable, but the microstate (H,T) is twice as probable as the macrostate (H,H) and (T,T)

The entropy associated with the number of conformations of a molecule is the conformational entropy. The concept is most commonly applied to biological macromolecules. To compute the conformational entropy, the molecule's potential conformations are first discretized into a finite number of states, usually characterized by unique combinations of certain structural parameters, each of which is defined by a unique combination of structural features and has been assigned an energy. These characteristics are used to define the degrees of freedom in the statistical mechanics sense of a possible "microstate"

The conformational entropies can be defined as Boltzmann sampling over all possible states:[3]

$$S = - R \sum_i p_i \ln(p_i)$$

where R is the gas constant and p_i is the probability i . [17]

The Boltzmann constant (k_B or k), is a physical constant relating to the average kinetic energy of particles in a gas with the temperature of the gas. [18]

It is the gas constant R divided by the Avogadro constant N_A :

$$k = R/N_A.$$

The variations in S / k_B for even minuscule amounts of substances in chemical and physical processes reflect amounts of entropy that are enormously vast compared to anything in data compression or signal processing, as Boltzmann's constant k_B illustrates.

In classical thermodynamics, entropy is defined in terms of macroscopic measurements and makes no reference to any probability distribution, which is central to the definition of information entropy.

But, in statistical mechanics, a microstate is a certain microscopic configuration of a thermodynamic system that the system may inhabit with a specified probability during its thermal fluctuations, according to statistical mechanics. In contrast, the macro-state of a system, on the other hand, refers to the system's macroscopic attributes, such as temperature, pressure, volume, and density. [19]

Treatments on statistical mechanics [20][21] define a macro-state as follows: a certain set of energy, particle number, and volume values of an isolated thermodynamic system is said to identify a specific macro-state.

Microstates emerge in this description as multiple ways for the system to accomplish a specific macro-state.

A probability distribution of possible states across a statistical ensemble of all microstates defines a macro-state. The probability of finding the system in a specific microstate is described by this distribution. In the thermodynamic limit, the microstates visited by a macroscopic system during its fluctuations all have the same macroscopic properties.

The entropy of a thermodynamic system in equilibrium measures the uncertainty as to which of all its internal configurations compatible with its macroscopic thermodynamic parameters (temperature, pressure, etc.) is actually realized.

It is certainly natural to at least suggest that the secret to quantum gravity might lie in a thermodynamic analysis, since the archetypal quantum gravitational object (the black hole) accidentally turned out to work just like a thermodynamic system.

There are fundamental degrees of freedom that give rise to horizon temperature and entropy.

What these degrees of freedom are up for debate?

w :: number of states or microstates, characterized by the position and velocity of all particles

so if you consider that the degree of freedom of a system can be viewed as the minimum number of coordinates required to specify a configuration. so YES ... W reflects the degree of freedom of a system

“The decrease in area and entropy is of a statistical nature, and is quite analogous to the decrease in entropy of a thermodynamic system due to statistical fluctuations.”” Benkenstein

With:

$$S_{BH} = k_B \ln(W) = k_B \frac{c^3 t \ln(2)}{16\pi^2 GM}$$

2.7 Entropic Information and Black Hole Entropy calculation

Here we browse along the black hole scale to take in account some of them to make our calculations on to prove the validity of entropic information formulae in regard to classic method to determine the black hole parameters

Those black Hole with their mass are taken in account to our calculation

1. GW170817 mass: 2.7 M_{\odot}
2. Cygnus X1 Black Hole mass: 8.7 M_{\odot}
3. Messier87 Black hole mass: 6,5×10⁹ M_{\odot}
4. Ton 618 mass: 66 billion M_{\odot}

2.7.1 The Constant for our calculations

$$k=1.380649*10^{-23}$$

$$G=6.6742*10^{-11}$$

$$c=299792458$$

$$h=6.62607015*10^{-34}$$

$$hb=1.05457182*10^{-34}$$

$$\text{masssolar}=1.989*10^{30}$$

$$M=\text{mass}*\text{masssolar}$$

2.7.2 The Classical entropy formulae

$$\text{rayon}=\frac{2GM}{c^2}$$

$$\text{entropy}=\frac{4\pi GM^2}{\hbar c}$$

2.7.3 The Entropic Information formulae

$$\text{Time_Shannon}=\frac{32\pi^3 GRM^2}{\hbar c^2 \ln(2)}$$

$$\text{Time_Bekenstein}=\frac{256\pi^3 G^2 M^3}{4\hbar c^4 \ln(2)}$$

$$\text{entropy} = k \frac{c^3 t \ln(2)}{16 \pi^2 GM}$$

2.7.4 Presentation of the results

The results presented here, are represented as three parts, one based on classical black hole approach, the second part is based on Entropic information approach and the third is a comparison between both, to easily determined if the entropic information method is coherent with the classical one. From the given mass of the different black hole chosen along the size scale of black hole, I have calculated the Black hole parameter, as Schwarzschild radius, and entropy (dimensionless or not) by the classical method with the 2.7.2 presented formulae. After that I have do the same with the Entropic Information approach using the formulae presented on the 2.7.3 point. To conclude, I have made a rapport between the two results given upper; the Entropic Information approach result in regards with the classical one to be able to compare results

The results are presented here under:

2.7.5 GW170817

```

Mass of Black Hole in solar mass                               :2.7

Classical method Results :
////////////////////////

Masse of the black Hole in kg                               : 5.3703e+30
Schwarzschild radius of black hole in meter                : 7976.022193357674
Entropy of the Black Hole Classical Method Dimensionless   : 7.650843355747418e+77
Entropy of the Black Hole Classical Method                  : 1.0563129228269317e+55

Entropic Information Results :
////////////////////////

Entropic Information Time Shannon                           : 2.3186715453271243e+75
Entropic Information Entropy with time Shannon              : 1.0563129228269317e+55

Entropic Information Time Bekenstein                       : 2.3186715453271247e+75
Entropic Information Entropy with time Bekenstein          : 1.056312922826932e+55

Comparison Results :
////////////////////////

Rapport between Classical Method and Entropic Information with Shannon time : 1.0
Rapport between Classical Method and Entropic Information with bekenstein time : 0.9999999999999998

```

Fig 5 GW170817 with a given mass of 2.7 M_{\odot} : results with classical method and entropic information one and with a rapport of comparison between

2.7.6 Cygnus X1 Black Hole

```

Mass of Black Hole in solar mass                               :8.7

Classical method Results :
////////////////////////

Masse of the black Hole in kg                               : 1.73043e+31
Schwarzschild radius of black hole in meter                : 25700.515956374722
Entropy of the Black Hole Classical Method Dimensionless   : 7.943653410103184e+78
Entropy of the Black Hole Classical Method                  : 1.096739713700555e+56

Entropic Information Results :
////////////////////////

Entropic Information Time Shannon                           : 7.757212663783706e+76
Entropic Information Entropy with time Shannon              : 1.0967397137005548e+56

Entropic Information Time Bekenstein                       : 7.757212663783709e+76
Entropic Information Entropy with time Bekenstein          : 1.0967397137005552e+56

Comparison Results :
////////////////////////

Rapport between Classical Method and Entropic Information with Shannon time : 1.0000000000000002
Rapport between Classical Method and Entropic Information with bekenstein time : 0.9999999999999998

```

Fig 6 Cygnus X1 Black hole with a given mass of 8.7 M_{\odot} : results with classical method and entropic information one and with a rapport of comparison between

2.7.7 Messier87 Black hole

```

Mass of Black Hole in solar mass                               :6500000000

Classical method Results :
////////////////////////

Masse of the black Hole in kg                               : 1.2928500000000002e+40
Schwarzschild radius of black hole in meter                 : 19201534909935.145
Entropy of the Black Hole Classical Method Dimensionless   : 4.434130751444835e+96
Entropy of the Black Hole Classical Method                  : 6.12197818785156e+73

Entropic Information Results :
////////////////////////

Entropic Information Time Shannon                           : 3.2351022361198057e+103
Entropic Information Entropy with time Shannon              : 6.121978187851557e+73

Entropic Information Time Bekenstein                        : 3.2351022361198073e+103
Entropic Information Entropy with time Bekenstein          : 6.121978187851561e+73

Comparison Results :
////////////////////////

Rapport between Classical Method and Entropic Information with Shannon time : 1.0000000000000004
Rapport between Classical Method and Entropic Information with bekenstein time : 0.9999999999999998
    
```

Fig 7 Messier87 Black Hole with a given mass of $6,5 \times 10^9 M_{\odot}$: results with classical method and entropic information one and with a rapport of comparison between

2.7.8 Ton 618

```

Mass of Black Hole in solar mass                               :66000000000

Classical method Results :
////////////////////////

Masse of the black Hole in kg                               : 1.31274e+41
Schwarzschild radius of black hole in meter                 : 194969431393187.6
Entropy of the Black Hole Classical Method Dimensionless   : 4.571615042199692e+98
Entropy of the Black Hole Classical Method                  : 6.311795736397963e+75

Entropic Information Results :
////////////////////////

Entropic Information Time Shannon                           : 3.3867235411033223e+106
Entropic Information Entropy with time Shannon              : 6.311795736397963e+75

Entropic Information Time Bekenstein                        : 3.386723541103322e+106
Entropic Information Entropy with time Bekenstein          : 6.3117957363979615e+75

Comparison Results :
////////////////////////

Rapport between Classical Method and Entropic Information with Shannon time : 1.0
Rapport between Classical Method and Entropic Information with bekenstein time : 1.0000000000000002
    
```

Fig 8 Ton618 with a given mass of 66 billion M_{\odot} : results with classical method and entropic information one and with a rapport of comparison between

3. Results and Discussion

Here as Starting point, the introduction in entropic information formulae of the Hawking temperature formula which express itself by all the constant in modern physics bringing together: relativity, gravitation, quantum physics and thermodynamics. This introduction leads to new expressions of black holes entropy. Those new formulations solve the Black holes entropy information issue, as in information theoretic terms, the information entropy of a system is the amount of "missing" information needed to determine a microstate, given the macro-state. Indeed, in regards to my calculations, I have taken black hole data from along all the black hole size scale taking extremes values to calculate the entropic information relation. By analyzing the results, we can see that the rapport of the result between classical method and entropic information theory is egal to one or very near. Thus, Entropic information formulas solve the problem of the entropy of black hole information by giving an explanation of the information processes involved in calculating entropy for black holes down to the quantum level.

Here is in formulae:

$$S_{BH} = \frac{1}{4} k \frac{c^3 t}{4\pi^2 GM} \ln(2) = \frac{1}{4} k \frac{c^3}{\hbar G} A$$

$$t = \frac{64\pi^3 M^3 G^2}{\hbar \ln(2) c^4}$$

$$M = \sqrt[3]{\frac{\hbar t \ln(2) c^4}{64\pi^3 G^2}}$$

And for Schwarzschild Metric

$$\frac{c^3 t}{16\pi^2 GM}$$

$$\frac{1}{4} \frac{c^3}{4\pi^2 GM} t$$

$$\frac{1}{4} \frac{c^2}{2 GM} c \frac{t}{2\pi^2}$$

With $\frac{c^2}{2 GM} = \frac{1}{R}$

$$k \frac{ct \ln(2)}{8\pi^2 R} = \frac{1}{4} k \frac{16\pi G^2 M^2 c^3}{\hbar c^4 G}$$

$t = \frac{32 \pi^3 R G M^3}{\hbar c^2 \ln(2)}$
$R = \frac{\hbar t c^2 \ln(2)}{32 \pi^3 G M^3}$
$M = \sqrt[3]{\frac{\hbar t c^2 \ln(2)}{32 R \pi^3 G}}$

For Shannon and Schwarzschild Metric

$$\frac{c^3 t}{16\pi^2 G M}$$

$$\frac{1}{4} \frac{c^3}{4\pi^2 G M} t$$

$$\frac{1}{4} \frac{c^2}{2 G M} c \frac{t}{2\pi^2}$$

With $\frac{c^2}{2 G M} = \frac{1}{R}$

$$\frac{ct}{8\pi^2 R} = \frac{2\pi c R M}{\hbar \ln(2)}$$

$t = \frac{16\pi^3 R^2 M}{\hbar \ln(2)}$
$R = \sqrt{\frac{\hbar t \ln(2)}{16\pi^3 M}}$
$M = \frac{\hbar t \ln(2)}{16\pi^3 R^2}$

$$S_{BH} = \frac{1}{4} k \frac{c^3 t}{4\pi^2 GM} \ln(2) = \frac{1}{4} k \frac{c^3}{\hbar G} A$$

Another form of the equation for Schwarzschild Metric

$$S_{BH} = \frac{1}{4} k \frac{c^3 t}{4\pi^2 GM} \ln(2) = \frac{1}{4} k \frac{c^3}{\hbar G} A$$

$$S_{BH} = \frac{1}{4} k \frac{ct \ln(2)}{2\pi^2 R} = \frac{1}{4} k \frac{c^3}{\hbar G} A$$

$$S_{BH} = \frac{1}{4} k \frac{c}{\pi} \frac{t \ln(2)}{2\pi R}$$

$$S_{BH} = \frac{1}{4} k \frac{c t \ln(2)}{2\pi^2 R} = \frac{1}{4} k \frac{c^3}{\hbar G} A$$

Black Hole Entropic Information

$$S_{BH} = k_B \ln(W) = k_B \frac{\overbrace{c^3 t \ln(2)}^{\text{relativity}} \underbrace{\hspace{1.5cm}}_{\text{Quantum Information}}}{\underbrace{16\pi^2 GM}_{\text{gravitation}}}$$

thermodynamics

Fig 9 Black hole entropy following entropic information with constant of modern physics bringing together: relativity, gravitation, thermodynamics and quantum information

4. Conclusions

The introduction of the Hawking Temperature permit to introduce the concept of entropic information to the problematic of Black Hole and express it as being an informational process down to quantum level. Moreover, entropic information theory provides a deeper and structurally different underlying theory that can explain what is the quantity describe by the entropy of black hole and which give rise to quantum gravity. Moreover, I am able to propose a new version of entropy concept, the entropic information with as formula: $k_B \frac{k_B T \ln(2)t}{h}$

equivalent to $S = k_B \ln W$ in regard to $\frac{1}{4} k \frac{c^3 t}{4\pi^2 GM} \ln(2)$ for the black hole entropy. Those new formulations of entropy based on entropic information approach are founded on the bit of information such as the number of bits of the system, the number of bits 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. Here i solve the problem of the entropy of black hole information by giving an explanation of the information processes involved in calculating entropy for black holes down to the quantum level. Entropic Information constitutes a new coherent global mathematical framework candidate for the theory of the Great Unification; with information as the ultimate building block of the universe.

7. References

1. Bekenstein, Jacob D. (1981). "[Universal upper bound on the entropy-to-energy ratio for bounded systems](#)" (PDF). *Physical Review D*. **23** (2): 287–298. [Bibcode:1981PhRvD..23..287B](#). [doi:10.1103/PhysRevD.23.287](#).
 2. Bekenstein, Jacob D. (2005). "How does the Entropy/Information Bound Work?". *Foundations of Physics*. **35** (11): 1805–1823. [arXiv:quant-ph/0404042](#). [Bibcode:2005FoPh...35.1805B](#). [doi:10.1007/s10701-005-7350-7](#). [S2CID 118942877](#).
 3. Bekenstein, Jacob (2008). "[Bekenstein bound](#)". *Scholarpedia*. **3** (10): 7374. [Bibcode:2008SchpJ...3.7374B](#). [doi:10.4249/scholarpedia.7374](#).
 4. Bousso, Raphael (1999). "Holography in general space-times". *Journal of High Energy Physics*. **1999** (6): 028. [arXiv:hep-th/9906022](#). [Bibcode:1999JHEP...06..028B](#). [doi:10.1088/1126-6708/1999/06/028](#). [S2CID 119518763](#).
-

- 5 Bousso, Raphael (1999). "A covariant entropy conjecture". *Journal of High Energy Physics*. **1999** (7): 004. [arXiv:hep-th/9905177](https://arxiv.org/abs/hep-th/9905177). [Bibcode:1999JHEP...07..004B](https://bibcode.org/1999JHEP...07..004B). [doi:10.1088/1126-6708/1999/07/004](https://doi.org/10.1088/1126-6708/1999/07/004). [S2CID 9545752](https://s2cid.com/9545752).
 - 6 Bousso, Raphael (2000). "The holographic principle for general backgrounds". *Classical and Quantum Gravity*. **17** (5): 997–1005. [arXiv:hep-th/9911002](https://arxiv.org/abs/hep-th/9911002). [Bibcode:2000CQGra..17..997B](https://bibcode.org/2000CQGra..17..997B). [doi:10.1088/0264-9381/17/5/309](https://doi.org/10.1088/0264-9381/17/5/309). [S2CID 14741276](https://s2cid.com/14741276).
 - 7 Bekenstein, Jacob D. (2000). "Holographic bound from second law of thermodynamics". *Physics Letters B*. **481** (2–4): 339–345. [arXiv:hep-th/0003058](https://arxiv.org/abs/hep-th/0003058). [Bibcode:2000PhLB..481..339B](https://bibcode.org/2000PhLB..481..339B). [doi:10.1016/S0370-2693\(00\)00450-0](https://doi.org/10.1016/S0370-2693(00)00450-0). [S2CID 119427264](https://s2cid.com/119427264).
 - 8 Bousso, Raphael (2002). "[The holographic principle](#)" (PDF). *Reviews of Modern Physics*. **74** (3): 825–874. [arXiv:hep-th/0203101](https://arxiv.org/abs/hep-th/0203101). [Bibcode:2002RvMP...74..825B](https://bibcode.org/2002RvMP...74..825B). [doi:10.1103/RevModPhys.74.825](https://doi.org/10.1103/RevModPhys.74.825). [S2CID 55096624](https://s2cid.com/55096624). Archived from [the original](#) (PDF) on 2010-05-23. Retrieved 2010-05-23.
 - 9 Jacob D. Bekenstein, "[Information in the Holographic Universe: Theoretical results about black holes suggest that the universe could be like a gigantic hologram](#)", *Scientific American*, Vol. 289, No. 2 (August 2003), pp. 58-65. [Mirror link](#).
 - 10 Bousso, Raphael; Flanagan, Éanna É.; Marolf, Donald (2003). "Simple sufficient conditions for the generalized covariant entropy bound". *Physical Review D*. **68** (6): 064001. [arXiv:hep-th/0305149](https://arxiv.org/abs/hep-th/0305149). [Bibcode:2003PhRvD..68f4001B](https://bibcode.org/2003PhRvD..68f4001B). [doi:10.1103/PhysRevD.68.064001](https://doi.org/10.1103/PhysRevD.68.064001). [S2CID 119049155](https://s2cid.com/119049155).
 - 11 Bekenstein, Jacob D. (2004). "Black holes and information theory". *Contemporary Physics*. **45** (1): 31–43. [arXiv:quant-ph/0311049](https://arxiv.org/abs/quant-ph/0311049). [Bibcode:2004ConPh..45...31B](https://bibcode.org/2004ConPh..45...31B). [doi:10.1080/00107510310001632523](https://doi.org/10.1080/00107510310001632523). [S2CID 118970250](https://s2cid.com/118970250).
 - 12 Tipler, F. J. (2005). "[The structure of the world from pure numbers](#)" (PDF). *Reports on Progress in Physics*. **68** (4): 897–964. [arXiv:0704.3276](https://arxiv.org/abs/0704.3276). [Bibcode:2005RPPh...68..897T](https://bibcode.org/2005RPPh...68..897T). [doi:10.1088/0034-4885/68/4/R04](https://doi.org/10.1088/0034-4885/68/4/R04). Tipler gives a number of arguments for maintaining that Bekenstein's original formulation of the bound is the correct form. See in particular the paragraph beginning with "A few points ..." on p. 903 of the *Rep. Prog. Phys.* paper (or p. 9 of the *arXiv* version), and the discussions on the Bekenstein bound that follow throughout the paper.
 - 13 Casini, Horacio (2008). "Relative entropy and the Bekenstein bound". *Classical and Quantum Gravity*. **25** (20): 205021. [arXiv:0804.2182](https://arxiv.org/abs/0804.2182). [Bibcode:2008CQGra..25t5021C](https://bibcode.org/2008CQGra..25t5021C). [doi:10.1088/0264-9381/25/20/205021](https://doi.org/10.1088/0264-9381/25/20/205021). [S2CID 14456556](https://s2cid.com/14456556).
 - 14 Jacob D. Bekenstein, *Black Holes and Entropy*, *Phys. Rev. D* **7**, 2333 – Published 15 April 1973 An article within the collection: [2015 - General Relativity's Centennial](#) and the [Physical Review D 50th Anniversary Milestones](#), DOI:<https://doi.org/10.1103/PhysRevD.7.2333>
 - 15 Denis, O. (2021). Entropic Information Theory: Formulae and Quantum Gravity Bits from Bit. *Physical Science International Journal*, **25**(9), 23-30. <https://doi.org/10.9734/psij/2021/v25i930281>
-

- 16 Tipler, F. J. (2005). ["The structure of the world from pure numbers" \(PDF\)](#). *Reports on Progress in Physics*. **68** (4): 897–964. [arXiv:0704.3276](#). [Bibcode:2005RPPh...68..897T](#). [doi:10.1088/0034-4885/68/4/R04](#).
- 17 Pickett SD, Sternberg MJ. (1993). Empirical scale of side-chain conformational entropy in protein folding. *J Mol Biol* 231(3):825-39
- 18 Richard Feynman (1970). [The Feynman Lectures on Physics Vol I](#). Addison Wesley Longman. [ISBN 978-0-201-02115-8](#).
- 19 [Macrostates and Microstates Archived](#) 2012-03-05 at the [Wayback Machine](#)
- 20 Reif, Frederick (1965). [Fundamentals of Statistical and Thermal Physics](#). McGraw-Hill. pp. 66–70. [ISBN 978-0-07-051800-1](#).
- 21 Pathria, R K (1965). [Statistical Mechanics](#). Butterworth-Heinemann. p. 10. [ISBN 0-7506-2469-8](#).